

Dumfries and Galloway Shoreline Management Plan

**Dumfries and Galloway Shoreline Management Plan Study:
Stage 1**

Volume 1



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Summary

Dumfries and Galloway Shoreline Management Plan

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Only a small proportion of the Dumfries and Galloway coastline presently has, or is likely to require, coastal protection or flood defences in the next 50 years. Nevertheless, it is important to set a strategy for such schemes, because of the great expense involved and the potential for damage to the environment that would result if works were undertaken without careful planning. This study is an initial step in developing a coastal defence strategy for the Dumfries and Galloway coastline; such a strategy is termed a Shoreline Management Plan.

The concept of Shoreline Management Plans was originally developed for the coastlines of England and Wales, where a relatively short and homogenous stretch of coast can be under the control of several local authorities, each of which has coastal defences. In Scotland, the number of coastal defence authorities is much smaller, and the need for co-operation between them thus more limited. Nevertheless, the underlying principles and benefits of a Shoreline Management Plan are still relevant to all stretches of coastline where significant assets are at risk of erosion or flooding. Such a Plan allows future defence options to be considered in a uniform and consistent manner, helping in the long term planning of development along the coastal margins of Scotland. At a local level, such a Plan helps in identifying the likely future investment needed to safeguard human lives, and a wide range of assets, from the threat posed by the sea.

The objective of this study was to provide Dumfries and Galloway Council with a document to be used when setting priorities for coastal defence management. It takes into account the issues of public safety, the preservation of property and infrastructure, the preservation (and where possible the enhancement) of the environment and the likely costs of defence management along a coastline. This report provides an understanding of the processes shaping the coast, based on a mixture of geomorphological analysis, interpretation of available data in waves, tides, movements of beach sediment and past shoreline changes.

In addition it provides information on the assets at potential risk from erosion or flooding, on the present coastal defences and on the natural and human environment of the nearshore area and the coastal strip. This involved not only a review of existing documentary information, e.g. previous reports and maps, but also a first-hand inspection and appraisal of much of the coastline by very experienced specialists in coastal processes and engineering. Much of the information gathered has been compiled in a Geographical Information System (GIS), which has been transferred to the Council and Scottish Natural Heritage. This will provide a basis for a range of possible future coastal management initiatives. Information has also been gathered from an initial consultation exercise, in respect of current concerns and longer-term aspirations for management of the coastline.

Based on the information gathered together, and the analyses made, this study has gone on to define sub-divisions of the coastline in Dumfries and Galloway, first into six “Coastal Process Units”, reflecting the different character and processes of different areas, and then into 37 smaller “Management Units”. These Management Units have been chosen bearing in mind not only the natural characteristics of the coastline, but also the usage and development of the

Summary continued

immediate hinterland. For each of these Units, the study has identified the present concerns and processes, any existing defences and the main assets at risk now or in the medium-term future. Information on the local environment, for example specially designated areas, and on the ancient monuments and archaeological interests has also been included.

For each of these Units, the study has gone on to consider a range of generic coastal defence strategy options, ranging from “No active intervention” to “Holding (or even advancing seaward) the present line” of coastal defences (or of the shoreline). For each option, consideration has been given to the three aspects of economics, environmental management and technical feasibility in order to ensure that suggested future management of the coastline can be carried out in as sustainable a manner as possible. The methods to be applied in developing a proposed policy for any stretch of coastline are presented in a transparent manner, with the most important implications of the suggested policy being summarised. Therefore, even if not all of the interested parties agree with the suggested strategy option, the basis for making that recommendation is clear.

The report also presents recommendations for further development of the Shoreline Management Plan process, and for the collection of further information, particularly in areas identified as of highest priority, for the consideration of coastal defence schemes.

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1. *Introduction to study*

This report was commissioned jointly by Dumfries and Galloway Council and Scottish Natural Heritage (SNH) in 2003. It describes the first stage in developing a strategic plan for coastal defence along the coastline of Dumfries and Galloway; this plan is called a Shoreline Management Plan (SMP). Before specifying the scope and purpose of this SMP (in Section 1.2), it is first useful to describe the overall approach to planning and installing coastal defences in the UK, first applied in England and Wales but now being extended to Scotland.

A Shoreline Management Plan is a non-statutory plan, and aims to support and inform other measures used in managing the coast and adjacent land, as explained in Section 1.3. The aims of this particular study are then explained in Section 1.4, followed by an explanation of how this project was executed.

1.1 THE STRATEGIC APPROACH TO COASTAL DEFENCE IN THE UK

Many coastal defences have been erected around the coastline of the UK, usually in a piecemeal fashion and in response to localized flooding or erosion problems. Elsewhere seawalls and the like have been installed to protect existing, or allow new, developments close to the sea, and these structures have gradually become larger in order to prevent damage to those developments as the coastline changes.

Such localised defences have often resulted in further problems, for example, restricting the normal evolution of the coastline and its habitats with detrimental consequences on the natural environment, or causing erosion elsewhere along the shoreline. The latter difficulty has sometimes led to the building of further coastal defence structures, at considerable expense, and leading to further similar problems. Problems are particularly likely to occur if defences are installed as a rapid response to a particular event, such as a major flood, because insufficient time is allowed to consider all of the complicated effects of such an intervention, and unnecessary expense and environmental damage can result.

Because of these difficulties, a more strategic approach to planning and installing coastal defences is now being adopted, to allow more time and consideration to be given to the need for and design of any structures.

To assist in the process of forming a long-term view of coastal defence management, the UK coastline has been divided into a number of "cells" and "sub-cells", chosen on the basis of the natural coastal processes rather than using the administrative boundaries, for example between adjacent Councils. This approach was first adopted for England and Wales, but has more recently been extended to Scotland (Figure 1). Originally the idea of separating the coastline into such natural units was based on the concept of beach sediment "cells", i.e. lengths of coastline that are relatively self-contained as far as the movement of beach sand and shingle is concerned. This is a convenient approach where beach sediment moves across administrative boundaries, since it emphasises the fact that any interruption to such movements, for example as a result of one authority installing coastal defences, could affect the beaches in an adjacent authority's area.

Recognising the importance of such effects has led to increased co-operation between local authorities in England and Wales in managing the coastline within each coastal "cell". In Scotland, using "sediment cells" as a basis for strategic planning of coastal defences is much less useful than south of the Border, due to the rocky coastline of much of the mainland and the many offshore islands. These concerns were recognised when the coastal "cells" for

Scotland were being defined, and in many cases the boundaries shown in Figure 1 reflect the general orientation and exposure to waves of the various sections of coastline, rather than considering the movement of beach sediments along the shoreline.

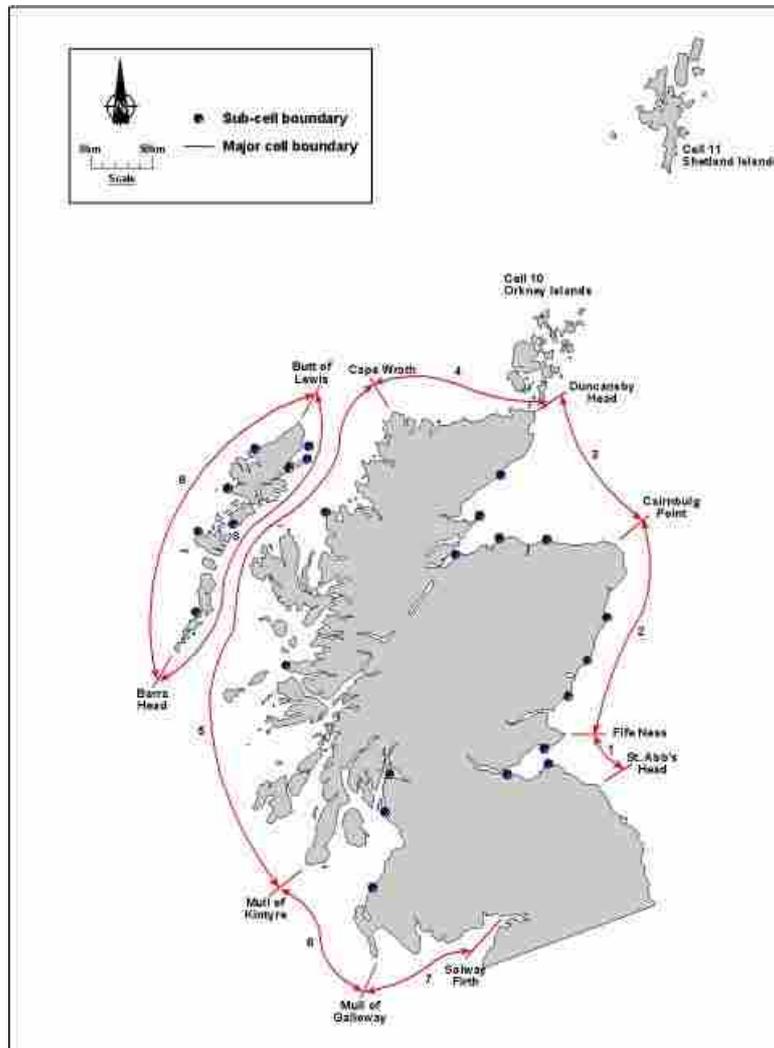


Figure 1 Coastal cells and sub-cells, Scotland (Ramsay and Brampton, 2000a,b)

It is further worth noting that the areas administered by the Unitary Councils in Scotland are much larger than those for the district/ borough/ unitary councils in England and Wales. As an example, in Figure 1, the coastline in Dumfries and Galloway comprises one complete “cell” (Cell 7) and the large majority of “sub-cell” 6d (i.e. from Loch Ryan to the Mull of Galloway) as well. In England, a coastal cell may cover the shoreline of 5-10 local authorities, or even more. It follows that in Scotland the need for co-operation between local authorities to improve the planning and management of coastal defences is much less important an issue than south of the Border.

Finally, the proportion of the coastline in Scotland protected by coastal defences, or affected by them, is much smaller than in England and Wales.

For these reasons the development of strategic plans for coastal defence in Scotland has, therefore, been much less of a priority than for England and Wales. Indeed south of the

Border, such planning has now extended over the whole coastline and a strategic plan for each sub-cell or cell is a fundamental requirement if such defences are to be (part-) funded by central Government. Where Councils in Scotland have decided to adopt such an approach to coastal defence planning, on a voluntary basis, they have largely followed the system used in England and Wales, starting with the development of a Shoreline Management Plan. This Plan covers a number of “sub-cells” within or extending beyond the boundaries of the Council.

A paper by Hansom *et al.*, (2000) considered the use of the sediment cell approach in the strategic consideration of coastal defences in Scotland. It concluded it was “Mainly suitable” for eastern Scotland (i.e. Cells 1,2,3) and for Strathclyde (i.e. cell 6 - see Figure 1) and “Mainly unsuitable” for the remainder of the coastline. However even for parts of the coast where there is little longshore sediment transport, there are a number of good reasons for developing a Shoreline Management Plan for the more loosely justified coastal “cells” identified in Figure 1, as explained in the following section.

1.2 SHORELINE MANAGEMENT PLANS

The main objective of any SMP, as introduced in England and Wales (Defra, 2001), is to promote a strategic, long-term approach to coastal defence, i.e. to manage the risks of marine flooding and coastal erosion. As a part of the development of the SMP, it is necessary to assess these risks at present, and how they may alter, for example as a consequence of climate change. In this context, “risk” implies not just the probability and extent of flooding or loss of land through erosion but also the consequences of such events in terms of risks to the public, damage to property etc.

An SMP is a high level document that is intended to provide a broad-scale assessment of risks and to indicate how they might be managed by indicating a policy for defences along each section of a coastline. To achieve this, the SMP will consider not only coastal “processes”, e.g. waves, tides and sediment movements, but also coastal “assets”, including buildings, infrastructure, natural habitats, archaeology and the like.

The main aim of an SMP is to indicate how best to reduce risks to people and the developed, historic and natural environment in a variety of ways including:

- The provision of adequate and cost effective flood warning systems;
- The provision of adequate flood and coastal defence measures that are technically, environmentally and economically sound and sustainable; and
- Discouraging inappropriate development in areas at risk from flooding or coastal erosion.

Although SMPs should not begin to develop policies for anything other than coastal defence management it is likely that, in due course, they may provide a strong baseline for the future development of Integrated Coastal Management Plans.

The minimum requirements for an SMP are:

- a) A clear focus on the assessment and management of flooding and coastal erosion risks over a consistent Plan timescale (50 years).
- b) Awareness of the longer-term (50-100+ years) implications of coastal evolution, climate change and sea level rise.
- c) Awareness of the uncertainties associated with predicting future shoreline management requirements.
- d) Recognition that the current shoreline management policy may no longer be feasible or acceptable at some point during the next 50 years. In such circumstances, the preferred

- policy should include a planned transition from the current SMP option to an alternative sustainable policy
- e) Identification of the consequences of adopting particular policies at an appropriate level of detail. This should involve, amongst other things, an assessment of the implications of policies on internationally and nationally protected sites as well as non-statutory sites and habitats considered by Biodiversity Action Plans.
 - f) Consideration of estuaries within the SMP process.
 - g) Efficient and focused consultation, with consultees invited to make representations on provisional policies and their likely consequences.
 - h) Identification of the anticipated sources of funding for any coastal defence works or operations that might be required to implement the preferred policies over the next 10 years.
 - i) Provision for informing and supporting the planning system in discouraging inappropriate development in areas at risk from flooding or coastal erosion.
 - j) Provision for standard format of Plans, especially within the same coastal cell.
 - k) Provision for dissemination of the Plan on CD-ROM and via the Internet.

It is intended that this SMP will be completed in four stages, namely:

- Stage 1 Data collection, analysis and preparation of suggested defence policy;
- Stage 2 Public examination;
- Stage 3 Shoreline Management Plan preparation; and
- Stage 4 Dissemination of Plan.

It should be borne in mind in reading this report that only the first stage of an SMP for the coastline of Dumfries and Galloway has so far been commissioned. Accordingly, the above requirements have only partially been met at present.

1.3 RELATION OF SMP TO LEGISLATION AND OTHER COASTAL PLANS

The long and varied coastline of Dumfries and Galloway is perhaps the region's most important natural asset. Much of the shoreline, including the inter-tidal zone and nearshore waters, are of great importance from the viewpoint of conservation of natural heritage, with significant areas having been designated as nationally and even internationally important. The aesthetic quality of the landscape has also been recognised, resulting in parts of the coast being designated National Scenic Areas. In addition, there is much of archaeological and historic interest within the coastal strip of Dumfries and Galloway, and the nearshore water areas, reflecting the long association of humankind with the sea, therefore it is important to preserve this rich heritage.

Not surprisingly, in the light of these factors, there are pressures to develop the coastal strip, in connection with tourism and recreation, particularly where there are sandy beaches. Despite this, much of the coastline remains undeveloped. Where there is development close to the coastline it is largely restricted to small areas close to harbours, or near the tidal limit in the estuaries of the major rivers. It is only at Stranraer, Annan and Southernness that substantial lengths of the coastline have been affected by the construction of seawalls, revetments or other structures.

1.3.1 *Legislative framework for coastal defence schemes*

Coastal management in Scotland is presently carried out largely using the existing legislative and planning framework. The primary legislative framework comprises:

- The Coast Protection Act (1949); and
- The Flood Prevention (Scotland) Act (1961).

The Coast Protection Act (1949) empowers “coast protection authorities”, in this case Dumfries and Galloway Council, to promote and carry out schemes to protect land, primarily against the effects of erosion. It further allows those authorities to regulate similar works carried out by others within their jurisdiction, e.g. landowners, who should obtain agreement for such schemes from the authority.

Following devolution the Scottish Executive administers the Coast Protection Act in Scotland, and if a coast protection authority wishes to carry out such works, they must obtain permission from the Scottish Executive.

This Act, however, gives the Council the power to carry out such works if they choose to do so, but does not place any obligation on the authority to undertake such schemes. A scheme of grants is available from the Scottish Executive in respect of coast protection schemes, providing funding for approximately 50% of their costs. However, such funding is restricted to “capital schemes”, e.g. the replacement and construction of entirely new defences. The 1999 Dumfries and Galloway Structure Plan (see Section 1.3.5) notes that “The Council has not allocated match funding for this purpose in the past” for such major defence schemes. However, there has been a programme to maintain existing coastal defences, but such works have been funded entirely by the Council.

The Flood Prevention (Scotland) Act 1961 permitted unitary authorities to carry out schemes to prevent flooding of non-agricultural land, subject to the permission of the Scottish Ministers. At the time of devolution, this Act was amended, “The Flood Prevention and Land Drainage (Scotland) Act 1997”, which further imposed new duties on Councils, including:

- Assessing watercourses to determine if they are likely to cause flooding of non-agricultural land;
- Maintenance of watercourses which appear to be in a condition likely to cause flooding of non-agricultural land; and
- Publish reports of flooding incidents, measures taken to prevent flooding and measures that the Council considers it should implement.

The Dumfries and Galloway Structure Plan (1999) further comments that responsibility for safeguarding land or property against flooding remains with the owner. While the Flood Prevention (Scotland) Act 1961 is primarily used in connection with fluvial flooding, it may also be used for estuaries, and along the coast, where flooding of non-agricultural land is a concern.

In addition to the powers given to the Council by these two Acts, there are other powers that can be used to carry out coastal defence works. The Roads (Scotland) Act 1984 allows schemes for the protection of roads against natural hazards, and would therefore allow both the Council, and the Scottish Executive for trunk roads, to undertake schemes to prevent flooding or erosion of coastal roads.

In addition, the Ministry of Defence, some port authorities and Network Rail also have permissive powers to carry out coastal defence schemes to protect their assets. In exercising this power, such authorities should consult with the coast protection authority (i.e. the Council), who can lodge an objection to such schemes with the Scottish Executive. However, the Council does not have the powers itself to prevent such a scheme.

For works above the mean low water mark, it is normally necessary for coastal defence schemes to obtain planning permission (under the Town and Country Planning (Scotland) Act, 1997). For works below mean high water, further permissions are needed, for example from:

- The Scottish Executive (Development Department, Transport Division) for navigation purposes;
- The Scottish Executive (Marine Laboratory) under the Food and Environmental Protection Act (1985); and
- The owner of the foreshore, often but not always the Crown Estate.

As an example of the consents and consultation needed to undertake coastal defence schemes, Appendix 1 to this report indicates the requirements for coastal protection works, i.e. those built to prevent erosion of or encroachment on the land by the sea.

1.3.2 *Natural Heritage Designations and Legislation*

Scotland's coastline is exceptionally important for nature conservation, supporting a wide variety of landforms, rock sequences and wildlife. The nature conservation interest and landscape of the coastline are safeguarded through a range of natural heritage designations, described in full in *Natural Heritage Designations in Scotland: A Guide* (Scottish Office, December 1998). The main national land-based designations for natural heritage in Scotland are Sites of Special Scientific Interest (SSSIs), National Nature Reserves (NNR), and National Scenic Areas (NSA). The third of these designations is discussed in Section 1.3.3.

Sites of Special Scientific Interest

The SSSI is the main land and fresh-water based nature conservation designation: they exist throughout Great Britain, give legal protection to the best sites for wildlife and geology and are designated in Scotland by Scottish Natural Heritage (SNH). An SSSI introduces conservation measures for land in public or private ownership, and influences changes in land use and management for which no planning approval is required. The first of these sites were identified in 1949 when the then Nature Conservancy notified local authorities of SSSIs, so their conservation interest could be taken into account during the planning process.

Around 400 SSSI's lie wholly or in part along the coastline of Scotland. Coastal erosion and/or flooding and/or accretion may be integral to the natural heritage interest of such a site. At some sites, continuing coastal erosion or flooding may actually form part of the designated interest, and so inappropriate coast protection may be damaging to the conservation interests. A total of 20 SSSI's are located on the Dumfries and Galloway coast.

Special Areas for Conservation and Special Protection Areas

Certain of these SSSIs, and other sites, are or may be designated as Special Areas for Conservation (SAC). This designation was introduced under the EC Habitats Regulations 1994 and is conferred upon sites considered to be of international importance because of the habitats that exist there. Because of their importance, SACs, along with Special Protection Areas (sites of international importance because of the bird populations that they support) are afforded high levels of statutory protection, so as to maintain the nature conservation interests that exist

there. Luce Bay SAC, River Bladnoch SAC, Solway Firth SAC, Mull of Galloway SAC, Upper Solway Flats and Marshes SAC and Torrs Warren SPA, are located on the Dumfries and Galloway coast.

National Nature Reserves

The idea of land reserved for the protection, study or research of nature is widely understood. Whereas SSSIs attempt to conserve the natural heritage while at the same time allowing or even encouraging traditional land uses to continue, in NNRs conservation itself should be the principal land use. NNRs are protected through the SSSI procedures described above, but the main protection comes through careful management to protect and enhance their natural value. To achieve these high standards they can be either owned or leased by SNH, or managed by agreement with the owner. Within Dumfries and Galloway the Caerlaverock NNR is located on the coast.

Permissions for coastal defence works in designated areas

Where planning permission is sought for coast protection works within (or in some cases close to) an SSSI then, under the Town and Country Planning (Scotland) Act (TCPA), SNH must be consulted. Coast protection works are, moreover, listed as a Schedule 2 category development under the Environmental Assessment (Scotland) Regulations 1988 (as amended), through which the EC1985 Directive on Environmental Impact Assessment is implemented. This means that, in reviewing proposed coast protection works, planning departments are obliged to consider whether or not the works are likely to cause significant environmental effects upon a “sensitive location”, such as an SSSI, NNR, National Scenic Area (NSA), SAC or SPA (or indeed sites proposed as SACs or SPAs but not yet designated as such). If so, then the planning authority may require the proponents of the scheme to prepare an environmental assessment of the impact of the works. Such an assessment must also include an outline of the main alternatives considered and the reasons for choosing the preferred option.

In addition to this, should a proposed coast protection scheme be deemed likely to have a significant impact upon an SAC, then the EC Habitats Regulations require that “an appropriate assessment” be undertaken by “competent authorities” (typically relevant Government Departments and the Local Authority). Guidance on the nature of the assessment is provided in the relevant legislation. Similar procedures apply to SPAs.

1.3.3 National Scenic Areas – Management Strategies

Three National Scenic Areas in Dumfries and Galloway include sections of the coastline, namely the Fleet Valley, Nith Estuary and East Stewartry Coast NSA’s. The Council has developed Management Strategies for each of these areas, including a section in each covering “Shoreline Issues and Opportunities”. The “Relevant Aim” and “Objectives” defined in each NSA are the same, namely:

- Identify, conserve, and where appropriate, strengthen locally distinctive landscape features to reinforce the character of the landscape;
- Conserve and enhance the character and distinctiveness of the shoreline, while working with the natural coastal processes, and seek to minimise levels of water, air, noise and light pollution; and
- Encourage enjoyment of the area where it is consistent with conserving and enhancing the environment, particularly where it plays a role in assisting economic and social opportunity.

In each Management Strategy, there is also a Shoreline Action Plan, which is relevant to the consideration, choice and design of coastal defence schemes. The following “actions” are common to the coastline in each NSA, namely:

- Support the study identifying potential areas of coastal realignment in the Inner Solway;
- Encourage the seeking of advice from Scottish Natural Heritage (SNH) and the Scottish Environment Protection Agency (SEPA) prior to undertaking coastal defence work to ensure no detrimental impact on coastal processes;
- Consider implementation of innovative “soft” engineering techniques, which are visually acceptable;
- Develop Shoreline Management Plan for the northern shores of the Solway; and
- Continue implementation of current Structure Plan policy on applications for protection against coastal erosion (see Section 1.3.5).

This Shoreline Management Plan considers the potential for “managed realignment” of coastal defences and of the existing shoreline, and the policy of “limited intervention” where any improvements to defences or the present shoreline are undertaken with minimum cost and environmental impacts. It further provides an overview of coastal processes, and therefore helps identify the likely effects on these of existing and any proposed defences.

1.3.4 *Solway Firth European Marine Site, Management Scheme (2000)*

This document sets out a wide range of management issues that need to be addressed for this important conservation site to be maintained in a “favourable condition”, and some of these (see table 5.1 of that document) relate to coastal defences, namely:

- Coast protection improvement works to protect agricultural land from erosion adversely affecting the Site;
- The English Shoreline Management Plan does not necessarily deliver SAC/ SPA interests and objectives;
- Evidence of private coastal defences being constructed without relevant permissions;
- The need for a co-ordinated management approach to coastal management which will take into account coastal protection, conservation and amenity;
- Flood and sea defence improvement works to protect agricultural land from flooding adversely affecting the Site; and
- Landclaim being undertaken without relevant permissions.

These issues are of concern because of a number of potential effects, or impacts, on the Site. These include:

- Resulting from coastal protection and flood defence schemes, e.g. damage and loss of habitats through increased risk of erosion and coastal squeeze*, loss of feeding and roosting grounds for birds, loss of nursery areas;
- Resulting from land-claim, e.g. direct loss of inter-tidal habitats, loss of biodiversity, loss of nursery areas for fish and shrimp; and
- Resulting from construction, e.g. disturbance to birds during main passage and wintering periods.

* Coastal squeeze is a term for the loss of habitats which would naturally move inland as sea level increases, but are prevented from doing so, and thus diminished, by the presence of an artificial “hard” barrier such as a coastal defence along the coastline.

The aim of the SMP is to provide a positive basis for sustainable shoreline management policies over the next 50 years and set a framework for future management of the Dumfries and Galloway coastline. The SMP outlines the risks to people and the environment from coastal erosion, flooding and coastal squeeze, identifies preferred policies to manage these risks, and sets out monitoring procedures for these policies to ensure that future land use and development of the shoreline take account of these factors.

1.3.5 *The Dumfries and Galloway Structure Plan*

The management and development of the coastal strip is strongly influenced by both national planning guidelines and the Development Plans (i.e. the Structure and Local Plans) developed by Dumfries and Galloway Council.

In 1997, the Scottish Executive updated previous national guidance, publishing NPPG 13 “Coastal Planning”, which forms a basis for the more detailed Structure and Local Plans developed by the Unitary Authorities. The NPPG 13 report indicates that the Structure Plans should provide a broad planning framework to guide future development activity along the coast, distinguishing between “Developed” and “Undeveloped” coasts. The latter category comprises agricultural and forestry land, low-intensity recreational uses and small settlements.

The Dumfries and Galloway Structure Plan was published, and became operative, in December 1999. This includes a specific policy (E7, p56) in regard to Coastal Development, stating that development proposals will be assessed in relation to the developed and undeveloped coastal areas, indicated in detail on Local Plans. This policy further states “When assessing coastal development proposals the Council will also consider the impact of natural heritage and coastal processes, including discharges to air and water, any engineering works required and the design and layout of the scheme”.

The Structure Plan also proposes (EP2, p57) that the Council, together with other agencies and local communities, would seek to develop and implement coastal management strategies where required. This report describes the first phase of a “Shoreline Management Plan” covering the whole coastline of Dumfries and Galloway, and therefore contributes to this proposed development of a coastal management strategy.

The Structure Plan also recognises that the development close to the coastline, or to the margins of estuaries, is likely to be affected by the risks of flooding and/ or of changes in the position of the shoreline, particularly where a coastline recedes landward (i.e. coastal erosion).

Policy S3 (page 66) states “Development will not normally be permitted where there would be a significant risk from flooding or where it could increase the risk of flooding elsewhere”. While the most significant flood risks to existing developments in Dumfries and Galloway are thought to be from rivers during periods of spate flow, these risks are compounded in or just upstream of estuaries, by the simultaneous occurrence of high tidal levels (for example at Whitesands, Dumfries). Further, there are parts of the coastline where exceptionally high tidal levels, together with waves, cause localised “marine” flooding of low-lying land, including roads and residential properties, i.e. independent of any river flows. In the light of the expected increase in sea levels, as a consequence of global warming, the risks of marine flooding are likely to increase in the future.

