Cromer Coastal Strategy Study

Executive Summary

Report EX 4363B
January 2003

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HR Wallingford

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Summary

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The Cromer Coastal Defence Strategy Study provides a framework for the sustainable management of the coastal defences that extend across the Cromer frontage. The Strategy identifies opportunities and constraints for coastal management over the next 50 years, as well as a more detailed Coastal Defence Implementation Plan for the next 2 years.

This Executive Summary provides an overview of the key issues presented within the main Strategy Report (Report EX 4363, December 2002). This includes a review of the key physical processes and their interaction with existing defences, consideration of the historical development of the coastline, identification and evaluation of a range of potential coastal defence management options and selection of the preferred management approach based on engineering, environmental and economic reasoning.

The town of Cromer is a popular seaside resort, with much of the foreshore and cliff top development linked to tourism. Cromer is also the base for the small but thriving crab fishery. With much of the seafront having been built during the last 100 years, and in many areas on steep cliffs, there is a need to derive a long term strategy that will both protect and enhance the facilities in the most economically efficient and sustainable manner. In doing so, there is also a clear need to recognise the importance of tourism and commercial activities to the long-term future of the town.

Historically the coastline within this study area has suffered from erosion, and landslide processes have shaped the cliffline into a series of near-vertical and vertical cliffs. A range of coastal defences have been constructed over the last century along the frontage including groynes, seawalls, parapets and cliff retaining walls, which are fronted by a sand/shingle beach. However these defences are considered to be nearing the end of their useful life (in their present state) which has led to degradation of the cliff slope and an increasing threat to cliff top buildings. As a result there is considerable concern among the local community.

Analysis of the erosion hazard suggests that under a ‘do nothing’ approach, assets valued at between £16.1M to £35.1M would be lost over the next 50 years, a best estimate gives a value of £29.2M (assuming a 3.5: annual discount rate). These losses have been predicted using a best judgement approach to predict realistic losses, rather than a maximum / minimum approach. Should sea level rise accelerate to 6mm/yr, as latest guidance suggests, these predicted losses would be conservative estimates.

***Summary** continued*

Within the study area a number of key issues and constraints have been identified. These have been taken into consideration in developing the management strategy and include:

- Longshore Drift
  The eastward longshore drift means that a disturbance to beach sediment supply and movement can have significant effects on coastal erosion. Therefore any management scheme needs to consider potential impacts along the whole coastline

- Rate and Location of Erosion
  The rate and location of erosion is influenced by the deterioration and failure of the existing defences. The location of defence failures will influence the rate and location of cliff-top recession.

- Value of assets
  Assets at risk range from residential housing, to recreational facilities, the esplanade and pier and an RNLI lifeboat station. The steps outlined below are considered to be a minimum required to protect the value of assets.

A Management Strategy has been developed that can be implemented progressively through two phases of work. It should be noted that this proposed strategy is considered to be the minimum required to protect assets at Cromer as the steps outlined below are all fundamental to the concept of protecting the seawall frontage. Failure of this frontage (or part of the frontage) is not considered an acceptable option.

The development of an optimum system will take a number of years and requires a monitoring programme to be established through which beach levels are assessed. Therefore a flexible approach to implementation of works has been proposed.

The key issues and stages of work proposed within the management strategy are outlined below:

Stage I:
Step 1 Seawall Repair
Of primary importance is the long term stability and maintenance of the seawall at Cromer. Refurbishment of the existing wall is proposed, with priority given to Sections 1-6 & 8, covering the pier area and frontage to the west. This should be undertaken at the earliest opportunity.

Step 2 Investigation / Design of Groyne System
The key to establishing a high and stable beach is through the effective use of groynes. To establish the optimum design of groynes requires a detailed investigation of beach process interactions before any design work can be initiated and repair and refurbishment of existing groynes and/or construction of new groynes can be carried out.

Summary *continued*

Stage II:
Step 3 Seawall Repair
Continued refurbishment of the existing sea wall is proposed, with priority now given to Sections 7, 9 & 10.

Step 4 Repair / Refurbishment of Groyne System
Following a more detailed assessment of groyne performance / design (as outlined above) the existing groynes should be refurbished and extended where appropriate. The need for an additional groyne has been identified, to aid stabilisation of beach levels around the pier head. The final design and location of this groyne is to be confirmed through physical model investigations. Following initial refurbishment, extension and construction, groynes are to be maintained and adjusted on an annual basis to establish stable and acceptable beach conditions.

Step 5 Beach Recharge
Following Steps 1-3 above, beach recharge is to be undertaken for the area between Groynes 2 & 4.

Stage III:
Step 6 Seawall Repair
Steps 1-5 comprise work required urgently to stabilise beach conditions and protect assets that are immediately at risk. Stage III seawall repairs are subsequently proposed for the remaining frontage covering wall Sections 11-15, to the east of the pier.

Implementation of the proposed defence works is dependent upon assessment for grant aid by the Department for Environment, Food and Rural Affairs (DEFRA). Economic analysis of the proposed management strategy shows a benefit-cost ratio of between 2.5 and 4.3, depending upon the discount rate used. Analysis through the MAFF (1997) priority scoring system produces a priority score for the proposed works of between 24 and 26 points, thus exceeding the traditional threshold for scheme approval. Towards the end of the project DEFRA produced a new method for calculating the priority scoring for schemes. When this new method was applied it produced a benefit-cost ratio between 5.6 and 6.2 and a priority score between 14.3 and 13.9 depending on which annual discount rate is used (6% or 3.5%). See section 10.6 of the main report for more details.

It should be recognised that should the scheme be approved for funding, it will then be necessary to undertake a more detailed scheme appraisal and design prior to any construction works.

Contents

1. INTRODUCTION

This Executive Summary Report presents an overview, conclusions and recommendations for the Cromer Coastal Strategy Study. Full details of this study may be found in the study report – *Cromer Coastal Strategy Study, Report EX 4363, December 2002.*

The study frontage is some 1.6km long extending across the Cromer frontage, located on the North Norfolk coast (Figure 1). This corresponds to the Shoreline Management Plan Management Unit RUN 3.

