

Coastal Flooding in Scotland

A guidance document for coastal practitioners



The James
Hutton
Institute



The Scottish
Government

CREW: Centre of Expertise for Waters

CREW is a hub which ensures that water research and expertise is available and accessible to the Scottish Government and its agencies. This is designed to ensure that existing and new research and expertise can feed into the development of water related policy in Scotland in a timely and effective manner.

All queries related to this document should be directed to the CREW Facilitation Team:

The James Hutton Institute
Craigiebuckler
Aberdeen AB15 8QH
Scotland UK

Tel: +44 (0) 1224 395395
Email: enquiries@crew.ac.uk

www.crew.ac.uk





Front Image: St Margaret's Hope, South Ronaldsay, Orkney; Photographer Ian Williamson.

© CREW 2012

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

The views expressed in this document are not necessarily those of CREW. Its members or agents accept no liability for any loss or damage arising from the interpretation or use of the information, or reliance upon views contained herein. Whilst this document is considered to represent the best available scientific information and expert opinion available at the stage of completion, it does not necessarily represent the final or policy positions of the project funders.

**CREW (Coastal Flooding)
The James Hutton Institute Project Team**

Sohan Ghimire (Project Manager)
Bex Holmes
Emily Hastings

The James Hutton Institute
Craigiebuckler
Aberdeen AB15 8QH
Scotland UK

Research Contractor
Sue Dawson

School of the Environment
University of Dundee
Perth Road
Dundee DD1 4HN
Scotland UK

Authors of individual chapters:

Chapter 2: Alan Werritty¹, Robert Duck¹

Chapter 3: Alan Werritty¹

Chapter 4: Sue Dawson¹, Victoria Powell¹

Chapter 5: Robert Duck¹

Chapter 6: Tom Ball¹

Chapter 7: Alastair Dawson², David Muir³

¹ Geography, School of the Environment, University of Dundee

² Aberdeen Institute for Coastal Science and Management, University of Aberdeen

³ Comhairle nan Eilean Siar, Stornoway

Acknowledgements

The CREW project team wishes to acknowledge the Society of Chief Officers for Transportation in Scotland (SCOTS) and coastal practitioners for assistance provided during the practitioner's consultation carried out at the beginning of this project. Help and support provided by Steve McFarland (SEPA Aberdeen Office) is also gratefully acknowledged.

Executive Summary

Project Reference:

Coastal Flooding in Scotland: A guidance document for coastal practitioners (February, 2012).

Project Contractors:

The James Hutton Institute, University of Dundee, CREW

Background to research:

This guidance has been produced as part of Scottish Government's Centre for Expertise for Waters (CREW) project on Coastal Flooding. The aim of the project is to synthesise existing information relating to coastal flooding in Scotland and produce a guidance document for those involved in the protection and management of coasts mainly those within Local Authorities and coastal practitioners.

Objectives of research:

The purpose of this guidance is to provide the most up-to-date knowledge and information relating to coastal flooding in Scotland ensuring that the information in this field is based on the best available scientific evidence. In particular, this aims to synthesise existing science and research on issues relevant to climate change, sea level rise, coastal flooding, coastal erosion and flood defences together with strategies of coastal adaptation.

Key findings:

Legislations relevant to coastal flooding:

- The key items of legislation relating to coastal flood risk management in Scotland are the Flood Risk Management (Scotland) Act 2009 (FRM Act), the Coast Protection Act 1949 and EU Floods Directive (2007/60/EC).
- The primary legislation on coastal flooding is the FRM Act which specifies how to manage all types of flooding whilst also meeting the requirements of the EU Floods

Directive. The FRM Act shifts the focus of flood risk management from over-reliance on engineering structures, such as walls and embankments, to a range of measures which collectively reduce flood risk.

- SEPA has been designated the competent authority with overall responsibility for national strategy and implementation of flood risk management. However local authorities, Scottish Water, and other public bodies have been designated the responsible authorities for effective delivery at the local level.
- Guidance for delivering the FRM Act requires the 32 local authorities be grouped into 14 local plan districts each with a lead local authority. The boundaries of these local plan districts reflect the configuration of river basins rather than local authority areas.
- The National Flood Risk Assessment has identified 243 Potentially Vulnerable Areas across the 14 Local Plan Districts with coastal flooding comprising 17% of the total risk.
- The lead Local Authorities are responsible for developing Local Flood Risk Management Plans to identify what actions will be taken by which authorities together with a time-table for delivery within a six-year planning cycle.
- The UK wide Coast Protection Act 1949 (CPA Act) still operative in Scotland is now implemented within the wider context of the FRM Act. Under this Act Local Authorities can carry out works needed to protect land from erosion or encroachment by the sea, and enter into agreements with others for the same purpose.
- In Scotland the former National Planning Policy Guideline 13 (Coastal Planning) encouraged local authorities to develop Shoreline Management Plans (SMPs) where coastal erosion is a problem. To date, SMPs have been developed in Angus, Fife, and Dumfries and Galloway.
- Management of the coastline not covered by SMPs has recently benefitted from non-statutory plans

prepared by Local Coastal Partnerships in dialogue with key stakeholders. As a result the Forth, Tay, Clyde and Moray Firths now have plans consistent with the concepts of Integrated Coastal Zone Management.

- The Marine (Scotland) Act 2010 introduced a marine planning system comprising a National Marine Plan along with Regional Marine Plans. The first Scottish National Marine Plan is due to be launched in 2012 with Regional Marine Plans following in due course.
- Coastal flooding is specifically covered in the UK Marine Policy Statement (MPS) which comprises the collective UK Administrations' visions for the UK marine area, general principles for decision making and the high level approach to marine planning. Since the statutory duties to reduce coastal flood risk in Scotland are entirely vested in the Flood Risk Management (Scotland) Act 2009, delivery of MPS requirements for managing flooding in Scotland will be undertaken under that Act.
- The CCRA projections report the potential loss of 45-225 hectares of beach by sea-level rise by the 2020s rising to 193-964 hectares by the 2080s (approximately 3% to 12% of the total area of beaches in Scotland).
- There are no readily accessible statistics on the contribution the emergency services currently make when flooding occurs in Scotland (Box 1). But extrapolating from data available for England and Wales, it is likely that this effort could roughly double by the 2050s and roughly triple by the 2080s.
- Road and railway networks close to and often parallel to the coastline provide essential transport links between coastal settlements. But their very location means that with sea-level rise they will be exposed to more frequent inundation and potential damage.
- The energy distribution and transmission system is more vulnerable to flooding, and it is likely that some of the 43 substations within SEPA's existing indicative flood map will be in the coastal zone.

Climate Change:

- The recent National Flood Risk Assessment (SEPA, 2011) estimates that around 30% of Scotland's population live in coastal areas with 21,250 properties, which is 17% of the estimated total of 125,000 properties, at risk of being flooded.
- A key component in flood risk management is the availability of insurance. The current Statement of Principles on the Provision of Flood Insurance between the UK Government and the Association of British Insurers is due to expire in July 2013. Continuation of the Statement of Principles, or some alternative arrangement, is vital to the operation of the mortgage market and wider housing market.
- Although the size of the mortgage fund at risk due to insurance becoming either unaffordable or unavailable was not assessed for Scotland as part of Defra's CCRA, based on figures for England and Wales, this could be of the order of £100 to £800 million by the 2050s and £200 million to £900 million by the 2080s for Scotland. This could have severe impacts on households and business leading to financial problems and business failure.
- It is highly likely that some properties not currently flooded will become subject to future flooding.
- As the incidence of flooding increases there are likely to be more deaths, injuries and mental health effects. The mental health effects of floods are estimated in the UK CCRA as around 30-40% of those flooded.
- Around 12% of the coastline is recognised as in a state of erosion as compared to 30% of the coastlines in England and Northern Ireland and 20% in Wales.
- With increases in extreme sea levels, caused through storm surges, high tides and wave action coastal flooding is likely to alter the composition and range of shallow marine habitats.
- Coastal flooding and erosion is seen in the CCRA for Scotland as one of the most pressing issues for immediate action given the threat posed by climate change.

Sea level rise around Scotland's coast:

- Recent satellite mappings show that on average the height of the ocean surface has been

increasing by just over 3 millimetres per year.

- Across Scotland there are 18 tide gauge datasets over 16 locations that typically show present rates of rise in the order of +2 millimetres per year.
- The tide gauge records and satellite data show recent patterns of relative sea level change made up from rates of present day vertical land rebound and sinking combined with the effect of changes in the volume of water stored in the oceans caused by global warming.
- Ocean wave modelling studies indicate the northern and western coastlines of Scotland will continue to be affected by higher surge events rather than in eastern areas.
- The tidal change around the majority of Scotland's coastline is between 3-4 metres. In some areas, however (for example the Solway Firth) the tidal range may exceed 6 metres.

Shoreline Management Plans and coastal strategies:

- As a consequence of the generally much lower population density than south of the border, combined with typically more durable rock types characterising the coast, only about 6% of Scotland's coastlines are defended compared with some 44% of those in England and Wales.
- Pressures on the Scottish coast and the need to install defences is far from uniform and is most acute where major conurbations coincide with the coasts of the Midland Valley as in the Firths of Clyde in the west and the Forth in the east.
- More enlightened approaches to erosion control and coastal zone management were accepted and became adopted since 1980s in Scotland. The planting of eroding dunes with marram grass (*Ammophila arenaria*) and lyme grass (*Leymus arenarius*) together with the placement of geotextile or jute membranes and with prevention of public access by the erection of fencing are now common occurrences.
- Management of the Scottish coast has evolved through the formation of seven voluntary

Local Coastal Partnerships (LCPs) and the implementation of Shoreline Management Plans (SMPs) on the basis of sediment cells.

- There are eight non-statutory Shoreline Management Plans (SMPs) in Scotland, however, the best developed are those for the coasts of Angus, Fife and the northern (i.e. Scottish) shore of the Solway Firth. Each plan evaluates the natural processes that are acting on a length of shoreline and predicts the way in which it will evolve into the future.
- The concept of the Process Defined Management Unit (PDMU) has been established to aid the identification of sites suitable for development on undeveloped coasts. The PDMU approach takes into account all sediment grain sizes, from very fine to very coarse and also takes into account sediment sources, sediment sinks and the intervening sediment transport pathways. This approach can improve upon previous coastal zone management and provide a flexible approach for Marine Spatial Planning.

Coastal defences and Asset Management:

- Because of the expense of constructing and maintaining coastal defences, and interconnectedness of coastal processes, 'soft' engineering measures are gaining in popularity. Such measures include dune stabilisation and beach replenishment, and in places, managed retreat or realignment.
- In order to solve financial constraints, local authorities have moved towards private maintenance partially supported through public funds.
- Only a small number of exclusively coastal schemes have been approved under the Flood Prevention/Protection Scheme Order process established under the Flood Prevention (Scotland) Act 1961.
- While the newer flood prevention schemes have conformed as far as possible to design standards advice (protection to a level of 1 in 200 years plus climate change), many of the older schemes were not designed to an equivalent standard. Consequently the actual level of protection offered by these older schemes can be hard to ascertain.

- The main substantive changes in the legislation as a result of the FRM Act 2009 will be the requirement to show contribution to, and no detriment to, the implementation of the local flood risk management plan. A further important procedural change compared to the previous legislation is the deemed grant of planning permission on confirmation of a scheme by Ministers, designed to speed up and simplify approval procedures.

Coastal Adaptation Strategies:

- The term 'adaptation' means different things to different people. For coastal management, the term 'adaptation' refers to practical measures undertaken to protect coastal communities from likely consequences of climate change that are deemed to be harmful.
- The needs for coastal adaptation in a given coastal area are often highlighted within individual Shoreline Management Plans.
- The selection of a specific form of adaptation is usually based on a wide range of measures that includes the political, technical, social and economic benefits that may arise.
- Scottish local authority planning policy in relation to coastal flooding varies between authorities but complies with Scottish Planning Policy.
- Improved flood warning is a significant adaptation measure which helps safeguard people at risk from coastal flooding.
- In many cases, 'soft-engineering' solutions prove themselves to be cost effective particularly if funded through a partnership of local stakeholders.

Contents

Executive Summary	4
1 Introduction	12
2 Legislation Relevant to Coastal Flooding	13
2.1 FLOOD RISK MANAGEMENT (SCOTLAND) ACT 2009	14
2.2 COAST PROTECTION ACT 1949 (CPA)	17
2.3 MARINE (SCOTLAND) ACT 2010 AND UK MARINE POLICY STATEMENT (2011)	18
3 Climate Change	19
3.1 RISK ASSESSMENT	20
3.1.1 Business and Services	20
Case Study 3.1: The Emergency Response to Rainfall and Flooding on 1 st Nov. 2009	22
3.1.2 Infrastructure and Buildings	22
3.1.3 Health and Well-being	23
3.1.4 Natural Environment	24
Case Study 3.2: Habitat changes at the Dornoch Firth	24
CLIMATE CHANGE: Conclusions	26
4 Relative Sea Level Rise	27
4.1 RELATIVE SEA LEVEL RISE	28
4.2 STORM SURGES AND EXTREME WAVES	30
4.3 COASTAL FLOODING, TIDES AND SEA LEVEL	30
RELATIVE SEA LEVEL RISE: Conclusions	31
5 Shoreline Management Plans and Coastal Strategies	32
5.1 COASTAL GEOLOGY AND GEOMORPHOLOGY	33
5.2 COASTAL PROTECTION	33
5.3 COASTAL ZONE MANAGEMENT	34
5.3.1 Sediment Cells and Shoreline Management Plans	34
5.3.2 Process Defined Management Units	36
6 Coastal Defences and Asset Management	37
6.1 UPDATE ON PREVIOUS WORK	38
6.2 FLOOD PROTECTION SCHEMES	39

6.2.1	Database and Records	39
6.2.2	New legislative provisions	40
6.3	CASE STUDIES AND LESSONS LEARNED	40
6.3.1	Informal programmes for flood defence and erosion protection	41
6.3.2	Ad hoc protection and defence work by coastal landowners: support by local authorities	42

7 Coastal Adaptation Strategies 43

7.1	SELECTING A FORM OF ADAPTATION	44
7.1.1	Other Forms of Coastal Adaptation	44
7.2	PLANNING POLICY	45
7.2.1	Emergency Planning – Flood Alert System	45
7.3	HOW TO ADAPT?	45
7.4	PROJECT COASTADAPT	47
7.5	COASTAL ADAPTATION CASE STUDIES	47
7.5.1	Case Study 1: Alleviating Coastal Flood Risk, Kilpheder, South Uist	48
7.5.2	Case Study 2: Coastal Dunes: the “Coastal Care Project”, Outer Hebrides	49
7.6	KEY RESOURCES	50

8 Other Relevant Information 51

9 Glossary of Terms 64

APPENDICES	65
APPENDIX 1	65
APPENDIX 2	66
CASE STUDIES ON FLOOD AND COASTAL EROSION DEFENCE	66
Case Study on Coastal Flood Protection Scheme: Saltcoats	66
Case Study on Natural Defences: St Andrews Links, Fife	67
Case study on ad hoc activity by coastal landowners: Shetland	68
REFERENCES	69

List of Figures

Figure 1:	Local Plan Districts (SEPA, 2011b)	15
Figure 2:	Requirements for each Local Plan District (SEPA, 2011b)	17
Figure 3:	Projected loss of UK beach area due to sea-level rise (Defra, 2010b p. 151)	20
Figure 4:	Dune restoration, St Andrews © Copyright Richard Webb	20
Figure 5:	Skara Brae (Source: Ian Williamson)	21
Figure 6:	Road damage on Orkney after December 2011 storms (Source: BBC News)	23
Figure 7:	Topographic map identifying key locations and processes (Source: HR Wallingford et al., 2012, p. 135)	25
Figure 8:	The average value of global mean sea level time series based on analysis of ocean surface altitude data. The black line is a linear plot through the data. The blue line represents the application of 60-day statistical smoothing. The different coloured circles correspond to successive series of satellite mapping and measurement (Colorado University Sea Level Research Group, 2012).	28
Figure 9:	Scotland experienced both sinking of the Earth's crust (central areas) and uplift (outer areas) due to the load imposed by the last Scottish ice sheet. Ten thousand years later the central areas are still continuing to rebound while the outer areas are sinking.	29
Figure 10:	Vertical land rebound map from UKCP09 (values in millimetres per year) (Bradley et al., 2009)	29
Figure 11:	Location of regions and areas covered by "Coastal Cells of Scotland" series and Shoreline Management Plans and analogous studies, (SNH, 2000)	35
Figure 12:	Flood protection, erosion protection and managed realignment schemes referred to in the text. Refer to tables 1a, 1b and 2 for scheme details. Reproduced from Baxter et al. (2011: 161). See: Scottish Government http://www.scotland.gov.uk/Publications/2011/03/16182005/67 .	41
Figure 13:	Flooding of golf courses at St Andrews following the storm of March 28th 2010. In this case, the construction of sea dykes paid by a private company (St Andrews Links Trust) was the particular adaptation measure chosen.	44
Figure 14:	The storm of January 11th 2005 in the Outer Hebrides presented major problems of how coastal communities adapt in response to extremes of climate change. Causeways that had been constructed to create an integrated transport network proved vulnerable to the effects of climate change.	46
Figure 15:	Forms of coastal adaptation can range from engineering structures to forms of beach nourishment through to the option of doing nothing (Cooper & McKenna, 2008).	47
Figure 16:	Sand blow fencing, North Uist	49
Figure 17:	Marram grass planting in Barra	49
Figure 18:	Overtopping of a barrier island in South Uist as a result of winter storms	50
Figure 19:	Map of Saltcoats showing basin areas that tended to flood prior to FPS construction (Johnson et al. 2010)	67

List of Tables

Table 1:	Flood risk management milestones (Scottish Government, 2011a)	16
Table 2:	UKCP09 relative sea level change estimates for 2020, 2050 and 2095 at Edinburgh (cm) according to 3 emissions scenarios (low, medium and high) for future climate change.	29
Table 3:	Relative sea level change (cm) for several locations across Scotland based on the UKCP09 medium emissions scenario.	30
Table 4:	Flood defences approved under the statutory regime - information listed in the Scottish Flood Defence Asset Database (see Figure 18).	39
Table 5:	Flood defences constructed out with the statutory regime	39
Table 6:	Coast protection schemes approved for grant aid funding since 2000 (see Figure 12)	41
Table 7:	Scottish Tide Gauge Data. Italic sites are shorter than 25 years in duration. Sea level trends are based on Woodworth et al. (2009)	65
Table 8:	(from Johnson et al., 2010) Net Sea Level Rise allowances adopted for Saltcoats Flood Prevention Scheme, N. Ayrshire	67

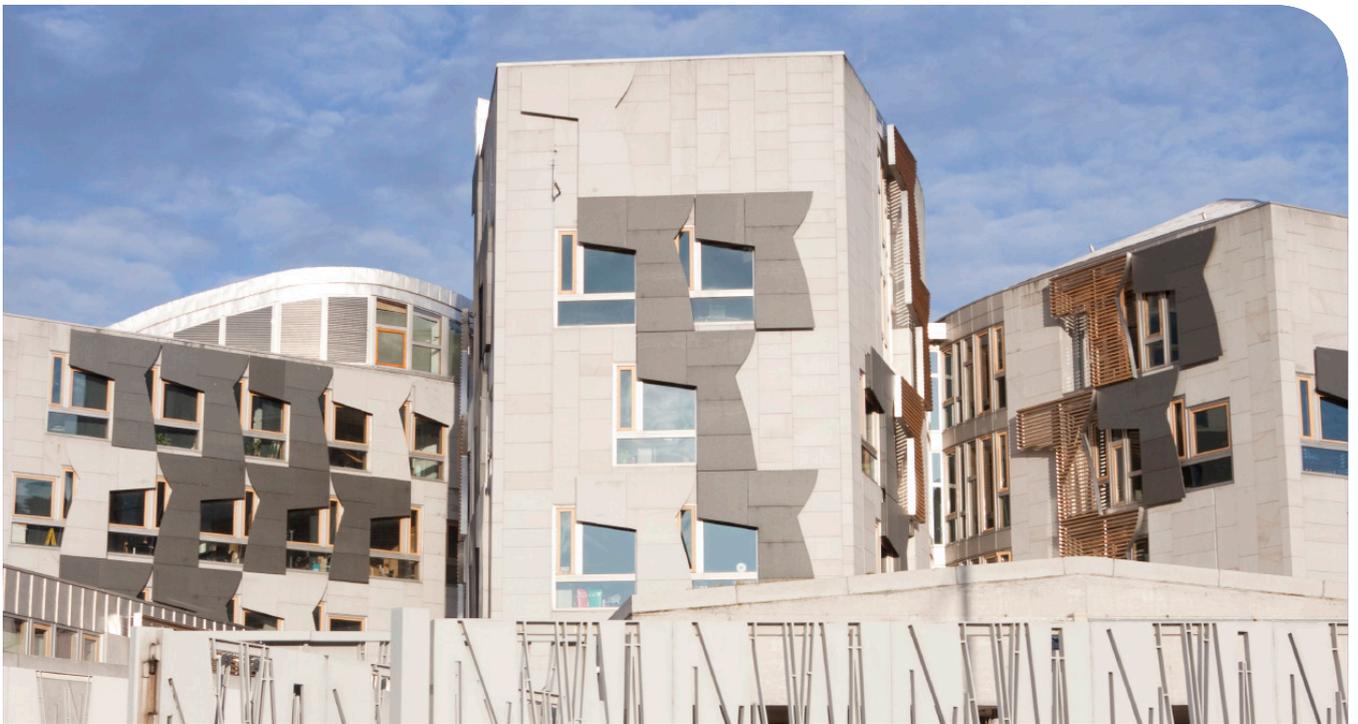


1. Introduction

This guidance has been produced as part of the Scottish Government's Centre for Expertise for Waters (CREW) project on coastal flooding as a collaborative venture between the James Hutton Institute (JHI) and the University of Dundee.