It also needs to be appreciated that gradual erosion and landwards retreat of coastlines is the norm, with for example some 70% of the world’s sandy beaches estimated to be eroding (Bird, 1985). The old and resilient rocks that form a framework for much of the coast of Dumfries and Galloway will change only slowly. In most areas, however, more recent and much softer

materials have been deposited on top of, or between these hard rock strata. Examples of these recent deposits include the extensive areas of saltmarsh (merse) and inter-tidal mudflats in the estuaries (particularly the Inner Solway Firth), the sandy beaches and dunes in Luce Bay, the “raised” beaches that form the strip of low-lying coastal land for example at Cairnryan, and the glacial till cliffs for example north of Drummore. These features are all at some risk of erosion, at least in the longer-term as sea levels rise, and in some cases erosion has led to concern about the loss of houses or undermining of coastal roads.

The Structure Plan does include a policy (D24) stating that caravan or chalet parks should not be developed on sand dunes but otherwise does not specifically aim to restrict development in areas at risk from coastal erosion. However, this potential concern is addressed by the more detailed Local Plans described next.

By compiling information on coastal processes over the whole coastline of Dumfries and Galloway, the SMP will assist in better identifying areas at risk of flooding and erosion.

1.3.6 Local Plans in Dumfries and Galloway

Development at or near the coastline of Dumfries and Galloway is further controlled by the four Adopted Local Plans (Wigtown, Stewartry, Nithsdale and Annandale and Eskdale) which were published as Finalised Plans between January 2002 and May 2003. These more detailed and localised Plans provide information on areas of coastal erosion and those at risk of flooding. They also define the areas of Developed Coast and Undeveloped Coast, as suggested by the “Coastal Planning” publication, NPPG13, and present General Policies for development in these areas.

For areas of “Developed Coast”, identified in the Proposals Map in each Local Plan, General Policy 47 states:

“Within these areas, development proposals will be required to demonstrate that they:

- a) Require a coastal location; or*
- b) Would result in the regeneration of derelict land; and*
- c) Would not have a material adverse effect on the integrity of the coast or its environs; and*
- d) Would not be at risk from erosion or flooding or increase the likelihood of erosion or flooding elsewhere”.*

In the justification for this policy, it is further noted that consideration of development proposals will be given to the relevant sections of the Solway Firth Strategy, Landscape Assessment and the Local Biodiversity Action Plan.

For the “Undeveloped Coast”, also identified in the Proposals Maps, General Policy 48 states:

“There will be a general presumption against development in these areas unless it can be demonstrated that:

- a) It requires a coastal location which cannot be located within the developed coast; and*
- b) Would not have a material adverse effect on the integrity of the coast and its environs; and*
- c) Would not be at risk from erosion of flooding or increase the likelihood of erosion or flooding elsewhere”.*

In the justification for this policy, it is further noted that these areas are more likely to be sensitive to development than the “Developed Coast” and that consideration of development proposals will be given to the relevant sections of the Solway Firth Strategy, Landscape Assessment and the Local Biodiversity Action Plan.

In addition to the above, General Policy 49 considers the erosion and protection of the coast. Areas where there may be a risk of erosion are identified on the Proposals Map, although it is noted that potential developers are expected to ascertain the risk and how it might be avoided or overcome at any proposed site. Although the classification in to Developed and Undeveloped Coast was carried out for the Local Plans prior to the preparation of this Shoreline Management Plan Study, the conclusions about coastal classification in the Finalised Plans are consistent with the appraisal carried out as part of this study. General Policy 49 states:

“There will be a presumption against development which would be at significant risk from coastal erosion. Planning applications for works which are being undertaken to protect land against coastal erosion will only be permitted where proposals will not have a material adverse effect on;

- *The adjacent coastline; and*
- *The wider shoreline management; and*
- *The nature conservation interests of the coastline and adjoining areas.*

Special attention will be given to areas designated for nature conservation”.

In the justification for this policy, it is noted that operations which are undertaken to protect properties from coastal erosion are often carried out without due consideration to their impact on the coastline or adjoining areas. It further notes that coast protection works can have an impact on nature conservation sites, e.g. the Inner Solway or Luce Bay, and that such works should have due regard to the conservation objectives in such areas.

The SMP will help identify those areas of coastline where erosion is likely to occur, and indicate the likelihood of coastal protection schemes affecting adjacent stretches of shoreline. Although the identification of areas at risk of erosion in terms of Local Plan General Policy 49 was carried out prior to the preparation of this Shoreline Management Plan Study, the areas identified as being at risk on the Local Plan Proposals Maps are consistent with the appraisal of coastal erosion carried out as part of this study.

1.3.7 Strategic Environmental Assessments

Strategic Environmental Assessment (SEA) provides a systematic method of considering the potential effects on the environment of strategies, plans and programmes that set a broad scale context for future development activity. SEA is seen as becoming a key component of sustainable development in that it ensures that alternative plans are transparently considered before final decisions are taken. One of the core environmental commitments made by the Scottish Executive is to legislate the introduction of SEA across the range of all new strategies, plans and programmes developed by the public sector in Scotland by 21 July 2004. Note that an SEA will not be required for the Dumfries & Galloway Shoreline Management Plan if this is completed by July 2006.

Relation of SEA to the EIA Directive

In the context of Directive 2001/42/EC (Assessment of the Effects of Certain Plans and Programmes on the Environment), SEA is a process for the early identification and assessment

of the likely significant environmental effects, positive and negative, of certain programmes and plans developed by the public sector.

In the context of the Scottish Partnership Agreement commitment, SEA has the same meaning but it also applies to public sector strategies. SEA applies at a broad level rather than to individual projects/developments that might arise under any particular strategy, programme or plan. It complements and does not replace environmental impact assessments on individual projects. It allows the cumulative effects of potential developments to be taken into account at an early stage and for alternative approaches to be considered before any decisions are taken at a broad level.

“Any environmental assessment carried out under the SEA Directive, shall not supersede the requirements of Directive 85/337/EEC (Environmental Impact Assessment) nor those of any other Community law requirements”.

One of the criteria for triggering the application of SEA is whether a plan or programme sets the framework for future development consent of projects listed in the annexes to the EIA Directive. These two directives should not normally overlap as the SEA Directive applies to **plans and programmes** whereas the EIA Directive applies to **specific projects**. Overlaps may occur when plans or programmes are provided for several projects to which the EIA Directive applies. In such cases, the application is cumulative. It would therefore be absurd to produce two essentially similar assessments for the same proposal and consequently, Article 11(2) of the Directive allows Member States to provide co-ordinated or joint procedures to fulfil the requirements of all relevant Community legislation.

With regard to the EIA Directive, this assessment is usually performed at a later stage of the decision making process than the SEA Directive, since it deals with projects rather than plans or programmes setting the framework for such projects. In some cases however, there may be overlaps between the two directives in situations where the plan or programme comprises the development consent for a specific project.

Relation of SEA to The Habitats Directive

The Habitats Directive (92/43/EEC) aims at setting up a coherent European ecological network of special areas of conservation (SAC). It requires Member States to propose sites as SACs and transmit a list of such sites to the Commission. Thus, the essence of such a proposal is to recognise the environmental value of the site. The proposal itself would not normally result in a planning or programming decision as it defines only the geographical scope in which protection measures must apply. The environmental effects following this procedure arise from the later protection measures and not from the proposal to designate a site as an SAC. Therefore, the proposal to designate protected sites under the Habitats Directive is not likely to require a SEA.

Plans and programmes that have been determined to require assessment pursuant to the Habitats Directive are also subject to the assessment procedure under the SEA Directive (Article 3(2)(b)). Therefore, the SEA Directive and the Habitats Directive apply cumulatively for all plans and programmes which have effects on protected sites pursuant to Article 6 or 7 of the Habitats Directive, and a combined procedure may be carried out provided it fulfils both the requirements of the SEA Directive and the Habitats Directive. In this case, the procedure has to include the procedural steps required by the SEA Directive, and the substantive test regarding the effect on protected sites required by the Habitats Directive.

The assessment under the Habitats Directive is a test to certify that a plan does not adversely affect the integrity of the site concerned; the competent national authorities must not adopt a

plan which has adverse effects impairing the site unless the conditions and criteria in Article 6(4) of the Habitats Directive are fulfilled.

The assessment under the SEA Directive has a broader coverage; it not only covers effects on protected sites and on selected species, but also on biodiversity in general and on other aspects like air or water quality or the cultural or architectural heritage. The steps of an optional combined SEA procedure for the plans which have been determined to require an assessment pursuant the Habitats Directive might be the following.

- Since the plan has been determined likely to have an effect on a site under the Habitats Directive, provided it complies with the other requirements of Articles 2 and 3 of the SEA Directive, it automatically comes within the field of application of that Directive.
- The effects on the environment of the plan or programme and reasonable alternatives to the plan or programme are to be identified, described and evaluated in an environmental report. Effects on protected sites and on selected species in accordance with the Habitats Directive are part of this report. It may, however, be preferable to describe them in a separate chapter as the findings on such effects are binding for the decision of the competent authorities on the plan or programme.
- The public and the authorities, which are likely to be concerned by the environmental effects of implementing plans, are to be consulted in accordance with Article 6 of the SEA Directive by making available the draft of the plan or programme and the environmental report. The consultation also includes the effects of the plan or programme on the sites and species, which are specially protected under the Habitats Directive.
- The report and the results of the consultations have to be taken into account before the plan or programme is adopted or submitted to the legislative procedure. If the plan or programme is found to adversely affect the integrity of the site concerned, the plan or programme may be adopted only under the limited conditions described in Article 6 of the Habitats Directive. For other effects on the environment, the relevant national legislation under the Habitats Directive describes the conditions under which the plan or programme may be adopted.
- Under Article 6 of the SEA Directive, the public and the designated authorities have to be informed about the decision on the plan or programme. The statement summarising how environmental considerations have been integrated into the plan or programme also includes the decision about whether the plan or programme conforms to the Habitats Directive.
- The effects on the environment of implementing the plan or programme have to be monitored (Article 10 of the SEA Directive). This monitoring includes effects on the sites and species protected under the Habitats Directive.

1.3.8 *Water Framework Directive*

The Water Framework Directive (WFD) is likely to be an important factor in the future consideration of flood and coastal management in Scotland. The overriding aim of the WFD, which came into force in December 2000, is to achieve good water quality, covering ecological as well as physical and chemical status, by 2015. The Scottish Executive has transposed the Directive's administrative and regulatory requirements into Scots law in the Water Environment and Water Services Act (2003).

The purpose of this legislation is to establish a framework for the protection of coastal waters, transitional waters, inland surface waters and groundwater, which:

- Prevents further deterioration, protects and enhances the status of aquatic ecosystems, and with regard to their water needs, terrestrial ecosystems;
- Promotes sustainable water use based on a long-term protection of available water resources;
- Aims at enhanced protection and improvement of the aquatic environment (in relation to a progressive reduction in priority hazardous substances);
- Ensures the progressive reduction of pollution of groundwater and prevents its further pollution; and
- Contributes to mitigating the effects of floods and droughts.

Where any water body has been affected by human development, for example by the construction of coastal defences along a shoreline, it is likely to be regarded, under the Directive, as a Heavily Modified Water Body and under the WFD there is a requirement to achieve a “good ecological potential”.

It is likely that the WFD will act to regulate management of the coastline, for example influencing the types of coastal defence that might be installed, and as an extra factor in setting priorities for such management, for example preventing erosion of contaminated land. It will be particularly important in the consideration of flood prevention schemes, along coasts, in estuaries or along rivers. There will be a need to maintain or improve the ecological quality of the areas affected as well as the effects on hydrology/ hydrodynamics of any such scheme.

At present, the emphasis is on the use of this legislation for river basins, and consequently less attention has been paid to the coastline, where in any event the water quality, especially along the shorelines of Dumfries and Galloway, is generally very good. However, in the near future, it is likely that this legislation will have an increasing influence on coastal defence policy, especially in regard to the ecological effects of proposed or existing defences.

1.3.9 *Dumfries and Galloway Local Biodiversity Action Plan*

Although locally driven and developed, the Dumfries and Galloway Local Biodiversity Action Plan is part of a national and international programme designed to maintain and enhance biodiversity globally. The Biodiversity Action Plan is comprised of a number of Local Habitat Plans. Those that are relevant to the coastal and marine environment include estuaries, inlets and enclosed bays, seagrass beds, shingle, sand dunes, coastal saltmarsh and cliffs and slopes. Open seas areas such as the Inner and Outer Solway, Wigtown Bay and Luce bay are also considered.

Each local habitat plan contains the following information:

Definition: The biological and physical characteristics of the habitat are described.

Key sites/Site Distribution: Sites or areas of known importance for each habitat are listed, together with any statutory designations that are applicable.

Key Species: Species of UK and local importance are listed for each habitat. These include Priority Species, Conservation Concern Species, Local Priority Species and Local Conservation Concern Species.

Objectives: The major objectives for each habitat are defined. The primary objective of the Local Biodiversity Action Plan is to ensure no net loss of area or reduction in quality of the coastal zone in Dumfries and Galloway. Additional objectives for each of the (coastal) priority habitats are presented below.

Estuaries:

- Improve estuarine habitats in order for them to sustain typical estuarine wildlife;
- Meet and maintain Class A (Excellent) water quality standards in all of the region's estuaries using the Scottish Environment Protection Agency's (SEPA's) Estuary Classification Scheme to monitor chemical, biological and radiological quality;
- Maintain and protect the quality and integrity of designated sites; and.
- Ensure that a comprehensive set of management plans are completed and monitoring programmes are instigated.

Inlets and Enclosed Bays:

- Establish management principles for Loch Ryan via the Loch Ryan Forum;
- Use these and resulting actions to inform management of other inlets and enclosed bays within the Dumfries and Galloway region.

Seagrass Beds:

- Restore seagrass to all areas where it was previously recorded as far as conditions allow.

Shingle beaches:

- Set up a five-year programme to raise awareness of biodiversity, its importance and the need for conservation in Dumfries and Galloway with particular reference to shingle.

Sand Dunes:

- Determine in detail the area, extent and condition of sand dune habitats in Dumfries and Galloway with a view to restoring, where conditions allow, all areas of sand dunes which have been subject to degradation.

Saltmarshes (Merse):

- Evaluate the benefit of existing saltmarsh for vegetation and wading birds; and.
- Review management using the results and set a target for increasing the area of saltmarshes in the region.

Maritime Cliff and Slope:

- Increase the continuity and area of maritime cliff and slope vegetation at five sites along the Rhins and Stewartry coast; and
- Choose sites where physical links between existing areas of wildlife importance can be maintained or established and which are representative of the habitat in this region.

Current Status: The geographical extent (where known) for each habitat in the UK, Scotland and Dumfries and Galloway is described. Information is also provided about major habitat losses or expansion.

Biodiversity Context: This section highlights the points from the UK Biodiversity Action Plan that are relevant to Dumfries and Galloway.

Current Factors affecting habitats: Those factors that affect the habitat in Dumfries and Galloway are listed including:

- Possible offshore windfarm developments;
- Sea level rise;
- Lack of sea defence planning;
- Coastal erosion;
- Wash from high speed ferries;
- Commercial shellfish harvesting;
- Pollution from land and marine sources, littering;
- Degradation due to unrestricted access;
- Extraction of sand/shingle;
- Afforestation;
- Development pressures e.g. land reclamation;
- Inappropriate grazing.

Opportunities and Current Action: The various biodiversity actions that are already being undertaken in Dumfries and Galloway are described.

Proposals for Action: Specific Actions that are recommended to meet all the objectives are presented.

Of particular relevance to the Local Biodiversity Action Plan, the Shoreline Management Plan provides a detailed description of the coastline including the information on designated areas and an assessment of coastal erosion, flooding and existing defences, recreational use of the coastal zone and concerns/aspirations for coastal development. A large number of these concerns are identified during the consultation process and as such, reflect the opinions of individuals and organisations with a strong local interest in the coastline. This information can be used to highlight specific factors affecting the coastal zone and to identify sensitive areas where immediate action is required.

1.3.10 Archaeology and Ancient Monuments

Dumfries and Galloway has a rich heritage of archaeological and historic sites, many of which are close to the shoreline and, therefore, at potential risk of damage by coastal erosion, or possibly by the construction of coastal defences. It is therefore important that coastal defence planning includes consideration of such sites, and this is an issue included in most Shoreline Management Plans.

The Ancient Monuments and Archaeological Areas Act (1979) is the main piece of legislation concerned with the protection of archaeological sites / ancient monuments in Scotland. It defines the term “monument” which covers a wide range of buildings, structures and works, above or below the land surface, and also includes caves, excavations, vessels, aircraft and vehicles, or the remains of all these. A small percentage of these “monuments”, that have been specifically “scheduled” or which are considered of particular public interest “by reason of the historic, architectural, traditional, artistic, or archaeological interest”, are designated as “Ancient Monuments” and receive special protection under this legislation.

Historic Scotland, an Agency within the Scottish Executive Education Department, is directly responsible to Scottish Ministers for safeguarding the nation's built heritage, and promoting its understanding and enjoyment. Much of the work it carries out is in partnership with Universities, Trusts and Historic Scotland is very conscious of the need to involve local

communities wherever feasible. Their “Shorewatch” project, in particular, is relevant to coastal defence planning and is based on the idea of supporting local groups to monitor coastal erosion of archaeological sites. Shorewatch is run by two organisations with grant-aid from Historic Scotland, Scottish Coastal Archaeology and Palaeo-Environmental partnership (SCAPE), based at the Centre for Environmental History and Policy in St Andrews, and the Council for Scottish Archaeology based at the National Museums of Scotland. The detailed survey of the coastline between Gretna and the Mull of Galloway, carried out by the Centre for Field Archaeology at the University of Edinburgh, and commissioned by Historic Scotland, is a very tangible demonstration of their interest in coastal archaeology.

The Historic Scotland report on “Archaeology and the Coastal Erosion Zone” (Ashmore, 1994) considers the options for avoiding damage to archaeological sites and concludes that where it is not possible to build coastal defences, then the alternative is to excavate the sites before they are destroyed. While the costs of coastal protection can be considerable, and there is no benefit in terms of understanding the past by such expenditure, the costs of excavation can be much greater. Because of this, detailed surveying of the archaeological interests in the coastal strip, together with predictions of the rate of erosion of the shoreline, is an important element in the appropriate management of such heritage sites.

As well as this national dimension, the Dumfries and Galloway Structure Plan (see Section 1.3.5) contains specific planning policies designed to protect archaeological interests in the area (Policies E12 and E13) and “Listed Buildings” (Policy E9).

If information on archaeological sites, ancient monuments and listed buildings is included in the development of a Shoreline Management Plan, then a strategic policy for coastal defence, particularly defence against erosion, can be developed bearing in mind the need to avoid damage to these features.

1.4 STUDY METHODS

This report describes the first stage of the development of a Shoreline Management Plan (SMP) for the coastline of Dumfries and Galloway. In general, an SMP is prepared in a number of stages, and this study comprised:

- Gathering, collating and analysing information and data;
- Initial consultation to identify concerns and aspirations for the coastline;
- Expert appraisal of the coastline, its processes and defences;
- Defining Coastal Process and Management Units;
- Reviewing and suggesting a defence policy for each Management Unit; and
- Presenting and reporting the study for the first stage of the SMP.

1.4.1 *Information collection and collation*

The first step in the study involved the collection and collation of information on:

- Coastal “processes”, e.g. tides, waves, sediment movement and shoreline change;
- The natural environment including geology, geomorphology, biology;
- Land use, heritage sites and the human environment; and
- Existing coastal defences.

The development of an SMP does not normally involve any numerical modelling, for example to calculate wave conditions, tidal currents or sediment transport rates, nor any detailed

analysis for example of past shoreline changes or the extent of flooding. Rather it is based on existing information presented in previous reports or studies.

A great deal of information was already available for many aspects that need to be considered in the development of an SMP, for example on existing coastal defences, coastal geology, land-use, archaeology and the natural environment. Information on past shoreline changes, waves and tidal currents is less readily available, with the notable exception of the coastline of Loch Ryan. Quantitative information on the extent of coastal flooding is particularly sparse, with no equivalent in Dumfries and Galloway to the maps showing areas at risk of inundation along the southern side of the Solway Firth. In this report, therefore, judgements on the risks of future coastal erosion and flooding have been based on anecdotal information, in part gathered from the consultation exercise, and on visual assessments made during the site visits (Sections 1.4.2 and 1.4.3 respectively).

In the present study, much of the information gathered has been stored in a Geographical Information System (GIS), allowing the many factors that influence the management of a stretch of coastline to be rapidly identified and presented.

1.4.2 Consultation

The first phase of an SMP study involves an initial consultation with organisations and individuals who may have relevant information, or have an interest in the coastline and its management. This initial consultation process was not a method for conflict resolution but rather a vehicle for information and opinion gathering, thus allowing a complete analysis of all factors relating to the coastline before a decision on the most appropriate policy option is reached.

As well as providing an opportunity to make known any current concerns, this consultation also seeks to identify aspirations for the future management of the coastline. As a result of involving, at an early stage, the diverse range of parties that live close to the coast, or have an interest in its future management, there is a greater chance of achieving the long-term success of the SMP.

In summary, this initial consultation process had the aims of:

- Collecting relevant information, for example on past studies or on past management schemes, shoreline changes etc.
- Identifying present concerns about the coast, particularly on erosion, flooding and existing defences;
- Gathering views on future aspirations for the development or management of the coast;
- Identifying other organisations/ individuals with an interest in the topic.

A list of relevant stakeholders and parties with an interest in the Dumfries and Galloway coastal zone was compiled and initial contact was made in the form of a letter informing them that an SMP was being produced, what it is and what the general aims of the plan are. A questionnaire was included with the letter and a press release was published in local Newspapers in November 2003.

In addition, a Working Group was set up to contribute to, and guide, the study. This Group comprises of the major stakeholders in coastal defence planning, i.e. Dumfries and Galloway Council, Scottish Natural Heritage (SNH) and the Scottish Environmental Protection Agency (SEPA).

A copy of the consultation letter and questionnaire is provided in Appendix 2. A total of 170 individuals and organisations were targeted in the initial consultation exercise. These included 47 Dumfries and Galloway councillors and 28 Community Councils.

Further individuals and organisations were identified during the consultation process both as a result of discussions with the initial consultees and through the press release. All responses were documented and the major issues catalogued accordingly. After an initial two-month period, around 30 responses had been received and a reminder was sent to those who had not replied. A total of 70 responses were received by the end of the consultation period. This represents 41% of those who received letters. The distribution of those who responded is shown in the table below and a full list is provided in Appendix 3.

Responses by organisation	Number of Responses
Dumfries and Galloway Council	6
Community Councils	14
Other organisations/ individuals	51

As well as offering an insight into the views of those people with an interest in the coast, this exercise was also beneficial in raising awareness of the concept of the SMP and its aims, with several responses requesting sight of the Plan when available.

1.4.3 *Appraisal of coastline and defences*

In order to gather information and impressions on coastal processes and management problems first hand, a number of site visits to the coastline of Dumfries and Galloway were undertaken by senior specialists from the Coastal and Seabed Group at HR Wallingford. Given the considerable length of this coastline, including the estuaries of the major rivers up to their normal tidal limits, the limited time available and the inaccessibility of some rocky frontages, it was not possible to inspect all of it. However, inspections were carried out wherever significant risks to coastal assets have previously been identified. This included, but was not limited to, frontages where defences have already been installed, by the Council or others, e.g. landowners. Where defences have been installed, an assessment of their condition and effects was made. For all frontages visited, consideration was given to the present and longer-term risks posed by erosion or flooding, with the objective of advising on the need for new or improved coastal defences.

An extensive collection of digital photographs was compiled, both from the site visits undertaken as part of this study, and collections from previous studies and visits undertaken by SNH or by (or on behalf of) Dumfries and Galloway Council.

1.4.4 *Definition of Coastal Process Units and Management Units*

Based on the various sources of information gathered together, as described above, the SMP suggests the sub-division of the coastline into six major sub-divisions known as “Coastal Process Units” (CPUs). These are “natural” divisions of the coastline, chosen purely on the basis of hydraulics and/ or sediment transport/ geomorphology. Generally the boundaries between these Units are chosen so that there is little or no connection between any changes of the coastline in adjacent CPUs. Hence there will be little or no transfer of sediment across

such boundaries, and any coastal defences in one CPU will generally have no effect on the natural development or the management of another CPU. Within each CPU, however, the general characteristics of the coast, such as wave conditions, beach types etc. will be similar throughout. The definition of appropriate CPUs for Dumfries and Galloway is described in chapter 2.

The detailed discussion of the coastline and its defences in this report (see chapter 3) is arranged in six sub-sections corresponding to these Coastal Process Units.

The decision on whether or not to intervene in the evolution of a coastline, for example to prevent flooding or erosion of the land adjacent to it, cannot sensibly be taken on the basis of the natural processes and character of the coastline alone. Such decisions will inevitably also need to take into account the assets at or close to the shoreline. This leads on to the idea of defining “Management Units” within each CPU.

Management Units are shorter lengths of coast, defined on the basis of the hinterland use, and hence the assets at risk, or reflecting existing coastal defences. Generally, the same coastal defence policy will be adopted for the entire coastline within a Management Unit (MU), but an adjacent MU will often require a different policy. For most SMPs, the first phase of their development will not extend beyond the definition of the Management Units.

The terms of reference for this particular project, however, required that a draft coastal defence policy for each Management Unit be suggested, chosen from a standardised list of options (see Section 1.4.5).

Further phases in the development of the SMP, yet to be commissioned, would include further discussion and consultation with the public, refinement of the policy options, adoption by the Council and publication of the completed plan.

1.4.5 Review of coastal defence policy options

In developing a suitable shoreline management policy for each Management Unit, the Department for Environment Food and Rural Affairs (DEFRA) recommends that shoreline managers in England and Wales identify appropriate strategic policy options. DEFRA carried out an assessment of the existing shoreline management plans in England and as a result of this review published revised guidelines, "Shoreline Management Plans, A guide for coastal defence authorities" (June 2001); within this document five common policy options for shoreline managers are listed. Dumfries and Galloway Council is advised to adopt these generic options, as described below, to improve the consistency of shoreline management across the UK. The generic policy options used in this Shoreline Management Plan are as follows:

- **Hold the existing defence line**
Improve or maintain the standard of protection provided by the existing defence line. This policy includes situations where works or operations are undertaken in front of and behind the existing defences (e.g. beach renourishment, additional toe protection, construction of offshore breakwaters to control beach response etc), to improve or maintain the standard of protection provided by the existing defence line.

This policy option has been the one most readily chosen in Shoreline Management Plans in England, especially where there are existing “built” coastal defences or assets such as coastal roads just inshore of a natural coastline. While preserving the *status quo* is often the easiest option in the short-term it can, however, lead to ever more difficult problems

in the future. Given the inevitability of coastal erosion and of continuing increases in sea levels, the costs and environmental damage involved in maintaining a defence or shoreline position will increase with time in many cases. Further, by adopting such a policy, there is an increased likelihood of the development of the coastal strip behind “the line”. These two factors, together, will therefore lead to a risk of future generations being faced with much more difficult problems to solve than are presently being experienced. In this study, therefore, the likely long-term problems along each stretch of coastline have been considered before recommending a “hold the Line” policy. Alternative options such as not trying to preserve the present position of the shoreline or defences, and instead relocating assets at risk, have always been considered. An example would be to move coastal roads inshore, e.g. at Soleburn, rather than trying to protect the existing route.

- **Advance the existing defence line**

Construction of new defences seaward of the original defences.

There are occasionally situations where installing a new line of coastal defence significantly further seaward than the existing shoreline may be worthwhile. However, the cost of building defences in deeper water is much greater than in shallower water, and is usually only financially viable where the extra land gained is used for, or in connection with substantial developments, e.g. ports. There are very few locations along the Dumfries and Galloway coastline where an “advance the line” policy option needs to be considered, the obvious exception being in connection with the further development of the port at Cairnryan.