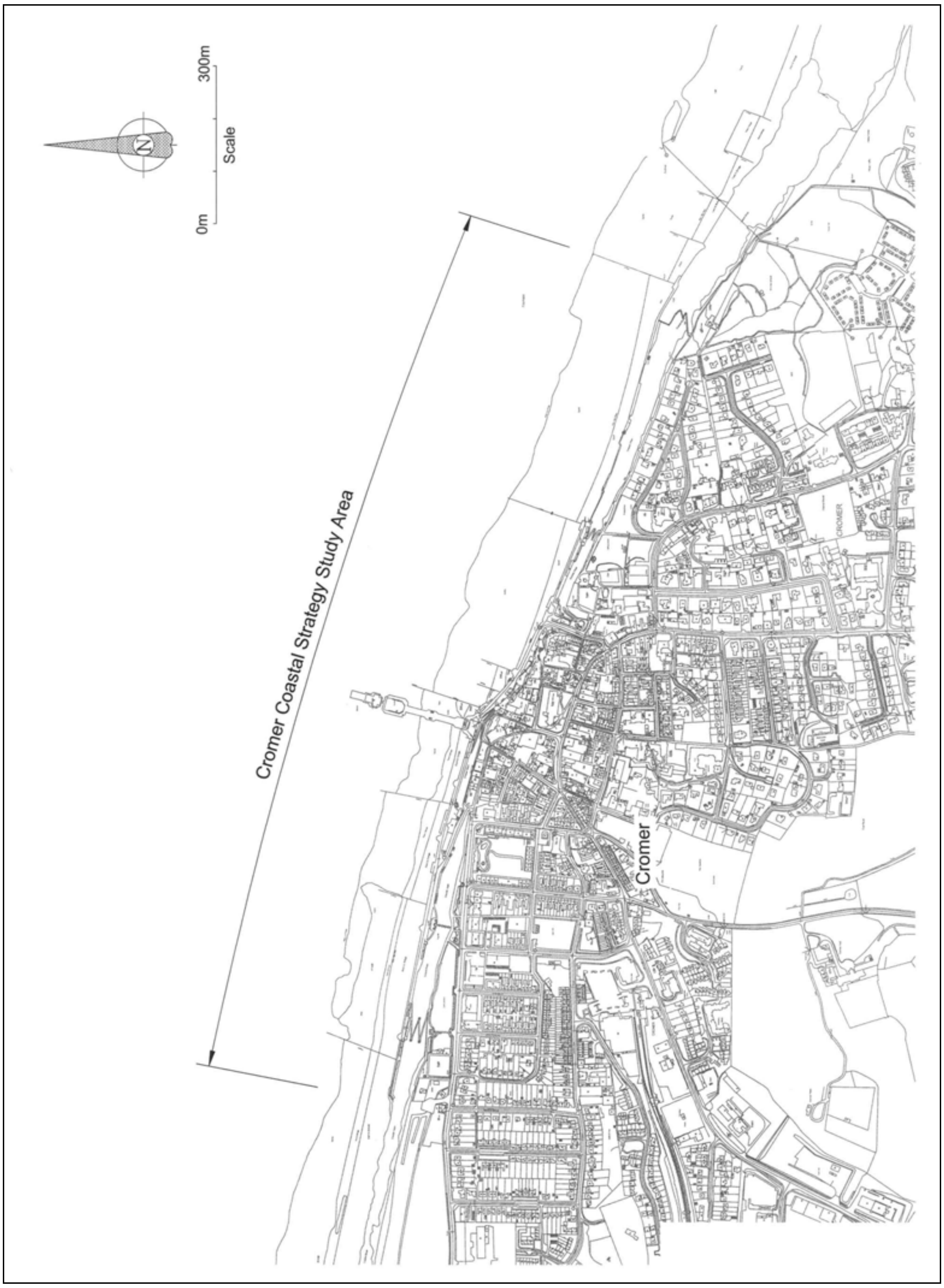

Figure 1 Extent of study area

The coastline on either side of the study area is renowned for problems associated with coastal erosion, and the cliffs along this part of the coast have been subject to recession at least since sea levels in the North Sea rose to approximately present-day levels, a few thousand years ago. Their geological composition, mainly of clay and sand, means that they are prone to frequent landslides, and have little resistance to marine erosion. The construction and maintenance of coastal defences, predominantly seawalls and timber groynes has virtually prevented recession of the cliff top during the past century.

However, the future deterioration of these structures could make the cliff-line highly vulnerable and transform what is effectively a stable slope to an actively unstable near-vertical cliff within a relatively short period of time. This may result in a dramatic initial surge of clifftop retreat, followed by the return to a relatively uniform long-term annual recession rate but with episodic recession events separated by periods of slow or no retreat and likely dramatic losses associated with storm surge events. As a consequence, very significant losses to commercial and/or residential properties would occur. As a further indirect result, there would undoubtedly be a reduction in the attractiveness of Cromer as a seaside resort, further adding to the impacts on the local economy.

2. THE STRATEGIC APPROACH

In 1993 the Ministry of Agricultural Fisheries and Food (MAFF) and the Welsh Office published their "Strategy for Flood and Coastal Defence in England and Wales". This publication identified the need to manage the shoreline from the perspective of coastal processes rather than in accordance with the administrative boundaries of the coastal operating authorities.

To assist this process, MAFF (now DEFRA) provided guidance that outlines the approach to developing management strategies that is consistent with their stated Policy objective of reducing risks to people and the developed and natural environment from flooding and coastal erosion. To enable management decisions to be taken within such a strategic framework, a hierarchy of 'Plans' and 'Appraisals' has evolved that consider the shoreline in progressively greater detail. This hierarchy comprises Shoreline Management Plans (SMP's), followed by Strategy Plans, followed by Scheme Appraisal (Figure 2). Each of these approaches becomes progressively more detailed and site specific, leading ultimately to the implementation of an appropriate management scheme for that stretch of coastline.

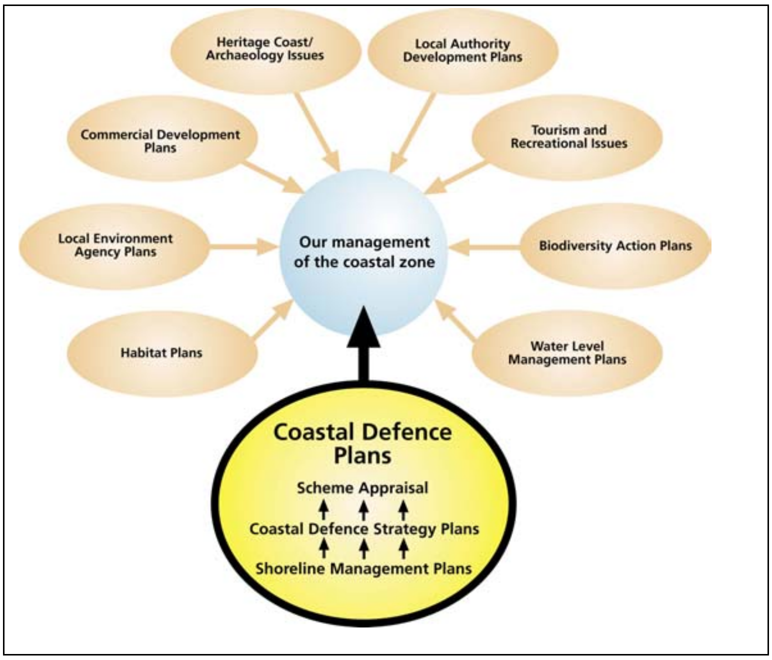

Figure 2 Hierarchy of coastal management plans and appraisals

The 'Cromer Coastal Defence Strategy Study' follows on from the earlier Shoreline Management Plan (1995), and provides recommendations for a management strategy, that includes the <u>outline</u> design of defences. Following possible acceptance of these recommendations by DEFRA, and approval for grant aided funding, a more detailed scheme appraisal / scheme design would be undertaken prior to any construction.