This project aims to ensure the successful transfer of knowledge on the issues associated with coastal flooding, to key stakeholders. The collaborative work supports CREW's aim to build networks which establish a delivery mechanism at the science, policy and practice interfaces. In addition, this work will form the basis for providing information and advice to the Scottish Government and partners for policy development and support. Knowledge Exchange (KE) such as this will underpin policy and operational needs for addressing the issues of coastal flooding. The main objective of this project is to synthesise the most up-to-date scientific knowledge and information relating to coastal flooding in Scotland in the form of a guidance document. The guidance document has been separated into various chapters relating to the existing science and research on climate change, sea level rise, coastal flooding, coastal erosion, flood defences and strategies for coastal adaptation.

A practitioner's consultation was carried out using a questionnaire to identify the current level of understanding, user needs, knowledge gaps and their expectation on the content of the guidance. Feedback was compiled into a report which was taken into consideration when drafting this guidance. This will be reviewed on a regular basis to ensure continual improvement and to reflect the needs of those involved in the management of risk from coastal flooding in Scotland. Web links have been provided to ensure that the guidance contains the latest information. The guidance is primarily aimed at those involved in the protection and management of Scotland's coastline, mainly within Local Authorities, as well as coastal practitioners.



2. Legislation Relevant to Coastal Flooding

The key pieces of legislation which determine the management of coastal flood risk in Scotland are:

- Flood Risk Management (Scotland) Act 2009 (FRM Act)
- Marine (Scotland) Act 2010
- Coast Protection Act 1949
- EU Floods Directive (2007/60/EC)

The Marine (Scotland) Act 2010 has spatial planning provisions which will have to be coordinated with other plans derived for the coastal zone. The EU Floods Directive (2007/60/EC) explicitly identifies coastal areas as flood sources.

The Flood Risk Management (Scotland) Act 2009 in part is a response to the EU Floods Directive which requires all EU member states to have in place a flood risk assessment (by 2012), flood hazard and risk maps (by 2013) and a flood risk management strategy by 2015.

The Water Environment and Water Services (Scotland) Act 2003 is also relevant as it poses a duty on Scottish ministers to promote sustainable flood management alongside its primary goal of promoting good ecological status in water bodies.

Much of the legislation is focussed on inland flooding (either from rivers or surface water) even though the National Flood Risk Assessment (SEPA, 2011a) attributes 17% of flood impacts to coastal flooding (out of a total of 125,000 properties). The following sub-chapters explain in more detail how the identified pieces of legislation relate to coastal flood risk.

2.1 Flood Risk Management (Scotland) Act 2009

The primary legislation on coastal flooding is the FRM Act which specifies how to manage all types of flooding whilst also meeting the requirements of the EU Floods Directive. The overall aim of the FRM Act is to manage flood risk cost-effectively, as well as enhancing the social, natural and cultural environment, in order to reduce the risk to people and property.

The fundamental premise of the FRM Act is that flooding cannot be prevented but, with appropriate actions, we can learn to live with floods. Thus the FRM Act shifts the focus of flood risk management from strictly hard-engineering defence of areas, such as walls and embankments, towards the protection of people by reducing risk such as reducing the likelihood of flooding, greater predictive power of occurrence and reducing the impact. The FRM Act shifts the focus of flood risk management from over-reliance on engineering structures, such as walls and embankments, to a range of measures which collectively reduce flood risk. These measures include enhanced flood warnings, property-level resilience, community action, robust spatial planning and the use of natural features to store water and reduce flood flows. As well as this the FRM Act also seeks to promote greater individual ownership of flood risk thereby lessening reliance on the state.

SEPA has been designated the competent authority with overall responsibility for national strategy and implementation of flood risk management. However local authorities, [Scottish Water](#), and other public bodies have been designated the responsible authorities for effective delivery at the local level. Guidance for delivering the FRM Act (Scottish Government, 2011a) requires the 32 local authorities be grouped into 14 local plan districts each with a lead local authority. Figure 1 denotes the boundaries of these local plan districts which, it should be noted, reflect the configuration of river basins rather than local authority areas. Thus Fife is divided between Tay Estuary and

The fundamental premise of the FRM Act is that although flooding cannot be prevented, with appropriate actions it can be managed.

Montrose (Local Plan District 7) and Forth Estuary (10). Coastal areas are embedded in all the Local Plan Districts other than Forth (9) (see Figure 1).

Given the timetable required by the EU Floods Directive, the following key milestones have been specified by the Scottish Government (2011a):

Dec. 2011	National Flood Risk Assessment (SEPA)
Dec. 2013	National flood hazard and flood risk maps (SEPA)
Dec. 2015	National and local flood risk management plans (SEPA and lead local authorities)

The first of these deadlines has already been met with [243 Potentially Vulnerable Areas](#) identified across the 14 Local Plan Districts with coastal flooding comprising 17% of the total risk (SEPA, 2011a). Other intermediate deadlines are itemised in Table 1.

The [Flood Risk Management Plans](#) covering each Local Plan District will comprise two sets of complementary plans:

- SEPA's Flood Risk Management Strategies will identify the main flood hazards and impacts and set out objectives for reducing risk;
- Lead local authorities' Local Flood Risk Management Plans will take these objectives and identify actions to be undertaken by local authorities together with a time-table for delivery, within a six-year planning cycle (see Figure 2 for further details).

Guidance for delivering sustainable flood risk management (Scottish Government, 2011a) stresses that the relevant authorities should:

- work holistically in designated river basins or appropriate units for coastal areas (reflecting coastal and estuarine processes and interactions between coastal area and catchments);
- work in partnership with each other and relevant stakeholders;
- where possible seek multiple benefits from the actions taken (e.g. enhancing biodiversity, storing carbon, improving water quality);

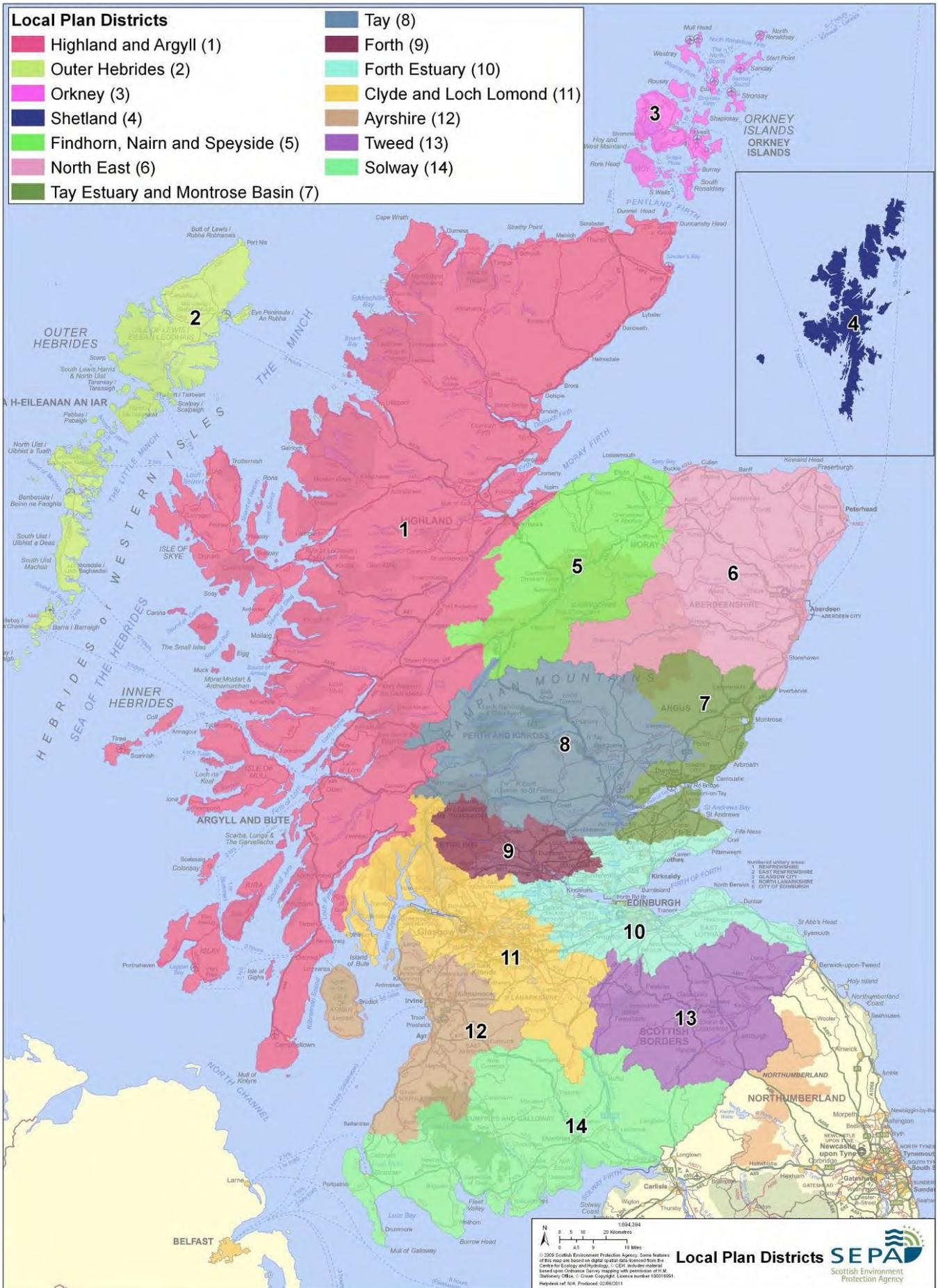


Figure 1: Local Plan Districts (Source: SEPA, 2011b)

Step	Date	Activity	Lead
Step 1: Preparatory work	June to December 2012	Characteristics of Local Plan Districts	SEPA
	January to December 2012	Natural flood management assessment and mapping of artificial and natural features	SEPA
	Commencing January 2012 with preliminary outputs in September 2012 and final maps published in December 2013	Flood hazard and flood risk maps	SEPA
Step 2: Identification of objectives, appraisal and prioritisation of actions	December 2012 to June 2013	Identification of objectives and actions to reduce flood risk	SEPA
	By April 2013	Objectives to be finalised	SEPA
	March to June 2013	Actions to reduce flood risk to be identified	SEPA
	By December 2012	Additional guidance on appraisal for Flood Risk Management	Scottish Government
	May 2013 and March 2014	Co-ordinate the appraisal of actions, in consultation with local authorities and Scottish Water	SEPA
	February and December 2014	Prioritisation of actions	SEPA
Step 3: Consultation on Flood Risk Management Strategies	December 2014	Draft Flood Risk Management Strategies for public consultation	SEPA
	December 2015	Final Flood Risk Management Strategies	SEPA

Table 1: Flood risk management milestones (Source: Scottish Government, 2011a)

The intended outcomes of sustainable flood risk management are:

- to use public funds to protect the most vulnerable areas including homes, people and property at greatest risk;
- storing water in rural and urban landscapes to slow down the progress of flood events;
- installing integrated drainage to reduce pressure on sewers and improve the water environment;
- raising awareness so that the public and businesses understand flood risk and adopt protective actions both for themselves and property;
- undertaking actions that will be adaptable to future changes in the climate.

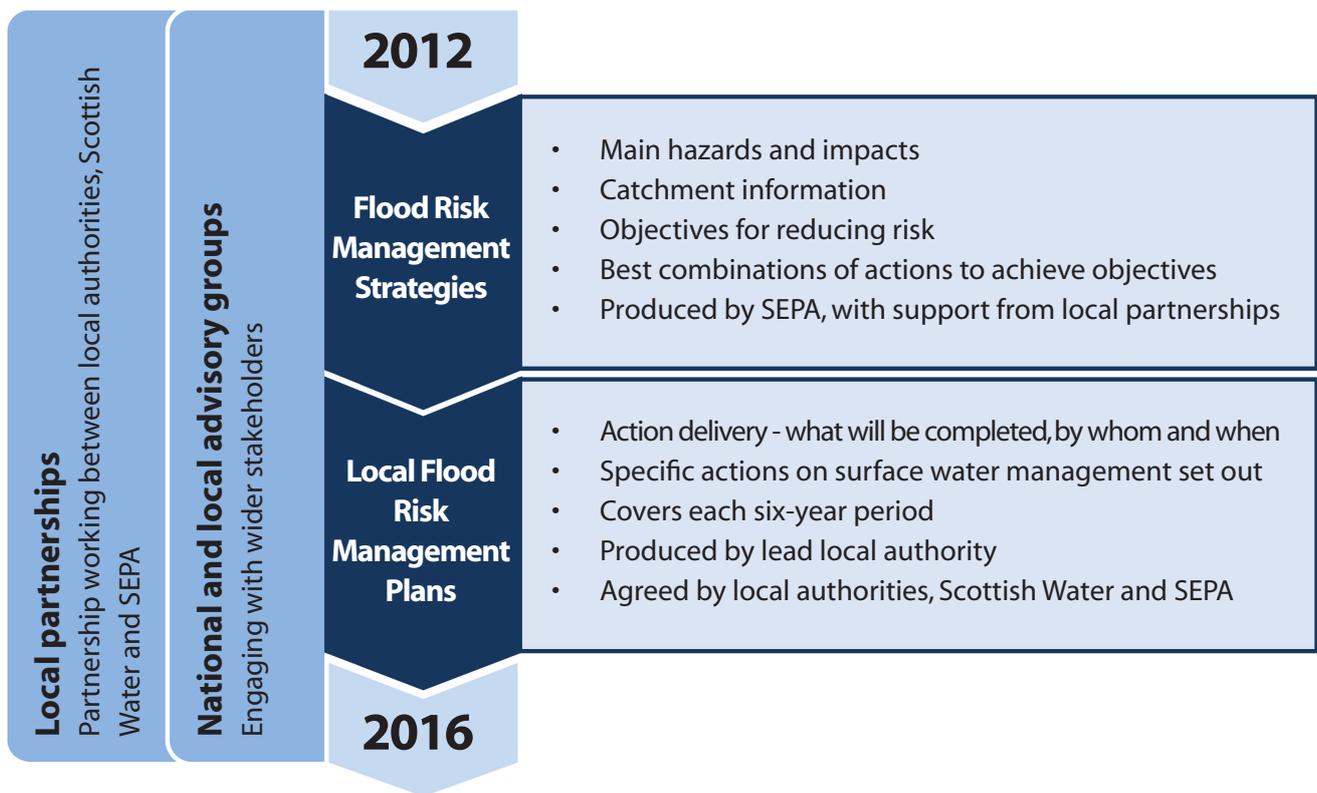


Figure 2: Requirements for each Local Plan District (Source: SEPA, 2011b)

2.2 Coast Protection Act 1949 (CPA)

The UK wide Coast Protection Act 1949 (CPA), which is still operative in Scotland, is now implemented within the wider context of the FRM Act. The term ‘coastal protection’ is not explicitly defined in the CPA, but it does distinguish between flood defence ‘concerned with protection of land from flooding by the sea’ and the ‘protection of coastal land against erosion or encroachment’ (implicitly coastal protection). In practice, similar processes (waves and storm surges) trigger the need for both coastal protection and flood defence; with specific projects undertaken by relevant public bodies fulfilling both of these functions.

Currently the responsibilities of local authorities are classed as “permissive powers” not duties. This means there is no general liability should a local authority fail to exercise these powers.

This distinction between coastal protection and flood defence is less important for Scottish local authorities as compare with those in England and Wales. This is because

Scottish local authorities are responsible for both the former (under the CPA) and the latter (under the FRM Act). It is important to note that the responsibilities in both instances are ‘permissive powers’ and not duties and, as with the FRM Act, there is no general liability should a local authority fail to exercise these powers.

Under the CPA, local authorities can carry out works needed to protect land from erosion or encroachment by the sea, and enter into agreements with others for the same purpose. Prior to the FRM Act, actions under the CPA were generally limited to engineering works (primarily sea walls and embankments) which were subject to standard planning requirements. In addition to public consultation, this would often involve approvals from SEPA ([Controlled Activities Regulations](#)), SNH (nature conservation designations) and the Scottish Government.

As the [Scottish Flood Defence Asset Database](#) reveals (see Chapter 6), very few coastal protection schemes were implemented by local authorities under the CPA due to a general lack of resources. It is likely that this will change as the threat of sea-level rise locally increases coastal flood risk. By contrast, many privately-funded schemes already

exist protecting high value infrastructure.

Before the FRM Act (Scotland) and the [Flood and Water Management Act 2010](#) (England and Wales) there was no statutory requirement requiring formal plans for coastal protection or flood defence measures along the coastline of the UK, although [Shoreline Management Plans](#) (SMP) have existed in England and Wales since the 1990s. In Scotland the former [National Planning Policy Guideline 13](#) (Coastal Planning) encouraged local authorities to

develop SMPs where coastal erosion is a problem. To date, SMPs have been developed in [Angus, Fife, and Dumfries and Galloway](#). Management of the coastline not covered by SMPs has recently benefited from non-statutory plans prepared by Local Coastal Partnerships in dialogue with key stakeholders. As a result the [Forth, Tay, Clyde and Moray Firths](#) now have plans consistent with the concepts of [Integrated Coastal Zone Management](#). These partnerships may take on more formal advisory roles as delivery of the FRM Act and Marine (Scotland) Act 2010 proceeds.

2.3 Marine (Scotland) Act 2010 & UK Marine Policy Statement (2011)

The Marine (Scotland) Act 2010 introduced a marine planning system comprising a National Marine Plan along with Regional Marine Plans. Powers granted include those for [Marine Spatial Planning](#) (MSP), marine licensing, marine conservation, sea fisheries conservation and seal conservation. [Marine Scotland](#) was established in 2009 and is responsible for the integrated management of Scotland's seas. Flooding (either riverine or coastal) is not mentioned in the Marine (Scotland) Act 2010.

Flooding does not warrant a single mention in the Marine (Scotland) Act 2010.

In contrast, coastal flooding is specifically covered in the [UK Marine Policy Statement](#) (MPS; UK Government, 2011) which comprises the collective UK Administrations' visions for the UK marine area, general principles for decision making and the high level approach to marine planning.

This UK MPS will lead to and inform the development of a National Marine Plan for Scotland, followed by Regional Marine Plans and ultimately to decisions being made on the basis of the MPS and the various Scottish plans. Within the MPS an increased risk of coastal flooding is identified as a climate change impact that will require careful adaptation in terms of "ensuring that proposed new developments are resilient over their lifetime" (MPS para 2.6.7.3). The MPS also advises relevant authorities to be aware of potential changes in offshore submerged banks and ridges that could impact on the pattern of on-shore sediment erosion and accretion and thus flood risk.

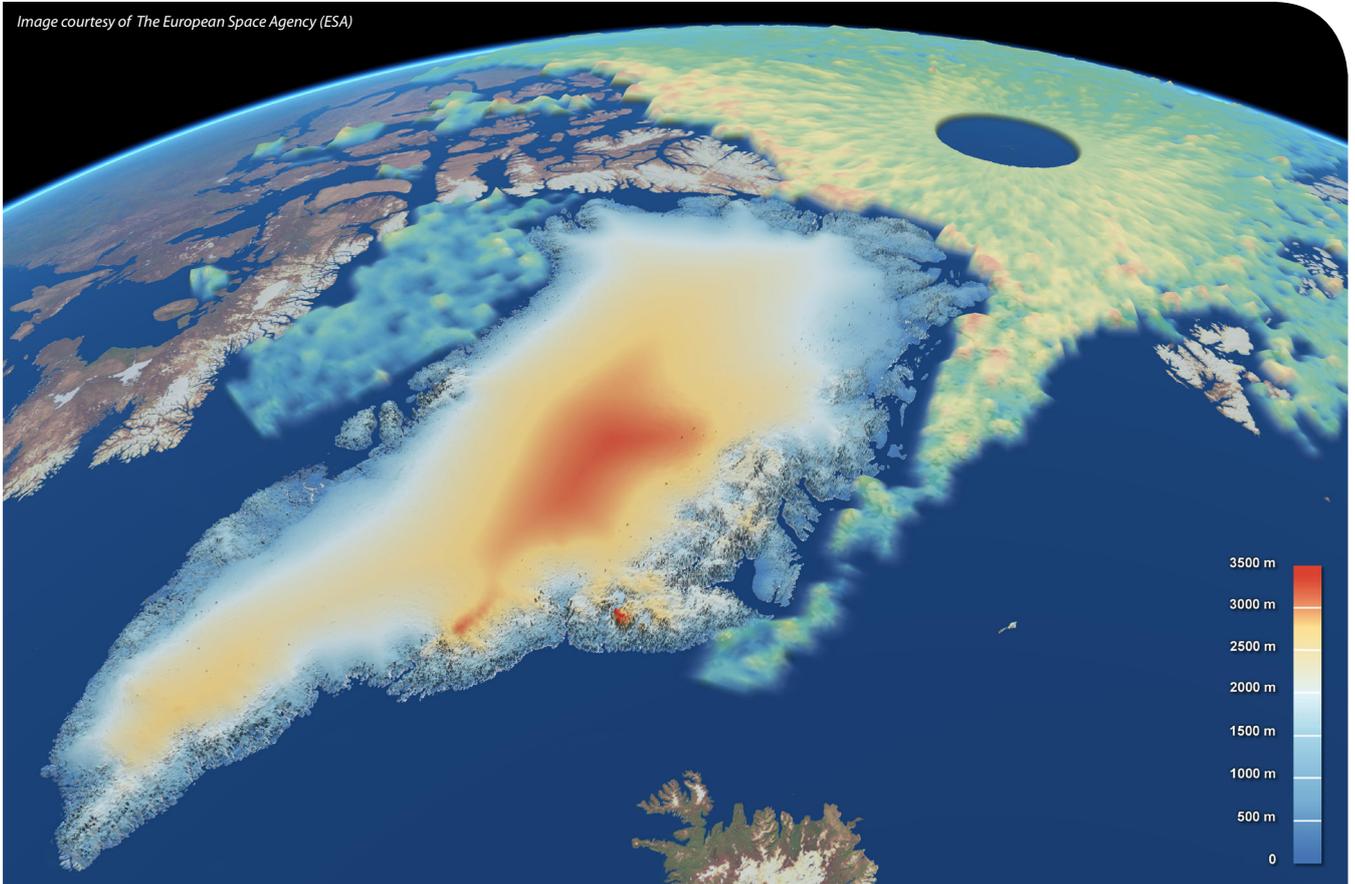
Furthermore, Marine Plan authorities are reminded that "inappropriate development should be avoided in areas of highest vulnerability to coastal change and flooding" and that "development will need to be safe over its planned lifetime and not cause or exacerbate flood and coastal erosion risk elsewhere" (MPS paras 2.6.8.5). In addition "Marine plan authorities should seek to minimise and mitigate any geomorphological changes that an activity or development will have on coastal processes, including sediment movement" (MPS para 2.6.8.6).