- **Managed realignment**

In this study, managed realignment is defined as the process of identifying a new line of defence, which might be naturally high ground, further landward than the existing shoreline, or any existing defences, and actively arranging for the shoreline to retreat to this new defence line. (Simply allowing natural processes of coastal evolution to continue unchecked, thus resulting in a landward recession of the shoreline is covered under “no active intervention” below).

Where the land between existing defences and the new “defence line” is below the level of highest tides, then is it sometimes beneficial to remove part or all of the existing defences, creating a new inter-tidal area which can provide valued habitats for wildlife, e.g. saltmarshes and inter-tidal mudflats.

The scope for such habitat creation by managed realignment of the coast of Dumfries and Galloway, however, is limited since in most cases the ground levels rise to the landward of the present shoreline. Therefore, even if existing defences were removed, there would be little or no extra inter-tidal area created.

- **Limited Intervention**

Reducing the risks of coastal erosion or flooding by working with natural processes to allow for natural coastal change. This may range from measures which attempt to slow down rather than stop coastal erosion, such as dune management, to measures which may include repairing existing defences when damaged but not investing in further capital works to maintain or upgrade the present standard of protection, against flooding for example.

- **No active intervention**

Where there is no investment in coastal defence assets or operations, i.e. no shoreline management activity other than monitoring or the provision of flood warning systems (which may also be appropriate for frontage where other policies are adopted).

All of the above policies need to be supported by strategic monitoring and must, when implemented, take account of existing Health and Safety legislation.

2. Overview of the Dumfries and Galloway coastline

2.1 SOLID AND DRIFT GEOLOGY

The character and evolution of today's shorelines are greatly influenced by both the solid rock strata and the more recent and softer "drift" deposits of gravel, sand and mud that overlie them. The older harder rocks, sometimes exposed at the coastline as cliffs, form the overall "framework" for the coast, for example the headlands on either side of the many bays, large and small, along the northern shoreline of the Solway. The drift deposits, which were mainly laid down at the end of the last Ice Age, form the raised beaches along much of the coast, and some boulder clay cliffs, as well as providing some of the gravel, sand and mud that make up the beaches and inter-tidal flats.

Details of the geology of the coastline of Loch Ryan and the Rhins of Galloway have been provided in a recent report by Kirk, McClure and Morton (2001). The solid geology of Loch Ryan is dominated by sedimentary rocks of Ordovician age, formed about 505 to 438 Million year ago, and dominated by beds of siltstones, shales or greywackes. The Southern Upland Fault crosses the coast at Glen App at the northern end of Loch Ryan, and then crosses the northern tip of the Rhins of Galloway (see Figure 2).

Younger, Silurian sediments, of similar lithology, occur over the southern half of the Rhins of Galloway. Much of this rock is exposed at the coastline in the form of cliffs that are resilient to marine erosion resulting in a relatively "neutral" coast, i.e. one showing little sign of either recession or advance.

Younger rock types, mainly New Red Sandstone of Permian age (290Ma to 245Ma), are located on and under the isthmus between Luce Bay and Loch Ryan. These are composed of sandstones and red breccias and form cliffs up to 45m high along the Loch Ryan shore. However, much of this outcrop is obscured by glacial deposits, e.g. at Kirkcolm (Kirk McClure and Morton, 2001).

The solid geology of the south-western coastline of Dumfries and Galloway is also dominated by Silurian siltstones, shales and greywackes, although these are somewhat younger than those on either side of Loch Ryan. These make up most of the southern part of the Rhins of Galloway and the coastline extending from Luce Bay to Kirkcudbright Bay (see Figure 2).

These rock strata tend to have a dominant north-east to south-west strike which influences beach morphology at a number of locations, such as the western side of Fleet Bay, (Mather, 1979). Where such rock outcrops at the coast, the variability in erosion rates between the Silurian mud and sandstones as compared to the greywackes has resulted in an indented coastline. Coastal erosion is further influenced by thin (generally 2m wide) igneous dykes that also run in the same direction.

Rocks of the Carboniferous era outcrop at the coast at two main locations, namely:

- Between Abbey Head and Balcary Point; and
- Underlying Preston Merse and the outer western coast of the Nith Estuary.

These rocks are composed of sandstones and mudstones, with limestone beds and basaltic lavas and are evident as inter-tidal outcrops or shore platforms. Landward of these Carboniferous deposits is a large mass of granite outcropping at the coast around Auchencairn Bay and Rough Firth, responsible for the rugged terrain of the area.

From Borron Point (greywacke) at the mouth of the Nith Estuary, eastwards, the solid rock strata are overlain by a substantial thickness of recent “drift” deposits (see below). For example at Redkirk Point in the inner Solway Firth, a geological excavation showed that the sandstone bedrock was overlain by 7-8m of sediments including peat layers, tree stumps, wood and more recent deposits of “carse clays” deposited by marine action (Gordon and Sutherland, 1993). Consequently the only visible signs of “hard rock” strata in this area are the scattered “scars” that outcrop on the foreshore in places. These have little effect on present-day coastal processes, or the morphology or evolution of the shoreline.

The region is characterised by glacial deposition and did not undergo, to the same extent, the scouring action of the ice sheets, which affected areas further north. Vast quantities of glacial sediments not only cover the coastal strip but also floor much of the Solway Firth. These sediments have provided some of the material for the beaches and sand-flats that occur along this coastline.

Much of the coastline of Loch Ryan, for example to the south of Kirkcolm and at Old House Point, consists of raised beaches. Around Kirkcolm itself, post glacial littoral sand and gravel overlie the Permian sandstone and small patches of glacial melt water deposits alternate with main areas of boulder clay containing variable amounts of sand as well as pebbles (Kirk McClure and Morton, 2001).

The most distinct raised beaches in Dumfries and Galloway, however, are on the eastern shoreline of Luce Bay. An almost continuous relict cliff line runs from Burrow Head to the inner part of Luce Bay and this is fronted by a raised beach of about 100m width, upon which the A747 runs. Raised estuarine deposits are also extensive along the inner Solway Firth coastline, especially east of the River Nith.

The estuaries, including the Inner Solway Firth, have accumulated large quantities of predominantly fine-grained sediment as sea-levels rose following the end of the last Ice Age. In the upper reaches of estuaries, and tidal inlets, there are fluvio-glacial sand and gravel deposits, i.e. brought downstream by rivers draining glaciers and ice sheets. The directions of movement of the sediments scoured from the high ground by the ice sheets and glaciers are shown by arrows on Figure 2 (Gordon and Sutherland, 1993).

At lower levels, the deposits are predominantly of marine origin, sometimes referred to as “carse clays”. The total volume of these deposits varies over time, with inputs continuing from the major rivers and erosion of the glacial till cliffs, but probably with some losses offshore into deeper water areas, carried in suspension in the water column. There are also likely to be transfers of fine-grained sediments from one area to another in the estuaries, for example, resulting in erosion on the northern shores of the Solway and deposition on the southern side or vice versa.

2.2 WAVES AND TIDES

2.2.1 *Waves and swell*

The distance over which the wind can act on the sea surface to produce waves, i.e. the fetch length, is an important factor in wave growth. For almost the whole of the Dumfries and Galloway coastline, both the heights and periods of waves are restricted by the limited fetch lengths across the Irish Sea to the coastlines of the Mull of Kintyre, Ireland, England and the Isle of Man. A summary of information on wave conditions off the coastline of Dumfries and Galloway is presented in Figure 3.

Within Loch Ryan, only the eastern and western coastlines in the northern half of the loch are subject to long period (12-15 seconds) swell waves (Kirk McClure and Morton, 2001). These primarily originate from the North Atlantic and the Irish Sea. There are also local wind generated waves predominantly from the south-east with a typical period of about 4-5seconds. Significant wave heights of greater than 0.9m occur only at locations near Lady Bay and Finnarts Bay elsewhere the wave climate is calm for over 30% of the time. Considerable concern has been expressed in recent years about the effects along the coastline of waves generated by the high speed ferries travelling into and out from Cairnryan and Stranraer harbours. A study by Kirk, McClure and Morton (2001) investigated these concerns, and speed restrictions are now enforced to reduce the size of waves generated by these ferries. However, the initial consultation carried out as a part of the present SMP study indicated that concerns regarding these ship-generated waves still persist.

The western coast of the Rhins of Galloway coastline is exposed to large wave conditions from the south generated within the Irish Sea. Again this wave window is narrow with waves experienced from approximately a 20° sector centred on due south.

The outer Solway Firth is open to waves from the south and south-westerly sectors. The dominant wind direction, and hence wave direction, is from the south-west resulting in the Firth being exposed to onshore wave conditions for a high percentage of the time. There is evidence of wind funnelling into the Firth, as reported by Black et al (1994). The topography of Galloway and outer Solway appears to cause north-westerly winds in the North Channel to swing into the firth. This effect is more evident on light winds in the summer months.

Between the Mull of Galloway and Burrow Head, the coast is exposed to a very narrow wave window where fetch lengths extend out past the western coast of the Isle of Man, through St George's Channel and into the Atlantic. A similar fetch extends from the Inner Solway Firth and past the eastern coast of the Isle of Man. However, waves undergo significant modification through refraction, diffraction and shoaling processes so long-period swell waves are much less significant in the entrance to the Solway Firth than they are in other more exposed locations along the coast of Scotland. The wave spectrum in the Solway is primarily composed of waves generated within the confines of the Irish Sea (Black et al., 1994). From other directions the fetch length is restricted to less than 250km.

Waves in the outer Solway have been measured using a wave-rider buoy that was deployed for one year (October 1991-1992) approximately 18km west of Maryport (Black et al 1994). The maximum significant wave height recorded was 3.9m, occurring in February and waves over 1.0m occurred for 40% of the recording time. By comparison, BODC (1991) show significant wave heights over 1.5m are experienced for 10% of the time at the outer boundary of the Solway Firth, with a corresponding wave height of 1.0m within Luce and Wigtown Bay and the Inner Solway Firth.

Luce Bay is directly exposed to the south-east where fetch lengths extend approximately 200km to the Lancashire coast, but will be dominated by the larger wave conditions generated from the south west which refract/diffract into the bay.

Drummore Bay is generally exposed to waves from the east with some waves arriving from north to south east; wave heights arriving at the seawall there were calculated during a study by HR Wallingford in 1987. The significant wave height expected to occur, on average, once a year was predicted to be about 2.5m.

The coastline of the outer part of the Solway Firth can also experience swell wave conditions arriving from the south-west (HR Wallingford, 1995). The maximum swell significant wave

heights have been calculated as 2.3m, 3.2m, and 4.1m for the 1,10 and 100 year return periods respectively. This is likely to be an overestimate of swell conditions in the Solway Firth due to shallow water effects and energy dissipation resulting from the shape of the coastline and the influence of the Isle of Man. Actual wave heights will be much smaller.

A wave climate has been derived on the 20m CD contour to the south east of Dundrennan (HR Wallingford, 2000) using 12 years of wind data from Chapelcross and calibrated against wave measurements at the same location. The wave climate is dominated by wave conditions from 210° N to 250° N (40% of the time) with extreme conditions dominated by storms from 190° N to 230° N.

Nearshore wave conditions have been derived at several locations in the Solway Firth. This showed that penetration of wave energy from the Irish Sea into the Solway Firth was extremely limited, due to the effects of the extensive inter-tidal flats. In the inner part of the Firth, locally generated wave conditions dominate, with waves from the Irish Sea limited to a significant wave height of less than 1m. Maximum wave heights are experienced when the wind blows from the south-west, but the severity of wave conditions inshore of a line between Abbey Head and Workington will be very sensitive to water level.

Predicted wave heights in Ross Bay show a great dependence upon their incident wave direction. Waves from the westerly sector are quite oblique to the site and refraction leads to a significant reduction in wave height. Wave heights of the order of 1.5m are predicted for the outer areas of Ross Bay whilst further inside the bay significant wave heights are considerably lower, in the region of 0.3m (HR Wallingford, 2000).

Wave refraction numerical modelling at a water level of MHWS indicates that the maximum depth limited wave height in the channel of the River Eden would be 2.8m and 1.4m closer inshore. However, it is unlikely that the most extreme wave conditions will exceed 2m in height (a 2m wave height is considered to have a return period of between 100 to 150 years in the channel to the south of Annan).

A summary of information on wave conditions along the coastline of Dumfries and Galloway is presented in Figure 3 and Table 2.1 below.

Table 2.1 Location of wave points along the Dumfries and Galloway coastline

Position Number	Type	Easting	Northing	Reference ID
1	Predicted	319799	562955	7
2	Predicted	285274	534467	7
3	Measured	283904	534490	7
4	Predicted	265997	542773	2
5	Predicted	265311	544611	2
6	Predicted	255363	534022	2
7	Predicted	268294	522771	7
8	Predicted	245655	522393	7
9	Predicted	216979	521827	7
10	Predicted	213709	537145	1
11	Predicted	215281	550692	3
12	Predicted	207357	522016	7
13	Predicted	204527	543146	7
14	Predicted	190881	572168	6
15	Predicted	201949	575815	5
16	Predicted	204447	571456	4
17	Predicted	203794	567448	4
18	Predicted	206798	567248	4
19	Predicted	205696	562064	4
Reference ID				
Reference:				
1	HR Wallingford, 1987. "Protection of the A716 coastal road, Drummole, Dumfries and Galloway", HR report EX 1625, Wallingford.			
2	HR Wallingford, 2000. "Metoceanographic data study for a pipeline route between Ireland and the United Kingdom", HR report EX 4221 (confidential to Bord Gais Eirann).			
3	HR Wallingford, 2002. "Wave Conditions at the Entrance to Loch Ryan. Numerical modelling results", HR report EX 4552.			
4	Kirk, McClure and Morton, 2001. "Investigation of coastal processes in Loch Ryan", report for Loch Ryan Advisory Forum and Scottish Natural Heritage.			
5	Operation Northern Lights 03: Nearshore wave forecasts required by the Royal Navy for operations in Luce Bay			
6	Ramsay D L and Brampton A H, 2000a. "Coastal Cells in Scotland: Cell 6 – Mull of Kintyre to the Mull of Galloway, Scottish Natural Heritage Research, Survey and Monitoring Report No 148.			
7	Ramsay D L and Brampton A H, 2000b. "Coastal Cells in Scotland: Cell 7 – Mull of Galloway to the Inner Solway Firth, Scottish Natural Heritage Research, Survey and Monitoring Report No 149.			

2.2.2 Tidal Levels

Expected tidal levels along the coastline of Dumfries & Galloway for mean spring and mean neap tides in the area are presented in Table 2.2, with the levels given in metres relative to Ordnance Datum Newlyn. This table also presents information on tidal ranges, i.e. the vertical differences in water level at high and low tide. It is clear that these tidal ranges vary substantially from a minimum at Stranraer to a maximum in the inner Solway Firth.

The Solway Firth is “macrotidal”, with the large tidal ranges due to the Irish Sea being close to its resonant frequency for the semi-diurnal tidal constituents, i.e. with a mean period of approximately 12.1 hours. The tidal wave takes approximately 3.5 hours to travel from the Mull of Galloway to the inner part of the Firth.

The range, i.e. vertical difference between low and high water, on spring tides increases from about 5.3m at Drummore to 7.4m at Hestan Islet and to over 8m at Silloth (on the southern side of the estuary). The observed tidal curve for Hestan Islet is relatively symmetrical but progressing upstream the flood tide becomes significantly shorter than the ebb (Black et al., 1994). This increase can be explained by the funnelling effect resulting from the narrowing of the firth.

However upstream of Silloth and Southernness, the shallow water causes frictional effects, which dominate over this funnelling, and the tidal range progressively reduces (Black et al., 1994). Near the head of the estuary at Redkirk Point, the spring tidal range reduces to 3.6m. However, the narrowing of the estuary raises the local mean sea level at Redkirk by several metres above the mean level at Silloth (Black et al., 1994). Thus, despite the reduced tidal range at Redkirk, the high tide level is greater relative to Ordnance Datum here than elsewhere along the coastline of Dumfries & Galloway. The estuary also slows down the propagation of the tide, such that under certain conditions, high tide at Redkirk is one hour and 45 minutes later than that at Maryport.

At Redkirk during spring tides, the ebb tide lasts approximately 6 hours as the water slowly drains from the shallow flats and marshes, followed by a 5-hour slack period at low water. The flood tide then can rise over 4m in 2 hours. At neap tides, however, Redkirk experiences almost no tidal action except for a gentle rise and fall of 0.6m lasting under 3 hours. It is reported (ABP, 1991) that under certain conditions a tidal bore can occur in the Solway Firth above Annan Waterfoot, reaching a height of 1.5m.

Information on tidal levels in the various major estuaries along the northern shoreline of the Solway is lacking, making the assessment of flood risks within and close to the mouths of these estuaries extremely difficult. In many cases, it appears that flooding in these areas, particularly at Whitesands in Dumfries, is a consequence of large freshwater discharges in the rivers coinciding with a high tidal level. Predicting the occurrence and consequences of such events is an inaccurate and challenging task, which would be made much easier by increased tidal level monitoring at carefully chosen locations in the Solway Firth.

In Table 2.2 the tidal elevations are quoted relative to Ordnance Datum Newlyn (the standard land based datum) from a variety of reports. The level of the local Chart Datum relative to Ordnance Datum, where known, is shown in the final column.

Table 2.2 Tidal levels and ranges along the Dumfries and Galloway coastline

Location	MHWS (m OD)	MLWS (m OD)	Spring Range (m)	MHWN (m OD)	MLWN (m OD)	Neap Range (m)	CD (m OD)
Stranraer	1.38	-1.52	2.9	0.78	-1.02	1.8	- 1.62
Portpatrick	2.18	-1.32	3.5	1.38	-0.72	2.1	- 1.62
Drummore	2.8	-2.5	5.3	1.8	-1.1	2.9	- 3.1
Port William	2.8	x	x	1.6	-1.5	3.1	- 3.6
Isle of Whithorn	3.1	-3.1	6.2	1.6	-1.7	3.3	- 3.8
Garlieston	3.2	x	x	1.9	-1.4	3.3	- 3.8
Kirkcudbright Bay	3.8	-2.9	6.7	2.2	-1.3	3.5	- 3.7
Hestan Islet	4.29	-3.11	7.4	2.29	-1.61	3.9	- 4.01
Annan Waterfoot	5.0	x	x	2.7	-1.9	4.6	- 2.1
Redkirk Point	5.51	1.71	3.8	x	x	0.6	x

NB: x – no information available

There is little information on extreme water levels within the Solway Firth. Research by Dixon & Tawn (1997) has provided a spatial analysis of extreme water levels at 20km intervals around the coastline of the UK mainland. Their predictions depend on the year of interest and also take into account trends in mean sea level.

Table 2.3 Estimated extreme tidal levels along the Dumfries and Galloway coastline

Location	1-year return	10-year return	100-year return	1000-year return
Corsewall Point	2.12	2.46	2.83	3.17
Portpatrick	2.25	2.54	2.86	3.15
Drummore	3.28	3.62	3.94	4.24
Carrick	4.95	5.38	5.77	6.14
Hestan Islet	5.22	5.66	6.07	6.46
Southernness	X	x	6.25-6.50	x
Annan Waterfoot	X	x	6.95-7.30	x

NB: x – no information available

Table 2.3 has largely been compiled using the results of Dixon & Tawn (1997) and the values are in metres above ODN. The columns indicate different probabilities of occurrence, expressed as “return periods”. As an example, a tidal level at Corsewall Point equal to (or greater than) 3.17m ODN has a probability of occurrence in any year of 0.001, i.e. one chance in 1000, or an expected “return period” of 1000 years.

Note that these are predictions from a numerical model, and require further long-term tidal level measurements at most locations to improve their accuracy. Further, these predictions do not take into account any increase in (mean) sea level after the year 2000. For predictions of extreme tidal levels in the future, it is therefore necessary to add an allowance for the expected increase in mean sea level. Guidance from the Scottish Executive suggests that the appropriate allowance for the coastline of Dumfries and Galloway is 4mm/ year, so that by 2050, the expected 1000-year return period tidal level at Corsewall Point would be 3.37m ODN.

In addition to the published results of Dixon & Tawn, presented in the first five rows of Table 2.3, an estimate of extreme tidal levels in the Moray Firth has been made as part of the present study in research carried out for an MSc Dissertation (S Wilson, 2004). By combining information on the predicted extreme tidal levels at Hestan Islet and Carrick, see Table 2.3, with information on the changing range of mean Spring Tides as they travel up the Solway Firth, see Table 2.2, approximate extreme levels have been predicted for Southernness and Annan Waterfront. These estimates (for a 100-year return period) are presented in the last two rows of Table 2.3, but should be treated with caution until further tidal level measurements and numerical modelling have been undertaken for the inner Solway Firth. Within Loch Ryan, an extreme water level for a 1:50 year period has been calculated to be 4.51m above chart datum (Kirk McClure Morton, 2001) or about 2.9m ODN.

The extremely high tidal levels presented in Table 2.3 will occur as a consequence of a combination of the “astronomical” (i.e. normal) tides and the effects of weather conditions, e.g. low atmospheric pressure and strong westerly or south-westerly winds. These meteorological factors can cause a significant increase in the height of predicted tides, in the form of a tidal “surge”. Information on surge elevations in the Irish Sea was presented in Carter (1988) based on data from Heaps & Jones (1975). In January 1975, strong westerly winds associated with a cyclone to the north west of Ireland resulted in a surge elevation of 1.25m at the Mull of Galloway and across the outer Solway Firth, and over 2m in the inner Firth. This is calculated to be approximately the 1:50 year return period surge elevation (BODC, 1991).

In a more recent study by HR Wallingford (2000) the 50 year surge was calculated to be 2.0m and above around Ross Bay area. In the same study, the 50 year return period extreme tidal level was predicted to about be 5.7m ODN, which ties in well with the predictions for Carrick in Table 2.3 above.

2.2.3 Tidal Currents

A summary of information on tidal currents along the coastline of Dumfries and Galloway is presented in Figure 4.

Peak spring rates across the mouth of Loch Ryan are approximately 1 ms^{-1} and decrease to the north. Within Loch Ryan, the main tidal stream flows inwards past Finnarts Point and along the eastern coastline with the outgoing stream tending to flow along the western side of the Loch. Current speeds are extremely low particularly towards the head of the loch. Computational modelling of the tidal currents and heights, conducted by Kirk McClure Morton and Queen’s University Belfast, indicate that the current speeds are generally less than 0.5 ms^{-1} and the peak dropping to less than 0.1 ms^{-1} near the head of the Loch.

Along the western coastline of the Rhins of Galloway, tidal currents run parallel to the shoreline on both flood (south going) and ebb (north going) tides. Off Black Head, and to the south, the peak spring rate on both flood and ebb is approximately 2.5 ms^{-1} . To the north this peak rate decreases to 2 ms^{-1} off Craig Laggan and to less than 1.5 ms^{-1} off Corsewall Point.

Tidal streams off the entrance to the Solway Firth rotate anti-clockwise. The main flood tide travels through the North Channel, around the Mull of Galloway and east into the Solway Firth with peak spring currents of up to 2 ms^{-1} . In Luce Bay, the tidal stream rotates anti-clockwise and has a peak spring rate of approximately 0.6 ms^{-1} . During the flood stream an eddy runs west towards Cailiness Point and then south to the Mull of Galloway. On the eastern coastline the tidal stream follows the coastline on both flood and ebb between Burrow Head and the Point of Lag. Towards the head of the bay, currents are weak and irregular. The tidal stream

runs parallel with the coast between Abbey Head and Hestan Islet with a peak spring speed of 1.5ms^{-1} on both flood and ebb.

In the outer part of Wigtown Bay, tidal streams run in an east-north-east and easterly direction on the flood and west backing south-west on the ebb. The peak spring rate is approximately 2ms^{-1} . In the inner part of the bay, the tidal streams run in and out of the River Cree reaching up to 2.5ms^{-1} on a spring tide on both the flood and ebb. This current speed can be affected by spate flows from the river. The main flood and ebb stream runs across the mouth of Kirkcudbright Bay with a peak rate of up to 2ms^{-1} . However, within the bay, the tidal streams can depend on the flow from the power station dam at Tongland. In general, tidal streams are weak with a total maximum average near-bed current speed of 0.5ms^{-1} . Speeds increase upstream, reaching 2.5ms^{-1} off Southernness Point.

The Solway Firth is an area of high tidal energy. Tidal currents can also be significant in the channels between the sandbanks at the head of the Solway Firth, and during surges throughout, as far west as the Nith Estuary. A report by ABP (1991) indicates that currents can reach a speed of 2.0ms^{-1} during spring tides above Annan Waterfoot, if assisted by a strong south-westerly wind ($> 10.3\text{ms}^{-1}$ or Force 5).

A summary of information on wave conditions along the coastline of Dumfries and Galloway is presented in Figure 3.

2.3 BROAD SCALE SEDIMENT TRANSPORT AND COASTAL MORPHOLOGY PROCESSES

A wide-scale overview of the sediment transport processes operating along the coastline of Dumfries and Galloway was presented in previous reports published by Scottish Natural Heritage (Ramsay and Brampton, 2000a, b). This is a useful starting place for the present study. Additional information has been added from these reports for some parts of the coastline.

A summary of information on sediment transport and coastal erosion areas along the coastline of Dumfries and Galloway is presented in Figure 5.

Within the Loch Ryan system there are few beaches, and the majority of these have coarse shingle and cobbles on the upper foreshore, with sand below but ending on a clay/ mud seabed not far below low water. Short fetch lengths restrict wave conditions and there appears to be little beach dynamic response within the Loch. Numerical modelling of sediment transport pathways undertaken by Kirk McClure Morton and Queen's University Belfast shows sediment transport occurring south of the cliffs at Clachan Heughs in a southerly direction. This study also reports a potential movement of sediment, from the northern coast of Loch Ryan to the southern coast, with deposition occurring at Stranraer as mudflats. Sediment is also moving north along the western shore from Soleburn to Kirkcolm Point, leading to deposition at The Wig.

The material dredged from Cairnryan (and from Stranraer) is mainly very fine-grained sediment, i.e. muds and clay, and is unlikely to contribute any useful material to the beaches in Loch Ryan or nearby. Nevertheless, thought should be given to a possible deposit site within Loch Ryan to avoid the long-term loss of this sediment from the Loch, and reduce the costs of transporting the dredged material out to the Beaufort Deep in the North Channel, the current practice. The following table gives details of the amounts dredged from Cairnryan and Stranraer between 1991 and 2000 and deposited in two adjacent disposal areas (denoted MA010 and MA015). Note that the extraction from Portnuaghan Bay was in connection with

the laying of a natural gas pipeline from here to Castle Robin, Northern Ireland the following year.

Table 2.4 Quantities of sediment dredged from Loch Ryan (1991-2000)

Year	From	Quantity (tonnes)	Disposal site
1987	Stranraer	6120	North Channel (MA015)
1990	Cairnryan	9600	North Channel (MA015)
1990	Stranraer	2200	North Channel (MA015)
1992	Stranraer	30000	North Channel (MA015)
1992	Stranraer	22378	North Channel (MA015)
1993	Stranraer	1020	North Channel (MA010)
1995	Portnaughan Bay	67375	North Channel (MA010)
1995	Stranraer	26134	North Channel (MA010)
1996	Cairnryan	13898	North Channel (MA010)
1997	Stranraer	1973	North Channel (MA010)

Along the western seaboard of the Rhins of Galloway, a number of pocket beach systems occur. These units are self-contained in terms of the sediment budget and there are virtually no longshore losses of beach material. The largest beach systems, at Broadsea Bay, Knock Bay and Port Logan, are dominantly sandy although shingle occurs on the upper beach at Broadsea. Despite this coast being the most exposed to severe wave action there is little evidence of significant erosion. At Port Logan, the original plan-shape of the bay was probably altered by the installation of the harbour breakwater.