3. ANALYSIS OF THE STUDY AREA

In order to develop a management strategy that takes into consideration the physical coastal processes, environmental issues and concerns of local industry and residents alike, it is first necessary to consult with all relevant organisations and to analyse the coastal processes (wind, waves, tides etc.). Consultation is undertaken through questionnaires and direct discussions and consultation with interested organisations, whilst the latter is undertaken through a combination of site visits, desk studies and computer simulation.

3.1 The consultation process

A total of 29 different organisations or representatives were contacted during the consultation process. Consultees included the Cromer Town Council, North Norfolk District Council, Utility Companies, the Environment Agency, English Nature, the Countryside Commission, RNLI, RSPB etc.

The aim of the consultation process was two-fold; firstly to inform all parties with an interest in the area of the opportunity to participate in development of the future strategy, and secondly to receive direct feedback on issues of concern that should be taken into consideration when developing the final strategy.

In addition to this initial consultation, there was a presentation of the Strategy Study to Cromer Town Council, which was attended by Councillors and several members of the public with the intention of encouraging those present to express their views and concerns as part of the consultation process. The main comments made reflected the keen interest of the Council to maintain and enhance the recreational and tourism attributes of the seafront at Cromer. In particular, the possible incorporation of one or more slipways for launching pleasure boats was seen as an important objective in future management of the Town's frontage, and hence in the design of any coastal defences. Direct comments on the existing defences indicated that the councillors were broadly content with the concrete seawalls, but had misgivings about the condition of some of the timber groynes and the low beach levels in the vicinity of the Pier.

3.2 Environmental value

A review of environmental interests in the study area included an assessment of any environmental designations, the geology, flora and fauna, historic environment and recreation.

Environmental Designations

There are two Sites of Special Scientific Interest (SSSI) in the study area. Two sections of cliff, one to the east (East Runton) and one to the west (Overstrand) of Cromer have been designated. These designations are based upon interest in the glacial deposits exposed within the eroding cliff faces. Key concerns here are to ensure that the cliffs are allowed to continue eroding naturally wherever possible.

The Overstrand Cliffs SSSI is also a designated a Special Area of Conservation (cSAC).

The cliffs between East Runton and Overstrand, thus including the whole of the Cromer town frontage, form the Cromer Sea Front County Wildlife Site (number 1201).

Much of the coastline and immediate hinterland of north Norfolk, stretching from Mundesley to Heacham, forms the major part of the Norfolk Coast Area of Outstanding Natural Beauty (AONB). However, most of the Cromer frontage is not included in this designation and the objectives and policies of the AONB need not be applied to the management of the coastline and its defences.

Geology

The geology of this area largely consists of glacial drift deposits comprising heterogeneous clays, silts, sands and gravels. This mixture of deposits reacts differently to the effects of waves, tides, rainfall and weather. The clay deposits are generally more resistant to erosion by the sea, and often remain as an outcrop, jutting seaward from the cliffs while sandy deposits on either side retreat more rapidly. The net result is a typically ragged cliff line, with numerous small bays and headlands.

While the erosion of the clay provides no useful beach sediments, the sandy deposits in the cliffs do add to the “sediment budget” for the coastline both locally and further along the coast to the east and south. However, due to the development of Cromer as a seaside resort, efforts over the last 200 years have been made to stabilise the cliffs along the frontage. It is important that due consideration be given to the geomorphological consequences of any coastal defence scheme so that a disruption to the drift regime will not adversely affect beaches along the coastline to the east.

<u>Flora & Fauna</u>
Although many of the cliffs along the coastline of Norfolk form important habitats for wildlife, the coastline considered in this study is of low biological interest. The long-established seawalls and drains along the frontage have largely stabilised the cliff faces, with the result that these are almost completely covered with vegetation (ranging from close-cut grass sward to shrubs and small trees). Narrow ledges on the cliff face to the west of the promenade provide nesting sites for Northern Fulmars. However, no particularly important flora or fauna, or associated conservation issues have been identified, nor are there any specific biological conservation issues in the inter-tidal foreshore that need to be addressed in the Strategy Study.

<u>Historic Environment</u>
The historic environment may be defined as comprising all traces of past human activity and including archaeological remains (on land and the seabed), historic buildings, parks and gardens and historic landscapes. Neither English Heritage nor the Archaeological Unit of Norfolk County Council (Gressenhall) identified any buildings or archaeological features of interest within a reasonable distance from the cliff edge. It is anticipated, however, that preservation of older buildings in the centre of Cromer, including the parish church, would be an important consideration in the sensitive management of the frontage.

<u>Tourism and Recreation</u>
Historically, Cromer was built around its port, fishing industry and market, but grew in importance in the late 18th century as a resort for sea bathing and promenading, in part its popularity stemming from its north-facing aspect, which is unusual in the UK. The arrival of the railway in the 19th century, and the building of the present pier in 1901, both added to the popularity of Cromer as a holiday resort. While this popularity has declined in the latter half of the 20th century, in common with other resorts around the UK coastline, the town still depends on tourism for a substantial part of its income. Indeed, the character of the town depends upon its seafront and any coastal defence schemes need to reflect this interrelationship as visitors regard the seafront as an important element in the enjoyment of their stay. The attractions of the seafront include the pier (and its theatre), the promenade that runs the length of the town frontage, the largely sandy beaches and the clean seawater. The seascapes from the parks and cliff tops walks, and the active if modest local fishing industry, also add to the attractiveness of the resort.

3.3 Hydrodynamic loading

Hydrodynamic loading refers to the waves, tidal currents and changes in tidal level at a site. It is important to analyse and understand these since they directly affect and change the shoreline. By understanding these processes, computer models may be used to simulate how these conditions may vary in the future if different types of defence were constructed at different locations. For this strategy study, a number of models were used to predict the different loading conditions and ultimately to predict the future changes in the cliff line. Figure 3 below is indicative of the type of data collected and analysed for the study and shows fetch lengths for the prediction of waves at Cromer and the distribution of waves (height, number, direction) generated from observed data.