The first Scottish National Marine Plan is due to be launched in 2012 with Regional Marine Plans following in due course. The boundaries for

There is a risk that spatial planning for Regional Marine Plans may not give due regard for flood risk management.

the associated Scottish Marine Regions have yet to be announced – but it is unlikely that they will coincide with the boundaries for the [Local Plan Districts](#) under the [Flood Risk Management \(Scotland\) Act](#).

Moreover, as already noted, since the statutory duties to reduce coastal flood risk in Scotland are entirely vested in the [Flood Risk Management \(Scotland\) Act 2009](#), delivery of MPS requirements for managing flooding in Scotland will be undertaken under that Act. Accordingly, there is a risk that spatial planning for Regional Marine Plans may not give due regard for flood risk management. It is to be hoped that appropriate guidance to local authorities will emerge to ensure that flood risk management is sufficiently covered.



3. Climate Change

A key issue for managing the coastal zone is the likely impact of climate change. Given projected increases in the magnitude and frequency of coastal flooding (see Chapter 4) this chapter explores the impacts of climate change on the coastal zone specifically focussing on flooding. These impacts can broadly be differentiated between those which are biophysical (operating on the natural environment) and those which are societal (changing the way society is organised and operates).

The main source for this chapter is the Climate Change Risk Assessment (CCRA) for the UK published by Defra in January 2012. This is a complex set of reports to navigate in terms of coastal flooding for Scotland as there are UK-wide reports (Defra, 2012a, b, c, d) to be consulted alongside the stand alone report for Scotland (HR Wallingford et al., 2012). It is important to note that the methodology for the Scotland report differs from that for the UK reflecting the lower availability of geo-referenced environmental and socio-economic data across Scotland. The evidence for changes in sea-level, wave heights and storm surges and projections based on the findings of UKCP09 will be explored in Chapter 4.

This chapter summarises the key findings from the CCRA in terms of a risk assessment across Business and Services, Infrastructure and Buildings, Health and Wellbeing, and Natural Environment.

3.1 Risk Assessment

3.1.1 Business and Services National Flood Risk Assessment

The recent **National Flood Risk Assessment** (SEPA, 2011) estimates that around 30% of Scotland's population live in coastal areas with 21,250 properties, which is 17% of the estimated total of 125,000 properties, at risk of being flooded. Given that the lower estimate of total flooding costs is £720 million (SEPA, 2011) the pro rata cost for all coastal properties is £122 million. At present there is no estimate of how much this might increase as a result of climate change, the estimates for non-residential properties in England and Wales are +40% by the 2050s and 60% by the 2080s.

Climate change will have severe impacts on households and businesses leading to financial problems and business failure.

A key component in flood risk management is the availability of insurance. The current **Statement of Principles on the Provision of Flood Insurance** between the UK Government and the Association of British Insurers is due to expire in July 2013. At present affordable flood insurance is available for properties built before 2009 and protected against a 1 in 75 year flood or if a flood protection scheme is planned within 5 years. Properties which flood more frequently can still obtain insurance although this often requires higher premiums and excesses. Continuation of the Statement of Principles, or some alternative arrangement, is vital to the operation of the mortgage market and wider housing market.

Although the size of the mortgage fund at risk due to insurance becoming either unaffordable or unavailable was not assessed for Scotland as part of **Defra's CCRA**, based on figures for England and Wales, this could be of the order of £100 to £800 million by the 2050s and £200 million to £900 million by the 2080s for Scotland. This could have severe impacts on households and business leading to financial problems and business failure. The socially vulnerable are also more exposed to coastal flooding and less likely to be insured raising challenging questions in terms of social justice (Werritty et al., 2007; Houston et al., 2011).

Climate change impacts on tourism

The large number of beaches around Scotland's coastline represents a major resource for recreation and tourism. The **CCRA projections** (Defra, 2010b) report the potential loss of 45-225 hectares of beach by sea-level rise by the 2020s rising to 193-964 hectares by the 2080s (approximately 3% to 12% of the total area of beaches in Scotland). Figure 3 reports projected changes under the Medium emissions scenario.

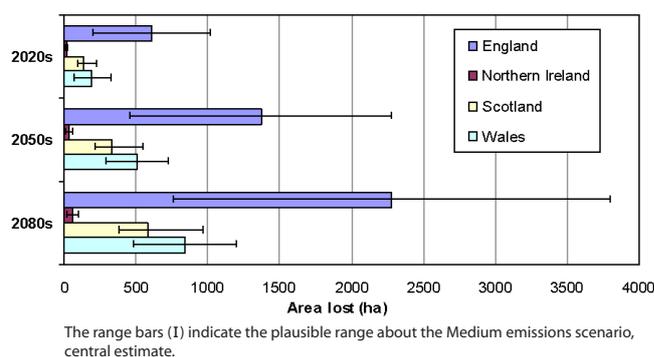


Figure 3: Projected loss of UK beach area due to sea-level rise (Defra, 2010b p. 151)

These rates of erosion are especially serious for many historic golf courses including the world famous links courses in St Andrews (Old Course), South Ayrshire (Turnberry) and Gullane (Muirfield). At St Andrews, dune restoration is currently being used to strengthen existing natural coastal defences, although its success will largely depend on controlling public access to the beach via designated hardened footpaths (Figure 4).



Figure 4: Dune restoration, St Andrews © Copyright Richard Webb



Figure 5: Skara Brae on Orkney (Source: Ian Williamson)

Ancient and historical sites located around Scotland's coast are also vulnerable to flooding and coastal erosion. Based on reports by [Scottish Coastal Archaeology and the Problem of Erosion](#) (SCAPE, 2012) more than 10,000 ancient and historic sites are vulnerable, one of the most iconic being Skara Brae on Orkney (Figure 5).

Emergency Services

The emergency services are mobilised when a flood occurs and provide immediate assistance to people and households already inundated or immediately at risk. They may also assist with post-flood recovery. The recently installed joint SEPA/Met Office [Scottish Flood Forecasting Service](#), coupled with [SEPA's Floodline Direct](#), provides much faster and effective flood warnings for coastal settlements. Although the location of future floods cannot be identified a long way ahead, locations at risk can now be identified within the [243 Potentially Vulnerable Areas](#) (SEPA 2011) with emergency service resources appropriately

deployed. There are no readily accessible statistics on the contribution the emergency services currently make when flooding occurs in Scotland (Case Study 3.1). But extrapolating from data available for England and Wales, it is likely that this effort could roughly double by the 2050s and roughly triple by the 2080s (HR Wallingford et al., 2012).

It is likely that emergency services during flooding could roughly double by the 2050s and roughly treble by the 2080s.

Should other important infrastructure components (e.g. hospitals, electrical power and communications) fail during a flood, the emergency services will be slowed down in their response leading to even greater impacts on those flooded.

Case Study 3.1

The Emergency Response to Rainfall and Flooding on 1st November 2009 (HR Wallingford et al., 2012, p. 135).

On 1st November 2009 torrential rain fell across large parts of Scotland, causing significant flooding and closure of many roads and rail regions across the country.

In the town of Stonehaven Aberdeenshire, a flood event estimated as having a return period of 1 in 200 years resulted in a large rescue operation by the emergency services. One hundred properties had to be evacuated, and another 200 homes across Aberdeenshire experienced flooding. In total, Grampian FRS received over 330 calls within 12 hours due to this rainfall event.

Many roads across Grampian and Tayside were closed by the police due to floodwaters, and the police received reports of motorists trapped within their vehicles. Car accidents, due to the bad weather required police and ambulance services to attend. The police also had responsibility of organising and starting evacuation procedures, as well as keeping the council updated. A council spokesman admitted that throughout the event resources were “stretched to the limit”. In Angus the emergency services were under similar strain, with fire crews rescuing trapped motorists, pumping burst culverts and property, and the police responding to flood incidents, car accidents and closure of roads. Furthermore, landslides occurred in Arbroath and Brechin.

3.1.2 Infrastructure and Buildings

Many of the risk assessments in this category are generic to flooding and not always specific to coastal flooding. Thus ‘transport’ has some specific features which relate to flooding on the coast, whereas ‘infrastructure’ and ‘buildings’ are more generic in terms of their risk assessment.

Transport

In January 2005 during an exceptionally severe storm, a causeway in Uist was overtopped resulting in five fatalities. Such tragedies are rare but they serve to illustrate the vulnerability of road networks in low-lying coastal areas especially in the Outer Hebrides and Orkney (Figure 6).

Road and railway networks close to and often parallel to the coastline provide essential transport links between coastal settlements. But their very location means that

with sea-level rise they will be exposed to more frequent inundation and potential damage.

To combat this Network Rail has sophisticated systems

Road and railway networks close to the coastline will be exposed to more frequent inundation and potential damage.

both to anticipate threats to the most vulnerable sections of track and, when damage has occurred, to rapidly restore service. Where the track runs very close to the shoreline, e.g. along the upper Forth and in Angus, the ballast

forming the track bed often serves as an informal coastal defence.

Storms and elevated wave heights can also produce the temporary loss of ferry services to the Western and Northern Isles. At present the costs of adverse wave action on ferry services to the Western Isles is of the order of £10 million per year (HR Wallingford et al., 2012).



Figure 6: Road damage on Orkney after December 2011 storms (Source: BBC News)

Infrastructure

Other strategically important infrastructure vulnerable to coastal flooding are power stations (which need water for cooling) and waste-water treatment plants. Existing power stations are well defended against extreme floods and, at present, there are no proposals to replace existing nuclear power stations. However, the energy distribution and transmission system is more vulnerable to flooding, and it is likely that some of the 43 substations within SEPA's existing *indicative flood map* will be in the coastal zone. It is often necessary to locate waste water treatment plants in the coastal zone. Any new substations within the coastal flood zone will require high levels of protection. As with electricity infrastructure these will need a very high standard of protection from future flooding.

Any new substations within the coastal flood zone will require high levels of protection.

Buildings and the urban environment

Flooding from the combination of sources is likely to increase with climate change. Where rising sea-levels cause more frequent 'tide-locking' of outfalls from sewers during normal tidal cycles, remedial measures will be needed to prevent local surface water flooding. Increased

coastal flooding due to high tides superimposed on storm surge and increased wave heights will also result in more damage to buildings. It is highly likely that some properties not currently flooded will become subject to future flooding. Where improving existing flood defences or constructing new ones is not possible, other measures such as rigorous planning controls and managed realignment of the coastline will need to be considered.

Where improving existing flood defences or constructing new ones is not possible, other measures such as rigorous planning controls and managed realignment of the coastline will need to be considered.

3.1.3 Health and Well-being

The health and well-being risk assessment for coastal flooding is also generic to all types of floods. As the incidence of flooding increases there are likely to be more deaths, injuries and mental health effects. Coastal flooding has the additional hazard of people being struck by waves and washed out to sea. In general the number of flood-related deaths in the UK is small: the fatalities on Uist in 2005 being a notable exception. Including wave-related

deaths during normal high tides, it is estimated that by the 2080s under the High emission scenario annual deaths and injuries in Scotland attributable to flooding will be around 5 and 100 respectively (Source: HR Wallingford et al., 2012, p. 170).

The mental health effects of floods are estimated in the UK CCRA (Defra 2012b) as around 30-40% of those flooded. UK data estimating increased mental health impact as result of climate change suggest that by the 2050s 4000-7000 could be affected rising to 5000-8000 by the 2080s (Source: HR Wallingford et al., 2012, p. 170). Making no allowance for future population change and allowing for the number of properties at risk of future flooding, comparable values for Scotland are like to be up to one tenth of the UK values.

3.1.4 Natural Environment

Coastal erosion

Along with the rest of the UK, the coastline of Scotland is subject to erosion (see Chapter 5) but only 12% of the coastline is recognised as in a state of erosion as compared to 30% of the coastlines in England and Northern Ireland and 20% in Wales. This reflects the fact that 70% of Scotland's coastline is made up of hard, resistant rocks in contrast to the soft, readily erodible rocks for much of eastern and southern England. But locally where softer rocks predominant, especially Scotland's eastern firths, the coastline is subject to higher and increasing rates of erosion (Ball et al., 2008) and flooding. Case Study 3.2 explores potential habitat change on the Dornoch Firth of these changing rates of erosion.

Case Study 3.2

Habitat changes at the Dornoch Firth (HR Wallingford et al., 2012, p. 135).

Morrich More in the Dornoch Firth is a transgressive dune plain resembling a staircase of sand dune ridges that extends from the Holocene cliff line down to the present day beach (Hansom, 2001). Within the lower and younger part of the dune system, saltmarsh occupies the low troughs that lie between the higher sand dune ridges. The extent of each habitat reflects subtle altitude changes and the frequency of inundation of sea water.



Morrich More, Dornoch Firth
(Source: ©P&A Macdonald/SNH)

The Dornoch Firth highlights a number of key changes which support the hypothesis that changes in sea level leads to geomorphological and ecological responses within the coastal zone. Erosion and frontal recession has replaced long-term accretion along the northeast facing frontal edge of the dune system. This appears to be the most extensive erosion in the 7,000 years, and is now reworking the eroded sediment towards the dune interior via the low-lying saltmarsh troughs. Ecological adjustments have also been identified and numerous examples can be seen of pioneer saltmarsh species invading lower edges of mature sand dune habitats.

Terrain analysis is being undertaken to establish the areas of sand dune which are likely to change into saltmarsh, under various climate change and sea-level rise scenarios. At a scoping level this analysis will help identify the gross landform and habitat changes that we might expect to our dynamic coastal habitats over the coming decades.

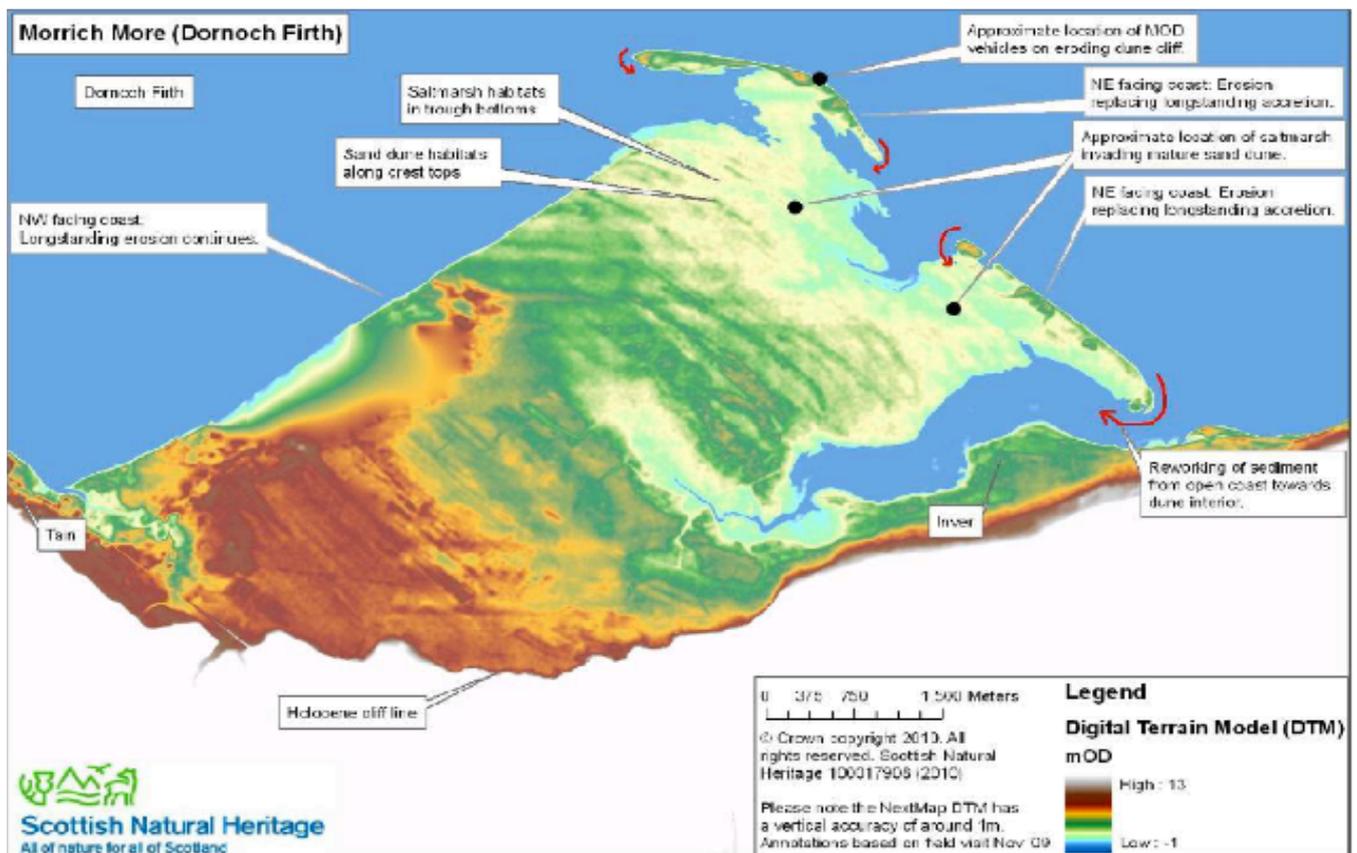


Figure 7: Topographic map identifying key locations and processes (Source: HR Wallingford et al., p. 135)

Lessons from Case Study 3.2 include:

- Sea-level rise will inevitably result in some habitats (here coastal dunes) being replaced by others (here salt marshes)
- This may have impacts in terms of changes in local biodiversity
- Erosion and flooding control in such sites is best undertaken by allowing natural processes to proceed rather attempting costly hard engineered defences

More generally, areas at particular risk will be low-lying coastal settlements with soft coastal defences (e.g. sand dunes) and those parts of the Orkney Isles and Western Isles where sea-level rises could cause widespread inundation.

Saline intrusion

One of the inevitable consequences of sea level rise is the movement of saline water into freshwaters and aquifers flooding protected habitats. In the Outer Hebrides rock basins will eventually become fully saline: whilst in the Northern Isles this is likely to occur on existing lagoons, especially as storms dismantle shingle barriers causing freshwater lochs to become saline. In general, the tolerance of species in existing freshwater habitats will be limited although in some instances saline intrusion may result in habitat gain (e.g. as a result of coastal realignment). Those habitats with limited ability to adjust will see the loss

of salt-intolerant species, changes in soil structure and changes in fauna (e.g. loss of invertebrates, fish and amphibians).

Extreme Events

Scotland's shallow marine and coastal habitats support many unique ecosystems which are highly valued in terms of tourism and aquaculture. With increases in extreme sea levels (caused through storm surges, high tides and wave action), coastal flooding is likely to alter the composition and range of shallow marine habitats. This may result in more frequent inundations of isolated lagoons, which are unable to adjust to the rate of their salinisation. The increased saltwater intrusion on terrestrial environments could also impact on important bird breeding sites and priority habitats alongside economically important recreational sites (Figure 7).

An additional impact of rising sea levels is greater turbidity and deeper waters which decreases light penetration to submerged vegetation. Sheltered habitats, currently stable in terms of sediment supply and loss, are likely to be damaged either from erosion caused by more frequent flooding, or by deposition of sediment burying plants and organisms. Thus the increasingly dynamic coastal environment resulting from climate change (e.g. the erosion of salt marshes and lagoons) is likely to be detrimental to organisms which depend on a degree of stability in order to become established.

Coastal Squeeze

As sea-levels rise, coastal landforms are forced to 'roll

over' and migrate landwards. If constrained by existing coastal defences, the result is 'coastal squeeze' which can result in a reduction in space for intertidal habitats such as salt marshes or coastal grazing marshes. These habitats are often designated by the EU for nature conservation as a **Special Protected Areas** for bird populations or as a **Special Areas of Conservation** for specific habitats or species. Increased tourism as a result of warmer and drier summers is likely to add to the pressures on vulnerable coasts – mostly notably by trampling and damaging marram grass which stabilises dunes thereby adding to natural coastal defences (Figure 4).

Climate Change: Conclusions

It is striking that two of the nine potentially most significant threats for Scotland arising from climate change involve coastal flooding with a further two relating to the impacts of generic flooding. Specifically these four most significant threats comprise (HR Wallingford, 2012):

1. Changes in coastal evolution affecting people, property, infrastructure, landforms, habitats and species
2. Increases in flooding both on the coast and inland affecting people, property, infrastructure, landforms, habitats and species
3. Increases in insurance losses, ICT disruption and transport network disruption resulting from an increase in the occurrence of extreme weather events
4. Increase in the number of people at risk of death, injury or mental health problems as a result of flooding

The CCRA for Scotland also assesses these risks in terms of the 'urgency of decisions' and again it is striking that coastal flooding forms a component of one out of the three high urgency issues and characterised as "increases in flooding and diffuse pollution both on the coast and inland affecting people, property, infrastructure, landforms, habitats and species" (HR Wallingford, 2012, p. xvii): with the recommendation that adaptation commence now and the capacity to address the issue be expanded.

In sum, coastal flooding and erosion is seen in the CCRA for Scotland as one of the three most pressing issues for immediate action given the threat posed by climate change.



4. Relative Sea Level Rise

Coastal flood events have been recorded in Scotland for many centuries and several sources have attempted to build databases of coastal flood events in the UK (Law et al., 2010; Black and Law, 2004). This history of coastal flooding has taken place against a background of rising sea levels around the Scottish coastline. Sea level rise, however, is just one of several processes that contribute to coastal flooding. However, given the scenarios of how climate is likely to change in the future, the significance of sea level rise is likely to increase in importance in the future in respect of how we understand changes in the magnitude and frequency of coastal flooding.