Siltation within Portpatrick Harbour is considered to occur due to sand sized material on the seabed being transported into the outer harbour. A small beach has formed in the outer harbour. Waves propagating through the harbour entrance result in a movement of this beach material towards the inner harbour and a gradual siltation at its entrance.

There is an abundance of sediments (sands and gravels) within the Solway Firth system but only at a few locations can the beach areas be described as well-nourished. Virtually all material within the Solway Firth is derived from glacial sources, both from the seabed of the Solway Firth and from terrestrial deposits that have been reworked. Rivers entering the Solway Firth do not bring any appreciable amounts of fresh sand or gravel. Present day reworking of hinterland deposits, e.g. cliff erosion, provides a low input of fresh sediment for the beaches but tends to be fairly localised with large-scale coastal edge erosion generally not appearing to pose a significant threat to infrastructure.

Much of the coastline is sheltered and longshore processes are generally restricted to the outer sections of the firth, e.g. around Luce Bay. However, due to the shallow and sandy nature of the seabed, nearshore sediment processes are highly dynamic. The general trend is for nearshore sediment movement to travel into the inner Solway Firth and also into the heads of the major bays, which occur along the north coast.

Shingle fringe beaches occur along much of the eastern coastline of the Rhins of Galloway with sand occurring over the lower foreshore. The dominant net drift is to the north and the lack of sand on the upper beaches is due to much of this material having been transported into the inner part of Luce Bay. The less mobile shingle does move northwards but at a much lower rate. The small bays along this coast demonstrate this, with much healthier shingle beaches at their northern end than to the south. Where sufficient volumes of shingle have accumulated some impressive shingle ridge beaches have formed, e.g. in Terally Bay. The northward drift of material has caused problems with siltation at Drummore Harbour with groynes having been installed immediately to the south to attempt to reduce the ingress of beach sediments.

Single and Hansom (1994) have summarised the present knowledge on sediment transport patterns within Luce Bay. As on the western side, the dominant net drift of beach material along the eastern coast is to the inner part of the bay. Again much of the upper beach is of shingle and the movement rate is extremely low and dependent upon the magnitude and direction of storm conditions. The movement of sand sized material on the lower foreshore and immediate nearshore zone into the inner bay is considerably greater, with accretion tending to be most evident at the eastern end of Luce Sands. Four factors have been identified which act to accrete sand in the inner bay:

- The indented nature of the bay constrains waves propagating into the bay to a unidirectional nature;
- Water depths in Luce Bay are shallow allowing sediment to be easily suspended due to wave action and transported by either waves or currents;
- Unconsolidated glacial sands and gravels, which are disturbed by wave action, form a thick covering over the seabed in the bay; and
- There is evidence that Luce Bay forms a major sediment trap for material transported south along the western coast of the Rhins of Galloway, around the Mull of Galloway and then moved northwards along a major flood channel on the western side of the bay.

Historically, coastal erosion problems are most evident on the western side of Luce Bay and a number of coastal protection schemes are in place mainly protecting the A716 (HR Wallingford, 1987). However, any present problems appear to be localised. Along the eastern flanks of the bay, a healthy shingle beach on the upper foreshore provides adequate protection. Some extraction of shingle has taken place in the past from this coastline.

Despite the Luce Sands area being generally one of accretion, localised erosion of the frontal dunes does occur. Single and Hansom (1994) state that the base of the dune scarp is at an elevation of 4.2m OD with MHWS at an elevation of 4.3m OD. However, erosion of the frontal dunes tends to be restricted to storm wave conditions at high water levels. The orientation of the beach to the south is conducive to dune formation, with embryo dunes evident at the eastern end of the Luce Sands, where the intertidal zone tends to be wider.

Burrow Head acts as a drift “divide” for wave induced sediment transport along the coastline in the inter-tidal zone (but not to sediments moved in the nearshore zone). However, despite the potential for wave-induced transport along the western side of the outer part of Wigtown Bay, the lack of sand and gravel and the rocky and indented nature of the coast result in minimal transport. Beach areas are thin and tend to be located in indented bays, e.g. Isle of Whithorn, Rig Bay and Garlieston. Due to the orientation of the beaches, coastal erosion is generally slow and restricted to small and localised areas.

The movement of fine sediments in the nearshore zone is more significant with the inner part of Wigtown Bay tending to accrete, as in Luce Bay. The sandbanks of the inner bay are dominated by tidal current actions, although wave action at high tide when the sandbanks are covered, will aid suspension of sediments. The wide inter-tidal zone is extremely effective in dissipating wave energy and little erosion of the coastal edge occurs. Further into Wigtown Bay, the Cree Estuary has historically been an area of considerable accretion, leading to a large amount of land being reclaimed for agricultural purposes (RCCE, 1911).

Fleet Bay, Kirkcudbright Bay, Auchencairn Bay and Rough Firth similarly act as traps to sediment moved by tidal action in the nearshore zone, with little longshore processes evident. The shallow water depths within these bays limits wave action, and hence erosion of the

coastal edge. Due to the rocky nature of much of this coast, any minor areas of erosion are localised.

Towards Southernness Point, the coastline becomes more exposed to the south-west and larger fetch lengths occur in the direction of the prevailing wind. The coastline is afforded much protection from waves propagating into the Firth by the extensive inter-tidal sandbanks of Mersehead Sands and Barnhourie. Despite this, significant erosion of the coastal edge occurs between Southwick and Southernness. This appears to be a long-term process with wave induced transport of sand to the east towards Southernness Point (where the rate of erosion tends to be least). Damage is also caused by public usage of the foreshore. Attempts have been made to stabilise the dunes at Southernness Golf Course. The rate of erosion tends to be variable along the frontage (Mather, 1979) and may perhaps be linked to shifting sandbanks in the immediate inter-tidal and nearshore zone.

Erosion occurs at various locations within the Inner Solway Firth, for example at Powfoot, Newbie, Annan, Redkirk Point and Gretna. In these areas, the shore-parallel tidal currents have an impact on shoreline conditions.

2.4 CLIMATE CHANGE AND ITS EFFECT ON COASTAL MANAGEMENT

2.4.1 *Introduction*

The importance of climate change in the context of coastal management has generally been equated to the problems caused by an increase in mean sea level. This remains an important issue, particularly for low-lying areas where economically important assets are situated close to or below, extreme tide level. Around most of Scotland, ground levels increase rapidly just landward of the coastline, with the result that the area at risk from tidal inundation is generally small. The main exceptions are in the major estuaries, e.g. the Clyde, Forth, Tay, where very substantial developments have taken place on low-lying and sometimes reclaimed coastal margins. An initial, broad-brush estimate of the potential hazards of coastal flooding in Scotland has been made (see Werritty et al., 2002), assuming that land lower than 5m ODN could be at potential risk at present or following an increase in mean sea level in future. This research has also been incorporated into the FORESIGHT Flood and Coastal Defence Project (see <http://www.foresight.gov.uk>). That report made little mention of coastal flood risk in Dumfries & Galloway, save for commenting on the flooding of Whitesands in Dumfries (which is probably caused by a combination of high tidal and high freshwater discharges down the River Nith). The simple assumption that the 5m ODN contour is an indicator of the likely extent of coastal flooding is also potentially misleading when considering the coastline of Dumfries and Galloway. Table 2.3 of this report (see Section 2.2.2) shows that the tide will not reach this level in the western part of the region, e.g. in Loch Ryan or Luce Bay, in the foreseeable future. In contrast, for much of the Solway Firth the tide may presently rise well above 5m ODN, and an increase in mean sea levels would increase the area at risk.

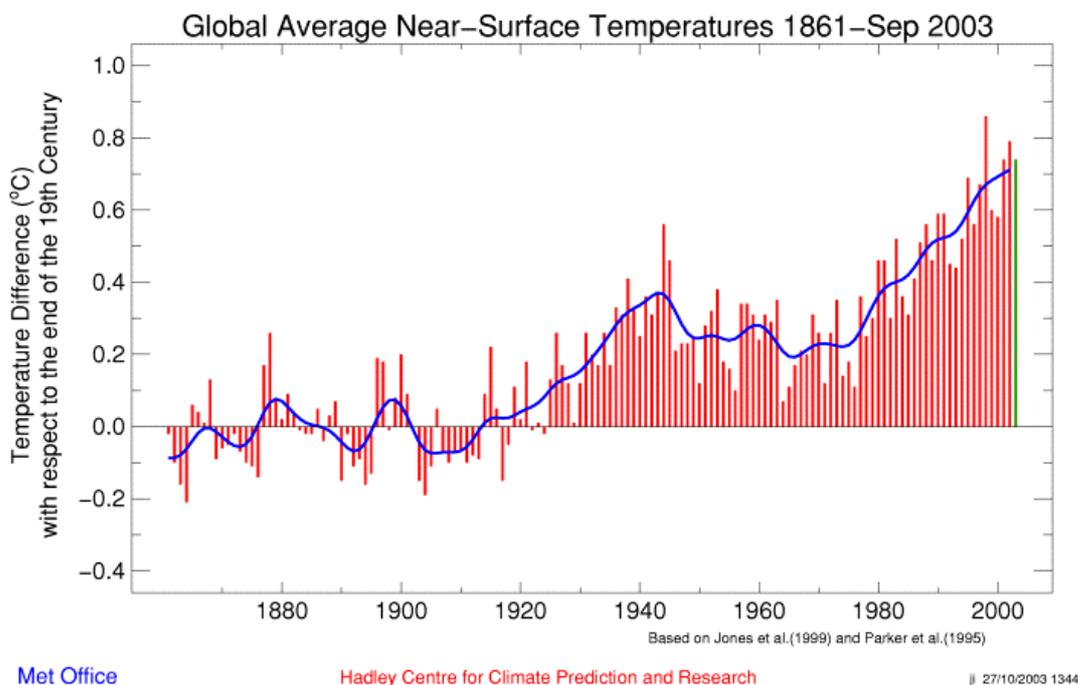
In addition, recent winters in the UK have indicated a number of other potential impacts of climate change affecting the management of the coastline and its defences that may be more important, at least in the short term. For instance, the eastern coastline of Scotland during the winter of 1995/96 suffered from an unusually high percentage of storm conditions from the easterly sector with a corresponding reduction in the proportion of storm conditions from the west. Changes in the mean wave direction, following a shift in wind patterns, will bring about changes in the longshore movement of sand and gravel, and hence provoke changes in the orientation of beaches with some areas accumulating sediment while other areas of the coastline will lose beach material and erode. An increase in the frequency, severity or the wind direction during storms will also cause greater problems for beaches and sea defences.

Increased erosion of the coast may be a greater concern in the western part of Dumfries and Galloway, where little of the coastal strip is low-lying, than any increase in flooding due to sea level rise.

2.4.2 Evidence of climatic change

General

There is a considerable body of literature and scientific study suggesting that the global climate is not only subject to significant fluctuations, but also that we are presently witnessing a rapid change indicating overall warming of the Earth's surface. An article by Parker and Folland (1995) indicated that globally averaged surface temperatures had increased in recent years, and that the five hottest years on record at that time (i.e. since 1860) had occurred in the last 12 years. Since then, the evidence for increasing temperatures has grown as shown on the figure below, obtained from the Hadley Centre web site.



Recent information on changes in global temperatures

This single measure of change is but one of many pieces of evidence, for at least the variability of the Earth's climate, and it is increasingly believed that recent changes have been partly caused by pollution of the atmosphere, e.g. by the emission of "greenhouse gases". Possible effects of changes in the climate on the coastline of Dumfries and Galloway are now discussed.

Mean sea level and tidal level changes

Geomorphological evidence shows a long-term pattern of sea level rise relative to the land around much of the UK coast, stretching back over 10,000 years to the end of the last Ice Age. Generally rates of sea level rise during this period have been higher than they are today although there have been several periods of "stands" in level, or even periods of falling levels.

Along much of Scotland's coastline, the rate of increase in global sea levels (so-called eustatic increases) is now occurring at a slightly greater rate than "isostatic" increases in land levels (e.g. the rebound in land levels following their pressing down by the weight of ice during the last Ice Age). Thus sea levels are now increasing relative to the land albeit slowly (and certainly much slower than being experienced along the south-eastern coast of England for example). It is important to make the point that much of the coastline of Dumfries and Galloway has the capacity to adjust to rising sea levels, retaining its character and attributes, albeit at the cost of a gradual landward retreat. Because so little of the coastline has been "fixed" by the construction of coastal defences, this landward retreat has not been resisted, with the overall result that the natural environment of the beaches, saltmarshes and inter-tidal areas has not deteriorated as a consequence of past sea level rise.

Nevertheless, future coastal defence policy in Dumfries and Galloway needs to recognise the strong possibility of acceleration in the increase in mean sea level relative to the land. Where the coast is not allowed to retreat naturally in response to this, there are likely to be repercussions on both the natural environment and calls for greater expenditure on coastal defences.

Dealing first with eustatic changes, the Intergovernmental Panel on Climate Change (IPCC) predicted, in a study carried out in 2001, that global mean sea level may rise as much as 88 cm (approximately 35 inches) by the end of the 21st century. This increase in the level of the seas and oceans is partly due to warming, leading to thermal expansion of the water and partly due to extra water entering the seas as glaciers and terrestrial ice sheets melt. However, the results from different predictions of the changes in the Earth's atmosphere as a result of continuing pollution from "greenhouse gases" vary considerably, and some organisations feel that this predicted increase may be an underestimate.

To convert this wide-scale, long-term prediction of the eustatic increase sea levels into more specific predictions of sea level rise, relative to the land in Dumfries and Galloway, requires further analysis. This has been the subject of a recent study commissioned by Scottish Natural Heritage (Dawson et al., 2001) which concentrated on the changes in relative sea level around Scotland's coast, and considered the effects of such changes. This report provides a range of predictions of the increase in relative mean sea level for the coast of Dumfries and Galloway, depending on the assumptions made about the future emissions of greenhouse gases such as carbon dioxide and methane. For the coastlines of Wigtownshire, Kirkcudbright and the Solway Firth (CPU's 3 to 7) their "best estimate" was that levels would rise by between 145 and 170mm by 2020, i.e. an annual increase of about 7-8.5mm per annum. For the coastline north of the Mull of Galloway, the predictions of the future rate of sea level rise are lower, because the isostatic (upward) changes in the landmass are greater here. The "best estimate" increase of mean sea level here by 2020 is given as "<145mm" (Dawson et al., 2001).

There are few measurements of the present rate of sea level rise relative to the land with which to compare these predictions of future increases. At Portpatrick, the recent rate has been estimated as about 1.25mm per annum from 27 years of tidal measurements between 1968 and 1998 and this is almost identical to the rate of relative sea level rise at Millport in the Firth of Clyde. There are no reliable figures for the Solway Firth and discussion of the need for tidal measurements in the Firth are returned to later in this report.

The responses of a coastline to changes in mean sea level are difficult to predict. Simple models relating the vertical increase in relative mean sea level to a horizontal adjustment in the position of the shoreline have been proposed in the past and are discussed below.

However, it is important to note that any increase in extreme tidal levels may not be the same as the increase in the mean sea level. There is not only a potential for long-term variations in the height and frequency of surges as a consequence of changes in the frequency or intensity of storms, but also a change in the range of the astronomical tides as a consequence of changes in mean sea level. The former effect could be particularly important in the Solway Firth. Here, the occurrence and height of exceptional sea levels will affect the erosion of coastal slopes, the flooding of low-lying land along the shoreline and in estuaries and morphological changes on the saltmarshes and merse areas. Such exceptional levels will arise as a consequence of the addition of a surge to a high “astronomical” tidal level, typically at times of low atmospheric pressure and south-westerly gales or storms.

Current research, however, does not predict any major change in the frequency of occurrence, or magnitude of storm surges (Werrity et al., 2002). This is linked with the difficulties of predicting future values of the North Atlantic Oscillation, i.e. the variation in the atmospheric pressure gradient between the “Azores High” and the “Iceland Low”, which is probably the major climatic factor in the occurrence of such surges around the UK coastline.

Changes in the range of astronomical tides (see Section 2.2.2) can arise as the various shallow water basins such as the Irish Sea and the Solway Firth approach closer to, or move away from resonance with the tidal period. Changes in tidal ranges are therefore most likely to occur at the heads of those estuaries that are presently close to resonance with the semi-diurnal tides. Very coarse scale modelling of the Irish Sea suggests that in the inner Solway Firth there may be a slightly greater increase in high tide levels than of mean sea level as a consequence of this mechanism. However, further investigations would be needed to confirm or revise this early result.

Wave climate change

Around most of the coastline of the UK, wave action is the principal driving force for evolution of the nearshore zone, i.e. the region where water depths are less than 5m at low tide. Hence changes in wave heights, either in terms of general trends or in severe storms, are of considerable importance. There is now no doubt that such periods of increase in wave height do occur and may continue to do so for some considerable time. Bacon and Carter, (1991) have conducted the most comprehensive review available of wave climate changes in the North Atlantic and North Sea. Their data suggests that mean wave height increased from about 1960 to a peak around 1980, with a subsequent decline. Recent winters, (particularly 1988-1989 and 1993) have produced severe storms in the northern North Sea that may affect these trends. This agrees with more recent work (Leggett et al, 1996) which analysed wave climate data in the northern North Sea between 1973 and 1995 and concluded that:

- In the northern North Sea, mean significant wave heights (H_s) have increased by approximately 0.2-0.3m (5-10%) since 1973. Wave conditions have been higher since 1988/89, with a secondary peak in 1982/83;
- Peak H_s values since 1988 have generally been significantly higher than those from the period 1973-1987. Recent years have seen storms with peak H_s of 12.5-14m, whereas peak values recorded before 1987 were around 11-12m, and
- Since the 1980's wave conditions appear to have become a little calmer in autumn and more severe in late winter.

There is also some qualitative information to suggest that the increase in severity of the wave climate in the North East Atlantic has occurred in parallel with an increase in the frequency of very deep low pressure systems in the North East Atlantic (Lynagh, 1996). This report

suggested that the latest peak in the frequency of occurrence of these low-pressure systems has passed and that the next few years will see a decrease in such systems. In the few years after this paper was published, however, some severe storms have caused major damage along the eastern coastline of the UK, indicating that predicting such long-term patterns is a thankless task.

It is now widely accepted that the severity of low-pressure systems, and wind strengths, across the UK is related to the North Atlantic Oscillation (NAO), a measure of the difference in atmospheric pressure between the “Iceland Low” and the “Azores High”. This pressure differential is similar to that in the Pacific (between Darwin and Tahiti) which leads to the well-publicised El Nino effect across the southern part of that ocean. When the Iceland – Azores pressure difference is large, and hence the NAO is high, winds and wave conditions around the UK (and indeed along the coastlines of western Europe) will tend to be more severe. Note that such a situation is likely to produce more storm surges as well. This situation has persisted and apparently worsened between about 1980 and the late 1990’s. Whether it will continue at the levels seen at the end of that period reduce or increase is not possible to predict. Such changes over a decade or two, however, have occurred in the past. Recent events over this length of time are not necessarily evidence of a permanent change.

Analysis of long-term wind climate data has revealed that there has been very little net change and no proof that recent increases in storminess are statistically significant. Unpublished work by Jenkinson and Collison (1977) found no significant change in wind speeds over the Atlantic or North Sea occurred between 1881 and 1976. Historical evidence analysed by Lamb and Weiss, (1979) detected a climatic cycle of about 200 years. Over the North Sea the change consisted mainly of changes in the relative proportions of northerly and westerly winds.

It is worth making the point here that wave direction can be expected to be as important as wave height in coastal management, and this is discussed later. However, there is not a sufficient length of time series, of reliable directional wave data, to assess any trends in direction along the coastline of Dumfries and Galloway, or indeed around much of the UK.

2.4.3 *Effects on coastal management*

General impacts on beaches

One method for predicting shoreline erosion caused by sea-level rise is known as the Bruun Rule (Bruun, 1983). This suggests that as sea levels rise, the beach will adjust to maintain a constant depth profile, i.e. the upper beach erodes while the nearshore bed accretes. There is some evidence to suggest that this also happens in real life, but this method assumes a two-dimensional response when the development of a beach will almost always be three dimensional. The amount of sediment available is also a critical factor in the response of a beach to sea-level rise, with those with a limited supply being more likely to retreat. However, the evidence for any link between coastline retreat as a result of sea level rise is far from conclusive.

In the UK, the effect of sea level rise on beaches is probably not as great as those associated with changes in the wave climate, in the short term at least. An increase in the occurrence of very large waves will, for example, alter beach profiles or cause dune erosion that may take many months, or even years, to repair naturally. Conversely an increase in the occurrence of more modest waves, may be accompanied by a decrease in the largest wave heights. This would lead to a general steepening of the beach profile and a reduction in erosion. Any change due to sea level rise may therefore go completely undetected.

Although a change in wave heights will cause changes to beach profiles, the long-term

evolution of the shoreline is almost always linked to changes in the longshore transport of beach sediments or, more precisely, the changes in transport from point to point along the coast. The longshore transport does depend on wave height, but more crucially on wave direction. The former influence, in the long term, can only increase or decrease the rate at which the coastline is eroding or accreting. However, a change in the “average” wave direction will often cause a change in the present trends of erosion and accretion (affecting both rates and patterns). At some locations, it has been found that erosion problems have recently occurred on stretches of coastline that have been stable or accreting for many years.

Impact on the beaches along the Dumfries and Galloway Coast

In terms of the beaches and “soft” coastlines it is extremely difficult to postulate what the responses to any climatic changes are likely to be. The situation is probably clearest along the Luce Bay coastline where shingle fringe beaches protect the immediate coastal edge. The movement of shingle on the upper beaches will only occur at high tide and given that wave conditions within Luce Bay are restricted, movement of shingle is only likely to occur during storm events. Wave conditions here also tend to be strongly unidirectional, i.e. travelling in a northward direction. Hence, there are unlikely to be any significant effects on the shingle beaches due to minor changes in wave directions, with increases in storminess also likely to have less of an effect than on an open coastline.

At the head of Luce Bay increases in extreme sea levels or frequency of storm conditions (and to a lesser extent, in mean sea levels) will, therefore, result in increased frontal dune and upper beach erosion. If the frequency of storm events also increased, there would be less time for the dunes to recover sand in calmer conditions. The result could then be a loss of sand from the beaches, with this material being redistributed over the seabed within the nearshore zone. However, much of this sand will remain in the Luce Bay beach system, as net longshore transport (in the wave breaking zone) is minimal.

The situation in the Solway Firth is much more complicated. Little is understood of the morphological interaction between river flows, tidal currents and waves and the impact these processes have on the formation of the sandbanks, flats and marshes. Increases in mean water level may well increase the length of time during the tidal cycle that both wave and tidal currents flow over these sandbanks, leading to increased sediment transport over them. What effect this will have on the surrounding coastline is not quantifiable with our present knowledge.

The effect on the saltmarshes in the Inner Firth depends heavily on the rate of sea level rise and on sediment availability. For instance, there appears to be a threshold value in the rate of sea level rise below which the saltmarsh surface is able to accrete and keep pace with the change. Above this threshold the marsh becomes submerged and is lost. Given that there is an abundance of sediment in the Solway Firth system and that there is a high tidal range, significant saltmarsh loss would not be expected as a result of sea level rise alone. There is also evidence to suggest that erosion and loss of saltmarsh is linked to increases in wave energy, which may be more of a problem in this region if increased water levels result in marginally larger waves interacting with the marsh for a longer period of the tidal cycle. Of greater threat are changes in river flows that can effect the location of the river channels.

Any increases in extreme water level may have substantial impact on flooding at the heads of the main bays in the region. Much of the land at the outlet of the rivers is low-lying with flood embankments providing protection against inundation. Where these defences are already overtopped during the highest tides, or where there are no defences, then more frequent flooding will result as mean sea level, and hence highest tidal levels, increase. In addition, higher tidal levels will impede the outflow of rivers, and such “backwater” effects could cause

an increase in the severity of flooding further up rivers as presently occurs on the Rivers Nith and Annan.

In general, such changes will become apparent only gradually, with much depending on weather conditions, so that the underlying influence of sea level rise may be difficult to discern. More dramatic changes may occur, however, if existing flood embankments fail as a consequence of one or more extreme tidal levels.

2.4.4 Other relevant effects of climate change

There are a number of other, climatic factors which may affect the coastline evolution and hence management techniques. Two of these are discussed below. In each case, however, little is known of the extent of any variations in these climatic factors and whether they will be of significance in managing the coast.

Changes in rainfall

There is a known past variation in the rainfall occurring in the UK. In the south of England an oscillation of about 40 years period has been observed. Stirling University has apparently recorded a similar oscillation when investigating River Tay flooding. As rainfall increases, a number of effects are likely to occur at the coastline, as follows:

- De-stabilisation of soft cliffs

Cliff falls are usually caused by a combination of marine erosion, e.g. undercutting of their front face, and geotechnical problems, e.g. rotational slips. The latter effect is increased by greater rainfall and hence higher run-off, higher water tables etc. Most of the cliffs along the coastline of Dumfries and Galloway are relatively resilient to marine erosion, so this is unlikely to be a significant problem in such circumstances. However, where there are cliffs of glacial till, for example in Luce Bay and Loch Ryan, then increased occurrence of land-slides could occur as a consequence of wetter winters and drier summers.

- Increased river flows

In many parts of the world, rivers still bring large quantities of sand and gravel to the coast, providing fresh supply. Increased river flows would increase the capacity of the river to transport sediment. Most of the rivers that discharge into the Solway Firth have a low sediment suspension capacity which is unlikely to cause any significant change in the supply of fluvial sediments to the coastal zone. However, changes in river flows will have an influence in the movements of channels over the sand and mudflats in the inner parts of the main bays.

The major impact of an increase in fresh water flows, however, would be felt not along the open coast but in the estuaries of the various rivers. A number of communities already experience flooding when spate flows meet high tidal levels in estuaries, perhaps most notably in Dumfries (Whitesands), where the road is inundated several times each year.

If as a result of climatic change, river flows were to increase by 20%, as often now considered in flood defence studies, then coupled with rising tidal levels, the chances of more regular and serious flooding in such locations will increase.

However, applying this general safeguard may well be over-cautious in Dumfries and Galloway. A recent report for the Scottish Executive considered the effects of climate change on river discharges in various parts of Scotland (Werritty et al., 2002) including

the River Nith. This research indicated that the likely peak discharges in the Nith would not change significantly even under the “worst case” assumption for greenhouse gas emissions. These predictions seem also to provide the best indication of future discharges for other rivers in Dumfries and Galloway, e.g. the Urr, Cree and Annan.

- Impacts on sand transport on beaches

In locations where a beach is affected by surface water run-off from land, there are often localised erosion problems, e.g. around outfalls. The frictional resistance of sand is reduced by the outflows, making it easier to be mobilised by waves and currents. It is therefore likely that increased rainfall will tend to cause localised beach erosion, but this may be a minor factor.

- Impacts on dune growth/ restoration

Wet sand on the foreshore will be much less easily transported by winds than if it is dry, reducing the supply to dunes. However, many dune-binding grasses suffer in drought conditions, and are generally healthier in moister climates. This would help to increase the trapping efficiency, and encourage them to colonise new areas more quickly. It is not clear, therefore, whether increased rainfall will assist dune growth or be detrimental to it.

Changes in winds

As well as changes in wind conditions altering wave conditions, as discussed earlier, there are other direct effects that may influence the coastline through the mechanism of aeolian sand transport. Strong winds are capable of transporting large quantities of sand, both along the coastline and perpendicular to it. The former effect can add to, or counteract, wave induced longshore drift, but tends to take place at higher levels on the beach profile. Onshore transport by wind typically dominates over offshore movement. This is partly because winds blowing over the sea are stronger (less affected by friction) than those blowing offshore.

A change in wind strengths or directions may also alter existing patterns of sand transport. It is likely that this will be most noticeable in changes in dunes, rather than on the beaches themselves. Large dune complexes such as in Luce Bay are most likely to experience such changes.