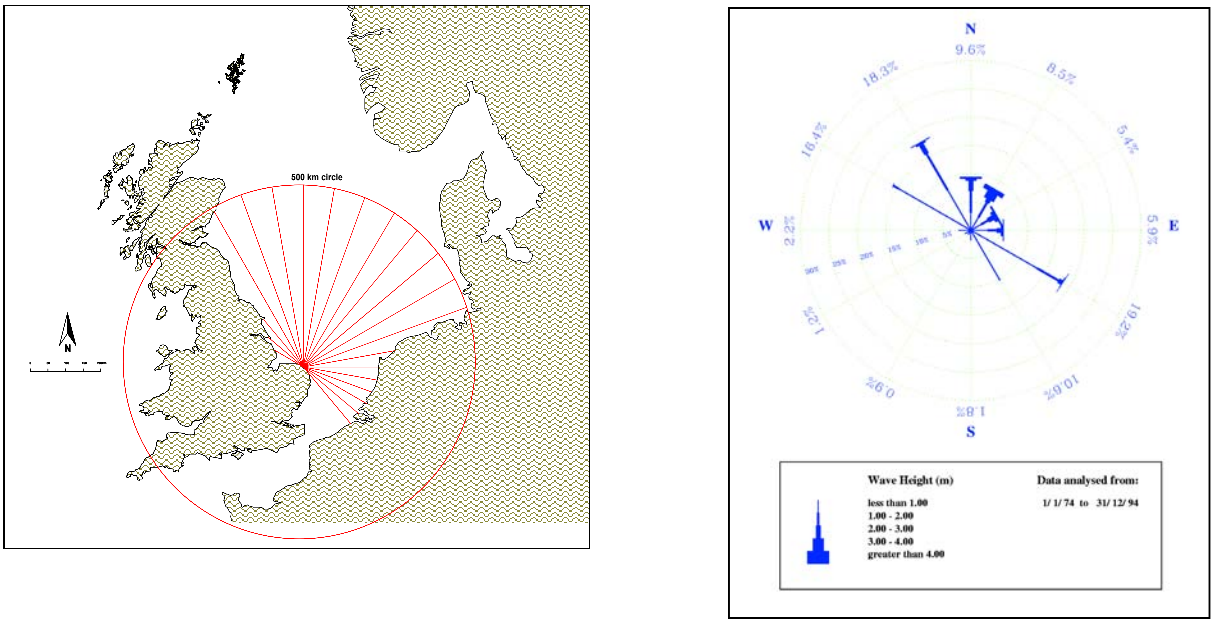

Figure 3 Waves prediction at Cromer

3.4 Littoral processes and shoreline evolution

Studying the interaction of the cliffs, beaches and seabed with the environmental loading allows an understanding of the beach processes and subsequent prediction of the cliff recession in response to natural forces and to the installation of coastal defence schemes. The following simplified flowchart shows the main processes and their interrelationship:

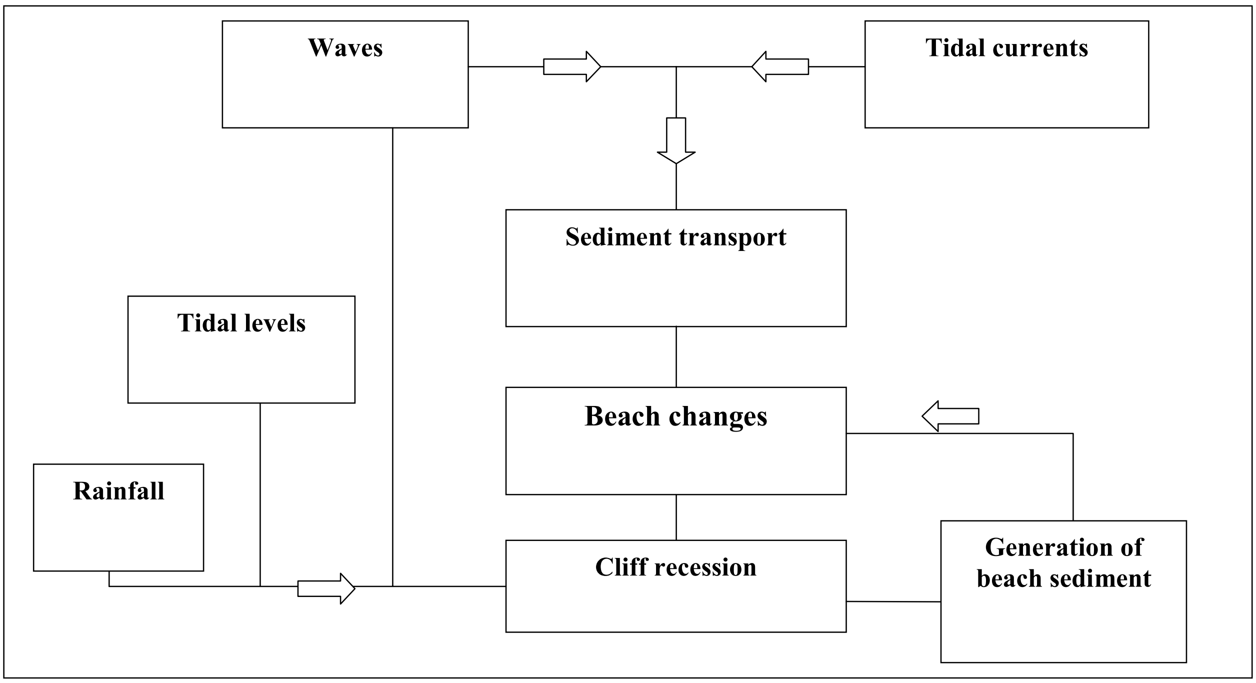

Figure 4 Simplified flowchart of littoral processes

This stretch of coast has been subject to erosion and retreat since the end of the last Ice Age when the North Sea basin filled (again) with water. The main processes responsible for coastal change can be summarised as follows:

- Variations in the rate of beach sediment transport (longshore drift) along the coast;
- Erosion of the nearshore seabed, which is of similar soft rock to the cliffs;
- Landwards migration of the beach profile in response to sea level rise;
- Loss of sand from the beaches to the nearshore seabed;
- Wave attack on the cliff face at and above the high water mark;
- Cliff weathering and erosion, e.g. by winds, rainfall, freeze-thaw etc; and
- Land-sliding of the cliff faces caused by saturation by groundwater flows.

Prior to the construction of coastal defences in the study area, the rates of cliff recession due to all these causes appears to have been at a rate of approximately 0.5m to 0.75m/year, although there were variations in this rate along the coast and in response to varying weather conditions. Following the construction of coastal defences, these natural processes were altered, leading to a reduction in cliff recession rates in some areas (typically where there was greatest human development of the cliff-top land) but at the expense of increased recession on undefended sections. This effect occurred on the eastern or southern side of any coastal defences. The reasons for this are as follows. First, the coastal defences reduced the erosion of the cliffs behind them, thus reducing the supply of sediment to the beaches locally. Second, and more importantly, the defences, particularly groynes, tended to trap beach sand travelling along the coast from the west and north. Both these effects reduced the amount of sand arriving on the beaches in front of the cliffs immediately to the east and south of the defences, a phenomenon known as “drift starvation”. Because the drift rate on the unprotected coast was now not supplied by (enough) sand arriving from the defended frontage, the beaches, and shortly afterwards the cliffs eroded to make up the deficit in the sediment budget.