There are five key processes that drive flood risk at the coast:

- Relative sea level rise – the local change of sea level relative to the land
- Surges – the temporary change in sea level resulting from meteorological (wind and atmospheric pressure) forcing of the ocean surface
- Waves – the wind induced disturbance of the sea that propagates across the surface
- Coastal morphology and sediment supply – change in the form of the seabed, shoreline and adjacent coastal land, and estuaries
- Socio-economic change – changes to population, demographics and asset value will affect the impact of flooding as well as our ability to recover'

(Horsburgh et al., 2010:1)

4.1 Relative Sea Level Rise

Relative sea level change is influenced by several factors including:

- Thermal expansion or contraction of the ocean volume due to global warming or cooling;
- Increased ocean volume due to water input from glaciers, ice caps, ice sheets and areas of permanently frozen ground (permafrost areas);
- Vertical Land Movement near the coast due to glacio-isostatic adjustment (GIA), tectonic uplift and subsidence, mining subsidence, etc.

Since 1993, data from satellites have enabled scientists to construct maps of the global ocean surface. Calculation of the average of all the measured values for each satellite mapping exercise (listed below) shows that on average the

- CU: 3.2 ± 0.4 mm/yr (Colorado University Sea Level Research Group, 2012)
- AVISO: 3.2 ± 0.6 mm/yr (Archiving, Validation and Interpretation of Satellite Oceanographic data, France)
- CSIRO: 3.1 ± 0.4 mm/yr (Commonwealth Scientific and Industrial Research Organisation)
- NOAA: 3.2 ± 0.4 mm/yr (w/ GIA) (National Oceanic and Atmospheric Administration)

height of the ocean surface has been increasing by just over 3 millimetres per year (Figure 8).

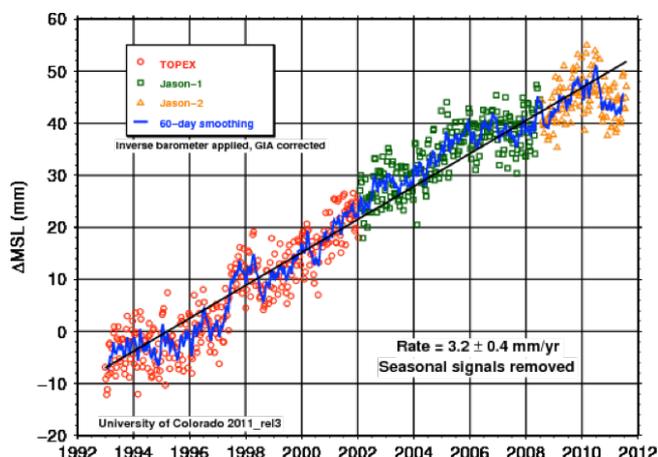


Figure 8: The average value of global mean sea level time series based on analysis of ocean surface altitude data. The black

line is a linear plot through the data. The blue line represents the application of 60-day statistical smoothing. The different coloured circles correspond to successive series of satellite mapping and measurement (Colorado University Sea Level Research Group, 2012).

The diagram illustrates just how complex it is to interpret the meaning of trends. For example, the blue line shows that between late 2010 and early 2011, average global mean sea level fell by around 6 millimetres. This lowering was due to extraordinary high rainfall across land areas bordering the Pacific. This caused

If we ignore relatively short-term effects, we can conclude that the average rate of global sea level rise is currently just above 3mm/yr.

a net lowering of sea level that ended when most of the freshwater was returned to the oceans. If we ignore such relatively short-term effects, we can conclude that the average rate of global sea level rise is currently just above 3 mm per year.

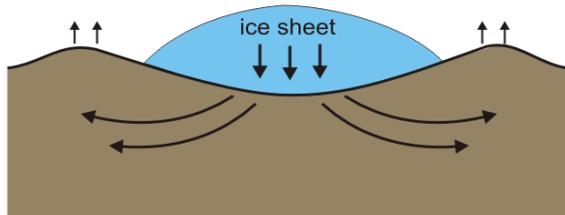
It is well known that around 80% of the increased warming of the atmosphere (global warming) is absorbed and stored within the world's oceans. As the ocean water column absorbs this heat, it expands very slightly causing the sea surface to rise. This process is known as the thermal expansion of ocean water. Other factors also contribute to the rise in sea the most well-known being the release of water from melting glaciers. Thermal expansion of ocean water is, however, the most important process contributing to the rise in sea levels worldwide and accounts for just over half of the observed rise in sea level during recent decades (IPCC Fourth Assessment Report (AR4)).

Vertical land movements are also crucial in determining at what rate relative sea level has changed across Scotland in the past (Figure 9). For most of the country, these vertical movements have been typically in an upward direction, but some peripheral areas may still be experiencing subsidence (Milne et al., 2006; Bradley et al. 2009).

For Scotland, relative sea level change has been calculated

from tide gauges (over the last century) and satellites (over the last several decades). Both methods produce different values as the tide gauge data are restricted to coastal areas while the satellite data covers the globe (Marcos et al., 2007).

a. Peak glaciation



b. During deglaciation

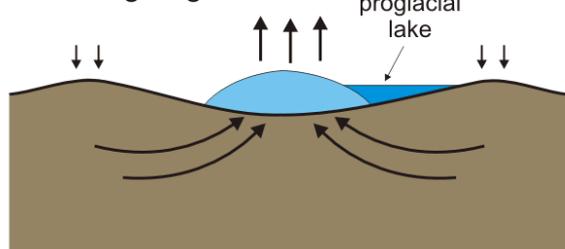


Figure 9: Scotland experienced both sinking of the Earth's crust (central areas) and uplift (outer areas) due to the load imposed by the last Scottish ice sheet. Ten thousand years later the central areas are still continuing to rebound while the outer areas are sinking.

Tide gauge records show that across the world, sea levels rose by approximately 19.5 cm between 1870 and 2004 at a rate of 1.7 millimetres per year (Church and White, 2006; Shennan et al. 2010, 2011). Across Scotland there are 18 tide gauge datasets over 16 locations

that typically show present rates of rise in the order of +2 millimetres per year (Table 9, in the Appendix 1).

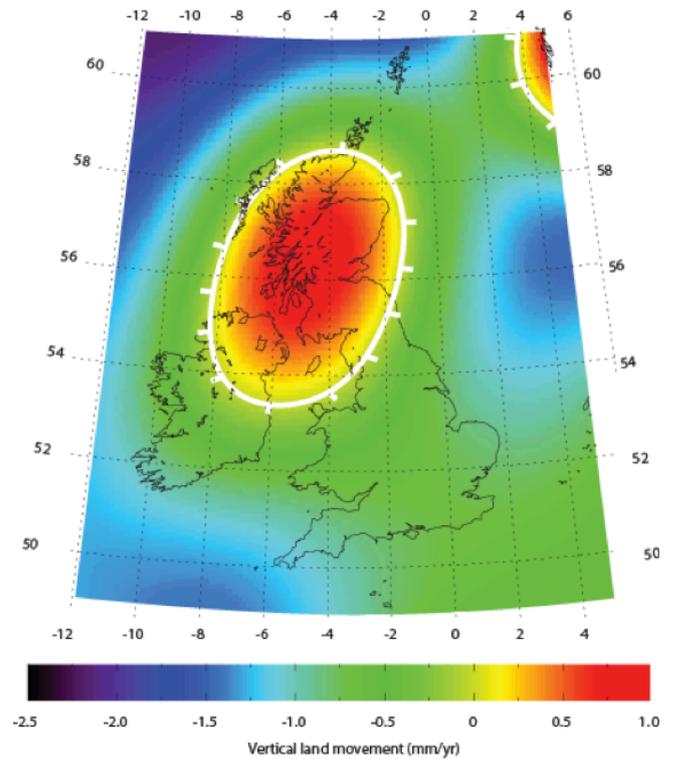


Figure 10: Vertical land rebound map from UKCP09 (values in millimetres per year) (Bradley et al., 2009).

The tide gauge records and satellite data show recent patterns of relative sea level change made up from rates of present day vertical land rebound and sinking combined with the effect of changes in the volume of water stored in the oceans caused by global warming (Figure 10). The most recent UK Climate Impacts Research Project (UKCP09) has estimated the likely relative sea level change patterns across the UK up to 2095 (Jenkins et al., 2009) (Tables 2 and 3).

Emissions Scenario	2020			2050			2095		
	5th	50th	95th	5th	50th	95th	5th	50th	95th
Low	0.6	4.3	8.0	1.9	10.5	19.1	5.2	23.4	41.6
Medium	0.9	5.7	10.6	2.6	13.9	25.2	6.7	30.5	54.3
High	1.3	7.5	13.7	3.6	18.0	32.3	9.0	39.2	69.5

Table 2: UKCP09 relative sea level change estimates for 2020, 2050 and 2095 at Edinburgh (cm) according to 3 emissions scenarios (low, medium and high) for future climate change.

Emissions Scenario	2020			2050			2095		
	5th	50th	95th	5th	50th	95th	5th	50th	95th
Edinburgh	0.9	5.7	10.6	2.6	13.9	25.2	6.7	30.5	54.3
Aberdeen	1.7	6.6	11.5	4.3	15.6	26.9	9.8	33.6	57.4
Wick	2.3	7.1	12.0	5.4	16.7	28.0	11.6	35.5	59.3
Lerwick	5.9	10.8	15.7	12.7	24.0	35.3	24.5	48.3	72.1
Ullapool	1.5	6.4	11.2	3.8	15.1	26.4	8.9	32.8	56.6
Stornoway	3.0	7.9	12.8	6.9	18.2	29.5	14.3	38.2	62.0
Tobermory	0.6	5.5	10.4	2.1	13.4	24.7	5.8	29.7	53.5
Millport	0.1	5.0	9.9	1.1	12.4	23.7	4.2	28.0	51.8

Table 3: Relative sea level change (cm) for several locations across Scotland based on the UKCP09 medium emissions scenario.

4.2 Storm surges and extreme waves

The effects of severe winter storms probably represent the greatest immediate threat to human life and property at the coast. If sea level rises as predicted, in the future the hazard of major storms at the coast may become more severe. The generally accepted view of climate change scientists is that North Atlantic storms will decrease in number in the future but may increase in intensity (*Lowe et al., 2009*).

Ocean wave modelling studies indicate the northern and western coastlines of Scotland will continue to be affected by higher surge events rather than in eastern areas. Individual coastlines will continue to be most affected by single rare events associated with often quite different

weather patterns. Thus coastal areas of the Outer Hebrides experienced the most destructive storm in living memory together with an estimated 2 metre surge on January 11th 2005 – caused by a deep Atlantic depression that tracked from the south and SW across western Scotland. By contrast, in eastern Scotland two of the worst storms associated with large surges took place respectively in January 1953 and March 2010. Both were associated with prevailing winds and waves from the N and NE. Whereas coastlines bordering the North Sea are rarely affected by storm-force winds from the north and NE, coastal areas of western Scotland are much more frequently affected by severe Atlantic gales from the south and SW.

4.3 Coastal flooding, tides and sea level

The tidal range around the majority of Scotland's coastline is between 3-4 metres. In some areas, however (for example the Solway Firth) the tidal range may exceed 6 metres. Tidal extremes vary annually, the greatest extremes being due to changes in the position of the moon and planets in relation to the Earth. When a major storm occurs across a given coastal area, the coastal damage may be negligible if the storm occurs during a period of low tide. The most

severe coastal damage usually occurs when a major storm is sustained over a long time interval, usually in excess of 12 hours. When the peak of the storm takes place during a period of high astronomical tides, as was the case with the destructive Outer Hebrides storm of January 11th 2005, storm-generated floodwaters have the greatest potential to cause severe flooding and damage to coastal infrastructure.

Relative Sea Level Rise: Conclusions

- Relative sea levels rose at a global average of 19.5 cm between 1870 and 2004. Thermal expansion of the ocean water column is generally regarded as the key factor influencing higher sea levels in the future;
- Analysis of UKCP09 sea level projections suggests an average sea level rise across Scotland of 22.7 cm by 2095 using the Medium emissions scenario. Higher emissions scenarios produce greater estimates of sea level rise;
- Sea level rise will increase the potential heights of sea surges although the nature of individual extreme weather events remains the key factor determining a specific surge height for a given location;
- Sea level change rates projected by the UKCP09 Medium emissions scenario are large enough to cause inundation, erosion and damage to the coast although individual extreme events represent the most important influence on rates of coastal erosion;
- The cumulative impact of sea level change, storm surges waves and tidal regime should be considered in the evaluation of any proposed coastal development. The history of such changes for a given area should be investigated before any development is contemplated.



5. Shoreline Management Plans and Coastal Strategies

For a relatively small country in terms of surface area, Scotland has a very long, complex and diverse coastline. The most recent measurement of its length by Scottish Natural Heritage, based on the Ordnance Survey's 1:10,000 coastal outline using ArcGIS, is 18,670 km (Angus et al., in press). Thus, Scotland's coastline is equivalent to approximately one eighth of the European total.

The pressures leading to coastal defence in Scotland have historically been far less than in England (Burbridge and Burbridge, 1994). Although around one fifth of Scotland's population live within 1 km of the coast and about 70% within 10 km (Scottish Executive, 2005), the low total population (c. 5 M people) relative to the area of the landmass results in many areas of essentially undeveloped coastline, especially in the north and west. Of the country's estimated 790 islands (Scottish Executive, 2003), only 130 are inhabited (Scottish Executive, 2005). As a consequence of the generally much lower population density than south of the border, combined with typically more durable rock types characterising the coast, only about 6% of Scotland's coastlines are defended compared with some 44% of those in England and Wales (DEFRA, 2001).

Nevertheless there are several important 'hotspots' of erosion around Scotland's fringes (for example Montrose Bay in Angus; Milne et al., 2012). Many of which have been aggravated by human intervention, and overall it has been estimated recently that some 12% of the country's coastline is subject to erosion (Baxter et al., 2008).

5.1 Coastal Geology and Geomorphology

The geological variation that characterises Scotland, overprinted by the impact of repeated glacial activity during the Pleistocene, has a profound influence on the nature and morphodynamics of the country's coasts. In the north and west the characteristically rocky coast is deeply embayed and indented with numerous structurally-controlled NW-SE trending sea lochs and islands. The lochs and the narrow straits between the islands and islets are the legacy of glacial erosion, exploiting the structural grain to produce over-deepened troughs which flooded as relative sea levels rose when deglaciation commenced some 18,000 years ago (Price, 1983).

By contrast, the generally softer rock types that characterise the eastern fringes have given rise to a much simpler coastal platform, with numerous

depositional forms, and three major estuaries; the Moray Firth, the Tay Estuary and the Firth of Forth. The highly complex, indented west coast results in a low potential for longshore sediment exchange between adjacent coastal sections. In the east, however, the degree of sediment interconnectivity is much higher owing to the much simpler coastal morphology that results in far longer, continuous sections of soft materials that facilitate sediment exchange (Hansom et al., 2004; Hansom and McGlashan, 2004).

Pressures on the Scottish coast and the need to install defences is far from uniform and is most acute where major conurbations coincide with the coasts of the Midland Valley as in the Firths of Clyde in the west and the Forth in the east.

5.2 Coastal Protection

Virtually all of Scotland's coastal towns and villages have some form of hard engineered coastal protection which typically fronts onto a promenade, a road or a railway formation. In consequence, basal scour at the toe has led in many instances to beach drawdown. Many walls were typically constructed from locally sourced materials thus exacerbating the problem of beach drawdown and basal scour. All types of sea walls are represented in the country; from vertical masonry structures to inclined, stepped and curving designs constructed of concrete or gabions. Energy absorbing rock armour revetments have seen increasing usage since the mid-1970s. Old-established fishing settlements typically are fronted by vertical masonry walls dating back to the 1800s and often showing a patchwork of repairs made over the decades.

Historical defences have often exacerbated coastal erosion problems as a result of starvation of longshore sediment transport.

In many such situations flanking erosion, along with the starvation of longshore sediment transport, is a localised

problem that has typically been tackled by progressively extending walls, adding sections of rock armour or concrete rubble in an attempt to prevent the impacts of wave attack. In many areas the piecemeal approach to coastal erosion management, which for decades was so typical in Scotland, has led to then installation of unsightly defences. Starvation of longshore sediment transport has occurred in several places owing to the installation of groynes and many such structures today lie semi-derelict. Harbour walls and jetties have unintentionally interrupted longshore sediment transport rates at numerous localities around the country.

The pressure on the Scottish coast and the need to install defences is most acute where major conurbations coincide with the coasts of the Midland Valley.

It was not until the 1980s that more enlightened approaches to erosion control and coastal zone management in general were accepted and became adopted in Scotland. The planting of eroding dunes with marram grass (*Ammophila arenaria*) and lyme grass (*Leymus arenarius*) together with

the placement of geotextile or jute membranes and with prevention of public access by the erection of fencing are now common occurrences. A recent example (2010) of such coastal stabilisation is along a section of restored

Scotland's beach-dune systems are actively receding, with growing pressures along many of the soft coasts.

dunes of the West Sands of St Andrews (Fife Environment Trust, 2010), which are not only subject to wave attack from the North Sea but also, as a Blue Flag Beach in a popular tourist destination, to very considerable recreational pressures during the summer months. Beach recharge schemes, however, are comparatively rare in Scotland with one of the earliest and most successful being at Portobello on the eastern side of Edinburgh, which dates back to the early 1970s.

5.3 Coastal Zone Management

Wide varieties of rock types and structures, differing exposure to wave activity in a range of relative sea level change scenarios and variations in sediment supply have resulted in a broad range of coastal landforms and coastal processes in Scotland. Although coastal erosion is not as extensive as in England, many of Scotland's beach-dune systems are actively receding and there are growing pressures along many soft coasts in the country. It was noted in the late 1990s that, "No strategic approaches to coastal defence in Scotland, nationally or regionally, have been adopted or promoted to date and consequently protective work has proliferated in an ad hoc and unregulated fashion" (Lees et al., 1998). This has been the catalyst for many of the erosion problems of today. Since that time, however, management of the Scottish coast has evolved (see Hansom and McGlashan, 2004) through the formation of seven voluntary Local Coastal Partnerships (LCPs), such as the Tay Estuary Forum (Burningham et al., 2000; Booth and Duck, 2010), and the implementation of Shoreline Management Plans (SMPs) on the basis of sediment cells.

5.3.1 Sediment Cells and Shoreline Management Plans

The concept of coastal cells and sub-cells was introduced to Scotland by HR Wallingford (1997) after their initial development in England. Those defined around the coast of Scotland use different types of boundaries from the cells defined for the English and Welsh coast (Motyka and Brampton, 1993), although the cells have been defined in both cases to concentrate on the movement of beach material (sand and gravel). Fine materials that would not normally be part of the beach face (silts and clays) are ignored in the delineation of the cells. The theoretical

cell would be entirely enclosed, with no input or export of beach sediment. Although a structure that could affect sediment movement (e.g. a coastal defence) may have an impact upon the beaches within the cell, it should not have an effect on adjacent cells.

There are two main types of boundary between cells: littoral drift divides and sediment sinks. A littoral drift divide is usually represented by a sharp change in coastal orientation, where sediment moves away from the divide on both sides; an example would be a major rocky headland. In some places drift divides do not coincide with changes in coastal orientation, and in such cases, the divide may migrate, depending on the wave conditions. Sediment sinks are the opposite, being areas where sediment collects from two converging transport paths, often in sheltered and deeply indented bays. Any interference on one side of a sediment sink will not normally affect sediment movement on the other. Because of the size of these cells, most have been divided into sub-cells which are regarded as being partly dependent and not totally sediment-tight (HR Wallingford, 1997).

In Scotland the preference has been to define cells using drift divides (e.g., headlands) rather than sediment sinks. This allows for major estuaries to be considered within one cell, although they may be divided into a number of sub-cells, resulting in the whole estuary being considered as one unit when considering the effects of coarse sediment movement and coastal defence. Each of the 11 cells and 40 sub-cells defined for Scotland was analysed by Hansom et al. (2004) with regard to their internal coarse sediment interconnectivity and thus their suitability for the SMP approach and it was found that only four were "mainly suitable" (Cell 1, St Abb's Head to Fife Ness; Cell 2, Fife Ness to Cairnbulg Point; Cell 3, Cairnbulg Point to Duncansby

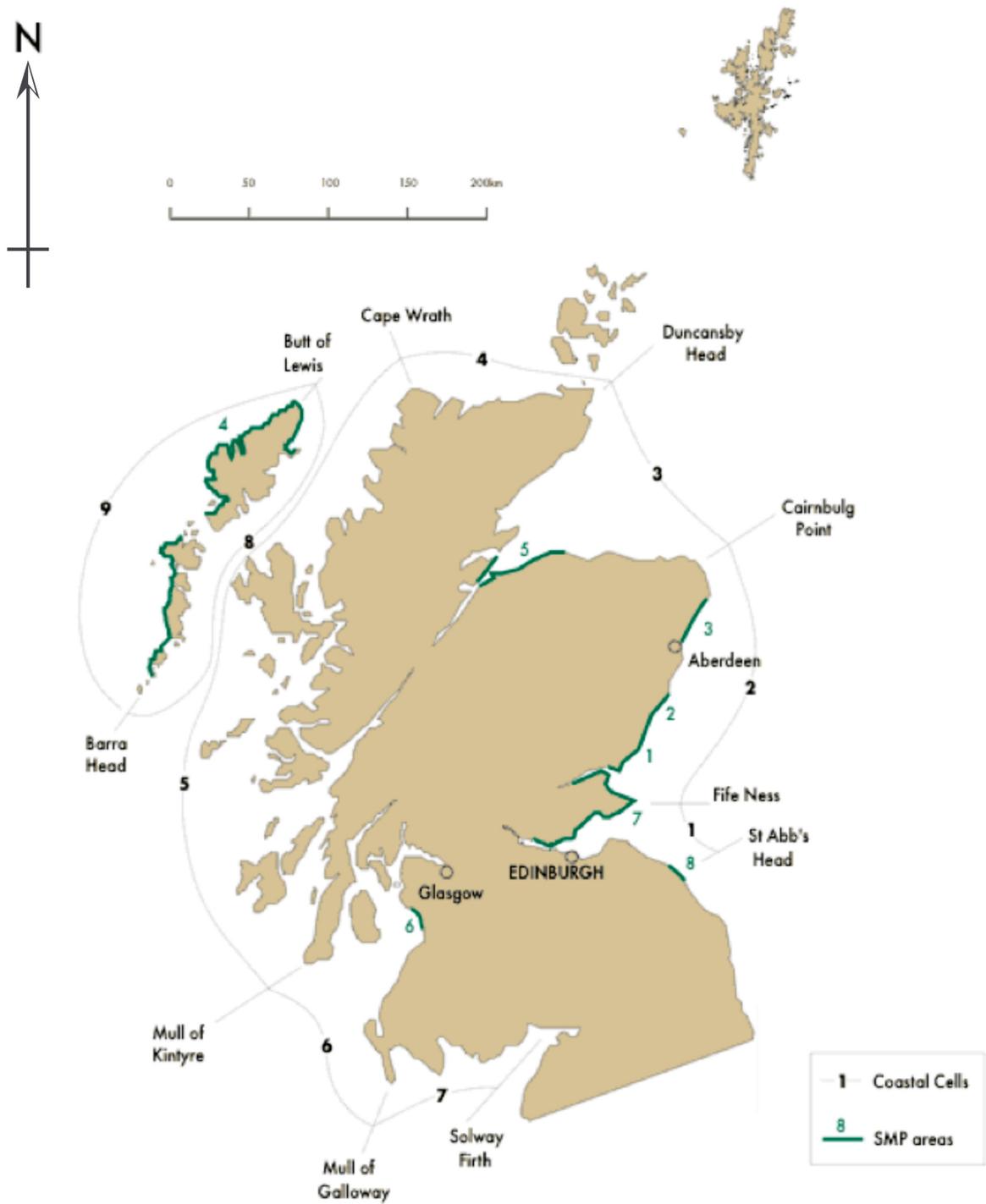


Figure 11: Location of regions and areas covered by “Coastal Cells of Scotland” series and Shoreline Management Plans and analogous studies. (SNH, 2000).