2.4.5 Summary of possible effects of climate change on coastal management in Dumfries & Galloway

The main effects of climate change relevant to coastal management in Dumfries and Galloway, as far as can be ascertained at present, are as follows:

Tidal levels

The widely-predicted increase in the rate of mean sea level rise, as the result of climate change/ global warming, may also lead to a change in tidal range in some areas. This could arise as a consequence of a change in the propagation of the tidal “wave”, particularly the resonance of its semi-diurnal component. Further work is needed to investigate the changes in tidal propagation in the Solway Firth at present and in the future, to understand whether high or low tidal levels will change more or less than the increase in mean sea level.

Surges will continue to be an important factor in producing very high tides, but as with waves, there is no strong evidence at present to suggest that climate change/ global warming will increase either the frequency or magnitude of storm surges.

Any design or review of coastal defences should incorporate an allowance for increased tidal levels; allowing for 5-8mm per annum over the next few decades would be prudent.

Waves

The generation of waves in the Irish Sea, the North Channel and the Firth of Clyde will continue to be influenced by changes in the North Atlantic Oscillation (NAO), i.e. the mean atmospheric pressure difference between the Azores High and the Iceland Low. Changes in the NAO have been unpredictable in the past, and there is only now some attempt to make predictions of how it may change in future decades. There is only weak evidence for any increased “storminess” following/ accompanying climate change/ global warming, especially prior to about 2080.

However, waves at the coastline may be affected in some areas by the increased water depth due to higher tidal levels, particularly where the coastline is “fixed” either by a hard rock shore-platform or by construction of seawalls. In such situations, review or design of coastal defences should allow for an increase in wave heights in shallow water, in line with the allowance made for increases in tidal levels.

River flows

Already the combination of large fluvial discharges and high tides leads to flooding problems in several areas of the coastline of Dumfries and Galloway. As a general rule, it is assumed that peak flows in rivers will increase as one of the consequences of climate change/ global warming, and often a 20% increase in discharges is assumed for flood defence planning.

However, a recent study that specifically considered the future flows in the River Nith indicated that there will not be any significant increase in flows in that river over the next few decades. This result can reasonably be extended to the other main rivers in Dumfries and Galloway (i.e. the Annan, Cree, Dee and Urr). However, there may still be some increase in flooding in the lower reaches of the estuary as gradually increasing tidal levels hamper the discharge of these rivers by “backwater” effects.

Further information is needed on the causes of such flooding events, and whether flood embankments will need to be raised, in some areas, to deal with future conditions. In particular, long-term measurements of tidal levels in the Solway Estuary are needed to understand the effects of surges and river flows on tidal levels.

Coastal erosion and retreat

Where the coastline is unprotected by defences, i.e. in a natural state, the expected future increases in tidal levels, together with corresponding changes in wave conditions in shallow water, are likely to lead to an acceleration in the present rates of coastal erosion and retreat. It has proved difficult in the past, however, to discern the effects of increasing sea levels from the many other factors that influence coastline change, particularly variations in wave heights and directions. Thus it may be many decades before the effects of an increased mean sea level can be shown to alter the present rate of change in the coastline.

The greatest rate of coastal retreat following an increase in sea level is likely to occur where the nearshore seabed/ beach gradients are shallowest, and in Dumfries and Galloway this means the Inner Solway Firth. However, the past advances and retreats of the saltmarsh/ merse in this area show that sea level rise will only be one factor in future changes. Changes in the position of the main river channels, particularly of the Esk, together with the vigour and extent of saltmarsh vegetation and changes in wave conditions will all contribute to changes in the mud flats and saltmarshes.

On coastlines with glacial till cliffs, a combination of increased winter rainfall and higher tidal levels will increase the present rate of cliff top retreat. This is likely to be a particular problem along the western coastline of Luce Bay and in Loch Ryan.

Where there are coastal defences, e.g. seawalls, then it can be expected that these will become gradually exposed to greater forces as tidal levels and hence waves against them increase. This is often accompanied by a lowering of beach levels at the toe of the defences, further adding to the wave heights and forces.

Coastal flooding

The areas most at risk from coastal flooding in coming decades are likely to be those already experiencing flooding problems, i.e. in the lower reaches of the major rivers where the discharge of high fluvial flows is hampered by high tidal levels.

Where flood embankments have been built some decades ago, there may be a need to check and if necessary raise their crest levels to account for recent and likely future increases in tidal levels. Again these embankments are principally located along the banks of the major rivers, including the Inner Solway Firth. It should also be noted that a gradual increase in the level of low tide will hamper drainage of low-lying land, e.g. merse areas, and as a consequence water levels in these areas will tend to increase, even if marine processes do not directly affect them.

2.5 THE SHORELINE MANAGEMENT PLAN AREA

The coastline of Dumfries and Galloway extends from the mouth of the River Sark in the Solway Firth to Galloway Burn, just north of Cairnryan in Loch Ryan in the north-west. The boundaries for this Shoreline Management Plan have been chosen to match those of the Council's responsibility. Normally, for such a Plan, the boundaries are chosen some distance beyond the administrative boundaries, in order to guard against works in one authority's area affecting the coastline in an adjacent authority's area. This might occur, for example, as a result of interfering with the longshore movement of beach sediment.

However, at the northern boundary in Loch Ryan, the shorelines at the base of the cliffs on either side of Galloway Burn are virtually sediment free, and no coastal protection works are likely to be undertaken. Hence, existing patterns of (scant) sediment movement across the boundary between Dumfries and Galloway and South Ayrshire will not be affected by any foreseeable coastal defence works.

Similar comments apply at the eastern end of this coastline, deep within the Inner Solway Firth. Here there is no conventional longshore sediment transport, since the foreshore is muddy and more affected by tidal currents than wave action. Further, there is little likelihood of any coastal defences being built in this area of great conservation value.

This is not to say, however, that there is no need for co-operation between Dumfries and Galloway Council and adjacent authorities when considering the management of the coastline in the Inner Solway Firth and in Loch Ryan. Mechanisms for such co-operation are already in place, through the Solway Firth Partnership and the Loch Ryan Advisory Management Forum.

2.6 COASTAL PROCESS UNITS

The next stage in the Shoreline Management Plan is to sub-divide the Council's coastline into a number of "coastal process units" (CPU) within which coastal processes are broadly similar and beach sediment movements can be regarded as largely self-contained, i.e. with little transfer into or out of adjacent CPU's.

Six of these have been chosen, as follows:

- | | |
|---------------------------------|---|
| 1. Inner Solway | River Sark to Borron Point |
| 2. Outer Solway Coast | Borron Point to Torrs Point, Abbey Head |
| 3. Wigtown / Kirkcudbright Bays | Torrs Point, Abbey Head to Burrow Head |
| 4. Luce Bay | Burrow Head to Mull of Galloway |
| 5. Rhins of Galloway (west) | Mull of Galloway to Milleur Point |
| 6. Loch Ryan | Milleur Point to Finnarts Point |

The extent of these CPUs is shown in Figure 6.

Some of the boundaries between these proposed CPU's, e.g. The Mull of Galloway and Abbey Head, are almost complete barriers to wave induced longshore transport along beaches, but even these are not a barrier to sediments moved by strong tidal currents. Elsewhere, the boundaries between the various CPU's have been chosen largely on the basis of changes in the wave exposure, often a consequence of changes in the orientation of the coastline.

2.6.1 Inner Solway – CPU 1

The Solway Firth is a sediment sink with material accreting in the inner part of the estuary. As such there is no definitive “upstream” boundary for CPU 1, with sediment probably transferring across the mouths of the Rivers Sark and Eden in either direction, depending on the natural changes in the low-water channels. Similarly there is no barrier to the movement of sediment laterally across the Solway Firth, so this Coastal Process Unit should therefore be considered as extending along both coastlines of the Firth. The seawards or downstream limit of this Unit has been defined here on the basis of a change in the sediments, in the upper part of the intertidal zone, from mud to sand and gravel. On the coastline of Dumfries and Galloway, the marked change in shoreline orientation at Southernness Point has been taken as the most convenient boundary. (It should be noted, however, that the coastline from here east and north to Carsethorn has beaches of sand and gravel, and there is an argument for treating this short stretch of coast as a part of CPU2.) The corresponding boundary of this CPU on the English coast would be at Grune Point near Skinburnness.

2.6.2 Outer Solway – CPU2

The coastline from Borron Point, near Southernness, going westwards to Torrs Point, near Abbey Head faces approximately south-south-east, and is either cliffed, or has cliffs to the rear of raised beach deposits nearer Southernness. There is a potential eastward drift of sediment, some of which has accumulated in Auchencairn Bay and the estuary of the Urr Water and Rough Firth, with the remainder contributing to the major sand accumulation at Mersehead. However, there is apparently little or no supply of beach sediment from further west, i.e. travelling around Abbey Head, so that any fresh sediment must either be derived from cliff erosion or carried into the area by tidal currents.

2.6.3 Wigtown and Kirkcubright Bays - CPU3

The central southern portion of the coastline of Dumfries and Galloway has a number of deeply indented bays, into which drain four major rivers, the Dee, the Water of Fleet, the Cree and the Bladnoch. The upper reaches of these estuaries are muddy, and flooding in the lower reaches of each river, near or below the normal tidal limit, is a concern. Between these estuaries, the shorelines are largely rocky, with isolated “pocket bay” beaches, for example Ross Bay, Brighthouse Bay and at Garlieston.

The eastern boundary of this CPU has been chosen at Torrs Point, near Abbey Head, where the coastline changes from a sedimentary estuary to a rocky coast, and changes direction, facing approximately south to the east of this location. Beach sediment transport around this headland is likely to be insignificant. Burrow Head, to the south of the Isle of Whithorn, is a similar “zero drift” headland marking the south-western extremity of Wigtown Bay.

2.6.4 *Luce Bay – CPU 4*

In the SNH report (Hansom et. al, 2000), it was suggested that the coastline of Luce Bay, from Burrow Head, just west of the Isle of Whithorn, to the Mull of Galloway, could have been identified as a “sub-cell” in the original “Coastal Cells in Scotland” report (Ramsay and Brampton, 2000a,b). This is an entirely justifiable suggestion, since there is no longshore sediment transport into this Bay from either side, and probably only an insignificant transport from Luce Bay eastwards around Burrow Head. From the viewpoint of coastal defence management, therefore, the beaches of Luce Bay can be treated as developing independently of those beyond these two headlands. In this report, therefore, this section of coast is regarded as CPU 4.

The whole of Luce Bay CPU is well exposed to waves approaching from the south-east, and the strong tidal currents across the mouth of the bay diminish towards its head. Both of these factors tend to produce a movement of beach sediments into the head of the bay, and Luce Sands is the largest sandy beach complex in Dumfries and Galloway. There are raised beaches, of varying width, along both sides of the bay, with predominantly greywacke cliffs at their rear. Coastal erosion is widespread and presently of greater concern in this CPU than elsewhere along the shoreline of Dumfries and Galloway.

2.6.5 *Western Rhins – CPU 5*

The Mull of Galloway forms a major boundary between Luce Bay and the much more exposed, and generally cliffed shoreline of the western part of the Rhins peninsula. This point was also chosen as the boundary between the major coastal cells 6 and 7 as introduced in the “Coastal Cells in Scotland” report (Ramsay and Brampton, 2000a,b) - see also Figure 1. While there may be some transport of sediment past the Mull of Galloway in deep water, by the very strong tidal currents off this promontory, there are no beaches close to it; longshore drift past the Mull of Galloway is therefore negligible.

The generally west-facing shoreline extends from this point, past the only major developments of Port Logan and Portpatrick. North of Portpatrick, the orientation of the coastline changes to face north-west, and then at Carsewell Point to face approximately north. Further east, at Milleur Point, there is a much more substantial change in the coastline orientation, of approximately 90°. This is therefore a good point to choose for the northern limit of CPU 5. Some sediment derived from cliff erosion may be driven eastwards along the base of the cliffs past Milleur Point, into the entrance to Loch Ryan but the quantities involved are likely to be insignificant in terms of coastal defence management.

2.6.6 *Loch Ryan – CPU 6*

Loch Ryan is a deeply indented bay, of very different character to the coastline of the Western Rhins, being almost completely sheltered from the predominant south-westerly waves generated in the Irish Sea. Tidal currents within the Loch are also much slower than off the coastline in CPU5. Milleur Point is a convenient choice of location for the boundary between these two CPUs, since the shoreline here changes orientation very markedly.

There is no correspondingly sharp demarcation in the coastline to mark the north-eastern limit of Loch Ryan and the beginning of the generally north-west facing coastline of South Ayrshire. The location chosen in this study was Finnarts Point, on the steeply sloping cliffs north of the mouth of Glen App. This leaves a stretch of coast from Finnarts Point north and east, past Ballantrae as a separate CPU, ending at the northern boundary to sub-cell 6d, Bennane Head, as defined in the “Coastal Cells in Scotland” report (Ramsay and Brampton, 2000a,b). The high cliffs at and on either side of Finnarts Point do not have any significant beach at their toe, and there is therefore little sediment transport across this chosen boundary of CPU 6.

2.7 IDENTIFICATION OF MANAGEMENT UNITS

Within each of the CPUs defined above, the next task in this Shoreline Management Plan study was to define shorter lengths of coastline that are termed Management Units. In general these have been defined based on coherent hinterland land use or coastal defences. However, where there are short sections of different land use or coastal defence within a much larger section of coherent frontage, these have generally been treated as one Management Unit to avoid over-fragmenting the coastline. In total, 37 Management Units have been chosen along the coastline, as shown in Figure 6.