In contrast, the beaches to the west and north of defended frontages tended to accumulate. Even this effect, however, can have disadvantages since it may reduce cliff erosion and hence the supply of extra beach material for the coastline as a whole.

Other causes of beach loss have also been mentioned in connection with the potential problems of coastal erosion in the Cromer area. Of these the most frequent concern is the effect of offshore dredging for aggregates. The nearest area of seabed where any such dredging has taken place in recent years is offshore from Caister, about 70km distant to the ESE. This dredging is too far away and in water too deep to affect waves, tidal currents or sediment transport processes in the Cromer area.

The process that is most influential in causing cliff recession (over and above the expected “natural” rate of about 0.5m to 0.75m/ year) is the variation in longshore drift rates along the study frontage. An assessment of longshore drift rates shows that the drift along this coastline is presently eastwards, at a modest rate. Consequently, the installation of coastal defences such as groynes, even if they are only partly effective at altering the “natural” drift rates, will cause changes in the beach plan shape. Any change in such defences along this coastline will similarly provoke changes in the beaches and hence, potentially, of the cliffs behind them.

3.5 Classification and behaviour of the Cromer cliffs

In order to predict the likely future evolution of the cliffs along the seafront at Cromer, it is important to first understand their structure and the various processes that have affected their past evolution.

A range of landslide processes, reflecting the variable geology, has shaped the cliff-line into a series of near-vertical cliffs and Under-cliffs (i.e. cliffs comprising a lower sea-cliff separated from a pronounced rear cliff that marks the landward limit of instability). Coastal defences, including seawalls fronted by a sand/shingle beach, currently protect the cliff-line. In places, the cliffs have been stabilised by a variety of landslide remedial measures, including drainage and retaining structures.

Any future failure of the coastal defences and slope stabilisation works along the Cromer frontage would lead to a renewal of cliff recession and coastal landslide activity, resulting in significant losses of property and environmental/amenity assets.

The implications of cliff behaviour for the future management of the Cromer cliffs are:

- The cliff line would be highly vulnerable to the failure or removal of the coastal defences. This would result in a rapid onset of wave attack at the cliff foot;

- The cliff face behind and adjacent to the breach would transform from what is effectively a stable slope to actively unstable near-vertical cliff within a relatively short period (<5 years). The area affected by instability would rapidly spread along the cliff-line.

- The renewal of cliff top recession behind and adjacent to a breach would probably involve:

    - A dramatic initial surge of cliff top retreat, possibly involving the loss of up to 50m within the first 5 years after defence failure/removal;

    - The establishment of a relatively uniform long-term average annual recession rate with episodic events separated by periods of very slow or no retreat. As the cliffs are low (<50m high), the individual landslides are likely to be small-scale failures, possibly involving around 2-5m cliff top loss in a single event (but up to 30m east of the Doctor’s Steps).

    - Dramatic, overnight losses associated with the impact of low probability storm surge events. It is possible that over 30m of retreat could occur in a single event.

The widely anticipated increase in sea level, together with other climate changes, will probably lead to changes in the frequency and, possibly, the magnitude of landslide events. This will result in increased recession rates. If the sea level rises over the next 60 years at an average rate of 5mm/year (in accordance with DEFRA recommended allowances), this would suggest a potential 2.5x increase in average annual recession rate.

As noted earlier the cliff recession process is episodic rather than continuous, and is caused by occasional relatively large landslides. For this reason it is better to express the long-term recession rate as up to 18.75m every 10 years rather than 1.875m/year.

4. THE ‘DO NOTHING’ SCENARIO

By predicting the processes that would occur if no action were taken to maintain or further protect the coastline, and combining this prediction with an estimate of the value and timing of assets (houses, property, business etc.) that may be lost during this process, a monetary value may be calculated for the ‘Do Nothing’ scenario. The cost of possible defence measures may then be compared against this value to demonstrate that the cost of the proposed works is justified by the value of assets protected.

As part of this assessment, it was therefore necessary to predict the residual life of the existing defences, the likely rate and location of coastal erosion, and the value of assets that may be lost. The residual life of the defences was determined through inspection. The rate of erosion was predicted using numerical models and expert judgement drawing on the information developed about the coastal processes, largely based on recent experience. The valuation of assets was undertaken using a combination of past property valuation data, specific valuations, current property sale prices and financial market indices. The value of assets included recognition of both tangible and intangible assets – for example, the value of the RNLI service at Cromer.

There is uncertainty surrounding many stages of the estimation process for predicting the ‘Do Nothing’ outcome, including:

- Prediction of the residual life of existing defences
- Prediction of failure mechanisms of the defences
- Prediction of cliff response following failure of defences
- Prediction of future longer term patterns of erosion / cliff retreat

Following these investigations it became clear that under the do nothing scenario, the likely sequence of events would be:

Failure of groynes / loss of beach / failure of seawall

↓

Breach development through seawall

↓

Instability of cliffs leading to slips and cliff retreat

↓

Loss of assets along frontage and cliff tops

Given the uncertainty, it was considered appropriate to consider two potential consequences of the ‘Do Nothing’ option, resulting in two different erosion scenarios.

Do Nothing Scenario 1 - Lower Loss Scenario

Under this scenario it is assumed that breaches occur in the following locations:

I Breach of the seawall just east of the Pier.
Wall residual life is very low (0-3 years) and the beach condition is poor (i.e. levels are low). This is the most likely failure location within the study area.
.

II Breach just to the east of Groyne 4.
Wall residual life is very short (3-5 years) and the beach condition is poor (i.e. levels are low) east of the groyne.

III Breach just to the east of Groyne 2a.
Wall residual life is very short (3-5 years) and the beach condition is poor east of the groyne.

IV Breach to the east of Groyne 5
East of Groyne 5 the wall residual life is very short (3-5 years) but the beach condition is fair until the groyne fails and beach condition drops to poor.

V Breach to the east of Groyne 2.
East of Groyne 2 the wall residual life is marginally longer (5-10 years); the beach condition will worsen as the beach adapts to progressive failure of the groyne system.

VI Failure at the western end of the seawall
The residual life of the wall is short (5-10 years) but there is a good beach in front initially (and then fair), it can be assumed that the wall will survive some years before breaching.

VII Failure at midpoint of Wall Section 14
The residual life of the wall is short (5-10 years) but there is a good beach in front held by Groyne 1; it has been assumed that the wall would survive some years before failing.

VIII Failure at midpoint of Wall Section 16
The residual life of the wall is short (5- 10 years), but with a good beach in front held by Groyne 2; it could be assumed that the wall would survive for some years before failing.

Do Nothing Scenario 2 (higher loss)

This scenario assumes that breaches occur in the same locations as identified in Scenario 1 but with two additional breaches as outlined below:

I Failure at the eastern end of Wall Section 2
The residual life of the wall here is low (3-5 years), although the beach is good in the short term (0-7 years).

II Failure at midpoint of Wall Section 11
The residual life of the wall here is low (0-5 years) and the beach condition is fair in the short term dropping to poor after around 7 years.