Head; Cell 6, Mull of Kintyre to Mull of Galloway) (Figure 11). The deeply indented west coast, in contrast to the much simpler planform in the east, is largely unsuited to sub-division into sediment cells.

Non-statutory SMPs were first conceived and introduced in England and Wales in 1993. Their aim is “to provide the basis for sustainable coastal defence policies within a sediment cell and to set objectives for the future management of the shoreline” (MAFF et al., 1995, p. 4), i.e. to provide a strategic framework for decision making along the coast,

especially with respect to defence, taking account of the natural coastal processes, human and other environmental influences and needs (Environment Agency). Today the whole length of the English and Welsh coast is covered by such plans, some in their second generation. Only eight exist for Scotland, however, of which the best developed are those for the coasts of Angus, Fife and the northern (i.e. Scottish) shore of the Solway Firth. Moreover, they do not tend to coincide with the defined coastal cell (see Hansom and McGlashan, 2004). Each plan evaluates the natural processes that are acting on a length of shoreline and

predicts, as far as possible, the way in which it will evolve into the future. The principal issues of concern relating to coastal erosion and flooding are determined, along with the ways in which the natural processes are managed and identification of coastal assets that may be affected by erosion or the current management practices. As such, each plan must take account of the potential impact of present and future coastal defence schemes, hard or soft engineered, on the natural environment and the likely environmental, financial and social costs involved (Brooke, 2000). The Marine (Scotland) Act 2010 thus brings many challenges; not least how to join marine spatial planning, in whatever regions that emerge from the consultation, with management of the country's highly complex coastal zone for which there is an incomplete set of both LCPs and SMPs.

5.3.2 Process Defined Management Units

McGlashan and Duck (2000) first introduced the concept of the Process Defined Management Unit (PDMU) as part of a protocol, established to aid the identification of sites suitable for development on undeveloped coasts. The term PDMU refers to a portion of coast that is defined in terms of scale on the basis of the appropriate natural processes that are relevant to the specific issue that is under consideration (McGlashan and Duck, 2010). Unlike the coastal sediment cells-based approach used as a basis for the establishment of Shoreline Management Plans, the PDMU approach takes into account all sediment grain sizes, from very fine to very coarse (McGlashan and Duck, 2002; 2010). Furthermore, the approach takes into account sediment sources, sediment sinks and the intervening sediment transport pathways – both at the bed and in the water column, as may be appropriate to the issue under consideration (McGlashan and Duck, 2010).

Importantly, as articulated by McGlashan and Duck (2010), the boundaries of a PDMU are not simply defined by the alongshore extent, rather they should extend both inland and seaward into the fully marine realm, as appropriate.

The boundaries of a PDMU are thus defined on a pragmatic basis that is related to the topic of interest, for example, dispersal of pollutants or habitat migration. PDMUs thus permit planning on the basis of variable units of analysis in terms of dimensions. This is in contrast to the usual approach of pre-identifying cell or sub-cell boundaries which, typically along a coast, are 'sediment tight' for only sand and gravel sized materials (Motyka and Brampton, 1993; HR Wallingford, 1997). Furthermore, it has been suggested that marine spatial planning should be underpinned by some form of process defined planning unit that is determined in

Process Defined Management Unit (PDMU) can improve upon previous coastal zone management and provide a flexible approach for Marine Spatial Planning.

scale by the nature of the intended development. In this regard, it is proposed that the flexible Process Defined Management Unit (PDMU) approach, which has been introduced recently as an aid to sustainable coastal decision making and to improve upon previous coastal zone management unit approaches, provides a basis that responds to difficulties already being recognised within marine spatial planning (Duck, 2012).

Process Defined Management Units (PDMU) approach takes into account sediment sources, sinks and transport pathways.



6. Coastal Defences and Asset Management

Flooding and coastal erosion threaten people, their property, infrastructure and businesses. A long standing approach to this threat has been to emplace engineered structures such as sea walls, groynes and other barriers. One published estimate from the late 1980s (Ritchie and McLean, 1988), was that 429 km of mainland Scotland's coast was in some way 'artificial'. 307 km was in the form of coastal defences, the rest being other developments such as piers and harbours.

Partly because of the expense of constructing and maintaining coastal defences, and also because of greater awareness of the interconnectedness of coastal processes, so-called 'soft' engineering is gaining in popularity among both managers and other coastal stakeholders where protection from flooding and erosion is regarded as essential for sustainability. Such measures include dune stabilisation and beach replenishment, and in places, managed retreat or realignment.

In many areas, neither erosion prevention nor flood protection is economically viable and the only solution may be no active intervention. Much of Scotland's coastline now comes under a non-statutory shoreline management plan framework within which this option, and others such as 'hold the line', can be considered (see "Shoreline Management Plan Policies" on p38; Hansom et al., 2004).

This chapter gives summary overviews of approaches for delivering coastal flood protection and managing assets in the context of climate change. There is significant overlap in a practical sense between erosion protection and flood defence, even though they have a different legal basis (see Chapter 2). An overview is offered of approaches that can be referred to by practitioners for guidance on management approaches for flooding and coastal erosion.

Summary data and overviews are provided, resulting from an analysis of Scottish case studies in three main categories of programmes:

1. Formal schemes commissioned under the statutory flood protection regime (formerly the Flood Prevention (Scotland) Act 1961 and now the Flood Risk Management (Scotland) Act 2009);
2. Informal programmes for defence and erosion prevention, frequently conducted as a result of activity by management authorities in conjunction with other bodies such as private landowners, other public bodies;
3. Ad hoc activity by individual landowners, facilitated and regulated by public bodies.

More detailed material on the case studies is set out in the Appendix 2. It should be noted that the three types of programme are often interlinked, and this linkage

may or may not be made through inclusion as part of management strategies in an SMP.

Shoreline Management Plan Policies (DEFRA, 2006)

Policies for Management Units:

- Hold the Line
- Advance the
- Managed Realignment
- No Active Intervention

Policies need to be combined into a series of policy scenarios. At this stage, policy appraisal can occur with stakeholder involvement.

For more detail on setting up and SMP, including data requirements and stakeholder engagement strategies, reference should be made to the DEFRA (2006) guidance documentation that has been followed by local authorities in Scotland.

6.1 Update on Previous work

SNIFFER Project FRM 10 (Coastal Flooding in Scotland: A Scoping Study) undertook an extensive consultation of coastal local authorities in 2008-9. The consultation found that in many authorities, coastal defences were known to be in need of repair but, owing to restricted budgets, priority was given only when flood prevention was noted as a severe and generally recurrent issue – particularly, a risk to property/ infrastructure from absence of a defence or breakdown of an existing defence – and this was generally revealed by actual floods or ‘near misses’ induced by storms.

Many authorities knew coastal defences were in need of repair, but owing to restricted budgets, priority was given to defences suffering severe recurrent flooding.

infrastructure affected were small, flood protection via formal schemes was often simply not feasible, financially or environmentally. Such large capital schemes required much early investment in terms of feasibility studies and development prior to seeking formal Ministerial approval, and that this could not often be justified.

To solve financial constraints local authorities have moved towards private maintenance partially supported through public funds.

Local Authorities reported that the best way forward for management was often found to be agreements, formalised to varying degrees, for private maintenance with public support via part funding, inspection and maintenance. These frequently provided a joint flooding/ erosion protection benefit.

Where the number of properties or amount of

6.2 Flood Protection Schemes

6.2.1 Database and Records

There is no central record of all historic coastal management schemes in Scotland whether for flood protection or coastal erosion (Baxter et al., 2011: 160). Coastal flood protection schemes that had been approved up to 2008 are archived by the Scottish Government in the *Scottish Flood Defence Asset Database* (SFDAD), which is maintained continuously. Recent inspection of this database shows the schemes in Table 4 that were promoted by the statutory flood prevention process and in Table 5 that were constructed outside of this process. Figure 12, reproduced from the *Marine Atlas for Scotland* (Baxter et al., 2011), shows the location of the schemes as well as the two schemes for managed realignment that have

been brought forward so far (more details on the schemes in Figure 12 can be found in Table 6). The reader is referred to Baxter et al., 2011, p160, for more detailed information and case studies on managed realignment.

It can be seen that only a small number of exclusively coastal schemes have been approved under the Flood Prevention/ Protection Scheme Order process established under the Flood Prevention (Scotland) Act 1961, and only a few more out with this process, giving 14 schemes in total. Data are lacking for many of the older schemes, particularly on design standard, construction cost and properties protected. However, it is clear that there has been a recent (post- 2000) increase in the number of coastal schemes

No	Location	Coastal only or combined	Year approved/ constructed	Number of properties protected	Cost/£ at construction
13	Bo'ness Foreshore	Coastal	2006/2009	269	7,468,500
2	Saltcoats	Coastal	2006/2008	240	1,811,000
3	Largs	Coastal	2002/2008	n/s	678,317
5	Rothsay	Coastal	2002/2004	208	1,625,200
10	Carnoustie revetment	Coastal	Not known		
11	Monifieth	Coastal	Not known		
9	Ness River	Combined	2007/n.y.f.	1034	23,000,000
7	North Renfrew	Combined	2008/n.y.f.	293	6,600,000
14	Prestonpans	Combined	1972/1972	2	51,100*

* 2004 adjusted price n.y.f.: not yet finished

Table 4: Flood defences approved under the statutory regime - information listed in the Scottish Flood Defence Asset Database (see Figure 12).

No	Location	Coastal only or combined	Year approved/ constructed	Number of properties protected	Cost/£ at construction
1	Ayr South Pier	Coastal	Not known		
4	South Lanarkshire Clydesmill	Combined	Not known		
5	Glasgow Dalmarnock		Not known		
11	Monifieth	Coastal	Not known		
12	Kincardine		Not known		700,000
8	Conon Bridge		Not known		100,000

Table 5: Flood defences constructed out with statutory regime

obtaining Flood Prevention Orders. While the newer flood prevention schemes have conformed as far as possible to design standards advice (protection to a level of 1 in 200 years plus climate change), many of the older schemes were not designed to an equivalent standard. Consequently the actual level of protection offered by these older schemes can be hard to ascertain.

6.2.2 New legislative provisions

Under the legislative regime that will come into force with the [Flood Risk Management \(Scotland\) Act 2009](#) (see Chapter 2), it will remain the case that local authority powers to implement flood protection schemes are discretionary. In terms of legislative arrangements, the s. 60 (2), of the 2009 Act sets out the formal requirements for such schemes. For approval by Ministers, scheme documentation must:

- contain a description of the operations the local authority proposes to carry out,
- include such maps, plans and specifications as may be specified by regulations by the Scottish Ministers,

- state how the operations will contribute to the implementation of current measures described in any relevant local flood risk management plan, and
- in as much as they will not so contribute, state the reasons why the local authority considers carrying them out will not affect the implementation of those measures.

The main substantive changes in the legislation will be the requirement to show contribution to, and no detriment to, the implementation of the local flood risk management plan (see Chapter 2 for more detail on such plans). Aside from this, Schedule 2 of the Act sets out formal procedures for notification and formal approval of schemes. New rights of entry are granted to local authorities to carry out flood protection works either as part of a flood protection scheme or otherwise, to carry out maintenance of such works or to carry out investigations. A further important procedural change in these compared to the previous legislation is the deemed grant of planning permission on confirmation of a scheme by Ministers (s. 65), designed to speed up and simplify approval procedures.

6.3 Case studies and lessons learned

A case study on flood prevention scheme delivery is provided in Appendix 2. The following main points emerge from analysis of the schemes already constructed with regard to flood defence scheme planning:

- Economic damage assessments generally proceed in a similar way to those for fluvial flooding, using depth-damage relationships. However, there are important differences. At the coast, a 'threshold' is passed in a flood event. Below this there is generally little damage, but it can be passed very rapidly in an event, which may have disastrous results including risk of death or serious injury.
- Consequently, in planning defences, there are often few historical events for reference, and assessments need to incorporate flood extents and depths from 2-dimensional models.
- For defences, whole-life costs, including maintenance, must be considered in any cost-benefit analysis. Costs must be annualised

- UK Climate projections
- SEPA indicative Flood Map (coastal)
- Tidal, surge information from the Proudman Oceanographic Lab
- Statutory planning guidance

Management authorities use these manuals in a wide variety of ways. For flood prevention management planning, a data gathering is often necessary to ascertain the return period of surge and wave conditions on a local level, and it is also essential to apply an allowance for sea level change (see Chapter 4). As a consequence of various sources of uncertainty, a conservative Standard of Protection is necessary (SoP). Freeboard needs to be added to allow for climate change and sea level rise. Recent formal schemes have added allowances for both surge and wave conditions based on a combination of UK climate impacts estimates and local knowledge. The resulting designs are necessarily conservative, i.e. incorporating generous freeboard.

Reference sources for management authorities included:

- Wave overtopping manuals
- The Rock Manual
- The Beach Management Manual

Aesthetics are an important consideration for planning defences. A sufficient period of public consultation must be allowed for, usually of at least six months to a year to inform on design.

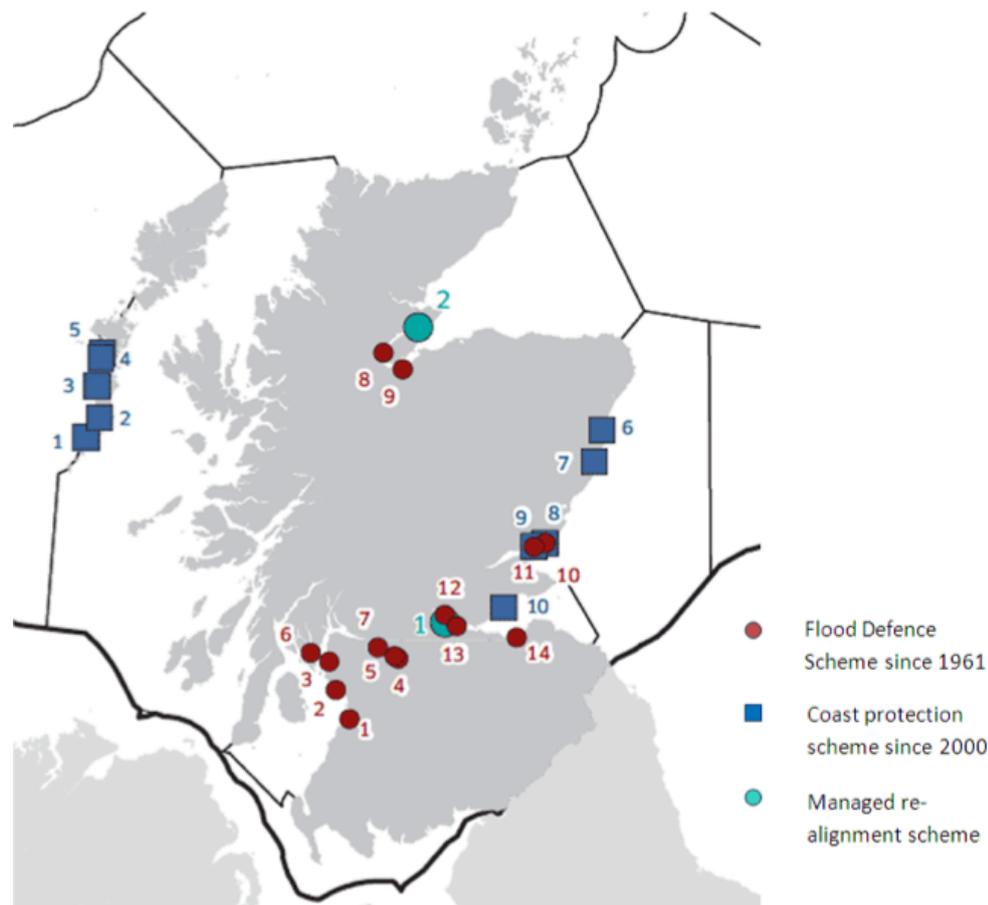


Figure 12: Flood protection, erosion protection and managed realignment schemes referred to in the text.

Refer to Tables 4, 5 and 6 for scheme details.

Reproduced from Baxter et al. (2011: 161). See Scottish Government <http://www.scotland.gov.uk/Publications/2011/03/16182005/67>

No	Location	Year approved	Length (km)	Cost (£m)
1	Craigston	2007	0.3	0.9
2	Ludag	2007	1.15	2.3
3	Stoneybridge	2007	0.5	0.2
4	Pol na Craan	2007	0.5	0.1
5	Balivanich	2007	0.15	0.5
6	Aberdeen Bay	2006	0.5	2.5
7	Stonehaven Bay	2000	No data	0.2
8	Carnoustie	2003	0.54	0.6
9	Tayview Caravan Park Monifieth	2003	0.4	0.4
10	Wemyss & Dysart	2000	No data	4.8

Table 6: Coast protection schemes approved for grant aid funding since 2000 (see Figure 12)

6.3.1 Informal programmes for flood defence and erosion protection

The statutory process for planning and delivering natural defences may not be appropriate for many management programmes, particularly those that are aiming to use

more natural or ‘soft engineered’ approaches for both flooding or erosion protection. On a local level, these methods are often more cost effective than hard defences, particularly if they can be carried out in partnership with local landowners, trusts and conservation bodies. The partnership at St. Andrews Links is an example of this (see Appendix 2).

Summary of schemes around Scotland's coast

- The most common approach is reinforcement of natural barrier systems such as coastal dune stabilisation. Piling fences, marram grass planting and occasional reinforcement by artificial means (such as geotextiles and gabion baskets) are used.
- In some circumstances beach replenishment has been tried and has had benefits, where the natural replenishment has been cut off (e.g. by an artificial defence).
- Because of the interconnectedness of natural defences with their sediment sources, strategic approaches are essential. Incorporation within the SMP framework is beneficial, but the land use planning process must have regard to the SMP.
- Similar considerations need to be given to standards of protection for 'soft' as per 'hard' flood defences, if they are to be relied upon for flood protection. However, often the data required to assess standards of protection accurately are lacking.
- Accurate modelling is needed to gauge the flood prevention benefit of the work. 2 dimensional modelling requires accurate LIDAR survey data. This is expensive and not always available, but when it is, it proves extremely helpful.
- Major landowners are often prepared to provide financial and management support partnership working between local authorities, private landowners and conservation bodies has led to excellent results in some areas (see Appendix 2). Common partners are: golf courses, the Ministry of Defence, port and Harbour management organisations.
- Historical/cultural assets have been protected by partnerships between various bodies and local authorities (see Chapter 3), which is often very important for tourism. However the viability of this work in the context of climate change is uncertain and must take into account locally specific information on such variables as sea level change and erosion rates.

6.3.2 Ad hoc protection and defence work by coastal landowners: support by local authorities

A further approach that offers potential to allocate funds fairly on an 'as necessary' basis is for the management authority to operate its own capital grant allocation scheme from its erosion protection/ flood protection funds, then publicise and invite landowners to apply to support from it. This delegates most or all responsibility to the landowner for actually carrying out the work, reducing public funding costs. Such approaches are generally quite rare. The case study provided in Appendix 2 provides one example of how such a system can operate.

- Such an approach requires careful design appraisal by the authority concerned for individual applications

and provision needs to be made for liaison with the landowner on design.

- When there are a large number of disparate, widely spaced properties so that the flood risk is spread along a long coastline, which is a common problem for areas in the Highlands and Islands, these schemes are more efficient and can work well. This is because they have the resources to be able to take on responsibility from the local authority to inspect and survey long lengths of coastline.

A disadvantage of the arrangements is that they are inherently reactive. Landowners will tend to apply to them only after they perceive a threat, and they may be more difficult to incorporate within an SMP unless there is an active stakeholder group involved that can plan strategically.



7. Coastal Adaptation Strategies

The term 'coastal adaptation' as used in this chapter refers to any change to the coastline which reduces harm to the coastal environment. These can include the exploitation of any opportunities as and when they arise. It also refers to any practical measures which are specifically undertaken to protect coastal communities from the likely detrimental consequences of climate change such as coastal flooding (e.g. Figure 13).

Several measures can be grouped under coastal adaptation, ranging from educational materials, changes to local planning decisions, coastal action plans including warning systems, soft engineering works including natural habitat restoration to hard engineering works. The selection of a specific form of adaptation is usually based on a wide range of considerations such as political, technical, environmental, social and economic restrictions as well as any specific benefits.