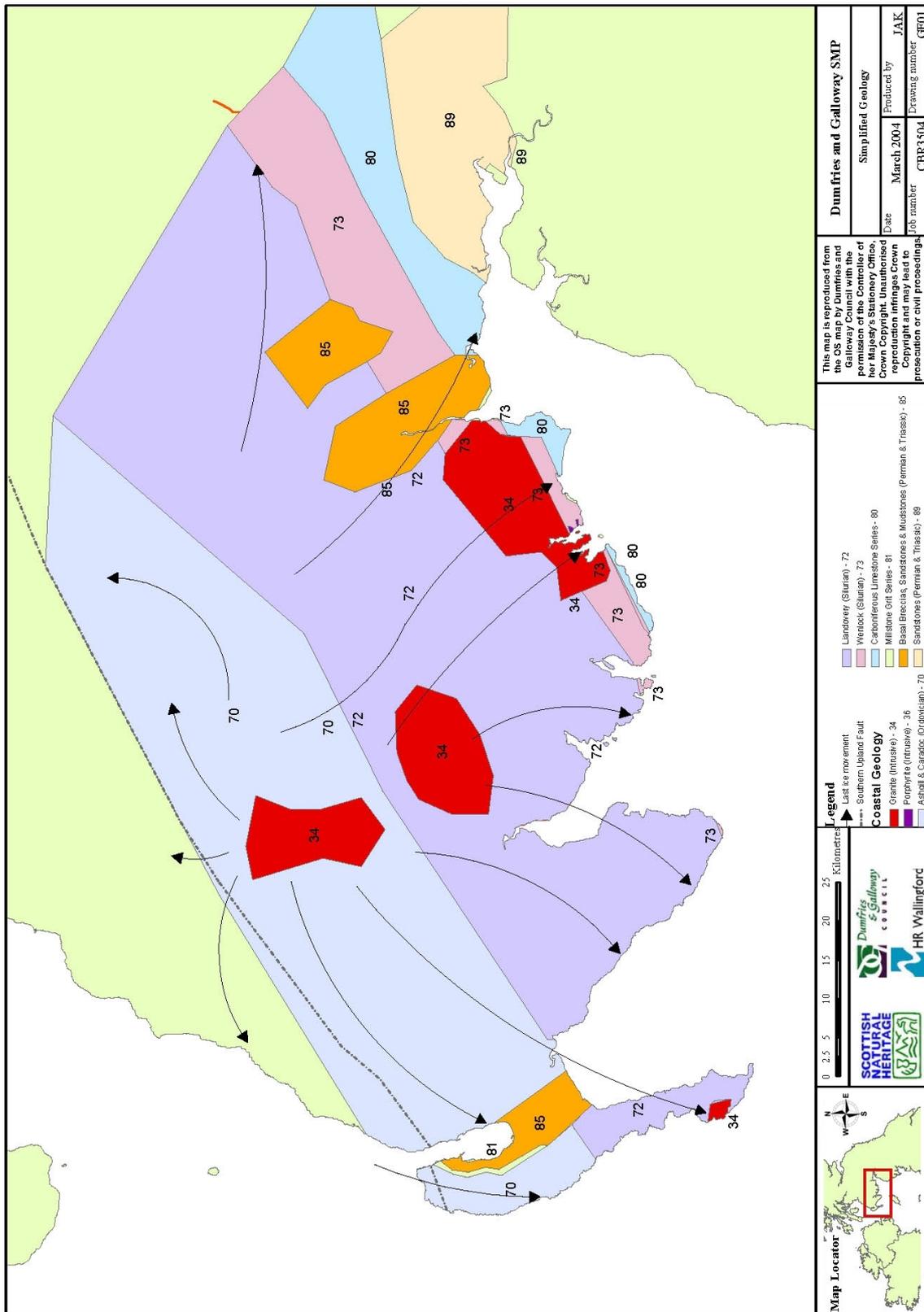


Figure 2 Simplified geology

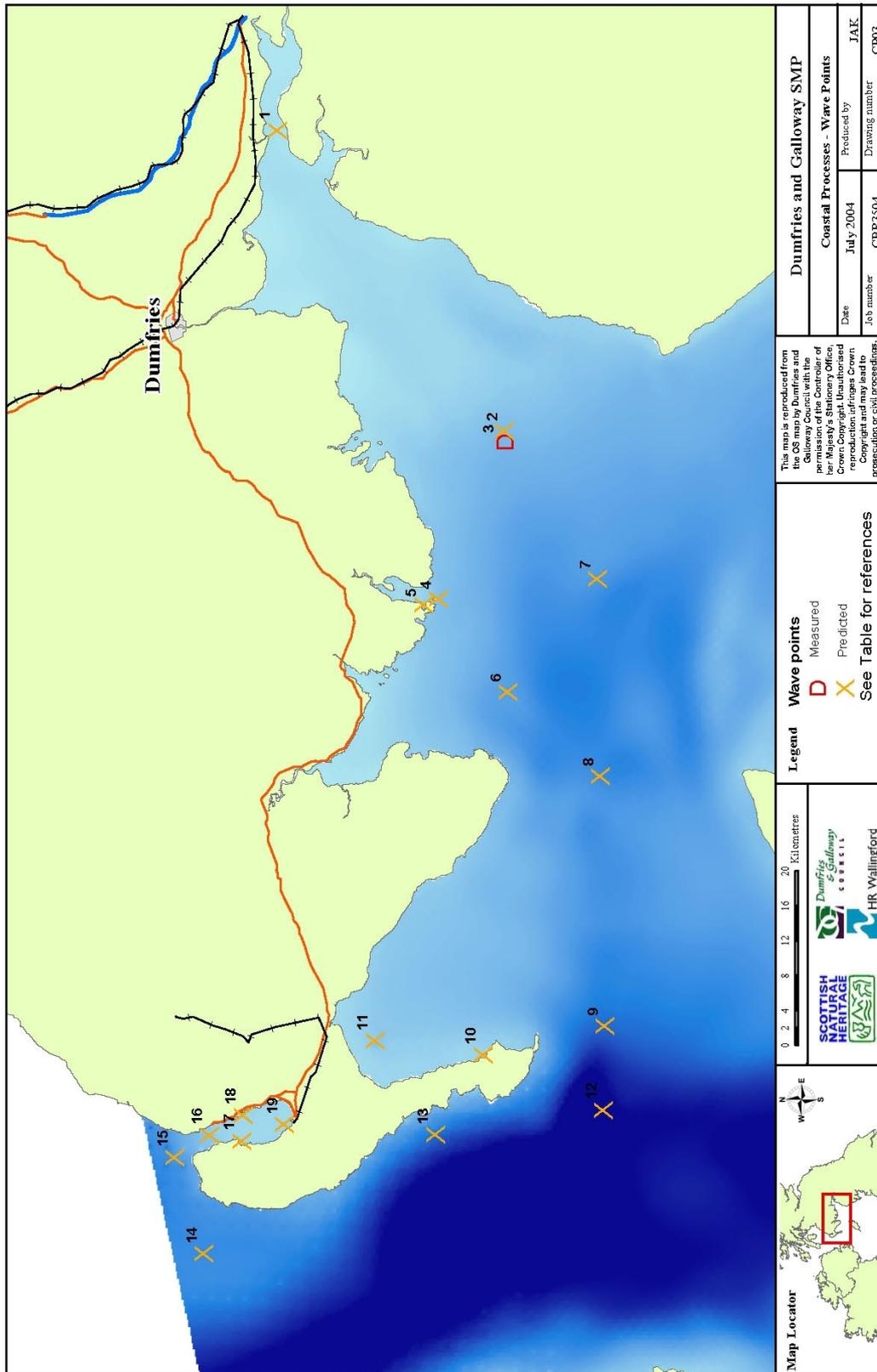


Figure 3 Summary of wave conditions along the Dumfries and Galloway coastline

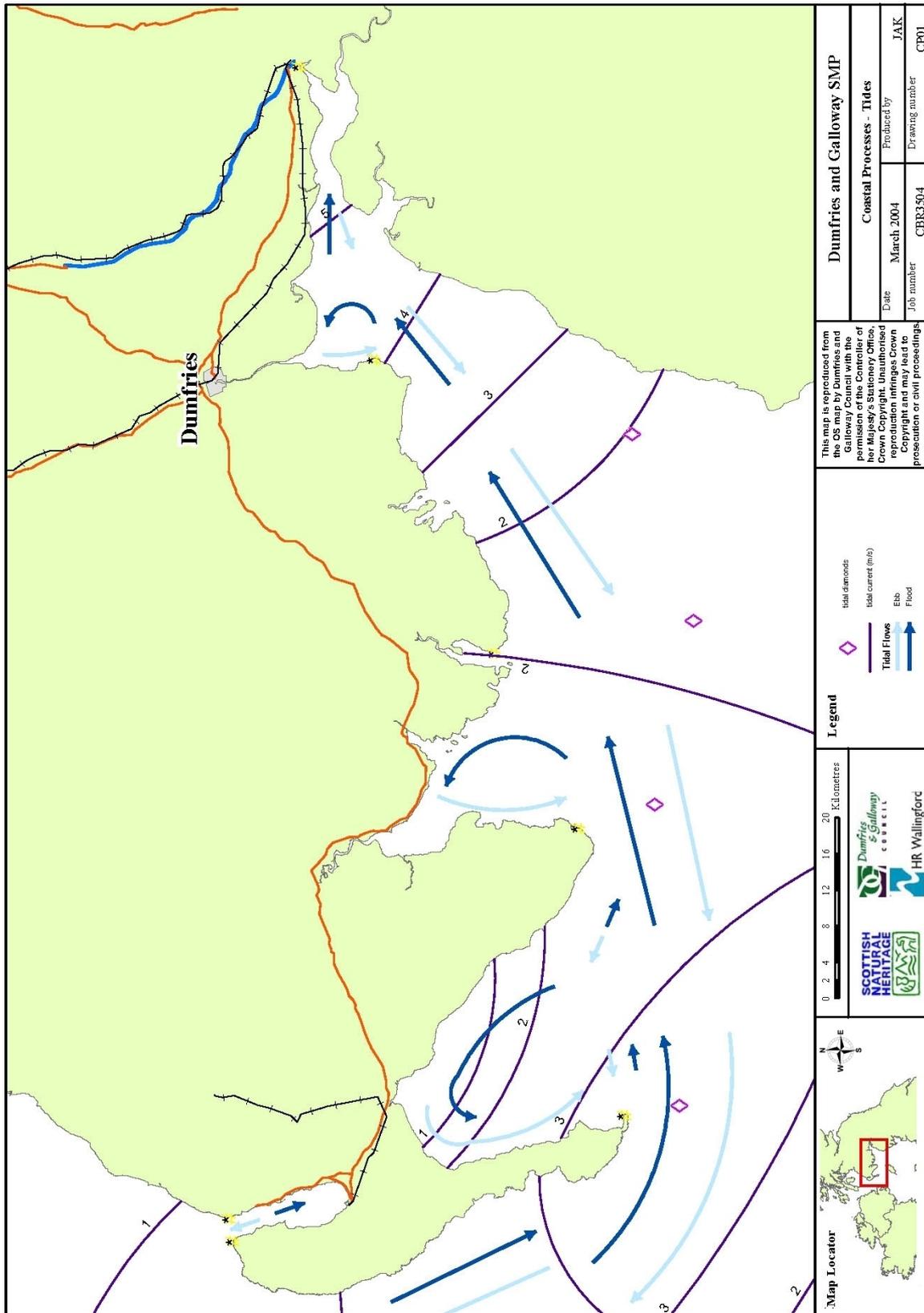


Figure 4 Coastal processes – tides

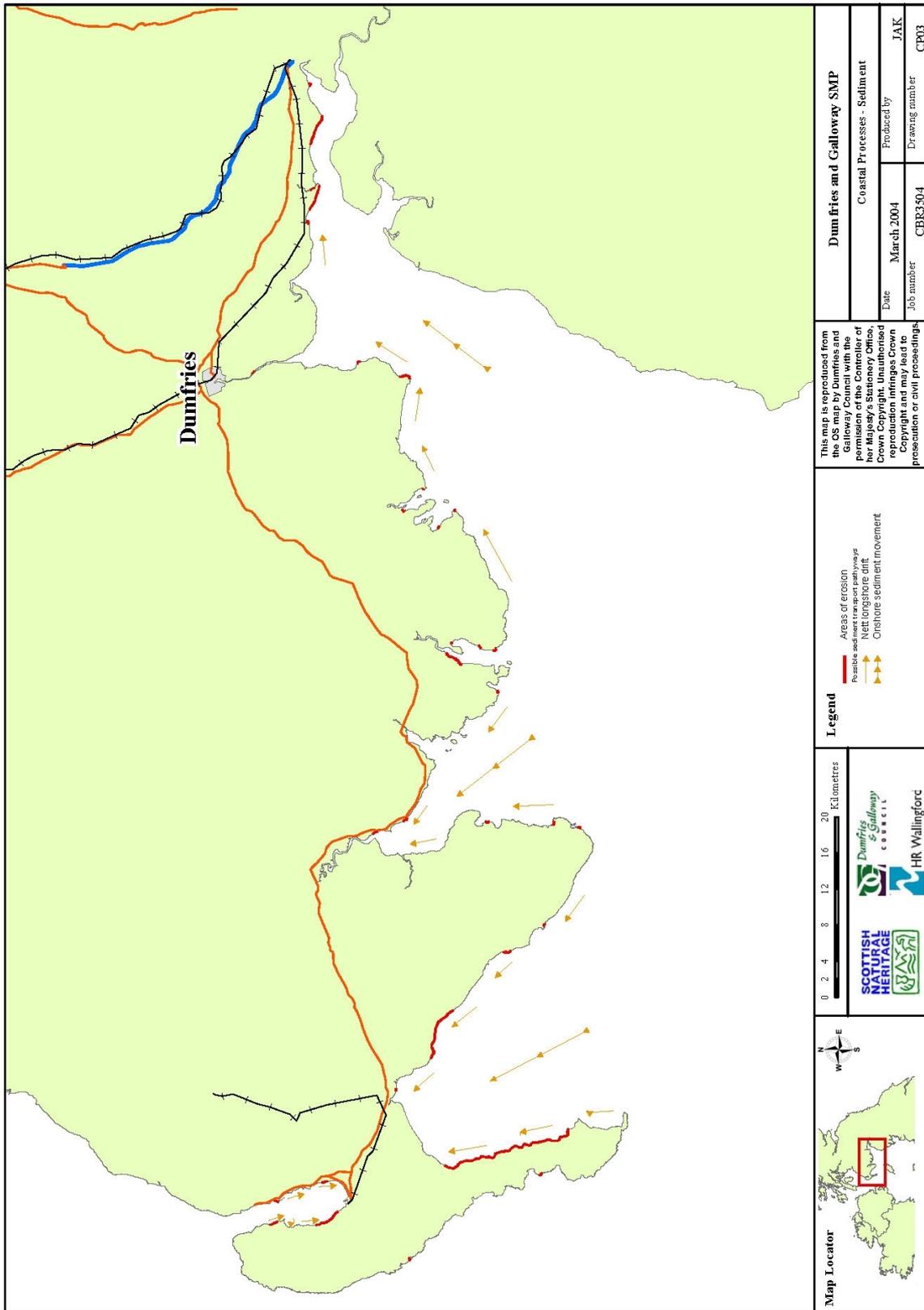


Figure 5 Coastal processes – sediment

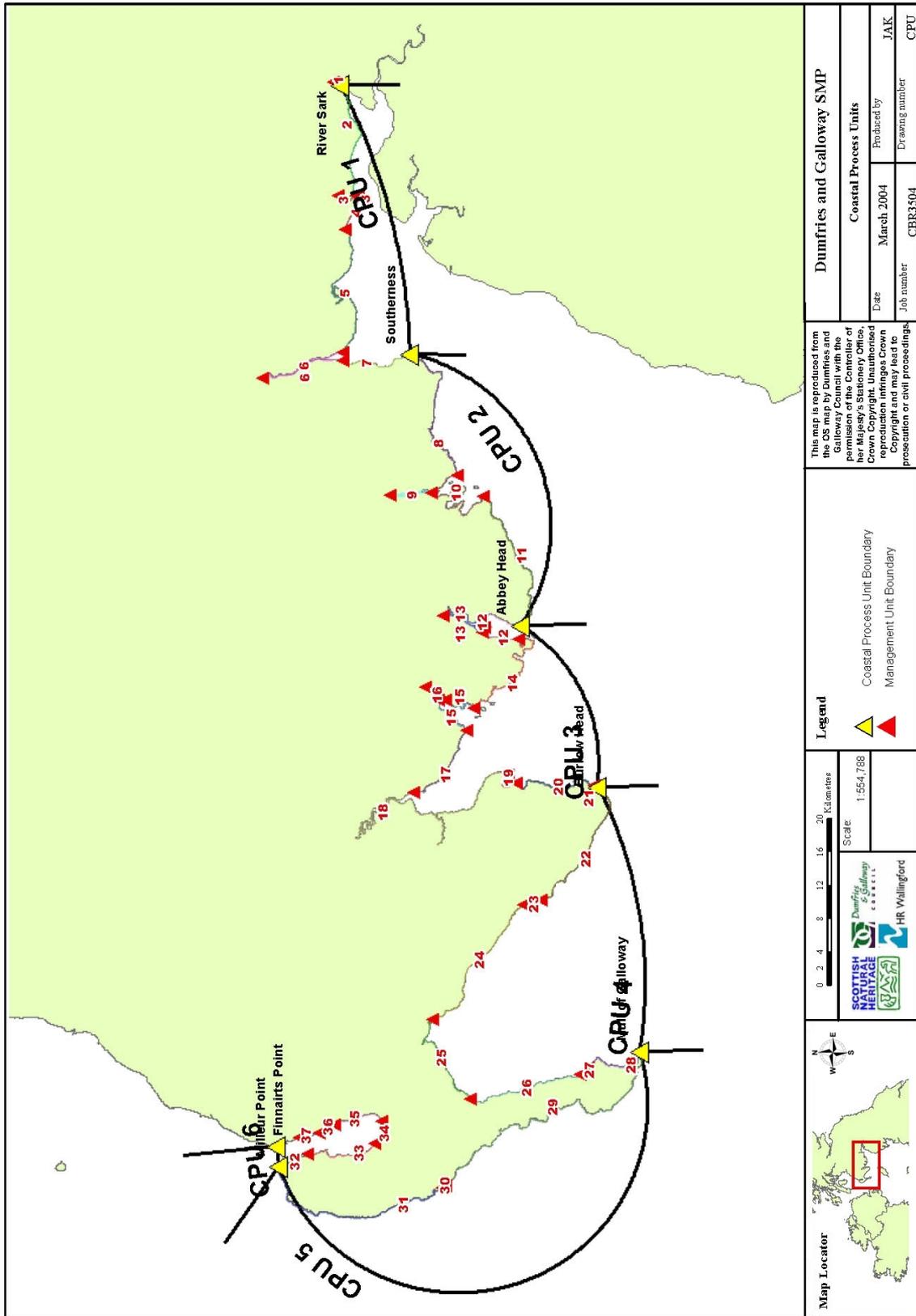


Figure 6 Coastal process units

3. *Description of Management Units and derivation of defence policy recommendations*

3.1 *Definition of management units*

As noted in Section 2.6, this study has suggested the division of the coastline of Dumfries and Galloway into 37 “Management Units”, i.e. sections of coastline that have more-or-less consistent characteristics along their length in terms of the following characteristics.

- Coastal defences, e.g. a continuous seawall, and/ or
- Land-use in the immediate hinterland, e.g. residential or farmland, and/ or
- Beach/ foreshore type and exposure to waves.

In such circumstances, it is expected that the management of the entire shoreline, including coastal defences, in these “units” will be consistent, i.e. the same decisions will be made about how to respond to the threats of erosion or flooding by the sea. In this first stage study, a rather “broad brush” approach to defining these Management Units has been taken. It is likely that as further information on the assets at potential risk, rates of erosion, flood risk etc. becomes available, then it may be appropriate to refine the suggested management units, by dividing or combining those suggested here, or by adjusting their boundaries.

In order to keep the defined Management Units to a reasonable number, it has also been decided, in some cases, to include short lengths of coastline with defences in a longer and otherwise natural Management Unit. As a consequence, the suggested defence policy option will potentially be different for different parts of that Unit.

A list of the Management Units along the coastline of Dumfries and Galloway, as defined in this study, is provided in Table 3.1 below.

3.2 **MANAGEMENT UNIT CHARACTERISATION AND POLICY CONSIDERATION**

For each Management Unit, a consistent format for presenting information, assessments and ultimately suggestions for appropriate defence management has been used. This format is as follows:

HEADER

Unit name, number and limits (with National Grid Co-ordinates).

COASTAL OVERVIEW

Brief description of morphology of coastline, erosion / flooding risks and main hinterland features.

COASTAL DEFENCES

A brief summary of the type and conditions of coastal defences, including flood defence embankments, where present.

DEFENCE ISSUES

This section considers the possible future risks from coastal erosion or flooding, including, where appropriate, the vulnerability of defences, and the feasibility and possible merits of installing or extending defences.

Table 3.1 Management Units

Management Unit number	Management Unit boundaries
1	A74(T) - Mouth of Sark
2	Mouth of Sark - Waterfoot
3	Waterfoot - Barnkirk Point
4	Barnkirk Point - Pow Water
5	Pow Water - Scar Point
6	Scar Point - Airds Point
7	Airds Point - Borron Point
8	Borron Point - Castlehill Point
9	The Port, Dalbeattie - Kippford
10	Castlehill Point - Balcary Point
11	Balcary Point - Torrs Point
12	Torrs Point - Bar Point
13	Seaward - Low Bridge of Tarff
14	Bar Point - Carrick Point
15	Carrick Point - Ringdoo Point
16	Rough Point - Fleet Bridge
17	Ringdoo Point - Point Fishery
18	Point Fishery - Eggerness Point
19	Eggerness Point - Ringan
20	Ringan - Isle Head, Isle of Whithorn
21	Isle Head - Screen, Isle of Whithorn
22	Screen, Isle of Whithorn - Airlour Creamery
23	Airlour Creamery - Low Drumskeog
24	Low Drumskeog - Balcary Holdings
25	Balcary Holdings - Carisbrooke Caravan Park
26	Carisbrooke Caravan Park - Inchmore
27	Inchmore - Back Bore
28	Back Bore - Mull of Galloway
29	Mull of Galloway - Lagnawinny
30	Lagnawinny - PortPatrick (North)
31	PortPatrick (North) - Milleur Point
32	Milleur Point - Clachan Heughs (South)
33	Clachan Heughs (South) - McCullochs Point
34	McCullochs Point - Bishop Burn Bridge
35	Bishop Burn Bridge - Bankhead
36	Bankhead - Glen Burn
37	Glen Burn - Galloway Burns

NATURAL & HERITAGE ENVIRONMENT

In order to set the scene for the assessment of possible coastal defence options, a table has been prepared that summarises the main features of the hinterland, comprising:

- Designations that may affect the desirability or type of coastal defences, including areas designated for reasons of environmental conservation e.g. SAC, SPA, SSSI, NSA, National/ Local Nature Reserves and sites/ monuments that are of importance from the viewpoints of heritage and archaeology;

- A summary of the main land uses(s) and ownership, any “sea uses” e.g. harbours, slipways, jetties etc., and the main recreational / amenity uses of the coastline, e.g. caravan/ chalet parks;
- A summary of the coastal defences (type, whether private or public and location); and
- The relevant statutory development plan(s) covering the Management Unit frontage.

CONSULTATION ISSUES

When responses from the consultation exercise (see Section 1.4.2) identified specific concerns or issues relating to the management of the Management Unit frontage, these are summarised. The number given at the beginning of each paragraph in this section provides a key identifying the source, as listed in Appendix 3.

ASSESSMENT OF ASSETS AT RISK

A standard table is provided listing both “tangible” assets i.e. those that can be evaluated in monetary terms and “intangible” assets together with an opinion on the short-term level of risk to those assets.

OPPORTUNITIES

Where the inspection of the coastline, or responses from the consultation exercise, indicated that coastal management, including the modification or installation of defences, could lead to possible improvements to the amenity, aesthetics or environment of the coastline, then these are noted. Similarly where it was felt that the natural character of the coastline would be damaged by such measures, this opinion was also noted.

STRATEGIC POLICY APPRAISAL

The gathering of information for each Management Unit, as summarised in the preceding paragraphs, formed the context for the consideration of the coastal defence options for that Unit. At the broad-brush level appropriate for this Shoreline Management Plan study, five strategic options were considered, as described in Section 1.4.5. For convenience, descriptions of these options are reproduced below:

- **Hold the existing defence line**

Improve or maintain the standard of protection provided by the existing defence line. This policy includes situations where works or operations are undertaken in front of and behind the existing defences (e.g. beach renourishment, additional toe protection, construction of offshore breakwaters to control beach response etc), to improve or maintain the standard of protection provided by the existing defence line.

This policy option has been the one most readily chosen in Shoreline Management Plans in England, especially where there are existing “built” coastal defences or assets such as coastal roads just inshore of a natural coastline. While preserving the *status quo* is often the easiest option in the short-term it can, however, lead to ever more difficult problems in the future. Given the inevitability of coastal erosion and of continuing increases in sea levels, the costs and environmental damage involved in maintaining a defence or shoreline position will increase with time in many cases. Further, by adopting such a policy, there is an increased likelihood of the development of the coastal strip behind “the line”. These two factors, together, will therefore lead to a risk of future generations being faced with much more difficult problems to solve than are presently being experienced.

In this study, therefore, the likely long-term problems along each stretch of coastline have been considered before recommending a “hold the Line” policy. Alternative options such as not trying to preserve the present position of the shoreline or defences,

and instead relocating assets at risk, have always been considered. An example would be to move coastal roads inshore, e.g. at Soleburn, rather than trying to protect the existing route.

- **Advance the existing defence line**

Construction of new defences seaward of the original defences.

There are occasionally situations where installing a new line of coastal defence significantly further seaward than the existing shoreline may be worthwhile. However, the cost of building defences in deeper water is much greater than in shallower water, and is usually only financially viable where the extra land gained is used for, or in connection with, substantial developments for example ports. There are very few locations along the Dumfries and Galloway coastline where an “advance the line” policy option needs to be considered, the obvious exception being in connection with the further development of the port at Cairnryan.

- **Managed realignment**

In this study, managed realignment is defined as the process of identifying a new line of defence, which might be naturally high ground, further landward than the existing shoreline or any existing defences, and actively arranging for the shoreline to retreat to this new defence line. (Simply allowing natural processes of coastal evolution to continue unchecked, thus resulting in a landward recession of the shoreline, is covered under “no active intervention” below).

Where the land between existing defences and the new “defence line” is below the level of highest tides then is it sometimes beneficial to remove part, or all of the existing defences, creating a new inter-tidal area which can provide valued habitats for wildlife, e.g. saltmarshes and inter-tidal mudflats.

The scope for such habitat creation by managed realignment of the coast of Dumfries and Galloway, however, is limited since in most cases the ground levels rise to the land of the present shoreline. Therefore, even if existing defences were removed, there would be little or no extra inter-tidal area created.

- **Limited Intervention**

Reducing the risks of coastal erosion or flooding by working with natural processes to allow for natural coastal change. This may range from measures which attempt to slow down rather than stop coastal erosion, such as dune management, to measures which may include repairing existing defences when damaged but not investing in further capital works to maintain or upgrade the present standard of protection, e.g. against flooding.

- **No active intervention**

Where there is no investment in coastal defence assets or operations, i.e. no shoreline management activity, other than monitoring or the provision of flood warning systems (which may also be appropriate for frontage where other policies are adopted).

To assess the potential suitability of each of these strategic policy options, a screening procedure is adopted. First any impractical options are discounted, with a brief statement explaining why these are not considered worth further consideration for this Management Unit.

For the remaining options, the next stage of the procedure is to assess how each option meets various generalised objectives for the management of that part of the Dumfries and Galloway coastline. These objectives were derived from consultations with the statutory and non-statutory

organisations with an interest in the future management of the Dumfries and Galloway coastal zone and from existing plans, namely:

- Existing planning policies relating to development of the coastline, i.e. the Local Plans;
- Management plans for areas or sites that have been designated for their natural, cultural or archaeological heritage or for their scenic qualities;
- Policies /concerns relating to the management or development of recreation/ amenity use of the coastline;
- Current and potential use of the coastline by industry, ports and the MOD; and
- Current and potential use of the coastline in relation to agriculture and fisheries.

This initial screening process identifies one or more “suitable” strategic defence options, i.e. those that are deemed to be compatible with the general management objectives. The “suitable” options are then carried forward into a second part of the assessment process, a consideration of the policy against five further criteria, namely:

- Effects on coastal processes: Could the policy lead to significant changes in the natural coastal processes, for example leading to disruption of longshore drift or reduction in supply of beach sediments?
- Effects on coast defences: Could the policy affect or particularly damage existing defences thus reducing the present standard of defence against flooding or erosion?
- Effects on natural environment: Could the policy lead to significant detrimental impacts on the natural environment (especially designated areas)?
- Effects on human/built environment: Could the policy lead to significant detrimental effects on recreation, amenity or “built heritage”, e.g. archaeology, historic buildings/ monuments etc?
- Economic viability: Are the benefits of implementing this policy likely to justify its cost?
- Compatibility with adjacent MU’s: Will the policy have significant impacts on adjacent management units?

This second stage of the assessment of the possible strategic policies is summarised in an “Impact Summary Matrix”, with brief comments as appropriate. The final row of this matrix summarises whether the proposed policy options are considered suitable, based on the above considerations.

SUGGESTED POLICY OPTION

Based on the strategic policy appraisal and impact summary matrix, suggestions are made for an appropriate coastal defence policy for the Management Unit. In cases of uncertainty, or where further work is required to resolve a given issue, then more than one option may be suggested. In conjunction with this there may be a requirement for monitoring or detailed study to address specific uncertainties. Where more than one option is suggested a preferred option is still identified. This should not, however, preclude the other potentially viable options being considered in any future more detailed studies.

In a number of cases, the suggested policy may be appropriate over most of the Management Unit but possibly unsuitable for some short frontages. For example, “No Intervention” may be suggested for a largely undeveloped length of coastline but potentially would not be appropriate for areas where there are isolated “assets” (e.g.. a small group of houses or a short stretch of coastal road). In such cases, a “hybrid” option has been suggested. (The alternative would have been to introduce further Management Units for each of these short stretches of coast with assets at risk, thus resulting in many more Management Units).

Furthermore, consideration has been given to whether the policy suggested may need to change during the intended lifetime of the Shoreline Management Plan. To emphasise the possible need to adapted to gradual changes in the coastline over coming years, three time-scales are used:

- Current/ Short-term Up to 10 years hence;
- Medium term From 10 to 50 years hence and;
- Long term Over 50 years hence.

AREAS OF POTENTIAL CONFLICT

Attention is drawn to potential areas of conflict that may arise due to the implementation of the preferred strategic policy. Potential conflicts are identified, for example:

- The loss of isolated assets when a “No intervention” policy is adopted, or
- Damage to environmentally sensitive areas, or to the coastline in adjacent Management Units, if it is decided to “Hold the Line”.

ADDITIONAL MANAGEMENT REQUIREMENTS

If there is thought to be a need for additional shoreline management activities, such as monitoring beach levels or cliff top retreat, these are identified. These activities are usually suggested in order to reduce uncertainty about the current and likely future risks of flooding or erosion, and hence help confirm or alter the suggested policy option.

3.3 DESCRIPTIONS OF INDIVIDUAL MANAGEMENT UNITS

Detailed descriptions and suggestions for the appropriate coastal defence policy for each of the Management Units, based on previous studies and on the consultation process and site visits undertaken as part of the present study, are presented in Volume 2 of this report. An electronic copy of this volume is provided on a CD-ROM attached to the rear cover of this volume of the report.

3.4 SUMMARY OF SUGGESTED DEFENCE POLICY OPTIONS

Table 3.2 below summarises the suggested coastal defence policy options for each of the Management Units. As foreseen and explained in Section 3.1 above, for some of these Units there are different defence policies suggested for different parts of the frontage. However for these Units, as for those where a single policy is suggested, there is a need for more detailed discussion and evaluation of the consequences of adopting such a policy. The final column of this table provides links to the explanatory notes presented in Table 3.3.

Table 3.2 Management Unit – suggested defence policies

MU no.	Management Unit boundaries	Short term	Medium term	Long term	See Note
1	A74(T) - Mouth of Sark	Hi	Hi	Hi	
2	Mouth of Sark - Waterfoot	Hi	Hi	Hi	
3	Waterfoot - Barnkirk Point	Hi	Hi	Hi	
4	Barnkirk Point -Pow Water	Hi	Hi	Hi	
5	Pow Water - Scar Point	Li	Li	Mr	1
6	Scar Point - Airds Point	Hi	Hi	Hi	2
7	Airds Point - Borron Point	Hi	Hi	Hi	
8	Borron Point - Castlehill Point	Li/ Hi	Li/ Hi	Li/ Hi	3
9	The Port, Dalbeattie - Kippford	Ni	Ni	Hi	4
10	Castlehill Point - Balcary Point	Hi	Hi	Hi	
11	Balcary Point - Torrs Point	Ni	Ni	Ni	
12	Torrs Point - Bar Point	Hi	Hi	Hi	
13	Seaward - Low Bridge of Tarff	Hi	Hi	Hi	5
14	Bar Point - Carrick Point	Li	Li	Li/ Hi	6
15	Carrick Point - Ringdoo Point	Hi	Hi	Hi	
16	Rough Point - Fleet Bridge	Hi	Hi	Mr	7
17	Ringdoo Point - Point Fishery	Hi	Hi	Hi	
18	Point Fishery - Eggerness Point	Hi	Hi	Hi/Mr	8
19	Eggerness Point - Ringan	Hi	Hi	Hi	9
20	Ringan - Isle Head, Isle of Whithorn	Hi	Hi	Hi	
21	Isle Head - Screen, Isle of Whithorn	H	H	H	10
22	Screen, Isle of Whithorn - Airlour Creamery	Li	Li	Li/H	11
23	Airlour Creamery - Low Drumskeog	H	H	H	12
24	Low Drumskeog - Balcarray Holdings	Hi	Hi	Hi	
25	Balcarray Holdings - Carisbrooke Caravan Park	Ni/Li	Ni/Li	Ni	13
26	Carisbrooke Caravan Park - Inchmore	Hi	Hi	Hi	14
27	Inchmore - Back Bore	H	H	H	15
28	Back Bore - Mull of Galloway	Hi	Hi	Hi	
29	Mull of Galloway - Lagnawinny	Hi	Hi	Hi	16
30	Lagnawinny - PortPatrick (North)	H	H	H	17
31	PortPatrick (North) - Milleur Point	Ni	Ni	Ni	
32	Milleur Point - Clachan Heughs (South)	Ni	Ni	Ni	18
33	Clachan Heughs (South) - McCullochs Point	Hi	Hi	Hi	15, 18
34	McCullochs Point - Bishop Burn Bridge	H	H	H	18,19
35	Bishop Burn Bridge - Bankhead	Hi	Hi	Hi	18
36	Bankhead - Glen Burn	Hi	A	A	18, 20
37	Glen Burn - Galloway Burns	Hi	Hi	Hi	18

Defence policy key:

- H Hold the line
- Hi No active intervention for the most part, but hold the line in individual areas
- Li No active intervention for the most part, but limited intervention in individual areas
- Mr No active intervention for the most part, but managed realignment in individual areas
- Ni No active intervention
- A Advance the line

Table 3.3 Explanatory notes for Table 3.2

Note	
1	Further studies of standard of defences, extreme tidal levels and of flood risk required
2	Managed realignment incompatible with canalised nature of estuary
3	Limited intervention in Sandy Hills Bay and Hold the Line at Southernness
4	The Flats, Dalbeattie and Palnackie Harbour may require formal defences in future, as sea level rises
5	Further studies of standard of defences, extreme tidal levels and flood risk required
6	Hold the line in Brighthouse Bay if local intervention proves to be insufficient
7	Further studies of standard of defences and of flood risk required
8	Further studies of standard of defences and of flood risk required
9	Upgrading of defences at Garlieston may be required to protect built environment
10	Monitor condition of harbour structures as they are integral defences
11	Hold the Line in Monreith Bay if erosion becomes critical
12	Downdrift erosion at Port William may require beach nourishment
13	Consider relocating golf course boundary in long term to allow “No intervention”
14	Hold the Line will incur increasing expenditure. Consider beach nourishment
15	Monitor beaches and structures
16	Hold the Line at only Port Logan
17	Hold the Line and monitor defences and harbour
18	Coastline management relevant to Loch Ryan Advisory Management Forum
19	Cliffs north of McCullochs Point may require stabilisation/toe protection
20	Development of Cairnryan ferry terminal will advance the line of the defences

In summary, it can be seen from Table 3.2 that adopting a “Hold the Line” policy is only recommended for five complete Management Units. For almost all the remaining units, the suggestion is for little or no intervention, except perhaps for some short stretches of coastline where defences may be justified depending on the value of assets at risk and the costs of defences proposed. A good example is provided by the suggestion of adopting a “Hold the Line” policy at Port Logan, in Management Unit 29, although for the rest of that Unit no intervention is recommended.

As predicted from comparisons with other Shoreline Management Plan areas, there is little opportunity for adopting a policy of “Advance the Line”. More surprisingly, there is also little scope for “Managed Retreat” of defences. Incurring the extra costs involved in deliberately removing defences, for example, to create new areas of habitat such as saltmarsh, will not be worthwhile when “No active intervention”, i.e. letting the coastline recede landward naturally, will have the same effect.

In many cases, the present scarcity of information on rates of erosion, on areas liable to suffer coastal flooding and on the relative levels of the highest tides and flood defences, means that the suggested policies may change when better information becomes available. In compiling the policy suggestions, therefore, particular attention has been drawn to those frontages where better information may lead to different decisions about defence policy being made (i.e. Management Units 1, 5, 13,14 and 27).

The relative priorities for action, among the Management Units, and the suggestions for such action, are detailed in Volume 2 of this report. An electronic copy of this volume is provided on a CD-ROM attached to the rear cover of this volume of the report.

4. *Conclusions and Recommendations*

4.1 CONCLUSIONS FROM STAGE 1 STUDY

4.1.1 *General review of existing knowledge*

One of the principal aims of a Shoreline Management Plan is to anticipate coastal changes over the next 50 years (or more) and hence assess the need to protect the assets that will be at risk over that period.

However much of the detailed information required in making such predictions is presently not available. In many areas of Dumfries and Galloway, the rate of coastline retreat is so slow that it is not possible to gain a reliable measure of its rate from past Ordnance Surveys. Similarly, information on coastal areas that have flooded in the past is largely anecdotal rather than quantified, i.e. the tidal levels reached and the weather conditions at the time.

For long stretches of the coastline, this lack of detailed information is of no great concern, since there are few assets at risk from erosion or flooding. In these areas, it would be totally unjustifiable, from an economic viewpoint, to install defences or even to justify the expense of more detailed studies of possible defence designs. This first stage of the Shoreline Management Plan has identified these areas, and suggested no active intervention at least as a short-term defence policy (see chapter 3). This does not mean that there are no concerns about flooding or erosion in these areas. Landowners and those living near to the coast in such areas are understandably keen to preserve their properties, and may well opt to undertake “self help” schemes if the Council is unable to justify public funding for such defences.

In other areas, however, there are already problems of erosion or flooding that affect sizeable communities and/ or publicly owned assets, particularly coastal roads. These areas include the shorelines of the southern part of Loch Ryan, the western shore of Luce Bay from Drummore to Sandhead and the shorelines of several estuaries including those of the Rivers Cree, the Dee, the Nith and the River Annan.

In order to prioritise such schemes, and to justify expenditure on them, it will become necessary to produce a better quantified assessment of present and future risks from erosion and flooding than it has been possible to provide in the present Stage 1 study.

In the first instance, therefore, the main requirement is for gathering basic data for use in quantifying the risks of coastal flooding and erosion. This would be a major and largely unnecessary exercise if it were to cover the whole coastline; it is therefore suggested, on the basis of the present study that such investigations are carried out for the coastlines at greatest risk.

For the frontages most at greatest risk from flooding and erosion, a programme of data gathering and analysis should be started. This programme should be jointly agreed, and funded by Dumfries & Galloway Council and other interested bodies, e.g. SEPA, Historic Scotland and Scottish Natural Heritage. It should aim to collect the following information:

- Past and present rates of shoreline change, based on analyses of charts, Ordnance Survey maps and specific surveying of beach levels and/ or of aerial photographs or other remotely-sensed data. The latter type of monitoring is preferable for estuarine areas where access is difficult or hazardous, and may cause disturbance to wildlife;

- Tidal levels, over a period of several years, to improve knowledge of extreme high tidal levels, and the effects of freshwater discharges on these;
- The crest levels and conditions of coastal defences, particularly of flood embankments along estuarine coastlines;
- Ground levels in low-lying coastal hinterland areas, building upon and validating existing information that can be provided, for example by the Ordnance Survey and commercial organisations;
- Formalised recording of flooding events, including details of timings, flood levels reached and the lateral extent of flooding.

Further details of recommended data gathering are presented in Section 4.2.

4.1.2 *Initial assessment of coastal erosion and flooding problems*

This section discusses those sections of the coast of Dumfries and Galloway presently at greatest risk of coastal flooding and erosion, and comments on the possible changes in these risks as a consequence of climate change.

Considering first **coastal erosion**, often resulting in the overtopping of defences and flooding of the hinterland, the main areas at risk tend to lie in the western part of Dumfries and Galloway, reflecting the larger waves along that part of the coastline. The frontages most at risk from these problems at present are:

- The western side of Luce Bay (Drummole to Sandhead - Management Units 26 & 27);
- The western shoreline of Loch Ryan (particularly Management Units 33 and 34);
- Carsethorne and Southernness (Management Units 6 and 7);
- The eastern shoreline of Loch Ryan (Management Units 35 to 37);
- Garlieston, Isle of Whithorn and Port William (Management Units 19, 21, and 23);
- Annan estuary to Powfoot (Management Units 3 and 4).