The impacts of each outcome were then weighted and combined to obtain a single representative figure for the losses incurred. The best estimate of the net present value for the overall ‘Do Nothing’ scenario is likely to be £29.2M.

Plates 4.1-4.3 Landslip just west of pier (February 2002)

5. OPTION IDENTIFICATION, EVALUATION AND SELECTION

Flood and coastal defences designed to reduce flood or erosion risk must be technically sound, economically viable and environmentally acceptable.

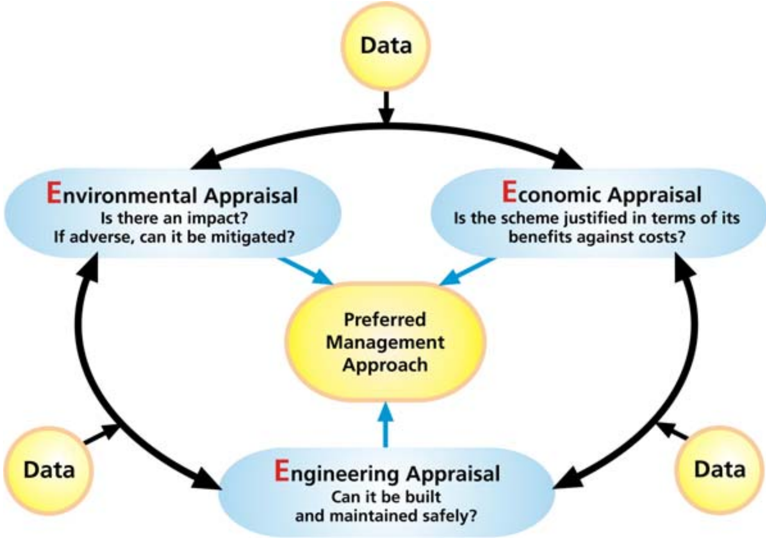

Figure 5 Option identification philosophy

These three objectives may be considered for each idea or solution proposed for inclusion within the management strategy and ultimately, each option prioritised against these conditions, leading to a preferred option or options. The procedure followed in developing defence solutions for this strategy study is shown in Figure 6 below.

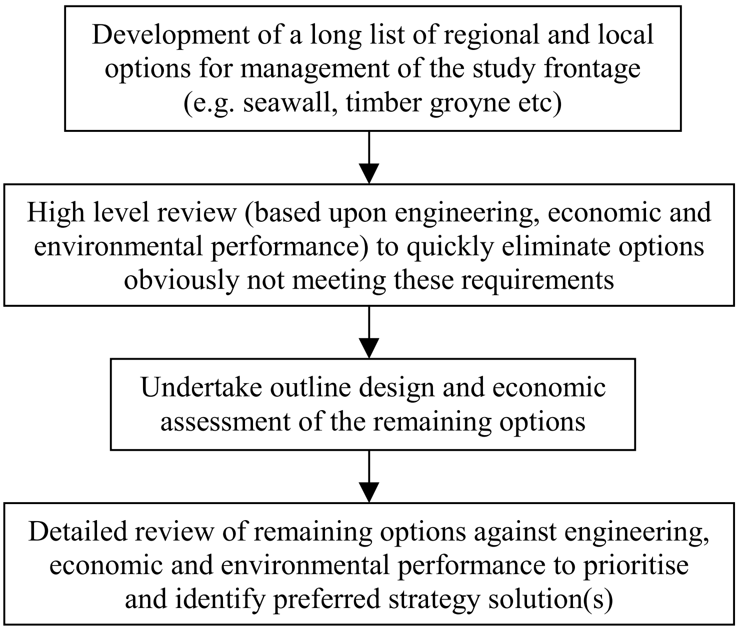

Figure 6 Defence option prioritisation process

From an initial list of 18 defence options, a total of 11 were identified for more detailed assessment. The remaining 7 were rejected during the broad level review. Of the 11 that were selected for more detailed assessment, the cost of the individual works ranged from £0.19M to £11.93M. However, many of the defence options considered offered only a specific type or location of defence that on its own would not offer a suitable defence strategy, but when combined with one or more of the other defence options could provide an acceptable solution. Combinations of defence options were then considered in developing the final management strategy.

6. THE MANAGEMENT STRATEGY

The issues of prime importance when deciding on an appropriate coastal defence strategy for Cromer are as follows:

- The principal objective of the defences is to prevent marine erosion of the soft cliffs along the Cromer frontage. These are already at risk from landslides, as evidenced by the slip just west of the Pier in February 2002 (see Plates 4.1 to 4.3) and life and property will be at peril if further recession occurs virtually anywhere along this Management Unit.

- The existing seawalls and promenades have become important in stabilising the cliffs, both by preventing wave attack and “under-cutting” at their base, and adding toe-weight that reduces the probability of deep-seated rotational slips. If these walls were to fail, this would precipitate sudden, serious landslides and recession of the cliff edge.

- The low beach levels already threaten the standard of protection provided by the seawalls, and their continued stability. Undermining at the toe of the walls has already occurred, and the lack of a wide beach has resulted in the abrasion of the seawall faces by the shingle within the beach sediments. Improving both the levels and width of the beaches, to protect the seawalls, is therefore an important component of a long-term coastal defence strategy.

- The need for higher, wider beaches will also preserve and improve the amenity value of the seafront. This is important to the socio-economic and environmental attributes of this popular seaside resort.

- The need to improve beach levels, without delay, means that beach recharge will be a vital element in any coastal defence strategy. Although longshore drift rates are modest, it is sensible to improve and maintain the existing groyne system and hence maximise the benefits of the recharge scheme.

6.1 Additional modelling

The proposed management strategy is supported by the analysis and findings of the strategy study and this earlier analysis provides a clear direction for the likely means of managing the study area. However, some additional modelling of the beach plan shape was also required to broadly confirm the final management approach.

Considering the options presented in Section 9 of the Strategy Study, and the issues above, the following may be concluded:

1. The strategy requires development and maintenance of a higher, more stable beach – particularly in the pier area – to provide protection for the seawall, increased stability for the cliffs and maintaining/improving the tourist amenity.

2. Creation of such a beach may be undertaken using the existing groyne system. However these groynes will need refurbishment (at minimum) and long term maintenance and adjustment to ensure optimum operation. Additional groynes or extension of the current groynes may also be required. Beach nourishment will also be necessary to provide immediate protection to the seawall.

3. The existing seawall is deteriorating and requires refurbishment or replacement to prevent undermining of the cliffs.

It is therefore likely that the management strategy will comprise a combination of / variation around three options (centred around beach nourishment, seawall and groyne repairs) with additional construction /

extension of timber groynes. This combination of work offers an acceptable engineering solution, with minimal environmental impact for the minimum cost (i.e. highest benefit cost ratio).

Having identified the likely approach for the final management strategy, additional modelling work was undertaken to confirm the likely beach behaviour for a range of development / management scenarios.