In Scotland there is only limited information on coastal adaptation, e.g. the Scottish Government Adaptation Strategy Framework has no specific website which stakeholders can use for information. In this chapter, different types of adaptation strategies have been discussed. Case studies of coastal adaptation measures are provided including their relative effectiveness and lessons learned. The first case study is based on a recent EU-funded research initiative called CoastAdapt aimed at safeguarding people living in North Atlantic coastal communities. The second is based on the Coastal Care Project in the Outer Hebrides, aimed at restoring dune systems as a form of soft engineering.

7.1 Selecting a Form of Adaptation

The needs for coastal adaptation in a given coastal area are often highlighted within individual Shoreline Management Plans. In other instances, need may arise following a destructive storm and/or extreme flooding event. If a coastal area is placed under stress, there will be a need for adaptation in order to reduce risk to people, property and wildlife. In many cases, the selected form of adaptation will represent a response to a perceived threat of increased erosion and/or flood risk – especially in areas where traditional forms of coastal defence may have failed to prevent accelerated coastal erosion and flood damage.

In many cases, however, the use of hard-engineering solutions as a form of coastal adaptation for coastal defence simply results in moving an erosion problem to adjacent stretch of coastline. In some instances, the economic cost of constructing ‘hard’ coastal defences far outweighs any economic benefits. In other instances, ‘soft’ defences put in place in order to ‘defend’ a coastal area subject to flooding represent little more than making coastal communities feel good that they are actively taking measures to protect a coastline but actually achieving

nothing. The knowledge base that underpins the selection of a specific form of coastal adaptation is therefore crucial since the stakeholder, whether it be a local authority or a private individual, needs to be properly appraised of the likely consequences of the adaptation measures being proposed.

7.1.1 Other Forms of Coastal Adaptation

While actions taken that are designed to influence the coastal environment are important, there are other forms of adaptation some of which require adjustments in human behaviour, for example through the processes of land use planning, and through improved emergency planning in relation to storms and coastal flooding. The use of local authority planning policy, and management of risk from all sources of flooding including coastal under Flood Risk Management legislation, are related directly to how people will adapt to a changing coast.



Figure 13: Flooding of golf courses at St Andrews following the storm of March 28th 2010. In this case, the construction of sea dykes paid by a private company (St Andrews Links Trust) was the particular mitigation measure chosen.

7.2 Planning Policy

Scottish local authority planning policy in relation to coastal flooding varies between authorities but complies with Scottish Planning Policy. Taking the proposed Outer Hebrides Local Development Plan as an example, the approach to be adopted for development proposals within areas at risk of flooding is:

1. Areas of low to medium risk: These areas will be suitable for most development with the exception of essential civil infrastructure such as hospitals, fire stations, etc. A flood risk assessment may be required.
2. Areas of medium or high flood risk: Developers will be required to provide a Flood Risk Assessment (FRA) undertaken to a competent standard, or other suitable information that demonstrates compliance with Scottish Planning Policy.
3. Areas bordering areas of medium to high flood risk: a topographical survey may be required to inform the needs or otherwise for a FRA.

The FRA will require to:

1. assess the level of risk of flooding arising from the proposed development;
2. demonstrate that the proposed development is compatible with the risk of flooding and;
3. include acceptable measures to mitigate the potential effects of flooding on and off the site arising from the proposal.

Where it can be demonstrated that the location is essential for operational reasons, e.g. harbours, piers, offshore energy and fisheries related activities, development proposals will be allowed in flood risk areas subject to sustainable flood management measures being incorporated at design stage that mitigate against flood risk.

In line with national policy, flood risk assessments and studies will be used in determining that acceptability of the site and proposed development, as well as any future flood risk implications arising from the development. Where the risk of flooding is deemed to be unacceptable the proposal will not be permitted. Where flood management measures are required, natural defences such as wetlands should be incorporated or developers should provide justification as to why they are impracticable.

7.2.1 Emergency Planning: Flood Alert System

A new system of providing direct flood warning alerts to members of the public is now operational in Scotland through the Floodline service. Improved flood warning is a significant adaptation measure which helps safeguard people at risk from coastal flooding. Members of the public, businesses, etc. can sign up to receive advance flood warning messages direct to their landline or mobile phone notifying when a flood warning has been issued for their local area.

Flood warning messages are published on the Floodline website operated by SEPA and through the Floodline recorded telephone service when flooding is predicted in local areas. Registered customers will also receive the message direct to their phone, encouraging them to go to Floodline for more detailed information to protect themselves and their property.

7.3 How to adapt?

There is a broad spectrum of adaptation measures that can be implemented. At one extreme is the use of engineering structures that alter and thus 'use' natural processes to achieve human-centred goals (Figure 14). In the middle area are 'soft' practices such as beach replenishment that augment sediment supply. At the opposite extreme is the attitude of doing nothing and not impeding coastal

processes by any form of human activity (Cooper and McKenna 2008). Such an extreme measure might be to surrender an area of farmland to the sea and transforming the area into a wildlife sanctuary.

All coastal communities and local authorities are presently learning how to adapt to the effects of climate change.

Some of the key issues include:

- How do communities and local authorities plan effectively for change?
- How should local authorities prioritise spending on coastal adaptation from their already financially stretched budgets?
- If no public infrastructure is threatened as a result of coastal damage, who pays for the adaptation measures?
- What implications do such plans have on local business, infrastructure and the historic and natural environment?

Coastlines are dynamic and change is of their nature. Erosion is just one form of change, and it is a natural part of coastal behaviour rather than a problem. Working with natural processes means that 'coastal protection' does not equal the protection of property or amenity. When there is a problem to be addressed, it is often wise to seek expert advice and to make sure that local residents play an important role in identifying the issues at stake and taking part in the decision-making process. There should always be a consultation process that included specialist coastal scientists and engineers, as well as meetings with local authority representatives, private individuals and other stakeholders.

For specific coastal problems, options to be considered on the basis of available finance include:

- Doing Nothing
- Monitor and Maintain
- Beach Replenishment
- Engineering work

Any given range of options should be reviewed at an expert workshop. Selected options should include an evaluation of the financial benefits accruing to a community set against the costs of the various forms of coastal adaptation measures proposed (Figure 15).

It should be borne in mind that coastal flood protection via formal schemes implemented by local authorities can often exacerbate coastal damage along a stretch of coastline adjacent to an area where coastal protection measures have been put in place.

Large capital schemes also require early financial investment to pay for feasibility studies prior to seeking formal Ministerial approval. If a proposed feasibility study proves to be too expensive, the whole project may founder at the first hurdle.

In many cases, 'soft-engineering' solutions prove themselves to be cost effective particularly if funded through a partnership of local stakeholders. Local authorities also need to be aware that if they employ a team of consulting engineers to provide a solution to a particular coastal problem, they may find that the consultants propose a

Care should be taken not to choose options which although providing community comfort, but no demonstrable positive outcome.



Figure 14: The storm of Jan. 11th 2005 in the Outer Hebrides presented major problems of how coastal communities adapt in response to extremes of climate change. Causeways that had been constructed to create an integrated transport network proved vulnerable to the effects of climate change.

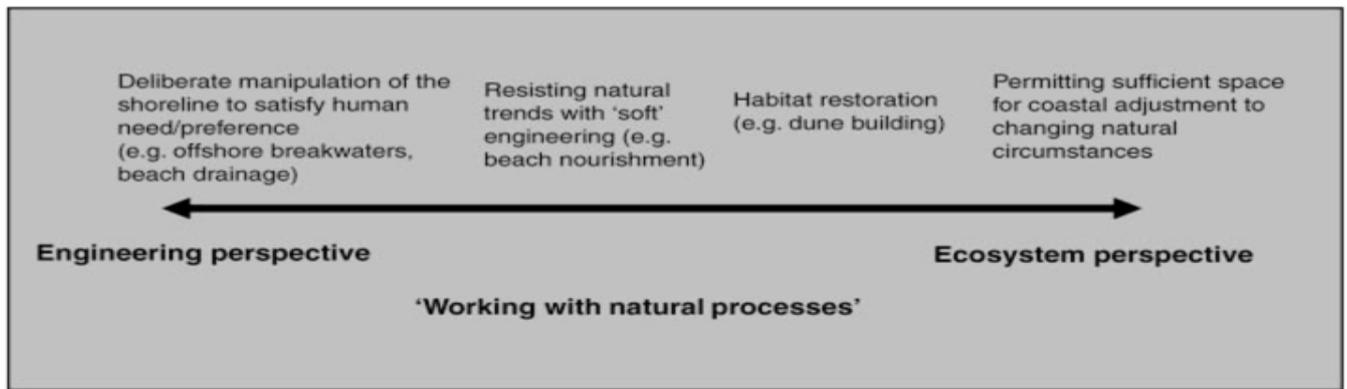


Figure 15: Forms of coastal adaptation can range from engineering structures to forms of beach nourishment through to the option of doing nothing (Cooper & McKenna, 2008).

relatively expensive 'hard-engineering' solution to the problem rather than a less expensive 'soft-engineering' solution.

The greatest danger is to select an option as a placebo—namely choosing a course of action on the basis that the community will feel good that something is being done even though the action itself has no demonstrable

positive outcome. This situation can often occur when the coastal protection works are relatively small-scale, when no external feasibility study has been undertaken and when a decision has been taken within a local authority to use part of its General Capital Grant (GCG) for environmental work to 'defend' a particular stretch of coastline come what may.

7.4 Project CoastAdapt

An international EU Project 'CoastAdapt', recently completed, has developed and implemented a range of adaptation strategies and tools to enable people living in coastal communities to take action and adopt strategies that deal with sea-level rise and reduce the negative impacts and risks associated with climate change as well as take advantage of the potential benefits.

CoastAdapt is an international partnership of local municipalities, environmental organisations and academic institutions involving local people and governments in a 'bottom-up' approach to the development of adaptive

response and preparedness to the impacts of climate change. The project is developing long-term recovery plans linked to the risk posed from natural hazards caused by climate change (e.g. storm impacts, instability of coastal cliffs). The CoastAdapt website provides data; information; tools such as handbooks, vulnerability assessments and adaptation implementation strategies and climate change networks across northern Europe. As such it provides a sustainable single site, one-stop web-based service to enable these resources to be accessed by end-users in coastal communities across the North Atlantic region.

7.5 Coastal adaptation case studies

Shown below are two case studies illustrating the processes involved in putting into place coastal adaptation measures. The case studies demonstrate very clearly the conflicts that can arise in choosing specific coastal adaptation strategies for given areas and that individual problems often have no

simple and straight-forward solutions.

Both examples and the key coastal adaptation issues are highlighted in the CoastAdapt video.

7.5.1 Case Study 1: Alleviating Coastal Flood Risk, Kilpheder, South Uist

When developing community based adaptation measures effective communication and consultation with and between all stakeholders at an early stage is essential. People may have a common purpose in seeking a solution to a particular coast related problem but each has their own view on how the problem should be addressed.

Background

The west coast of South Uist consisting largely of low-lying sandy plain (known as machair) and associated sand dune systems are vulnerable to Atlantic storms. The coastline is eroding due to a number of factors which include rising sea levels and past human intervention through using mechanised means of extracting sand and shingle from beaches. At Kilpheder, a 200 metre stretch of coast is particularly vulnerable to the impacts of erosion with a low machair edge protecting a large area of ecologically rich hinterland inland, much of it lying below high water tide level. Each storm further erodes the edge thereby lowering it and providing less protection from the next storm.

The land at this location is held in crofting tenure and owned by the community landlord. Organisations and people with an interest in the issue include the local crofting community, the community landowner, Scottish Natural Heritage (SNH) as well as the local authority who are participants in the CoastAdapt initiative. Pressure from the local community who fear loss of agricultural land through inundation by the sea has helped to persuade the community landowner to implement a scheme that would strengthen the coast where it was most vulnerable to erosion. The decision-making process involved public meetings called to explore what options were available, where funding could be sourced from, and who would take the lead in the development of a scheme.

Intended Outcome

The objective of any intervention measures was to provide an environmentally friendly and sustainable means of protecting a large area of low-lying land and inland loch system.

Decision-making process and options

Funding was granted by SNH to the landowner to develop and construct a coastal protection scheme. CoastAdapt offered advice from coastal experts who provided a range of options, but who preferred a scheme which would enable the coast to remain mobile and reposition and 'heal' itself over time. However, the experts recognised the concerns from the community that the loss of agricultural land on which a scheme would be constructed be kept to a minimum, and that time-constrained funding for a structure had been secured. The experts recommended the construction of an artificial dune using like for like materials in existence at the site enabling continued interchange of wind-blown sand from beach to dune. This ridge or 'bund' would be located on the landward slope behind the coastal edge curved at a shallower angle than that of the existing edge. The bund should be planted with dune grasses to strengthen the dune. The experts further recommended that a programme be put in place that would facilitate (or at least investigate the possibility of) gradual withdrawal from this particular area to enable future natural migration of the machair. Their opinion was that if this were to occur, then people would be truly adapting to coastal change, rather than merely mitigating the impact in the short term. Their proposal was to construct a bund consisting of crushed quarry rock sized (10mm-125 mm) placed over the coastal ridge and across the foreshore with sand placed behind the stone to a height of 2 m creating a 15m wide structure. Seaweed was then spread over the bund and dune grasses planted through the seaweed into the sand. Concern remains about the future sustainability of the structure as it is comes under attack by storm waves.

Key Points

- Future sustainability of whatever solution is adopted must be at the forefront of the decision-making process. Short-term fixes are to be avoided as are solutions driven by availability of funding streams.
- Beach erosion is only a 'problem' in human perception and is often caused by past human activities. Stakeholders should gain an understanding of coastal processes before embarking on schemes for coastal protection and expert advice should be sought at an early stage.

- Adapting to the impacts of erosion can offer a low cost solution, for example, moving an access track or accepting loss of land may result in a longer term solution than building expensive structures designed to fix the coastline in one place. Beaches and dunes are dynamic environments and should be recognised as such when addressing so called problems.

Conclusion

Although the outcome of the case of Kilpheder was not the best, and the process highlighted issues and tensions which in some ways pre-existed the need to find a solution, examples of good practice were demonstrated. Stakeholders recognised the need for discussion to take place as shown by the numerous meetings held by various parties. Momentum was built up and those having responsibility for safeguarding the land, and having capacity to take the scheme forward were instrumental in delivering the coastal protection scheme. However, the opportunity was lost for a more sustainable medium to long-term solution through desire for a visible short-term answer to be found that resulted in minimum impact on human activity.

7.5.2 Case Study 2: Coastal Dunes, the “Coastal Care Project”, Outer Hebrides

Coastal erosion, flooding, and the effects of climate change on the islands’ low-lying coasts are of major concern and this was borne out at the conference of the local coastal partnership, ‘Coast Hebrides’, held in 2006. People attending a series of coastal change seminars held since the conference have highlighted the need for action to tackle erosion on areas of soft, sandy coasts vulnerable to Atlantic storms.

The problem and related issues

Rising seas and storms are capable of breaching coastal dunes and inundating areas of low-lying land. Sustainable solutions include dune restoration and planting of marram grass. Erosion of sand dunes is a natural phenomenon and dune grasses rely on wind-blown sand to help them grow. However, blowouts in dunes, often caused by man-made activity, result in loss of sand from the dune system.

Blowouts also increase the vulnerability of the coast to erosion from the sea leading to loss of land.



Figure 16: Sand blow fencing, North Uist



Figure 17: Marram grass planting in Barra

The Coastal Care project is designed to implement a range of sand dune restoration projects in support of one of the main strategic aims of ‘Coast Hebrides’ to, ‘take forward the issues of climate change and develop projects to help mitigate and adapt to the effects of these changes’.

The projects are being put into practice on a partnership basis using local knowledge and community action as key to achieving a number of objectives:

- Raising awareness of coastal processes, the impact of human use of the dunes, and the need for sustainable dune control methods;
- Identification of vulnerable areas requiring restoration;
- Development and implementation of measures such as erecting sand blow fencing (Figure 16) and marram grass planting (Figure 17) designed to trap and stabilise wind-blown sand; and

- Where possible, the introduction of new methods such as the use of end-of-life fish farm cage nets made suitable for use in sand blow fencing.



Figure 18: Overtopping of a barrier island in South Uist as a result of winter storms

Implementation of measures

In order to help build up sand where it has been removed by wind, fences are located at right angles to the prevailing wind in rows across the blowout, starting towards the back, about four times their height apart.

An innovative approach is using fish farm cage nets with lead weights and nylon fittings removed, cut into manageable sizes of ca. 8m in length and 3m in width, to create sand fencing instead of more traditional wooden pallets, chestnut paling, or other pieces of timber. Marram grass is transplanted in the floor of dune blowouts.

Marram grows long roots in search of water and thrives when sand covers it encouraging new growth. The long strands of grass and root help to stabilise the newly built dune. In areas where fencing is found not to be successful, the materials are removed and used elsewhere. Dune control measures are not new. However, innovative methods such as using fish farm nets which otherwise would have gone into landfill, has the added benefit of being cheap and easy to erect and fosters community engagement.

Key Points

- Effective community engagement is fundamental to the success of such a project.
- It is important to involve people who have an interest in their natural environment and are willing to undertake work as part of a group on a voluntary basis.

Conclusion

Dune control measures in the cases study region have been undertaken for many years and are not something new. However, using innovative methods such as the end of life fish farm nets which otherwise would have gone into landfill, and has the added benefit of being cheap and easy to erect, makes it attractive for people to take part. However, care must be taken that fencing is erected in the correct location as the objective is for them to be quickly buried by wind-blown sand. Fencing which does not do what is intended should be removed.

7.6 Key Resources

- CoastAdapt
- Impacts of climate change on disadvantaged UK coastal communities
- Scotland's Climate Change Adaptation Framework - Biodiversity and Ecosystem Resilience
- Scotland's Climate Change Adaptation Framework- Sector Action Plans
- Adaptation Scotland
- Scottish Coastal Archaeology and the Problem of Erosion (SCAPE)



8. Other Relevant Information

This section details the key stakeholders and provides brief description about their roles and responsibilities in coastal management in Scotland. Also, the details about relevant legislations, policies and guidelines are provided. The websites are given for more information. The list is not exhaustive.

www.adaptationscotland.org.uk

Adaptation Scotland (formerly SCCIP)

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>Adaptation Scotland (AS) (formerly the Scottish Climate Change Impacts Partnership - SCCIP) was established to “increase the resilience of organisations and infrastructure in Scotland to meet the challenges and opportunities presented by the impacts of climate change. AS acts as a forum for information on environmental change adaptation and specifically aims to support policy framework implementation; provide adaptation planning support for organisations and communities; delivering adaptation skills training to help build capacity; act as a gateway for adaptation information in Scotland and provide technical support on the application of the UK Climate Projections.</p>	<p>Adaptation Scotland provide educational materials such as holding workshops and events aimed at policy and decision makers as well as key practitioners (‘Adaptation to a Changing Coast’, March 2012; ‘Marine & Coastal: New climate change tools and information for decision makers’, March 2010).</p>

Association for British Insurers (ABI)

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>The ABI is a trade organisation made up of insurance companies and aims to represent the insurance, investment and long-term savings industry. The ABI's role is to represent and lead debate for the UK insurance industry, to government, regulators and policy makers in the UK, EU and internationally. ABI also influence public policy and regulation whilst promoting the benefits of insurance to the government, regulators, policy makers and the public. They also provide useful information to the public about insurance.</p>	<p>ABI is active in implementing a strategy in Scotland for climate change adaptation. Part of this includes the provision of public information about house and contents insurance in at risk flood areas, measures home-owners can use to protect their properties. They also contributed to the formulation of the Climate Change (Scotland) Bill and the Flood Risk Management (Scotland) Bill, giving both written and oral evidence.</p>

A Co-ordinated Agenda for Marine, Environment and Rural Affairs (CAMERAS)

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>CAMERAS is a partnership initiative with an aim to further align and coordinate the scientific activity of the partner organisations to ensure their science supports the delivery Government's single purpose, they make best use of existing resource, they provide enhanced support to Scottish Government policy development and delivery.</p>	<p>Provides policy materials and allows for dissemination of scientific knowledge to wider stakeholder groups relating to coastal flooding and marine environment.</p>

Department for Environment, Food and Rural Affairs (DEFRA)

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>DEFRA is the government department responsible for environmental protection, food protection and standards, agriculture, fisheries and rural communities in the UK. DEFRA have an agreement which sets out an agreed framework for co-operation between it and the Scottish Government, which has devolved responsibilities for these matters.</p>	<p>DEFRA is the lead department for fisheries in the UK and has a major role in EU and international negotiations, as well as in managing and implementing fisheries policy.</p>

East Grampian Coastal Partnership

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>The East Grampian Coastal Partnership (EGCP) is a voluntary group of individuals, with representatives from local authorities, industry, conservation bodies, recreation & tourism groups and local residents. EGCP provides a framework in which these stakeholders can strategically look at the management of the coastline in the East Grampian region. EGCP was also set up to aid in the delivery of Integrated Coastal Zone Management in the area, between Kinnaird Head, Fraserburgh and the mouth of the River North Esk, by St Cyrus.</p>	<p>EGCP offers a numbers of services which relate to long-term planning and resilience building of communities against coastal flooding by acting as a forum for multi-agency issues. Services and products include the promotion of sustainable development in communities along the coastline; assisting the delivery and policy development of Integrated Coastal Zone Management; assisting in the protection of natural and cultural heritage sites along the coastline; provision of educational materials and improved information networks (seminars and workshops); partnering with other organisations through the Scottish Coastal Forum to help deliver practical regional and national scale projects; and seeks to promote research relating to coastal zone management.</p>

Firth of Clyde Forum

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>The Firth of Clyde Forum (FCF) is a voluntary group of individuals, with representatives from local authorities, industry, conservation bodies, recreation & tourism groups and local residents. FCF provides a framework in which these stakeholders can strategically look at the management of the coastline of the Firth of Clyde.</p>	<p>The FCF provides a forum for individuals and organisations to discuss issues that affect the quality of the coastal environment of the Firth of Clyde. Including educational materials on how each actor's actions affect quality of the firth's environment as well as finding new ways for multiple stakeholders to communicate and work together.</p>