Further coastal areas are at risk from flooding, without necessarily being prone to erosion. Most of these additional frontages suffer flooding as the result of a combination of high tidal levels and large river discharges. The flood risks in all of these areas will steadily increase as a consequence of the widely expected increase in sea levels, one of the consequences of global warming. In most cases, the risks of flooding will also be affected by any increase in freshwater discharges down the major rivers. In approximate order of priority, the greatest risks are in the following areas:

- The Nith Estuary, particularly at Dumfries, Kingholm Quay and Glencaple, (Management Units 6 and 7);
- The Annan Estuary (Management Unit 3);
- The Dee Estuary (Management Unit 9);
- Wigtown (Management Unit 18);
- Creetown and Carsluith (Management Unit 17);
- River Sark (Management Unit 1).

In addition to these areas, flooding occurs near the tidal limit of other estuaries, for example at Newton Stewart, Gatehouse of Fleet and Glenluce. Such areas are not generally regarded as

“coastal” sites, and therefore are not normally considered in a Shoreline Management Plan. Nevertheless, this Plan is an appropriate opportunity for indicating these problems, and in the following section of the report, recommendations are made for further gathering and analysis of information in order to address the concerns that have been identified.

A number of further sites have been identified, and noted in the description of individual Management Units, where farms or other privately owned land was being eroded or flooded. The economic justification for public funding of coastal defences for these areas is extremely low in general, although the inconvenience and loss of income, for example to caravan/holiday chalet sites, is of great concern to the owners. Therefore, it is likely that, as in the past, the landowners at these sites will consider “self-help” defence schemes. Based on the review of the coastline carried out for this study, there is a strong probability that such “private” schemes could be unsightly and detrimental both to the natural environment and to adjacent shorelines. There may well be a conflict between the understandable wishes of the landowner and the Council, particularly if such schemes are built in areas where the Council, after completing the Shoreline Management Plan, has adopted a “No active intervention” policy. Further consideration of such difficulties is returned to in Section 4.2.2 below.

The widely predicted acceleration of sea levels, as a result of global warming, will worsen the existing problems in all the areas identified above. Where existing defences are presently too low to prevent flooding, either by wave overtopping or simply because they are lower than extreme high water levels, the increase in mean sea levels will make such events more frequent, and more damaging.

There is no strong evidence, at present, to support the view that waves or storm surges will change greatly as a consequence of global warming, although it would be prudent to keep this evidence under review in the coming decades. Even given similar meteorological conditions, however, any increase in sea levels due to global warming will tend to increase the problems of erosion and wave overtopping of beaches or coastal defences.

Finally, it has been noted above that in many cases, coastal flooding is presently thought to be due to a combination of high tides and large freshwater discharges from the major rivers. Evidence to hand, from a study of the River Nith, presently suggests that global warming will not produce an increase in river discharges in Dumfries and Galloway. However, such a possibility will need to be borne in mind in the future.

Eventually, difficult decisions will have to be taken on abandoning some assets to the sea in such areas, or protecting them at considerable expense, and with inevitable effects on the natural environment. At present, the expenditure on maintaining existing coastal defences in Dumfries and Galloway is modest, especially given the great length of coastline between the River Sark and the boundary with South Ayrshire. In future, where assets such as coastal roads can be replaced further inland, this would be a more sustainable, and ultimately a better policy.

However, it is probably inevitable that improvements in coastal defences will be needed in some areas in the coming decade, and the construction of these will be a major financial burden on the Council, even assuming that Grant Aid from the Scottish Executive is available. The suggested collection of data will help quantify the risks of flooding and erosion, and hence provide essential evidence to justify the urgency and benefits of such defences.

4.1.3 *The natural environment*

A surprisingly large number of the consultation responses identified the importance of maintaining or enhancing the natural environment of the Dumfries and Galloway coastline. In some cases these views were linked to tourism and recreation, e.g. aesthetics, and in others there was a desire to avoid “hard” coastal defence schemes, because of their likely adverse effects on adjacent shorelines and on important habitats. In the light of the potential damage to important inter-tidal habitats that might follow construction, or maintenance of “fixed” defences such as seawalls, a number of consultees have indicated a preference for “managed realignment” of the coastline. Such an option, in the correct circumstances, can create new inter-tidal habitats.

Unfortunately from the viewpoint of enhancing the natural environment, there is very little scope for Dumfries and Galloway Council to adopt a “Managed Realignment” coastal defence policy, as defined in Sections 1.4.5 and 3.2. There are a few areas of low-lying farmland in the Inner Solway where the removal of private coastal defences, i.e. flood embankments, would result in new inter-tidal areas being created. However, while the Council may welcome the creation of such areas from an environmental viewpoint, it is not likely to become involved in providing coastal defences for farmland in such areas or elsewhere. In these circumstances, it seems likely to be difficult for the Council to adopt a policy to favour the landwards realignment of private defences, unless some funding was made available to the landowner in return for his co-operation. It is unclear whether this type of scheme could be legitimately regarded as “coastal protection” or “flood defence” when funding is needed.

Concerns about the natural environment, e.g. aesthetics and disturbance to birds, are also quoted as a reason for resisting development of the coastal strip.

4.1.4 *The human environment*

As in the concerns expressed about the natural environment, a number of responses from the initial consultation indicated an opposition to further development of the coastal strip for holiday accommodation and tourist related activities.

There were a number of comments about the existing recreational uses of the beaches and shoreline, principally for walking, cycling, bird-watching, horse-riding and calls for improvements to paths along the coastline, to facilitate the first two of these activities. There were also several comments about litter and the dumping of waste along the coastline, the latter often associated with “self-help” defence schemes as mentioned in Section 4.1.1.

There were important concerns expressed about public safety in Loch Ryan, with continuing concern about the “wash” created by the High Speed Ferries using Cairnryan and Stranraer. Statements of concern received during the consultation undertaken during the present study also mentioned the associated problems of coastal erosion and damage to birds nesting on the beaches.

This concern has been strengthened recently by the publication of two reports by the Marine Accident Investigation Branch, of the Department for Transport, relating to swamping of two small boats launched from Lady Bay in July and September 2003. The former incident resulted in three people being drowned. Dumfries and Galloway Council have commissioned a risk assessment study to investigate the problems caused by the ferry-generated waves on Loch Ryan.

4.2 RECOMMENDATIONS

4.2.1 *Data gathering*

The principal justification for the funding of coastal defence schemes comes from information on the rate of erosion or the frequency and extent of flooding events, as described in Section 4.1.1. It is therefore recommended that this type of data gathering is given the greatest priority.

The main requirement in terms of information on hydrodynamics is for improved knowledge of tidal levels. It is suggested that such measurements are needed in the lower reaches of the estuaries of the River Annan, the Nith, the Dee and the Cree. In addition, better information on tidal levels unaffected by fresh water flows is also needed, perhaps from sites off Newbie and Southernness.

Even this substantial investment in data collection would then need to be supplemented by numerical modelling of the propagation of tides and river floods, with the measurements being used to calibrate and verify the modelling. The modelling would then be used to predict more severe events and the effects of an increased mean sea level.

To carry out such modelling, information on the land and seabed levels over much of the Inner Solway will also be required. On land, this information may be available from remote sensing surveys, e.g. LIDAR, although local checks on levels in flood-prone areas are always valuable. Seabed levels will probably have to be measured by conventional hydrographic surveying, since doubts remain about the accuracy of remote sensing of such information, particularly in wet inter-tidal areas with fine-grained sediments.

This aspect of data gathering and analysis is of value both to the Council and to SEPA, and a joint effort to obtain suitable information is appropriate. In addition, better knowledge of tidal levels in the Solway would also be of value to those responsible for flood defence and perhaps coast protection along the English coastline, i.e. the Environment Agency and perhaps Carlisle City and Allerdale District Councils.

It will also be important to obtain “ground truth” on both shoreline retreat and flooding. The following is recommended as a modest programme of monitoring, concentrating on the areas most likely to require coastal defences in the short- to medium-term future.

1. Gretna

Flooding has occurred in the past, but the flood risk may now be reduced since the flood embankments have been raised locally. Flooding extents should be catalogued and collated against meteorological conditions.

2. Annan

Flooding has been noted, affecting primarily amenity land. However, there is a risk that the old port may be affected by flooding, even if it has not been so to date. Flooding extents should be catalogued and collated against meteorological conditions.

3. Annan to Powfoot

This frontage is an important shoreline walk. Erosion is not only unsightly but may cause loss of public access, as well as threatening several private properties/commercial frontages. Monitor by photographing upper foreshore once yearly and after storms. If erosion is seen to increase, monitor by surveys along a few beach profiles at worst locations.

4. Nith Estuary

This was straightened by dredging and is affected by erosion (on outside of river bends) as well as flooding. Potential flood risk areas are Glencaple to Kelton, Kingholm Quay, as well as the urban frontage of Dumfries. Flooding extents should be catalogued and collated to meteorological events.

5. Carsethorn, Southernness and Kippford

These frontages have concentrated development close to the shoreline and may be affected by erosion during severe (infrequently occurring) storms. Monitor by photographing the upper foreshore once yearly and after storm erosion. Supplement by surveys along a few beach profiles at worst locations.

6. Kircudbright, Gatehouse of Fleet, Creetown, Newton Stewart and Wigtown, Garlieston, Isle of Whithorn and Port William

Flooding would affect shoreline development and should be catalogued and collated to meteorological events.

7. Port William to Auchenmalg

Erosion may affect the coast road and several individual properties. Monitor by photographing the upper foreshore once yearly and after storm erosion.

8. Sandhead to Drummore, Luce Bay

Erosion and flooding affects the coast road in the western part of Luce Bay from Sandhead to Drummore. Monitor by photographing the upper foreshore at all the locations mentioned in the management unit descriptions. Supplement by beach profiles at worst locations for erosion, e.g. Kilstay Bay in front of the seawalls. Here further beach lowering could lead to seawall collapse and major coast protection works may be needed in the medium-term future.

9. Wig Sands to Broadstone, western side of Loch Ryan

Erosion and a potential flood risk affect the coast road between Dikefoot and Soleburn Bridge. Erosion affects the foot of unstable cliffs in the McCulloch's Point/Bradstone frontage. Monitor by photographing the upper foreshore once yearly and after storm erosion. Supplement by beach/cliff profiles at McCulloch's Point/Broadstone. The role of the wakes from ferries needs to be kept under review along this frontage, although it should be a less serious problem than in the past, or compared to the situation at Lady Bay further north.

10. Innermessan to Old House Point

Erosion affects developed frontages and the coast road at several locations that are mentioned in the management unit descriptions. Monitor by photographing the upper foreshore once yearly and after storm erosion (ferry wash is likely to be less serious now that movements of the vessels are controlled, but may still be a problem along this stretch of the Loch Ryan coastline).

4.2.2 Continuation of the Shoreline Management Plan process

This report describes the study that has been carried out during the first phase of producing a Shoreline Management Plan for the coastline of Dumfries and Galloway. This section discusses the further development of the Plan, bearing in mind various other current initiatives relevant to the management of the coastal zone.

In England and Wales, Shoreline Management Plans have been formulated and adopted by local authorities, for the whole coastline. This has become a requirement for coastal defence schemes to be considered for Grant Aid from the Department for Environment, Food and Rural Affairs. In Scotland, there is no equivalent formal requirement for Shoreline Requirement Plans, and only two or three Plans have been completed so far. It is fair to say, however, that if a Council plans major coastal defence schemes, and Grant Aid for these is going to be sought, then a completed Shoreline Management Plan would be helpful to the Scottish Executive.

Normally the next stage in the development of the present Plan would be an extensive consultation process, followed by a revision of the initial draft Plan and the adoption of the revised Plan by the Council. However, immediately progressing the Plan in this manner is not recommended for a number of reasons.

First, and most importantly, there is a lack of information on several fundamental issues, including accurate estimates of extreme tidal levels in the Solway Firth, of nearshore wave conditions and the present rates of beach and shoreline recession. This information, together with the dimensions of the existing seawalls and flood embankments, is needed to produce reliable assessments of the “standard of defence” they presently provide. Consequently the conclusions drawn in this report about where the risks of flooding or erosion are presently greatest are based on a combination of information (often anecdotal) on past problems and the judgement of specialists involved in the Working Group and site visits during this study.

In view of this uncertainty, it has only been possible in this study to *suggest* an appropriate coastal defence policy for each of the defined Management Units. Further and more detailed consideration of at least those parts of the coastline regarded to have the more pressing problems is necessary before a more definite *recommendation* for the appropriate defence policy can be made.

Secondly, there is no immediate need for, or intention to undertake any coastal defence schemes along the coastline of Dumfries and Galloway. Hence there is no need *at present* for a completed Shoreline Management Plan in support of an application for Grant Aid from the Scottish Executive. Nevertheless, it is strongly recommended that the Plan be advanced in the future, along with a number of other initiatives relevant to the long-term management of the coastal zone in Dumfries and Galloway.

At a local level, the main value of the present study is to help inform and support the Council’s planning framework, specifically the Local Development Plan. In particular, following this study’s review of the coastline, it is likely that future development and the problems of flooding and erosion, together with the suggestions for an appropriate defence policy, can be used to reinforce or adjust the present planning policies on “developed” and “undeveloped” coastlines (see Section 1.3.5 above).

Rather than undertaking a specific public consultation on the present study, and its suggestions and recommendations, as part of the development of a Shoreline Management Plan, it is suggested that this is included as part of the wider consultation that will be undertaken for the Local Development Plan. In this way, discussions about the appropriate defence policy for any part of the coast can be held in the context of consideration of plans for the development (or not) of the hinterland.

At a broader scale SEPA is implementing the Water Framework directive, see Section 1.3.8, over the whole of Scotland. As part of this initiative, a nation-wide high level study of the risks of flooding of the coastal zone is planned, to improve the knowledge of the present

situation and anticipate the likely consequences of an increase in sea levels. For the Dumfries and Galloway coastline, this study will also require better information on the height reached by exceptionally high tides, and on land levels, particularly in the inner Solway Firth, and near the mouths of the major rivers, the Nith, Annan, Dee etc.

It is recommended, therefore, that the Council seek to gather this information in co-operation with SEPA and with the corresponding authorities on the southern side of the Solway (i.e. the Environment Agency and the various local authorities represented in the North West Coastal Group). It is worth making the point here that while such co-operation is valuable in terms of understanding the natural processes in the Firth, there is presently a major regional monitoring programme being discussed for the coastline of North Wales and north-west England, and this may include tidal measurements and well as beach/ saltmarsh surveys in the Solway Firth.

However, it is very unlikely that the decisions made by Dumfries and Galloway Council on coastal defence management along their shoreline of the Solway Firth will affect the English coast, or vice versa. Co-operation on both defence management and, at an earlier stage on data collection, could be initially pursued through the Solway Firth Partnership.

As well as pursuing further information on coastal flood risks, it would also be valuable to review rates of coastal erosion along those frontages where this appears to be a significant cause for concern (see Section 4.2.1). The areas of particular concern include the western shoreline of Luce Bay, both shorelines of Loch Ryan and the Garlieston, Isle of Whithorn and Port William frontages, where coastal roads are at risk. At the same time as information on erosion rates is being compiled, thought also needs to be given to the feasibility of re-routing such roads, or relocating other important assets as an alternative to coastal protection schemes.

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Appendix 1 Coastal protection works – Requirements for consents and consultation

(Adapted from David Tyldesley Associates & SNH, 2000)

Table 1 Requirements for a Coast Protection Authority (operating within its own area)

Proposer	Administrative Locality	Location of Works	CPA Pt1 SERAD Consent	CPA Pt1 CPAu Consent	CPA Pt2 SEDD Consent	FEPA SERAD Consent	Scale	TCPSA	EA Regulations 1988 / 1994	Habitats Regulations 1994	WCA S.28
Coast Protection Authority	Within its own area	Those works above MHWS	Requires consent	Not required if proposed by CPAu in its own area	Not required	Not required	>£100,000	Full planning permission required	If significant environmental effects, ES required with full planning application, cannot be P Dev	If significant effect on a Natura 2000 site, PA and SERAD must undertake appropriate assessment	OLD notice not required
			Requires consent	Requires consent if proposed by CPAu in its own area	Required if likely to endanger navigation	Requires consent	<£100,000 or <200 cubic metres and <4m high	Permitted development	P Dev if no significant environmental effects	Permitted development if no adverse effect on the integrity of a Natura 2000 site	OLD notice required if on SSSI
		Works between MHWS and MLWS	Requires consent	Not required if proposed by CPAu in its own area	Required if likely to endanger navigation	Requires consent	>£100,000	Full planning permission required	If significant environmental effects, ES and full planning application required cannot be P Dev	If significant effect on a Natura 2000 site, PA and SERAD must undertake appropriate assessment	OLD notice required if on SSSI
			Requires consent	Requires consent if proposed by CPAu in its own area	Required if likely to endanger navigation	Requires consent	<£100,000 or <200 cubic metres and <4m high	Permitted development	P Dev if no significant environmental effects	Permitted development if no adverse effect on the integrity of a Natura 2000 site	OLD notice required if on SSSI
		Works below MLWS	Requires consent	Not required if proposed by CPAu in its own area	Required if likely to endanger navigation	Requires consent	Any scale	Not applicable	If significant environmental effects, ES required with FEPA and CPA Pt1 applications	If significant effect on a Natura 2000 site, SERAD should undertake appropriate assessment	OLD notice only required if SSSI below MLWS

Key: CPA = Coast Protection Act 1949; CPAu = Coast Protection Authority; EA = Environmental Assessment; FEPA = Food and Environment Protection Act 1985; OLD = Operation Likely to Damage; PA = Planning Authority; P Dev = Permitted Development; SERAD = Scottish Executive Rural Affairs Department; SEDD = Scottish Executive Development Department (Transport Division); TCPSA = Town and Country Planning (Scotland) Act, 1997; WCA = Wildlife and Countryside Act 1981

Table 2 Requirements for a Roads Authority (Works required for or incidental to the maintenance or improvement of a road)

Proposer	Administrative Locality	Location of Works	CPA Pt1 SERAD Consent	CPA Pt1 CPAu Consent	CPA Pt2 SEDD Consent	FEPA SERAD Consent	Scale	TCPSA	EA Regulations 1988 / 1994	Habitats Regulations 1994	WCA S.28
Road Authority	Works required for or incidental to the maintenance or improvement of a road	Those works above MHWS	Not required	Requires 28 days notice to the CPAu	Not required	Not required	Any scale within or adjoining the boundaries of a road	Permitted development	If significant environmental effects, ES required with full planning application	If significant effect on a Natura 2000 site, must submit application to PA for approval, PA must undertake an appropriate assessment	If permitted development OLD notice required
		Works between MHWS and MLWS	Not required	Requires 28 days notice to the CPAu	Required if likely to obstruct or endanger navigation	Requires consent	Any scale within or adjoining the boundaries of a road	Permitted development	If significant effects, ES required with full planning and FEPA application	If significant effect on a Natura 2000 site, must submit application to PA for approval, PA must undertake an appropriate assessment	If permitted development OLD notice required
		Works below MLWS	Not required	Requires 28 days notice to the CPAu	Required if likely to obstruct or endanger navigation	Requires consent	Any scale	Not applicable	If significant effects, ES required with FEPA application	If significant effect on a Natura 2000 site, SERAD should undertake appropriate assessment	OLD notice only required if SSSI below MLWS

Key: CPA = Coast Protection Act 1949; CPAu = Coast Protection Authority; EA = Environmental Assessment; FEPA = Food and Environment Protection Act 1985; OLD = Operation Likely to Damage; PA = Planning Authority; P Dev = Permitted Development; SERAD = Scottish Executive Rural Affairs Department; SEDD = Scottish Executive Development Department (Transport Division); TCPSA = Town and Country Planning (Scotland) Act, 1997; WCA = Wildlife and Countryside Act 1981

Table 3 Requirements for a Private Landowner (for a private coast protection scheme under the Coast Protection Act)

Proposer	Location of Works	CPA P11 SERAD Consent	CPA P11 CPAu Consent	CPA P12 SEDD Consent	FEPA SERAD Consent	Scale	TCPSA	EA Regulations 1988 / 1994	Habitats Regulations 1994	WCA S.28
Private Landowner under Coast Protection Act as a private coast protection scheme	Those works above MHWS	Not required	Consent of CPAu required	Not required	Not required	Any scale	Full planning permission required	If significant effects, ES required with full planning application	If significant effect on a Natura 2000 site, PA and SERAD should undertake appropriate assessment	OLD notice not required
	Works between MHWS and MLWS	Not required	Consent of CPAu required	Required if likely to obstruct or endanger navigation	Consent required	Any scale	Full planning permission required	If significant effects, ES required with full planning and FEPA application	If significant effect on a Natura 2000 site, PA and SERAD should undertake appropriate assessment	OLD notice not required
	Works below MLWS	Not required	Consent of CPAu required	Required if likely to obstruct or endanger navigation	Consent required	Any scale	N/A	If significant effects, ES required with FEPA application	If significant effect on a Natura 2000 site, SERAD should undertake appropriate assessment	OLD notice only required if SSSI below MLWS

Key: CPA = Coast Protection Act 1949; CPAu = Coast Protection Authority; EA = Environmental Assessment; FEPA = Food and Environment Protection Act 1985; OLD = Operation Likely to Damage; PA = Planning Authority; P Dev = Permitted Development; SERAD = Scottish Executive Rural Affairs Department; SEDD = Scottish Executive Development Department (Transport Division); TCPSA = Town and Country Planning (Scotland) Act, 1997; WCA = Wildlife and Countryside Act 1981

Table 4 Requirements for a Private Landowner (under Land Drainage Act (Scotland) 1958 an improvement order to combat erosion)

Proposer	Location of Works	CPA Pt1 SERAD Consent	CPA Pt1 CPAu Consent	CPA Pt2 SEDD Consent	FEPA SERAD Consent	Scale	TCPSA	EA Regulations 1988 / 1994	Habitats Regulations 1994	WCA S.28
Private Landowner under Land Drainage (Scotland) Act 1958 an improvement order to combat erosion	Those works above MHWS	Order must be approved by First Minister	Not required	Not required	Not required	Any scale	Normally a deemed planning permission or P Dev but see next column	If significant effects, ES required with full planning and order and FEPA application P Dev if no significant effects	If significant effect on a Natura 2000 site, PA and SERAD should undertake appropriate assessment P Dev if no adverse effect on integrity of Natura 2000 Site	No OLD notice required
	Works between MHWS and MLWS	Order must be approved by First Minister	Not required	Required if likely to obstruct or endanger navigation	Consent required	Any scale	Normally a deemed planning permission or P Dev but see next column	If significant effects, ES required with full planning and order and FEPA application P Dev if no significant effects	If significant effect on a Natura 2000 site, PA and SERAD should undertake appropriate assessment P Dev if no adverse effect on integrity of Natura 2000 Site	No OLD notice required
	Works below MLWS	Order must be approved by First Minister	Not required	Required if likely to obstruct or endanger navigation	Consent required	Any scale	N/A	If significant effects, ES required with order and FEPA application	If significant effect on a Natura 2000 site, SERAD should undertake appropriate assessment	OLD notice only required if SSSI below MLWS

Key: CPA = Coast Protection Act 1949; CPAu = Coast Protection Authority; EA = Environmental Assessment; FEPA = Food and Environment Protection Act 1985; OLD = Operation Likely to Damage; PA = Planning Authority; P Dev = Permitted Development; SERAD = Scottish Executive Rural Affairs Department; SEDD = Scottish Executive Development Department (Transport Division); TCPSA = Town and Country Planning (Scotland) Act, 1997; WCA = Wildlife and Countryside Act 1981

Appendix 2 Consultation Letter and Questionnaire

Copy of initial consultation letter

Page 1

26th October 2003
Dear Sir/Madam

DUMFRIES & GALLOWAY SHORELINE MANAGEMENT PLAN: STAGE 1

I am writing to inform you that Dumfries and Galloway Council is in the process of producing a Shoreline Management Plan (SMP) in partnership with HR Wallingford. This Plan will be a forward-looking document that sets out the strategy for coping with the risks of coastal erosion and flooding over the coming decades covering the shoreline from the mouth of the River Sark to Loch Ryan. The initial draft plan is scheduled for completion in mid-2004.

As part of the consultation process, and to ensure that an accurate and thorough knowledge of the Dumfries and Galloway coast is compiled, we wish to invite you to contribute to this Plan by completing the reply form attached. Thank you in advance for your assistance.

The study will consider wave and tidal processes, sediment transport, the condition and performance of the existing coastal defences and how they interact with the human and natural environment. The study will go on to identify the best sustainable approach (or approaches) to managing risks from flooding and coastal erosion (including cliff instability). The first step will be to recommend a defence “policy” for each stretch of coastline, indicating whether to protect assets with coastal defences, to manage risks through other means, or not to intervene and allow the shoreline to evolve naturally.

In summary, the main objectives in developing the Shoreline Management Plan are as follows:

- To define the risks to people and the developed, historic and natural environment within the Dumfries and Galloway Council’s area;
- To recommend appropriate local policies for managing these risks over the next 50 years;
- To identify the consequences of implementing the preferred policies;
- To set out procedures for monitoring the effectiveness of the SMP policies;
- To ensure that future land use and development of the shoreline takes due account of the risks and the preferred SMP policies; and
- To comply with international and national nature conservation legislation and biodiversity obligations.

Recognising the great importance of much of this coastline to the natural environment, Scottish Natural Heritage will be involved in the management of this study throughout.

We can only achieve the above objectives if we are fully aware of the needs and concerns of all parties and individuals interested in the coastline and its future evolution. This consultation letter therefore is an important initial step in developing this understanding, which will depend greatly on the information we receive from consultees. We are therefore particularly interested in your views on the following issues:

- Coastal erosion, flooding, and cliff stability issues, particularly where damage to assets has occurred in the past, or there are concerns that it may occur in the near future;
- Environmental concerns where these have been, or may be affected by natural coastal changes or by developments or defences built along the coast;
- Views on the present and possible future amenity uses of the coastline in the study area (e.g. effects on beaches and dunes, access for formal or informal recreation);
- Opinions about any works, such as coastal defences, that have been or may need to be carried out along the shoreline (e.g. need for new defences, condition of existing defences, health and safety concerns, pollution).

Since this Plan is to be a forward-looking document, it is important not only to reflect the past and present situations, but also to investigate the hopes and fears regarding the future.

Please consider the above issues and use the enclosed reply form to send your comments back to me, Alan Brampton, at the above address, if possible by 19th December 2003. Responses will then be compiled and, where necessary, further information will be sought to ensure that we fully understand the interests and issues raised by this initial consultation.

At this stage we only wish to make you aware of the development of the Dumfries and Galloway Shoreline Management Plan and to have your initial thoughts and comments. As the project proceeds, interested parties will be kept informed of the plans. Your comments on these plans and further relevant information will be welcomed. Where conflicts of interest arise, every effort will be made to find compromise solutions.

If you require further information, or wish to discuss the Plan in more detail, please contact me at the telephone number given below. Thanks again for your interest and participation; we look forward to receiving your comments.