6.2 Preferred management programme

A staged series of works are proposed within an overall management strategy. The following points summarise the management programme and should be reviewed in conjunction with Figures 7 and 8.

Stage I:
Step 1 Seawall Repair
Of primary importance is the long term stability and maintenance of the seawall at Cromer. Refurbishment of the existing wall is proposed, with priority given to Sections 1-6 & 8, covering the pier area and frontage to the west. The poor condition of the existing wall and potential damage that could occur through failure means that this action takes highest priority within the strategy and should be undertaken at the earliest opportunity.

Step 2 Investigation / Design of Groyne System
Maintaining a high and stable beach is vital for the long-term stability of the frontage. This protects the seawall from wave attack and increases seawall and cliff stability (as well as providing an attractive facility for tourists). The key to establishing and maintaining such a beach is the effective use of groynes. To establish the optimum design of groynes requires a detailed investigation of beach process interactions, most likely through the use of physical modelling. This investigation and design work should be initiated as soon as possible (whilst Step 1 seawall refurbishment is underway) in order that repair and refurbishment of the existing groyne system (see below) may be undertaken simultaneously with the extension and construction of new groyne(s).

Stage II:
Step 3 Seawall Repair
Continued refurbishment of the existing sea wall is proposed, with priority now given to Sections 7, 9 & 10.

Step 4 Repair / Refurbishment of Groyne System
Following a more detailed assessment of groyne performance / design (as outlined above) the existing groynes should be refurbished and extended where appropriate. An additional Groyne 2c has been identified for construction to aid stabilisation of beach level around the pier head. Final design and location of this groyne is to be confirmed through the physical model investigations. Required work on the groyne system is estimated to comprise:

Groyne 1:	Refurbishment of existing 160m groyne
Groyne 2:	Refurbishment of existing 145m groyne – extension by 30m to 175m
Groyne 2a:	Refurbishment of existing 60m groyne – extension by 60m to 120m
Groyne 2b:	Refurbishment of existing 45m groyne
Groyne 2c:	Construction of new 120m groyne
Groyne 3:	Refurbishment of existing 130m groyne – extension by 20m to 150m
Groyne 4:	Refurbishment of existing 130m groyne – extension by 20m to 150m
Groyne 5:	Refurbishment of existing 95m groyne
Groyne 6:	Refurbishment of existing 140m groyne

Following initial refurbishment, extension and construction, groynes are to be maintained and adjusted on an annual basis to establish stable and acceptable beach conditions.

Step 5 Beach Recharge
Following Steps 1-3 above, beach recharge to be undertaken for the area between Groynes 2 & 4 (See development Option 15).

Stage III:
Step 6 Seawall Repair
Steps 1-5 comprise work required immediately to stabilise beach conditions and protect assets immediately at risk. Stage III seawall repairs are subsequently proposed for the remaining frontage covering wall Sections 11-15, to the east of the pier.

Monitoring

Fundamental to the protection of the Cromer frontage is the creation of a stable beach frontage. This in turn depends upon the effective positioning and functioning of the groyne system. Development of the optimum groyne system will take a number of years and requires a programme of monitoring to be established through which beach levels in relation to groyne performance may be assessed.

It is suggested that the monitoring programme includes:

- Identification of fixed beach cross sections 10m either side of each groyne, to be surveyed initially (first 3 years) every 3 months (Jan, Apr, Jul, Oct) and subsequently a minimum of twice per year (winter, summer)
- Monthly walkover survey with photos taken from the pier and at each groyne (either side)

It should be noted that this proposed strategy is considered to be a minimum of works required to protect assets at Cromer. The steps outlined above are all fundamental to the concept of protecting the seawall frontage. Failure of this frontage (or part of the frontage) is not considered an acceptable option.