Flood Liaison and Advice Group (FLAG)

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>FLAGs are set up on a catchment basis and enable planners to develop strategies in partnership with planners in adjoining councils on a catchment wide basis. They also enable discussions to take place informally with key stakeholders such as insurers, property developer representatives, SEPA, emergency planners, building control, landowners, academics, Non-Governmental Organisations (NGOs), Scottish Water, Network Rail, and community representatives.</p>	<p>FLAGs provide a forum for the exchange of information and data, and to enable discussion of catchment drainage management, flood prevention schemes and other mitigation measures, watercourse repair and maintenance, development plan land allocations and significant development proposals.</p>

www.forthestuaryforum.co.uk

Forth Estuary Forum

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>The Forth Estuary Forum (FEF) retains neutral status and is a registered company, limited by guarantee (SC175839) and a charity registered in Scotland (SC027467). FEF is a voluntary group of individuals, with representatives from local authorities, industry, conservation bodies, recreation and tourism groups and local residents. FCF provides a framework in which these stakeholders can strategically look at the management of the coastline of the Firth of Forth.</p>	<p>The FEF provides a forum for individuals and organisations to discuss issues that affect the quality of the coastal environment of the Forth Estuary. Including educational materials on how each actor's actions affect quality of the firth's environment as well as finding new ways for multiple stakeholders to communicate and work together.</p>

Historic Scotland

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>Historic Scotland is an Agency of the Scottish Government and is directly responsible to Scottish Ministers for safeguarding the nation's historic environment, and promoting its understanding and enjoyment. Responsibly for delivering policy and advise on all aspects of the historic environment. Carry out statutory functions relating to two acts of Parliament- the Ancient Monuments and state care, and the Planning (Listed Buildings and Conservation and Areas) (Scotland) Act 1997 that grants them the authority to list structures by architectural or historical significance.</p>	<p>Preserves heritage sites along the Scottish coastline.</p>

Local Planning Authorities (LPAs)

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>Implement and enact policy at a local scale.</p>	<p>Construct and maintain sea defences in coastal regions, support emergency services during flood events and remedial work. Responsible for development planning, and avoiding new properties and assets being located in flood risk areas.</p>

Marine Alliance for Science and Technology for Scotland (MASTS)

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>MASTS provides the academic platform and knowledge for marine governance and commerce by helping to establish a Scottish strategy for marine science that will deliver increased value to the public from its investments.</p>	<p>MASTS promotes the following goals, Scotland as a world player in marine science through the delivery of science excellence in the field; A healthier environment as a result of a better informed public and policies to manage human activity based on the best available evidence; Wealth creation and protection facilitated by sound science supporting industries such as renewable energy, marine fisheries and aquaculture; an economy able to plan for the effects of climate change; the efficient provision of best available scientific knowledge (BASK) to the policy makers; High level awareness by the public of the value and heritage of Scotland’s marine environment.</p>

Marine Climate Change Impacts Partnership (MCCIP)

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>The MCCIP provides guidance on adaptation and related advice, to policy advisors and decision-makers. Develop and maintain a coordinating framework for marine climate change partners in the UK; Build the knowledge base and consolidate evidence of marine climate change impacts, with emphasis on the spatial dimension where possible; Provide effective mechanisms for the efficient transfer of marine climate change knowledge from the scientific community to policy advisers and decision makers; Develop guidance and build upon best practice for adaptation tolls and strategies available to stakeholders (e.g. ‘climate smart’ approaches); Identify present shortcomings in UK marine climate science (i.e. what other science could be done/ supported to help decision makers and UK marine industries); Actively engage with partners and consult wider communities in requirements for climate change tools and information (e.g. marine scenarios of climate change).</p>	<p>Provide guidance and best practice for climate change adaptation including coastal regions. The intended target audience of MCCIP is marine and coastal stakeholders including policy makers, requiring marine climate change knowledge in an accessible format, enabling them to make informed decisions based upon quality assured science (e.g. MCCIP annual report card).</p>

Marine Scotland

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>Marine Scotland is the directorate of Scottish Government responsible for the integrated management of Scotland's seas.</p>	<p>Marine Scotland provide services such as Marine Planning and Legislation; Marine Energy; Licensing Policy; Compliance; Science; Sea Fisheries Policy; Farmed Fish and Shellfish; Performance and Consultation.</p>

Moray Firth Partnership

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>The Moray Firth Partnership states it is not a lobby group, but retains neutral status and is a registered company, limited by guarantee (no. 196042) and a charity registered in Scotland (No SC 028964) in 1996. The Moray Firth Partnership merged with the Cromarty Firth Liaison Group (CFLG) and continues to support the original aims of CFLG. MFP is a voluntary coastal management partnership that promotes joined-up thinking in marine and coastal zone management through dialogue and consensus.</p>	<p>The MFP provides a forum for individuals and organisations to discuss issues that affect the quality of the coastal environment of the Moray & Cromarty Firths. Including educational materials on how each actor's actions affect quality of the firth's environment as well as finding new ways for multiple stakeholders to communicate and work together.</p>

National Trust for Scotland (NTS)

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>The National Trust for Scotland is a registered charity, established to protect and promote Scotland's natural and cultural heritage. The NTS owns and manages 130 historical properties and listed buildings across Scotland.</p>	<p>The NTS owns 21 properties in close proximity to Scotland's coast as well as aiding in the conservation of coastal properties owned by others through 'Conservation Agreements' many of which are of national, European or global importance. As well as ongoing maintenance NTS also has responsibility over any private flood protection and management of sites against coastal flooding and erosion, including remediation works. The NTS also owns parts of Unst, Arran and Mull, Shieldaig Island, Murray's Isles and Rough Island.</p>

Ready Scotland

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>Ready Scotland is the Scottish Government's public information portal on preparing for and responding to emergencies, through the use of social media, email and mobiles.</p>	<p>Ready Scotland have a specific Flooding section, which details public information on SEPAs Floodline service, flood kits, property protection and insurance advice. There are also links to emergency services, the role of local government and the Scottish Flood Forum.</p>

Royal Society for the Protection of Birds (RSPB)

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>RSPB is a charitable organisation registered in Scotland. It works to promote conservation and protection of birds and the wider environment through public awareness campaigns, petitions and through the operation of nature reserves.</p>	<p>The RSPB manages 200 nature reserves and provides parliamentary briefings such as 'Flooding in Scotland: How to achieve sustainable flood management' as well as information for policy makers and practitioners such as 'Coast in Crisis: Protection wildlife from climate change and sea level rise'.</p>

Scottish Association for Marine Science (SAMS)

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>The Scottish Marine Institute delivers research and education that aim to improve our understanding and sustainable use of the marine environment. SAMS is based at the Scottish Marine Institute, which also houses the European Centre for Marine Biotechnology and SAMS Research Services Limited.</p>	<p>Provides policy materials and allows for dissemination of scientific knowledge to wider stakeholder groups.</p>

Scottish Coastal Forum	
Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>The Scottish Coastal Forum coordinates Scotland's coastal partnerships and forums, including shared interests, information, educational materials and policy responses.</p>	<p>The Scottish Coastal Forum encourages the formation of local coastal fora, providing a point of coordination for these as well as acting as a central point to communicate their views and concerns; Encourage debate on coastal issues at a national level; Seek opportunities for better coordination of national frameworks and policies, consider the need for further advice and guidance and assist in its preparation; Gather information about approaches to coastal management and disseminate good practice to local Fora. Its members advise Marine Scotland, from an operational perspective, on the development of policy relating to marine planning and licensing within a sustainable marine environment. The Forum also provides a network for circulating information and best practices in coastal management amongst its own varied membership and the wider ICZM community.</p>

Scottish Environment Link	
Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>Scottish Environment LINK is a forum used by 30 member bodies constituting voluntary environment organisations. It therefore represents a wide range of environmental interests with the common goal of contributing to a more environmentally sustainable society. Scottish Environment LINK is used to disseminate information to a wider set of stakeholders with varying interests from biodiversity to the social impacts of flooding. LINK provides a forum for its member bodies enabling informed debate, and assisting co-operation within the voluntary environmental sector.</p>	<p>The Scottish Environment Link respond to Scottish Government consultations relating to the marine environment including those affecting the coastal zone.</p>

Scottish Environment Protection Agency (SEPA)

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>SEPA is Scotland's environmental regulator and is a non-departmental public body, accountable through Scottish Ministers to the Scottish Parliament. SEPA advises Scottish ministers, regulated businesses, industry and the public on environmental best practice.</p>	<p>SEPA undertakes environmental monitoring and reports on findings, using this to inform independent regulation activities. SEPA is building on the National Flood Risk Assessment by leading on the preparation of Flood Risk Management Plans. The Flood Risk Management Planning in Scotland: Arrangements for 2012-2016 provides further information on how and when these will be produced. SEPA is also responsible for delivering Scotland's flood warning system, the coastal flood watch service and the provision of Flood Extent Maps. The tidal level monitoring and alert system based on threshold exceedances of a combination of astronomical and meteorological conditions in nine broad coastal zones. SEPA duty officers issue Flood Watches via Floodline to the public and directly to professional partners. SEPA also gives advice to LPAs on coastal flood risk.</p>

Scottish Flood Forum (SFF)

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>The SFF is funded by the Scottish Government and works in partnership with SEPA, local authorities, voluntary sector and other relevant organisations.</p>	<p>SFF establish community flood groups, provides flood information, awareness, education materials and training (to all sectors) to reduce risk and assist in the recovery of flooding both riverine and coastal.</p>

Scottish Government (SG)

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>The Scottish Government (SG) is the executive branch of the devolved government of Scotland and is accountable to the Scottish Parliament.</p>	<p>Various other bodies listed are directly responsible to Scottish Government including SEPA, SNH, Marine Scotland, Scottish Water, Ready Scotland etc.</p>

Scottish Natural Heritage (SNH)

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>SNH is responsible through Ministers to the Scottish Parliament and is funded by the Scottish Government. SNH is a national organisation but active locally, primarily focussed on the preservation, promotion and improvement of Scotland's natural heritage covering wildlife, habitats, landscapes and natural beauty.</p>	<p>SNH work with Local authorities and SEPA to develop Flood Protection Schemes and Flood Risk Management Plans by providing advice on the impact of these schemes on designated sites and species of national and international importance. SNH also advises the National Advisory Group and local advisory groups in a similar capacity.</p>

Scottish Water

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>Scottish Water is a statutory corporations that provides water and sewerage services and is accountable to the public through the Scottish Government. Responsible for water distribution networks, wastewater treatment works, overflow outputs, pump stations, abstraction and cleaning.</p>	<p>Maintenance and integrity of water network structures in coastal areas such as wastewater treatment works and pump stations. overflow outputs, abstraction and cleaning. Infiltration of seawater into freshwater reserves. Destabilisation of the coastline and services such as desalination plants, sewage outfalls.</p>

SNIFFER

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>SNIFFER is a registered charity which delivers knowledge-based solutions on resilience and sustainability issues. It brokers knowledge for use across all sectors such as public, private, third sector and academia.</p>	<p>SNIFFER provides policy documents aimed at informing policy makers and practitioners such as 'Coastal Flooding in Scotland: a Scoping Study' (2008).</p>

Society of Chief Officers of Transportation in Scotland (SCOTS)

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>The Society of Chief Officers of Transportation in Scotland (SCOTS) is a strategic body comprising of transportation professionals from all the 32 councils and the seven regional transport partnerships. The society’s work involves improving performance and innovation in the design, delivery and maintenance of transportation systems. It responds to consultations, provides advice on legislation, develops best practice such as SUDs for Roads and providing training courses, advises COSLA, local authorities and stakeholders.</p>	<p>The SCOTS Flood Risk Management Group deals with strategic flooding issues. The group developed strategies to transition from old to new legislation such as the implications of the Flood Risk Management (Scotland) Act 2009.</p>

Solway Firth Partnership

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>The Solway Firth Partnership (SFP) states it is not a lobby group, but retains neutral status and is a registered company, limited by guarantee (SC250012) and a charity registered in Scotland (SC034376).MFP is a voluntary coastal management partnership that promotes joined-up thinking in marine and coastal zone management through dialogue and consensus and formed in response to formal support for integrated coastal zone management (ICZM) from UK Government and agencies.</p>	<p>The SFP provides a forum for individuals and organisations to discuss issues that affect the quality of the coastal environment of the Solway Firth. Including educational materials on how each actor’s actions affect quality of the firth’s environment as well as finding new ways for multiple stakeholders to communicate and work together.</p> <p>The need for ICZM around the Solway Firth is particularly pressing because the Solway crosses a national boundary, this results in a necessary increase in the number of agencies and organisations working together under different legal, cultural and social systems. The importance of ICZM is further emphasised by the complexity and diversity of the Solway Firth as it contributes to the regional economy has a dramatic landscape which provides a haven for wildlife and is also of social importance.</p>

Tay Estuary Forum

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>The Tay Estuary Forum (TEF) brings together organisations and individuals with a common interest in the welfare of the Tay Estuary and adjacent coastline. The forum consists of a steering group, comprised of representatives from key organisations such as various local authorities, SEPA, SNH & RSPB, meet regularly to manage the direction and progression of the work of the Forum and a Secretariat based at the University of Dundee who runs the day-to-day workings.</p>	<p>The TEF provides a forum for individuals and organisations to discuss issues that affect the quality of the coastal environment of the Tay Estuary. Including educational materials on how each actor's actions affect quality of the firth's environment as well as finding new ways for multiple stakeholders to communicate and work together.</p>

UKCIP

Roles and responsibilities	Responsibilities and initiatives related to Coastal Flooding
<p>UKCIP coordinates and influences research into adapting to climate change, and shares the outputs in ways that are useful to stakeholders. We encourage organisations to use our tools and information to help them consider their climate risks, and to plan to adapt.</p> <p>UKCIP was established in 1997 by the UK government, when it was then known as the UK Climate Impacts Programme. Since it began, UKCIP has been based at the Environmental Change Institute at the University of Oxford.</p>	<p>UKCIP provides UK sea level projections and policy materials.</p>



9. Glossary of Terms

Climate Change	Long-term changes in climate, either through natural variability or human intervention.
Coastal Flooding	Flooding that results from a combination of high tides and stormy conditions.
Coastal Squeeze	A term used to describe what happens to coastal habitats that are trapped between a fixed landward boundary, such as a sea wall, and rising sea levels and/or increased storminess. The habitat effectively becomes 'squeezed' between the two forces and diminishes in quantity and quality.
Flood Risk	A combination of the likelihood and consequences of a flood event in terms of impacts on people, the economy and the environment.
Glacio-Isostatic Adjustment (GIA)	The relative change in the height of the land surface in areas where ice sheets were present during the last glacial period, approximately 10,000 to 40,000 years ago.
Potentially Vulnerable Area (PVA)	Area where a significant flood risk exists now or is likely to occur in the future as a result of climate change.
Residual Risk	The risk which remains after risk management and mitigation.
Resilience	A measure of the ability of something to recover from a flood.
Return Period	Also known as a recurrence interval; the average time between events of certain intensity or size. The theoretical return period is the inverse of the probability that the event will be exceeded in any one year. If the average time is T years, the probability of that event is 1/T per year. For example, a 100-year flood has a 1% chance of being exceeded in any one year.
Sea Level	The measured height of the sea above or below a set datum. Common datums are Admiralty Chart Datum (ACD) and Ordnance Survey Datum Newlyn (ODN). The eustatic sea level is the sum of the tide and unpredicted residual components.
Storm Surge	A rise of water caused primarily by high winds and low pressure systems raising the ocean's surface. The surge may increase the risk of flooding of low-lying coastal areas.
Tide	Rise and fall of the sea level as a result of astronomical forces acting on the ocean.

Appendices

Appendix 1 Scottish Tide Gauge Data

Table 7: Sites shown in italics are shorter than 25 years in duration.
Sea level trends are based on Woodworth et al. (2009).

Station Name	Institute	Lat.	Long.	Time Span	Completeness (%)	Rate (mm/yr)
Portpatrick	PSMSL/BODC	54.850	-5.117	1968-2010	97	1.95 ± 0.44
Millport	PSMSL/BODC	55.750	-4.933	1968-2010	77	1.20 ± 0.53
<i>Islay (Port Ellen)</i>	<i>PSMSL/BODC</i>	<i>55.633</i>	<i>-6.200</i>	<i>1991-2010</i>	98	
<i>Tobermory</i>	<i>PSMSL/BODC</i>	<i>56.617</i>	<i>-6.067</i>	<i>1989-2010</i>	85	
Ullapool	PSMSL/BODC	57.900	-5.150	1981-2010	91	2.12 ± 1.15
Stornoway	PSMSL/BODC	58.200	-6.383	1977-2010	89	2.22 ± 0.90
<i>Kinlochbervie</i>	<i>PSMSL/BODC</i>	<i>58.450</i>	<i>-5.050</i>	<i>1991-2010</i>	82	
Lerwick	PSMSL/BODC	60.150	-1.133	1957-2010	91	-0.68 ± 0.34
Wick	PSMSL/BODC	58.433	-3.083	1965-2010	94	1.55 ± 0.43
<i>Invergordon</i>	<i>PSMSL</i>	<i>57.683</i>	<i>-4.167</i>	<i>1959-1971</i>	96	
<i>Moray Firth</i>	<i>BODC</i>	<i>57.683</i>	<i>-4.167</i>	<i>1994-2010</i>	100	
<i>Buckie</i>	<i>PSMSL</i>	<i>57.667</i>	<i>-2.967</i>	<i>1971-1982</i>	99	
Aberdeen I	PSMSL/BODC	57.150	-2.083	1931-2010	91	0.87 ± 0.10
Aberdeen II	PSMSL	57.150	-2.083	1862-1965	100	
Rosyth	PSMSL	56.017	-3.450	1964-1993	99	1.99 ± 0.92
<i>Leith</i>	<i>PSMSL</i>	<i>55.983</i>	<i>-3.167</i>	<i>1956-1971</i>	81	
<i>Leith II</i>	<i>PSMSL/BODC</i>	<i>55.983</i>	<i>-3.167</i>	<i>1989-2010</i>	89	
Dunbar	PSMSL	56.000	-2.517	1913-1915	99	0.47 ± 0.31

Appendix 2

Case studies on Flood and Coastal Erosion Defence

Case Study on Coastal Flood Protection Scheme: Saltcoats²

Background

Saltcoats, N Ayrshire, is one of the recent examples of a medium-cost flood protection scheme (c £2m) that illustrates well the requirements in terms of feasibility studies, progression through the statutory approvals process and conformity with design standards. Floods in 1998, 1991 and 2001 had shown the inadequacy of the existing defences, built in the 1920s, with high vulnerability to wave overtopping. Areas affected included the shopping centre, a town hall, and several roads and residential streets. The overtopping of the existing defences was made particularly problematic by the persistence of water in poorly drained low basin areas, where residential areas, infrastructure (including shops) and car parks were located.

Key issues

Key issues involved (and likely to be faced in future such schemes in similar areas) were:

- low flood risk under normal tidal conditions: but a threshold is passed at around 1 in 10 years return period for tide, surge and wave action, when flooding becomes extensive
- the volume of water and rate of flow over defences results in both threat to property and safety hazards (risk of injury or drowning) especially because of rapid transition between no overtopping at all and very extensive overtopping the risk of damage was to the heart of the town and social centres, as well as key infrastructure such as electricity substations.

Any action taken had to be holistic since action addressing the cause of flooding from one section would be jeopardised if other sections were not also considered (Johnson et al., 2010).

The Site lay within a Site of Special Scientific Interest, in this case due to geological features.

Scheme design appraisal

Ten design options were considered and separately costed, including a do-nothing scenario. Several of these options could be rejected without significant further analysis, on a combination of technical, environmental, social and economic criteria. After short listing, a detailed economic comparison was conducted on the remaining options, with the top three options going forward to a public consultation with a display in public buildings and questionnaire. The favoured option (increased defence crest levels and extensive armouring of rock breakwaters) was chosen. This option had least impact on amenity and the SSSI.

The designers had to comply with the minimum protection standards to obtain a Flood Prevention Order and associated central grant aid. At the time of design (and still at the time of writing this report) these were a 1 in 100 year return period plus an allowance for climate change. In addition, a detailed investigation needed to be carried out into the potential for wave overtopping on different parts of the scheme, using both observational data and a mathematical model. Two main parts needed to be considered: the risk of overtopping of harbour walls (addressed by construction of rock breakwaters) and containment and drainage of any water ingress from residual overtopping, particularly along the promenade and associated car parks. The observational and modelling period was a very labour intensive and time consuming part of the work, and was made necessary due to the lack of accurate data on wave return periods at a sufficiently local level. Observations and video records of recent flood events were used to support the output of a numerical model (DIFFRAC). Together, these revealed that there was an underestimation of the risk of overtopping due to the Mach-Stem effect, which doubled the height of the incident waves. This problem was dealt with in a concept design by using three short breakwaters to interrupt the progression of waves along the harbour wall.

The designers also needed to choose an appropriate standard of construction to allow for projected sea level rise and possible increases in storminess over the next 50 years. An initial return period of 1 in 250 years was chosen for the SOP, on the basis of extreme tide and wave conditions, and sea level projections based on the Defra Supplementary note to operating authorities, 2006. This buffer was well in excess of the minimum required for the granting of a Flood Prevention Order by central Government. However, climate change was expected to reduce the SOP to 1 in 80 years by 2050. This estimated the net sea level allowance as shown in Table 8.

² Material on which this study is based is taken from Johnson et al. (2010).