Yours sincerely

Dr Alan H Brampton
Project Manager, HR Wallingford

Telephone 01491 822245

On behalf of Dumfries and Galloway Council

DUMFRIES AND GALLOWAY SHORELINE MANAGEMENT PLAN – STAGE 1

October 2003

Consultation Reply Form

(Please return by post, by fax to 01491 825539, or email responses to ahb@hrwallingford.co.uk)

Organisation: _____

Principal Contact: _____

Job Title (if appropriate) _____

Telephone: _____

Facsimile: _____

Email: _____

1. Coastline of main interest to you (approximate limits)

2. Subjects/ activities of interest to you (e.g. historic, archaeology, nature conservation, recreation, coastal defence)

3. Concerns regarding coastal erosion (location, consequences etc.)

4. Concerns regarding coastal flooding (location, consequences etc.)

5. Concerns regarding coastal defence

6. Concerns regarding threats to, or degradation of, the natural environment

7. Aspirations for enhancement of the natural environment

8. Concerns regarding recreation use of the coastal zone
9. Aspirations for improved recreation / tourism
10. Any aspirations for development near the coast/ estuaries
11. Views / issues that may constrain development (e.g. public access, risk of erosion, loss of habitat, visual impact)
12. Information you would like us to review / be made aware of (e.g. publications, field data, historical photographs, information on past flooding / erosion)?
13. Please provide names and contact details of any key consultees you feel we have missed (see attached list.)
14. Please give details of other relevant concerns
15. Are you aware of any previous studies/ reports that you think may be relevant? (please give details)
16. Any other comments – please use extra pages if required

If you wish to discuss the development of the Shoreline Management Plan further, please contact:
Dr Alan Brampton, HR Wallingford Ltd, Howbery Park, Wallingford OX10 8BA, UK

Appendix 3 List of Responses to Consultation Letter

We wish to acknowledge and thank all those who responded during the consultation exercise, and particularly the following for their help and interest.

Ref. No.	Responder/ position	Organisation/ company/ etc.
R1	Cllr. Ian Callender	Dumfries & Galloway Council
R2	Kirsty Hutchison	Farming and Wildlife Advisory Group
R3	Cllr. Lavinia Vaughan	Dumfries & Galloway Council
R4	D Rothwell	Hoddum & Kinmount Estates
R5	Mr Tony Wood	Maritime & Coastguard Agency
R6	Joe Scofield	Kirkcudbright Training Area
R7	Mr W W Hilton	Stena Line
R8	Norma Hart	Dumfries & Galloway Tourist Board
R9	James Robbins(?)	Solway Fisheries Trust
R10	Mr Tony Grant	SUTRANS
R11	Mr Julian Warman	Scottish Wildlife Trust
R12	Dr Mhairi Harvey	University of Glasgow, Crichton
R13	Mrs Anne Higham	Port William & District Community Council
R14	Patrick Ashmore	Historic Scotland
R15	Mr Peter S Allison	Dalbeattie Community Council
R16	Mrs Caroline McLean	Royal Burgh of Wigtown & District Comm. Coun.
R17	Cllr. Joan Mitchell	Dumfries & Galloway Council
R18	Mr Michael Fawkes	Dumfries & Galloway Council
R19	D Dewar, Factor	Glenapp Estate
R20	Cllr. M Gordon	Dumfries & Galloway Council
R21	David Tollick	Lochryan Forum
R22	Mr Gaven M Campbell	Farmer
R23	Mrs Carol Lloyd	
R24	E A Fleming-Smith	Factors, Stair Estates
R25	Mr Robert Gladstone	Factor, Weatherall Scott Trust
R26	Mr Thomas Florey	Caerlaverlock Estate
R27	G G Armstrong	Kirvennie/ Crook of Baldoon Farms
R28	Dr Tom Dawson	The SCAPE trust
R29	Douglas Ralston	Scottish Enterprise, Dumfries & Galloway
R30	Ms Tracy Davidson	Cairnryan Community Council
R31	Ms Mona Parr	Access Officer, British Horse Society (D&G)
R32	Mrs Elizabeth McKie	Kirkmabreck Community Council
R33	Mr Jamie Blackett	Owner, Arbigland Estate Trust
R34	Mr Jamie Blackett	Owner/, Arbigland Estate Trust
R35	L Moore (Sec.)	Eastriggs, Dornock & Gretna CC
R36	R Oxley	Owner, Barholm Mains
R37	Anon	Tongland Community Council
R38	Ms Jean Marshall, Sec.	Isle of Whithorn Community Council
R39	Robin H Christie, MD	Dourie Farming Co. Ltd.
R40	Jo Doake, Secretary	Scottish Rights of Way & Access Soc.

Ref. No.	Responder/ position	Organisation/ company/ etc.
R41	Mrs W Horrocks	Southernness Community Council
R42	Mrs Joanne Blain	Springfield and Gretna Community Council
R43	Dr Colin Shedder(?)	British Assoc. for Shooting & Conservation
R44	D F R Evans	Ardwell Estates
R45	Clair Spray	Solway Heritage
R46	Thomas S Willacy	Annan Harbour
R47	P Murray Fisher	Murray Fisher Foundation
R48	Alan Burdekin	Scottish Executive
R49	Caroline Salthouse	North West Coastal Forum
R50	T.C Foxley(?),Factor	Caerloverock Estate
R51	Alan Walker	National Grid Transco
R52	Graham Robertson	Gatehouse & Fleet Community Council
R53	Mr Mike Holt-Kilonan	Borgue Community Council
R54	Suzanne Roberts	Keep Scotland Beautiful
R55	Dr D.F. Shaw	Irish Sea Forum
R56	Douglas Hemming	South Ayrshire Council
R57	Charles Clemie	Dumfries & Galloway Council
R58	Raymond Liptrott	Kirkmaiden Community Council
R59	Dr J.D. Hansom	Dept. Geography & Geomatics, Univ. of Glasgow
R60	P. Hyles	Scottish Water
R61	Anon	Gretna and Rigg Community Council

(Non specific responses)

O1	Helena Kennedy	Crown Estate
O2	Christina Tracey	Forestry Commission
O3	Charles Prosser	RFACS
O4	Rebecca Jones	RCAHMS
O5	Mrs Jo Doake	Scotways
O6	Jenny Wilson	Dumfries & Galloway Arts Assoc.

Dumfries and Galloway Shoreline Management Plan

**Dumfries and Galloway Shoreline Management Plan Study:
Stage 1**

Volume 2



**Report EX 4963
Rev 2.0
June 2005**

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Project Manager	Dr Alan Brampton
Project Sponsor	Dr Paul Sayers

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Authorised

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Summary

Dumfries and Galloway Shoreline Management Plan

Dumfries and Galloway Shoreline Management Plan Study: Stage 1

Report EX 4963
June 2005

Only a small proportion of the Dumfries and Galloway coastline presently has, or is likely to require, coastal protection or flood defences in the next 50 years. Nevertheless, it is important to set a strategy for such schemes, because of the great expense involved and the potential for damage to the environment that would result if works were undertaken without careful planning. This study is an initial step in developing a coastal defence strategy for the Dumfries and Galloway coastline; such a strategy is termed a Shoreline Management Plan.

The concept of Shoreline Management Plans was originally developed for the coastlines of England and Wales, where a relatively short and homogenous stretch of coast can be under the control of several local authorities, each of which has coastal defences. In Scotland, the number of coastal defence authorities is much smaller, and the need for co-operation between them thus more limited. Nevertheless, the underlying principles and benefits of a Shoreline Management Plan are still relevant to all stretches of coastline where significant assets are at risk of erosion or flooding. Such a Plan allows future defence options to be considered in a uniform and consistent manner, helping in the long term planning of development along the coastal margins of Scotland. At a local level, such a Plan helps in identifying the likely future investment needed to safeguard human lives, and a wide range of assets, from the threat posed by the sea.

The objective of this study was to provide Dumfries and Galloway Council with a document to be used when setting priorities for coastal defence management. It takes into account the issues of public safety, the preservation of property and infrastructure, the preservation (and where possible the enhancement) of the environment and the likely costs of defence management along a coastline. This report provides an understanding of the processes shaping the coast, based on a mixture of geomorphological analysis, interpretation of available data in waves, tides, movements of beach sediment and past shoreline changes.

In addition it provides information on the assets at potential risk from erosion or flooding, on the present coastal defences and on the natural and human environment of the nearshore area and the coastal strip. This involved not only a review of existing documentary information, e.g. previous reports and maps, but also a first-hand inspection and appraisal of much of the coastline by very experienced specialists in coastal processes and engineering. Much of the information gathered has been compiled in a Geographical Information System (GIS), which has been transferred to the Council and Scottish Natural Heritage. This will provide a basis for a range of possible future coastal management initiatives. Information has also been gathered from an initial consultation exercise, in respect of current concerns and longer-term aspirations for management of the coastline.

Based on the information gathered together, and the analyses made, this study has gone on to define sub-divisions of the coastline in Dumfries and Galloway, first into six “Coastal Process Units”, reflecting the different character and processes of different areas, and then into 37 smaller “Management Units”. These Management Units have been chosen bearing in mind not only the natural characteristics of the coastline, but also the usage and development of the

Summary continued

immediate hinterland. For each of these Units, the study has identified the present concerns and processes, any existing defences and the main assets at risk now or in the medium-term future. Information on the local environment, for example specially designated areas, and on the ancient monuments and archaeological interests has also been included.

For each of these Units, the study has gone on to consider a range of generic coastal defence strategy options, ranging from “No active intervention” to “Holding (or even advancing seaward) the present line” of coastal defences (or of the shoreline). For each option, consideration has been given to the three aspects of economics, environmental management and technical feasibility in order to ensure that suggested future management of the coastline can be carried out in as sustainable a manner as possible. The methods to be applied in developing a proposed policy for any stretch of coastline are presented in a transparent manner, with the most important implications of the suggested policy being summarised. Therefore, even if not all of the interested parties agree with the suggested strategy option, the basis for making that recommendation is clear.

The report also presents recommendations for further development of the Shoreline Management Plan process, and for the collection of further information, particularly in areas identified as of highest priority, for the consideration of coastal defence schemes.

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1. Description of Management Units and derivation of defence policy recommendations

1.1 DEFINITION OF MANAGEMENT UNITS

As noted in Section 2.6 of Volume 1, this study has suggested the division of the Dumfries and Galloway coastline into 37 “Management Units”, i.e. sections of coastline that have more-or-less consistent characteristics along their length in terms of the following characteristics.

- Coastal defences, e.g. a continuous seawall, and/ or
- Land-use in the immediate hinterland, e.g. residential or farmland, and/ or
- Beach/ foreshore type and exposure to waves.

In such circumstances, it is expected that the management of the entire shoreline, including coastal defences, in these “units” will be consistent, i.e. the same decisions will be made about how to respond to the threats of erosion or flooding by the sea. In this first stage study, a rather “broad brush” approach to defining these Management Units has been taken. It is likely that as further information on the assets at potential risk, rates of erosion, flood risk etc. becomes available, then it may be appropriate to refine the suggested management units, by dividing or combining those suggested here, or by adjusting their boundaries.

In order to keep the defined Management Units to a reasonable number it has also been decided, in some cases, to include short lengths of coastline with defences in a longer and otherwise natural Management Unit. As a consequence, the suggested defence policy option will potentially be different for different parts of that Unit.

A list of the Management Units along the coastline of Dumfries and Galloway, as defined in this study, is provided in Table 1 below.

1.2 MANAGEMENT UNIT CHARACTERISATION AND POLICY CONSIDERATION

For each Management Unit, a consistent format for presenting information, assessments and ultimately suggestions for appropriate defence management has been used. This format is as follows:

HEADER

Unit name, number and limits (with National Grid Co-ordinates).

COASTAL OVERVIEW

Brief description of morphology of coastline, erosion / flooding risks and main hinterland features.

COASTAL DEFENCES

A brief summary of the type and conditions of coastal defences, including flood defence embankments, where present.

DEFENCE ISSUES

This section considers the possible future risks from coastal erosion or flooding, including, where appropriate, the vulnerability of defences, and the feasibility and possible merits of installing or extending defences.

Table 1 Management Units

Management Unit number	Management Unit boundaries
1	A74(T) - Mouth of Sark
2	Mouth of Sark - Waterfoot
3	Waterfoot - Barnkirk Point
4	Barnkirk Point - Pow Water
5	Pow Water - Scar Point
6	Scar Point - Airds Point
7	Airds Point - Borron Point
8	Borron Point - Castlehill Point
9	The Port, Dalbeattie - Kippford
10	Castlehill Point - Balcary Point
11	Balcary Point - Torrs Point
12	Torrs Point - Bar Point
13	Seaward - Low Bridge of Tarff
14	Bar Point - Carrick Point
15	Carrick Point - Ringdoo Point
16	Rough Point - Fleet Bridge
17	Ringdoo Point - Point Fishery
18	Point Fishery - Eggerness Point
19	Eggerness Point - Ringan
20	Ringan - Isle Head, Isle of Whithorn
21	Isle Head - Screen, Isle of Whithorn
22	Screen, Isle of Whithorn - Airlour Creamery
23	Airlour Creamery - Low Drumskeog
24	Low Drumskeog - Balcarry Holdings
25	Balcarry Holdings - Carisbrooke Caravan Park
26	Carisbrooke Caravan Park - Inchmore
27	Inchmore - Back Bore
28	Back Bore - Mull of Galloway
29	Mull of Galloway - Lagnawinny
30	Lagnawinny - PortPatrick (North)
31	PortPatrick (North) - Milleur Point
32	Milleur Point - Clachan Heughs (South)
33	Clachan Heughs (South) - McCullochs Point
34	McCullochs Point - Bishop Burn Bridge
35	Bishop Burn Bridge - Bankhead
36	Bankhead - Glen Burn
37	Glen Burn - Galloway Burns

NATURAL & HERITAGE ENVIRONMENT

In order to set the scene for the assessment of possible coastal defence options, a table has been prepared that summarises the main features of the hinterland, comprising:

- Designations that may affect the desirability or type of coastal defences, including areas designated for reasons of environmental conservation e.g. SAC, SPA, SSSI, NSA, National / local Nature Reserves and sites/ monuments that are of importance from the viewpoints of heritage and archaeology;

- A summary of the main land uses(s) and ownership, any “sea uses” e.g. harbours, slipways, jetties etc., and the main recreational / amenity uses of the coastline, e.g. caravan/ chalet parks;
- A summary of the coastal defences (type, whether private or public and location); and
- The relevant statutory development plan(s) covering the Management Unit frontage.

CONSULTATION ISSUES

When responses from the consultation exercise identified specific concerns or issues relating to the management of the Management Unit frontage, these are summarised. The number given at the beginning of each paragraph in this section provides a key identifying the source, as listed in Appendix 3, Volume 1.

ASSESSMENT OF ASSETS AT RISK

A standard table is provided listing both “tangible” assets i.e. those that can be evaluated in monetary terms and “intangible” assets together with an opinion on the short-term level of risk to those assets.

OPPORTUNITIES

Where the inspection of the coastline, or responses from the consultation exercise, indicated that coastal management, including the modification or installation of defences, could lead to possible improvements to the amenity, aesthetics or environment of the coastline, then these are noted. Similarly where it was felt that the natural character of the coastline would be damaged by such measures, this opinion was also noted.

STRATEGIC POLICY APPRAISAL

The gathering of information for each Management Unit, as summarised in the preceding paragraphs, formed the context for the consideration of the coastal defence options for that Unit. At the broad-brush level appropriate for this Shoreline Management Plan study, five strategic options were considered, as described in Section 1.4.5 Volume 1. For convenience, descriptions of these options are reproduced below:

- **Hold the existing defence line**

Improve or maintain the standard of protection provided by the existing defence line. This policy includes situations where works or operations are undertaken in front of and behind the existing defences (e.g. beach renourishment, additional toe protection, construction of offshore breakwaters to control beach response etc), to improve or maintain the standard of protection provided by the existing defence line.

This policy option has been the one most readily chosen in Shoreline Management Plans in England, especially where there are existing “built” coastal defences or assets such as coastal roads just inshore of a natural coastline. While preserving the *status quo* is often the easiest option in the short-term it can, however, lead to ever more difficult problems in the future. Given the inevitability of coastal erosion and of continuing increases in sea levels, the costs and environmental damage involved in maintaining a defence or shoreline position will increase with time in many cases. Further, by adopting such a policy, there is an increased likelihood of the development of the coastal strip behind “the line”. These two factors, together, will therefore lead to a risk of future generations being faced with much more difficult problems to solve than are presently being experienced.

In this study, therefore, the likely long-term problems along each stretch of coastline have been considered before recommending a “hold the Line” policy. Alternative options such as not trying to preserve the present position of the shoreline or defences, and instead relocating assets at risk, have always been considered. An example would be

to move coastal roads inshore, e.g. at Soleburn, rather than trying to protect the existing route.

- **Advance the existing defence line**

Construction of new defences seaward of the original defences.

There are occasionally situations where installing a new line of coastal defence significantly further seaward than the existing shoreline may be worthwhile. However, the cost of building defences in deeper water is much greater than in shallower water, and is usually only financially viable where the extra land gained is used for, or in connection with, substantial developments, e.g. ports. There are very few locations along the Dumfries and Galloway coastline where an advance the line policy option needs to be considered, the obvious exception being in connection with the further development of the port at Cairnryan.

- **Managed realignment**

In this study, managed realignment is defined as the process of identifying a new line of defence, which might be naturally high ground, further landward than the existing shoreline or any existing defences, and actively arranging for the shoreline to retreat to this new defence line. (Simply allowing natural processes of coastal evolution to continue unchecked, thus resulting in a landward recession of the shoreline is covered under “no active intervention” below).

Where the land between existing defences and the new “defence line” is below the level of highest tides then is it sometimes beneficial to remove part or all of the existing defences, creating a new inter-tidal area which can provide valued habitats for wildlife, e.g. saltmarshes and inter-tidal mudflats.

The scope for such habitat creation by managed realignment of the coast of Dumfries and Galloway, however, is limited since in most cases the ground levels rise to the land of the present shoreline. Therefore, even if existing defences were removed there would be little or no extra inter-tidal area created.

- **Limited Intervention**

Reducing the risks of coastal erosion or flooding by working with natural processes to allow for natural coastal change. This may range from measures which attempt to slow down rather than stop coastal erosion, such as dune management, to measures which may include repairing existing defences when damaged but not investing in further capital works to maintain or upgrade the present standard of protection, e.g. against flooding.

- **No active intervention**

Where there is no investment in coastal defence assets or operations, i.e. no shoreline management activity, other than monitoring or the provision of flood warning systems (which may also be appropriate for frontage where other policies are adopted).

To assess the potential suitability of each of these strategic policy options, a screening procedure is adopted. First any impractical options are discounted, with a brief statement explaining why these are not considered worth further consideration for this Management Unit.

For the remaining options, the next stage of the procedure is to assess how each option meets various generalised objectives for the management of that part of the Dumfries and Galloway coastline. These objectives were derived from consultations with the statutory and non-statutory organisations with an

interest in the future management of the Dumfries and Galloway coastal zone and from existing plans, namely:

- Existing planning policies relating to development of the coastline, i.e. the Local Plans;
- Management plans for areas or sites that have been designated for their natural, cultural or archaeological heritage or for their scenic qualities;
- Policies /concerns relating to the management or development of recreation/ amenity use of the coastline;
- Current and potential use of the coastline by industry, ports and the MOD; and
- Current and potential use of the coastline in relation to agriculture and fisheries.

This initial screening process identifies one or more “suitable” strategic defence options, i.e. those that are deemed to be compatible with the general management objectives. The “suitable” options are then carried forward into a second part of the assessment process, a consideration of the policy against five further criteria, namely:

- Effects on coastal processes: Could the policy lead to significant changes in the natural coastal processes, for example leading to disruption of longshore drift or reduction in supply of beach sediments?
- Effects on coast defences: Could the policy affect or particularly damage existing defences thus reducing the present standard of defence against flooding or erosion?
- Effects on natural environment: Could the policy lead to significant detrimental impacts on the natural environment (especially designated areas)?
- Effects on human/ built environment: Could the policy lead to significant detrimental effects on recreation, amenity or “built heritage”, e.g. archaeology, historic buildings/ monuments etc?
- Economic viability: Are the benefits of implementing this policy likely to justify its cost?
- Compatibility with adjacent MU’s: Will the policy have significant impacts on adjacent management units?

This second stage of the assessment of the possible strategic policies is summarised in an “Impact Summary Matrix”, with brief comments as appropriate. The final row of this matrix summarises whether the proposed policy options are considered suitable, based on the above considerations.

SUGGESTED POLICY OPTION

Based on the strategic policy appraisal and impact summary matrix, suggestions are made for an appropriate coastal defence policy for the Management Unit. In cases of uncertainty, or where further work is required to resolve a given issue, then more than one option may be suggested. In conjunction with this there may be a requirement for monitoring or detailed study to address specific uncertainties. Where more than one option is suggested a preferred option is still identified. This should not, however, preclude the other potentially viable options being considered in any future more detailed studies.

In a number of cases, the suggested policy may be appropriate over most of the Management Unit but possibly unsuitable for some short frontages. For example, “No Intervention” may be suggested for a largely undeveloped length of coastline but potentially would not be appropriate for areas where there are isolated “assets” (e.g. a small group of houses or a short stretch of coastal road). In such cases, a “hybrid” option has been suggested. (The alternative would have been to introduce further Management Units for each of these short stretches of coast with assets at risk, thus resulting in many more Management Units).

Furthermore, consideration has been given to whether the policy suggested may need to change during the intended lifetime of the Shoreline Management Plan. To emphasise the possible need to adapted to gradual changes in the coastline over coming years, three time-scales are used:

- Current/ Short-term Up to 10 years hence;
- Medium term From 10 to 50 years hence and;
- Long term Over 50 years hence.

AREAS OF POTENTIAL CONFLICT

Attention is drawn to potential areas of conflict that may arise due to the implementation of the preferred strategic policy. Potential conflicts are identified, for example:

- The loss of isolated assets when a “No intervention” policy is adopted, or
- Damage to environmentally sensitive areas, or to the coastline in adjacent Management Units, if it is decided to hold the line.

ADDITIONAL MANAGEMENT REQUIREMENTS

If there is thought to be a need for additional shoreline management activities, such as monitoring beach levels or cliff top retreat, these are identified. These activities are usually suggested in order to reduce uncertainty about the current and likely future risks of flooding or erosion, and hence help confirm or alter the suggested policy option.

Detailed descriptions and suggestions for the appropriate coastal defence policy for each of the Management Units, based on previous studies and on the consultation process and site visits undertaken as part of the present study, are presented in the following section of this report.

3. Summary of suggested defence policy options

Table 3.1 below summarises the suggested coastal defence policy options for each of the Management Units. As foreseen and explained in Section 1.1 above, for some of these Units there are different defence policies suggested for different parts of the frontage. However for these Units, as for those where a single policy is suggested, there is a need for more detailed discussion and evaluation of the consequences of adopting such a policy. The final column of this table provides links to the explanatory notes presented in Table 3.2.

Table 3.1 Management Unit – suggested defence policies

MU no.	Management Unit boundaries	Short term	Medium term	Long term	See Note
1	A74(T) - Mouth of Sark	Hi	Hi	Hi	
2	Mouth of Sark - Waterfoot	Hi	Hi	Hi	
3	Waterfoot - Barnkirk Point	Hi	Hi	Hi	
4	Barnkirk Point - Pow Water	Hi	Hi	Hi	
5	Pow Water - Scar Point	Li	Li	Mr	1
6	Scar Point - Airds Point	Hi	Hi	Hi	2
7	Airds Point - Borron Point	Hi	Hi	Hi	
8	Borron Point - Castlehill Point	Li/ Hi	Li/ Hi	Li/ Hi	3
9	The Port, Dalbeattie - Kippford	Ni	Ni	Hi	4
10	Castlehill Point - Balcary Point	Hi	Hi	Hi	
11	Balcary Point - Torrs Point	Ni	Ni	Ni	
12	Torrs Point - Bar Point	Hi	Hi	Hi	
13	Seaward - Low Bridge of Tarff	Hi	Hi	Hi	5
14	Bar Point - Carrick Point	Li	Li	Li/ Hi	6
15	Carrick Point - Ringdoo Point	Hi	Hi	Hi	
16	Rough Point - Fleet Bridge	Hi	Hi	Mr	7
17	Ringdoo Point - Point Fishery	Hi	Hi	Hi	
18	Point Fishery - Eggerness Point	Hi	Hi	Hi/Mr	8
19	Eggerness Point - Ringan	Hi	Hi	Hi	9
20	Ringan - Isle Head, Isle of Whithorn	Hi	Hi	Hi	
21	Isle Head - Screen, Isle of Whithorn	H	H	H	10
22	Screen, Isle of Whithorn - Airlour Creamery	Li	Li	Li/H	11
23	Airlour Creamery - Low Drumskeog	H	H	H	12
24	Low Drumskeog - Balcarry Holdings	Hi	Hi	Hi	
25	Balcarry Holdings - Carisbrooke Caravan Park	Ni/Li	Ni/Li	Ni	13
26	Carisbrooke Caravan Park - Inchmore	Hi	Hi	Hi	14
27	Inchmore - Back Bore	H	H	H	15
28	Back Bore - Mull of Galloway	Hi	Hi	Hi	
29	Mull of Galloway - Lagnawinny	Hi	Hi	Hi	16
30	Lagnawinny - PortPatrick (North)	H	H	H	17
31	PortPatrick (North) - Milleur Point	Ni	Ni	Ni	
32	Milleur Point - Clachan Heughs (South)	Ni	Ni	Ni	18
33	Clachan Heughs (South) - McCullochs Point	Hi	Hi	Hi	15, 18
34	McCullochs Point - Bishop Burn Bridge	H	H	H	18,19
35	Bishop Burn Bridge - Bankhead	Hi	Hi	Hi	18
36	Bankhead - Glen Burn	Hi	A	A	18, 20
37	Glen Burn - Galloway Burns	Hi	Hi	Hi	18

Defence policy key:

- H Hold the line
- Hi No active intervention for the most part, but hold the line in individual areas
- Li No active intervention for the most part, but limited intervention in individual areas
- Mr No active intervention for the most part, but managed realignment in individual areas
- Ni No active intervention
- A. Advance the line

Table 3.2 Explanatory notes for Table 3.1

Note	
1	Further studies of standard of defences, extreme tidal levels and of flood risk required
2	Managed realignment incompatible with canalised nature of estuary
3	Limited intervention in Sandy Hills Bay and Hold the Line at Southernness
4	The Flats, Dalbeattie and Palnackie Harbour may require formal defences in future, as sea level rises
5	Further studies of standard of defences, extreme tidal levels and flood risk required
6	Hold the line in Brighthouse Bay if local intervention proves to be insufficient
7	Further studies of standard of defences and of flood risk required
8	Further studies of standard of defences and of flood risk required
9	Upgrading of defences at Garlieston may be required to protect built environment
10	Monitor condition of harbour structures as they are integral defences
11	Hold the Line in Monreith Bay if erosion becomes critical
12	Downdrift erosion at Port William may require beach nourishment
13	Consider relocating golf course boundary in long term to allow “No intervention”
14	Hold the Line will incur increasing expenditure. Consider beach nourishment
15	Monitor beaches and structures
16	Hold the Line at only Port Logan
17	Hold the Line and monitor defences and harbour
18	Coastline management relevant to Loch Ryan Advisory Management Forum
19	Cliffs north of McCullochs Point may require stabilisation/toe protection
20	Development of Cairnryan ferry terminal will advance the line of the defences

In summary, it can be seen from Table 3.1 that adopting a hold the Line policy is only recommended for five complete Management Units. For almost all the remaining units, the suggestion is for little or no intervention, except perhaps for some short stretches of coastline where defences may be justified depending on the value of assets at risk and the costs of defences proposed. A good example is provided by the suggestion of adopting a hold the line policy at Port Logan, in Management Unit 29, although for the rest of that Unit no intervention is recommended.

As predicted from comparisons with other Shoreline Management Plan areas, there is little opportunity for adopting a policy of “Advance the Line”. More surprisingly, there is also little scope for “Managed Retreat” of defences. Incurring the extra costs involved in deliberately removing defences, for example to create new areas of habitat such as saltmarsh, will not be worthwhile when “No active intervention”, i.e. letting the coastline recede landward naturally, will have the same effect.

In many cases, the present scarcity of information on rates of erosion, on areas liable to suffer coastal flooding and on the relative levels of the highest tides and flood defences means that the suggested policies may change when better information becomes available. In compiling the policy suggestions, therefore, particular attention has been drawn to those frontages where better information may lead to different decisions about defence policy being made (i.e. Management Units 1, 5, 13,14 and 27).