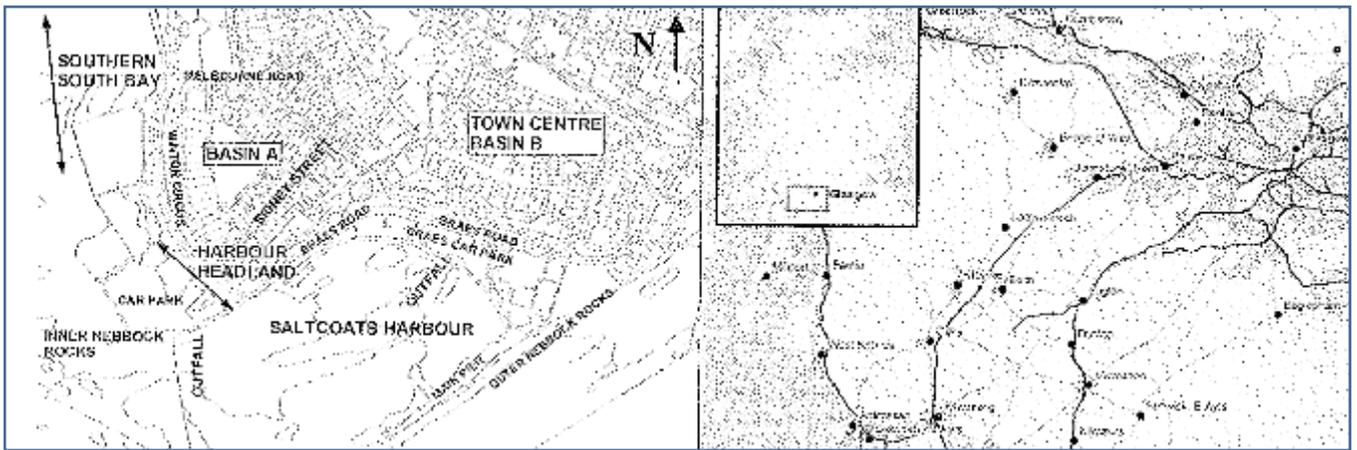


Figure 19: Map of Saltcoats showing basin areas that tended to flood prior to FPS construction (Johnson et al., 2010)

Net Sea Level Rise (mm/yr)	1990-2005	2025-2055	2055-2085	2085-2115
	2.5	7.0	10.0	13.0

Table 8: Net Sea Level Rise allowances adopted for Saltcoats Flood Prevention Scheme, North Ayrshire (Johnson et al., 2010)

Case Study on Natural Defences: St Andrews Links, Fife³

Golf development has often provided a spur to partnership working between local authorities, private landowners and conservation bodies in Scotland. The lengths of links coastline involved, the importance of the industry for tourism, plus the close interplay between the dynamics of the natural coastal dune systems make this approach of national importance. Hence it is useful to look in some detail at how these partnership arrangements have been formalised, and how they interact with conservation and amenity objectives and strategic planning/ SMPs.

At St Andrews, the Links Trust maintains seven courses, four to the West and three to the East of the town. Those in the West, in particular, are subject to erosion at the North end of the Old, New and Jubilee courses, located at the southern mouth of the Eden Estuary. The estuary at this point has high conservation status mainly due to wintering bird habitat, comprising SSSI, SAC SPA and Ramsar designations. Importantly, the Links network as a whole provides protection to lower lying areas of the Northern side of St Andrews and associated roads.

Dunes along West Sands beach and the Out Head area are susceptible to coastal storms, and will become more vulnerable due to sea level rise and possible increases in storminess. The most drastic future projections have shown the importance of the links in maintaining flood prevention.

The Links Trust has promoted research, in partnership with Fife Council, Scottish Natural Heritage and the Fife Coast and Countryside Trust. Based on the results of this, several targeted coastal protection measures have been taken since 2000, which have required multiple permissions under the Environmental Impact (Scotland) Regulations as well as Control of Pollution Act (COPA) and the Food and Environment Protection Act (FEPA), compliance with which is monitored and enforced by SEPA.

A combination of approaches has been applied, in conjunction with the Eden Estuary Project that assisted in providing staffing and project management guidance:

- Gabions, sloped to natural beach contours, to provide protection for most susceptible areas
- Targeted sand recharge. Beach nourishment projects buried gabions and artificially constructed dunes along the remaining soft dune systems, with appropriate mitigation measures to reduce habitat damage.
- 'Soft coastal engineering' including chestnut paling fences alongside sea lyme grass and marram grass planting (Figure 3, Chapter 3)

³ For more information see:

www.sgeg.org.uk/documents/Publications%20and%20Case%20Studies/SGEG%20Env%20Case%20Study%20-%20Landscape%20%26%20Cultural%20Heritage%20-Coastal%20Erosion%20and%20Dune%20Repair%20-%20SALT.pdf

A management plan to co-ordinate the work, developed by a collaboration of local organisations, the West Sands Partnership, with the support of Fife Coast and Countryside Trust through its EU funded SUSCOD (Sustainable Coastal Development in Practice) (St Andrews Links Trust, 2010).

The St Andrews example is, in some ways, unusual, in that there is a vested interest by a major private landowning Trust in protecting high value land, both in terms of economic/ amenity and conservation value that has a flood protection benefit for other areas. Other examples emerged from consultations of the local authority making arrangements with golf clubs for a management plan to prevent coastal erosion and flooding, such as at Royal Troon, S. Ayrshire. There are many other examples of coastal areas susceptible to erosion where the land under immediate threat is of less value. In such areas, the local authority as flood protection authority may have to spend a portion of its limited maintenance revenue budget on such defences. Strategic approaches are essential. could be rejected without significant further analysis, on a combination of technical, environmental, social and expected to reduce the SOP to 1 in 80 years by 2050. This estimated the net sea level allowance as shown in Table 8.

In Summary

- Accurate modelling is needed to gauge the flood prevention benefit of the work. 2 dimensional modelling requires accurate LIDAR survey data.
- Major landowners are often prepared to provide financial and management support Common partners are: golf courses, the Ministry of Defence, port and Harbour management organisations.
- Historical/ cultural assets have also been protected by partnerships between various bodies and local authorities (see Chapter 3), which is often very important for tourism. However the viability of this work in the context of climate change is uncertain and must take into account locally specific information on such variables as sea level change and erosion rates.

Case Study on ad hoc activity by coastal landowners: Shetland⁴

Shetland Islands Council operates a scheme whereby landowners can apply for grants from the local authority out of its protection budget. Landowners will often seek support where the loss of land is leading to a flooding problem. In most cases, 80% support is given by the local authority, with a typical grant being around £1-4800. The council report that the scheme is reactive, and cannot fully replace a programme of maintenance by the authority. Nevertheless, the big advantage of the discretionary grant allocated to the scheme is that it allows each case to be taken on its merits.

In some cases, where protection is to be enhanced to publicly owned assets such as roads, the local authority will fund schemes in excess of £50 000. Clearly, such an approach requires careful design appraisal by the authority concerned, but can work well if there are a large number of disparate, widely spaced properties at risk spread along a long coastline.

⁴ For more information see:

www.shetland.gov.uk/conservation/FloodingandCoastProtection.asp

References

- Angus, S., Hansom, J.D. and Rennie, A. (in press). Oir-thìrean na h-Alba ag atharrachadh: Habitat change on Scotland's coasts. In: *The Changing Nature of Scotland*. Marrs, S.J., Foster, S., Hendrie, C., Mackey, E.C. and Thompson, D.B.A. (Eds), The Stationery Office, Edinburgh.
- Ball, T., Werritty, A., Duck, R.W., Edwards, A., Booth, L., and Black, A. R. (2008) *Coastal Flooding in Scotland: A Scoping Study*. Report to Scottish and Northern Ireland Forum for Environmental Research, Edinburgh.
- Baxter, J.M., Boyd, I.L., Cox, M., Cunningham, L., Holmes, P. and Moffat, C.F. (2008) *Scotland's Seas: Towards Understanding their State*. Fisheries Research Services, Aberdeen, 174 pp.
- Baxter, J.M., Boyd, I.L., Cox, M., Donald, A.E., Malcolm, S.J., Miles, H., Miller, B., Moffat, C.F. (eds) (2011) *Scotland's Marine Atlas: Information for the national marine plan*. Marine Scotland, Edinburgh, 191 pp.
- Black, A. R. and Law, F. M. (2004) Development and utilization of a national web-based chronology of hydrological events. *Hydrological Science Journal*, vol. 49, pp. 237-246.
- Booth, L.M. and Duck, R.W. (2010) A decade of delivering sustainable coastal zone management: The Tay Estuary Forum, a voluntary local coastal partnership in Scotland. *Proceedings of the Littoral 2010 Conference*, London. <http://www.dundee.ac.uk/crsem/TEF/TEF%20Littoral%202010%20Paper%20BoothDuck.pdf>
- Brooke, J. (2000) Strategic coastal defence planning: the role of the planning system. *Journal of the Chartered Institution of Water and Environmental Management*, 14, 140-142.
- Burbridge, P.R. and Burbridge, V. (1994) *Review of Scottish Coastal Issues*. Scottish Office Central Research Unit Report, Edinburgh, 138 pp.
- Burningham, H., Duck, R.W. and Watt, A.M. (2000) Perspectives from a newly formed ICZM voluntary partnership: the Tay Estuary Forum (Scotland). *Periodicum Biologorum*, 102, Suppl. 1, 101-105.
- Campbell, K. (2011) *Marine Planning Partnerships – A Report to Marine Scotland presented at the Scottish Coastal Forum Conference, Edinburgh 2011*. Dundas and Wilson. <http://scotland.gov.uk/Resource/Doc/295194/0122651.PPT>
- Colorado University <http://sealevel.colorado.edu/content/global-mean-sea-level-time-series-seasonal-signals-removed>
- Colorado University Sea Level Research Group. Global Mean Sea Level Time Series. (12/02/2012) <http://sealevel.colorado.edu/content/global-mean-sea-level-time-series-seasonal-signals-removed>
- Cooper, J.A.G. and McKenna, J. (2008) Working with natural processes: the challenge for coastal protection strategies, *The Geographical Journal*, 174, 315–331.
- DEFRA (2001) *Charting Progress: Section 3.2 Coastal Defence*. http://chartingprogress.defra.gov.uk/feeder/Section_3.2_Coastal%20Defence.pdf
- DEFRA (2012a) *UK Climate Change Risk Assessment: Government Report* <http://www.defra.gov.uk/publications/2012/01/26/pb13698-climatechange-riskassessment/>

DEFRA (2012b) The UK Climate Change Risk Assessment 2012 Evidence Report, <http://www.defra.gov.uk/environment/climate/government/risk-assessment/#evidence>

DEFRA (2012c) The UK Climate Change Risk Assessment 2012 Evidence Report Annex A and Annex B http://randd.defra.gov.uk/Document.aspx?Document=Evidence_Report_Annex_A_and_B.pdf

DEFRA (2012d) Climate Change Risk Assessment for the Floods and Coastal Erosion Sector <http://randd.defra.gov.uk/Document.aspx?Document=CCRAfortheFloodsandCoastalErosionSector.pdf>

Duck, R.W. (2012) Marine Spatial Planning: Managing a dynamic environment. *Journal of Environmental Policy and Planning*, in press.

Environment Agency (2010) *The coastal handbook: A guide for all those working on the coast. A collaborative project between the Environment Agency and Maritime Local Authorities.* London: Crown.

Environment Agency. Shoreline Management Plans (SMPs). <http://www.environment-agency.gov.uk/research/planning/104939.aspx>

European Commission (2007) Directive on the Assessment and Management of Floods, <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:288:0027:0034:EN:PDF>

Fife Environment Trust (2010). Newsletter, Issue No. 11. <http://www.fifecoastandcountrysidetrust.co.uk/userfiles/FET2010.pdf>

Hansom, J., Lees, G., McGlashan, D.J., John, S., (2004) Shoreline Management Plans and Coastal Cells in Scotland. *Coastal Management* 32: 227-242.

Hansom, J.D. and McGlashan, D.J. (2004) Scotland's coast: Understanding past and present processes for sustainable development. *Scottish Geographical Journal*, 120, 99-116.

Hansom, J.D., Lees, G., McGlashan, D.J. and John, S (2004) Shoreline Management Plans and coastal cells in Scotland. *Coastal Management*, 32, 227-242.

Horsburgh, K., Ball, T., Donovan, B. & Westbrook, G. (2010) Coastal Flooding in MCCIP Annual Report Card 2010-11, MCCIP Science Review. (01/10/2011) www.mccip.org.uk/arc

Houston, D., Werritty, A., Bassett, D, Geddes, A., Hoolachan, A. and Mcmillan, M. (2011) Pluvial (rain-related) flooding in urban areas: the invisible hazard, Joseph Rowntree Foundation, York.

Jenkins, G. J., Perry, M. C. and Prior, M. J. (2009) *The Climate of the United Kingdom and Recent Trends (Revised Edition).* Met Office Hadley Centre, Exeter, UK.

Jet Propulsion Laboratory, California Institute of Technology, NASA. Ocean Dynamic Topography Compared to Geoid. (12/02/2012a) <http://sealevel.jpl.nasa.gov/education/classactivities/onlinetutorial/tutorial3/topogeoid/>

Jet Propulsion Laboratory, California Institute of Technology, NASA. Ocean Surface Topography from Space. (12/02/2012b) http://sealevel.jpl.nasa.gov/images/ostm/newsroom/press-releases/images/topo_arrows.gif

Johnson, E.A., Guthrie, G, Battison, A, Sarker, M, Hopewell, R., (2010) Saltcoats Flood Prevention Scheme: Design, Analysis and Construction. In *Coasts, Marine Structures and Breakwaters: Adapting to Change.* Institution of Civil Engineers, London.

Joint Nature Conservation Committee (2012) The Scottish MPA Project. <http://jncc.defra.gov.uk/page-5469>

- Law, F.M., Black, A.R., Scarrott, R.M.J., Miller, J.B. and Bayliss, A.G. British Hydrological Society's Chronology of British Hydrological Events. (20/01/2010) www.dundee.ac.uk/geography/cbhe
- Lees, R.G., Gordon, J.E. and McKirdy, A.P. (1998). Coastal erosion, coastal defences and Earth Heritage in Scotland. In: Coastal Defence and Earth Science Conservation. Hooke, J. (Ed), 133-150, The Geological Society, London.
- Levina, E. And Tirpak, D. (2006) Adaptation to climate change: key terms, Organisation for Economic Co-operation and Development (OECD), COM/ENV/EPOC/IEA/SLT(2006)1, 75pp, Paris.
- Lowe, J. A., Howard, T., Pardaens, A., Tinker, J., Jenkins, G., Ridley, J., Leake, J., Holt, J., Wakelin, S., Wolf, J., Horsburgh, K., Reeder, T., Milne, G., Bradley, S. and Dye, S. (2009) Marine and Coastal Projections Report. UK Climate Impact Programme. (12/01/2010) <http://ukclimateprojections.defra.gov.uk>
- MAFF (Ministry for Agriculture, Fisheries and Food); The Welsh Office; Association of District Councils; English Nature, and National Rivers Authority (1995). Shoreline Management Plans: A Guide for Coastal Defence Authorities. London: MAFF, 24p.
- Marcos, M., Wöppelmann, G., Bosch, W. and Savcenko, R. (2007) Decadal sea level trends in the Bay of Biscay from tide gauges, GPS and TOPEX. *Journal of Marine Systems*, vol. 68, pp. 529-536.
- Marine Scotland (2010) Scottish Marine Regions: Defining their Boundaries – a Consultation. The Scottish Government, Edinburgh, 47 pp. www.scotland.gov.uk/Resource/Doc/332178/0108097.pdf
- McGlashan, D.J. and Duck, R.W. (2000) Undeveloped coasts: a protocol or the assessment of development potential. *Periodicum Biologorum*, 102 Suppl. 1, 329–332.
- McGlashan, D.J. and Duck, R.W. (2002) The evolution of coastal management units: towards the PDMU. In: Gomes, F.V.; Pinto, F.T., and Das Neves, E.L. (Eds), *The Changing Coast*, Volume 1. Porto, Portugal: EUROCOAST and EUCC, pp. 29–33.
- Milne, F.D., Dong, P. and Davidson, M. (2012) Natural variability and anthropogenic effects on the morphodynamics of a beach-dune system at Montrose Bay, Scotland. *Journal of Coastal Research*, in press.
- Milne, G. A., Shennan, I., Youngs, B. A. R., Waugh, A. I., Teferle, F. N., Bingley, R. M., Bassett, S. E., Cuthbert-Brown, C. and Bradley, S. L. (2006) Modelling the glacial isostatic adjustment of the UK region. *Philosophical Transactions of the Royal Society*, vol. 364, pp. 931-948.
- Motyka, J.M. and Brampton, A.H. (1993) Coastal Management: Mapping of Littoral Cells. Wallingford, U.K. HR Wallingford, Report SR 328.
- NASA Jet Propulsion Laboratory, California Institute of Technology <http://sealevel.jpl.nasa.gov/education/classactivities/onlinetutorial/tutorial3/topogeoid/>
- NASA Jet Propulsion Laboratory, California Institute of Technology http://sealevel.jpl.nasa.gov/images/ostm/newsroom/press-releases/images/topo_arrows.gif
- Price, R.J. (1983) *Scotland's Environment during the Last 30,000 Years*. Scottish Academic Press, Edinburgh, 224 pp.
- Ritchie, W. and McLean, L. (1988) U.K. – Scotland. In Walker, H.J. (ed.) *Artificial*
- Scottish Environmental Protection Agency (SEPA) (2006) Flood risk map. (12/06/2011) www.sepa.org.uk

Scottish Environmental Protection Agency (SEPA) (2011a) National Flood Risk Assessment, Scottish Environment Protection Agency, available at http://www.sepa.org.uk/flooding/flood_risk_management/national_flood_risk_assessment.aspx

Scottish Environmental Protection Agency (SEPA) (2011b) Flood Risk Management Strategies and Local Flood Risk Management Plans, Scottish Environment Protection Agency, available at <http://www.sepa.org.uk/flooding/idoc.ashx?docid=ab161a16-c497>

Scottish Executive (2003) Scotland in Short: Factsheets. <http://www.scribd.com/doc/334117/Scotland-in-Short>

Scottish Executive (2005) Seas the Opportunity: A Strategy for the Long Term Sustainability of Scotland's Coasts and Seas. Edinburgh, 40 pp.

Scottish Government (2003) The Water Environment and Water Services (Scotland) Act 2003, available at <http://www.hmso.gov.uk/legislation/scotland/acts2003/20030003.htm>

Scottish Government (2009) Flood Risk Management (Scotland) Act 2009, available at http://www.legislation.gov.uk/asp/2009/6/pdfs/asp_20090006_en.pdf

Scottish Government (2010a) The Marine (Scotland) Act 2010, available at http://www.legislation.gov.uk/asp/2010/5/pdfs/asp_20100005_en.pdf

Scottish Government (2010b) Scottish National Planning Policy, available at <http://www.scotland.gov.uk/Resource/Doc/300760/0093908.pdf>

Scottish Government (2011a) Delivering Sustainable Flood Risk Management, available at <http://www.scotland.gov.uk/Publications/2011/06/15150211/15>

Scottish Government (2011b) Scotland's National Marine Plan: Pre-Consultation Draft. The Scottish Government, Edinburgh, 132 pp + Annexes. <http://www.scotland.gov.uk/Publications/2011/03/21114728/29>

SEPA (2011a) National Flood Risk Assessment, Scottish Environment Protection Agency, available at http://www.sepa.org.uk/flooding/flood_risk_management/national_flood_risk_assessment.aspx

SEPA (2011b) Flood Risk Management Strategies and Local Flood Risk Management Plans, Scottish Environment Protection Agency, available at <http://www.sepa.org.uk/flooding/idoc.ashx?docid=ab161a16-c497>

Shennan, I., Milne, G. and Bradley, S. (2011) Late Holocene relative land- and sea-level changes: Providing information for stakeholders. *GSA Today*, vol. 19, pp. 52-53.

Shennan, I., Milne, G. and Bradley, S. (2012) Late Holocene vertical land motion and relative sea-level change: lessons from the British Isles. *Journal of Quaternary Science*, vol. 27, pp. 64-70.

SNH (2000) A guide to managing coastal erosion in beach/dune systems, Available (online): <http://www.snh.org.uk/publications/on-line/heritagemanagement/erosion/index.shtml>

Social Research and Marine Scotland (2011) Analysis of Responses to the Public Consultation on Scottish Marine Regions – Defining their Boundaries. Scottish Government Social Research, Edinburgh, 42 pp. www.scotland.gov.uk/Resource/Doc/360905/0122041.pdf

Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B., Tignor, M. and Miller, H. L. (eds.) (2007) *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

St Andrews Links Trust, (2010) *The Old Course: A guide to the Environmental Management of the Links for Wildlife Conservation*. Available at http://www.randa.org/en/TheGolfCourse/The-golf-course/~//media/RandaCourse/Downloads%20and%20Free%20Publications/Open%20wildlife%20booklets/2010%20Old%20Course_Wildlife.ashx

Strategy for Scotland's Coasts and Inshore Waters - Task Paper 7: Coastal Defence And Structures and Shorelines. Kluwer. 127-135 as quoted in Scottish Coastal Forum:

UK Government (1949) *Coast Protection Act 1949*, available at <http://www.legislation.gov.uk/ukpga/Geo6/12-13-14/74>

UK Government (2011) *UK Marine Policy Statement: HM Government, Northern Ireland Executive, Scottish Government, Welsh Assembly Government*. The Stationery Office, London, 47pp. available at <http://www.defra.gov.uk/publications/files/pb3654-marine-policy-statement-110316.pdf>

Wallingford, H.R. (1997) *Coastal cells in Scotland*. Scottish Natural Heritage Research, Survey and Monitoring Report, 56, Edinburgh.

Wallingford, H.R. et al. (2012) *A Climate Change Risk Assessment for Scotland* <http://randd.defra.gov.uk/Document.aspx?Document=CCRAforScotland.pdf>

Woodworth, P. L., White, N. J., Jevrejeva, S., Holgate, S. L., Church, J. A. and Gehrels, W. R. (2009) Evidence for the accelerations of sea level on multi-decade and century timescales. *International Journal of Climatology*, vol. 29, pp. 777-789.



CREW Facilitation Team

James Hutton Institute
Craigiebuckler
Aberdeen AB15 8QH
Scotland UK

Tel: +44 (0) 844 928 5428
Email: enquiries@crew.ac.uk

www.crew.ac.uk