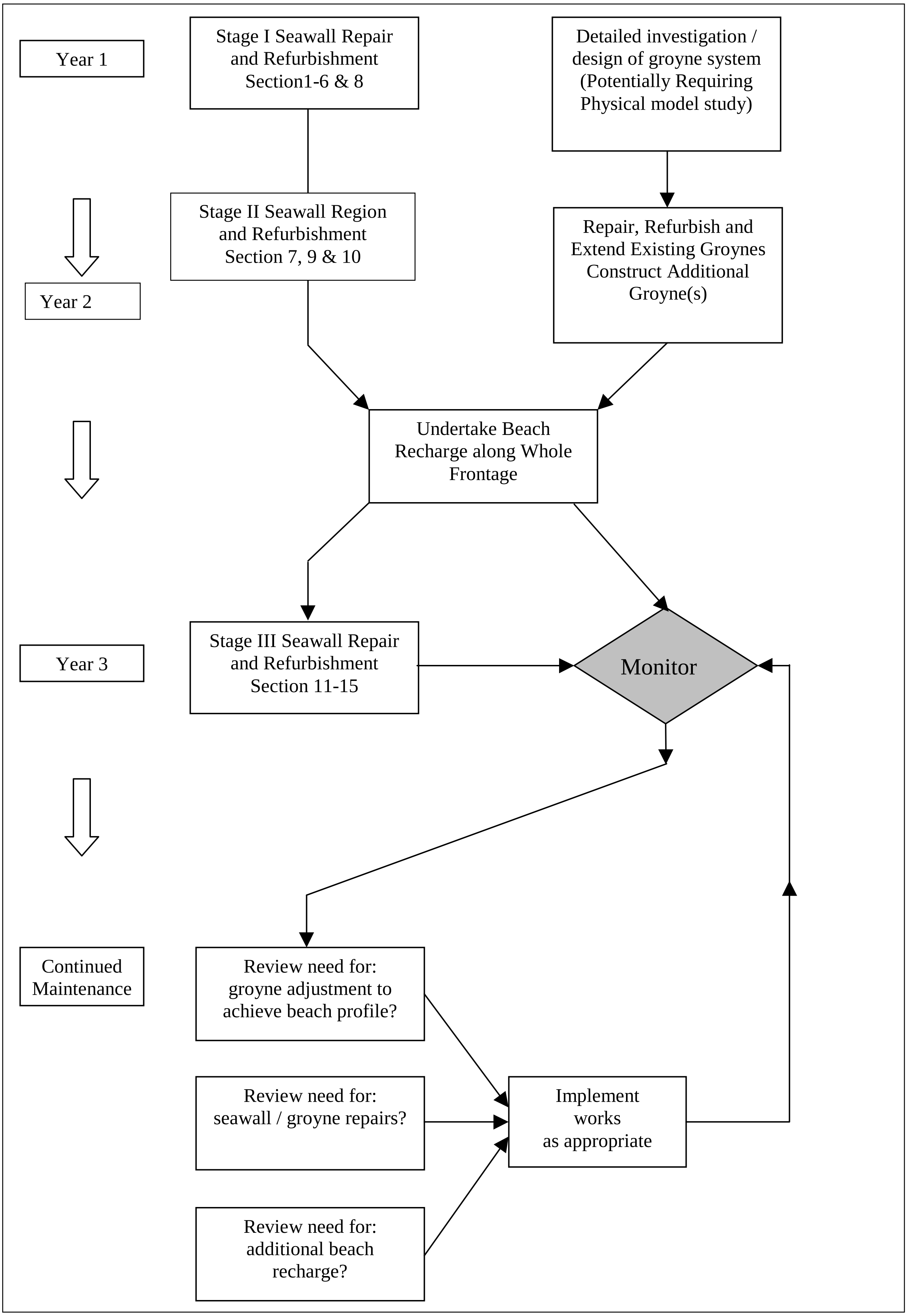

Figure 7 Coastal management strategy

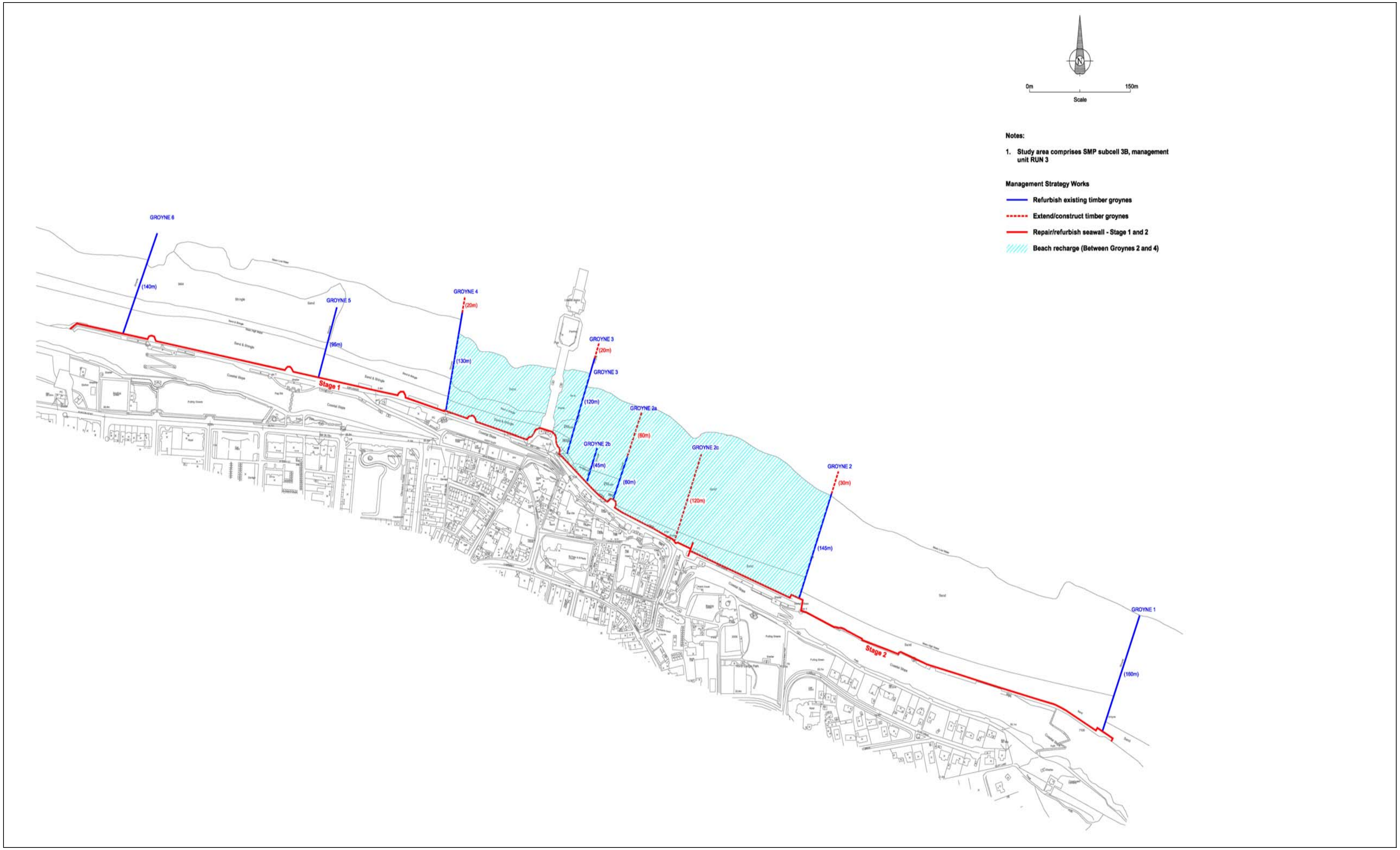

Figure 8 General arrangement of defence works

6.3 Economic viability

The economic viability of the proposed management strategy has been demonstrated through analysis of the benefit cost ratios associated with each stage of the works. The strategy is based on the concept of progressively increasing the extent of defences (to a maximum) to allow an assessment of performance and identification of the need for additional measures. The BC ratio for the works therefore depends upon the extent of protection eventually required, and the timing of such works. In calculating these figures consideration was also given to the value of assets that remain at threat under the proposed management solution.

Taking all of the costs into consideration, the value of assets at risk has been established for each scenario and can be summarised as:

Scenario	**-**	**Best Estimate**	**+**
1	£15.0M	**£20.5M**	£25.6M
2	£17.2M	**£22.3M**	£27.9M

It can be seen from these results that both scenarios vary by approximately £5M either side of the best estimate value. The best estimate NVP for the overall "Do Nothing" scenario was found to be:

TOTAL NPV (with sensitivity ranges) = £16.1M - **£21.4M** - £26.7M

Analysis of the potential benefit cost ratios for the best estimate and sensitivity analysis values provides the following figures:

Best estimate Benefit Cost Ratio:	**4.8**
Sensitivity range Benefit Cost Ratio:	**3.6 ↔ 5.9**

6.4 DEFRA priority scoring for grant aid

The proposed management strategy has been reviewed according to the priority scoring methodology published in 1997. Under this system a score of 8 has been allocated to land use and hazard, 8 to urgency and between 8 and 10 for economic justification.

This results in a combined total DEFRA score of between 24 and 26 points, which exceeds the current threshold for an acceptable coastal defence scheme.

6.5 Strategy revisions and activities to support future coastal management

Typically, a coastal defence management strategy should be reviewed every 5 years. The overriding issue of concern along this study frontage is the creation of stable sea defences via a seawall, protected by stable and higher beaches, in turn created through the efficient and effective use of timber groynes.

Key issues for any strategy review and update will therefore include:

- Successful refurbishment of seawall defences
- The performance of existing timber groynes for creating and maintaining a stable beach along the whole frontage
- The need to update the strategy

The predictions of coastline changes in this strategy study, under the various management scenarios considered, are inevitably prone to error. Factors such as the future wave conditions and the strength of the cliffs are indeterminate, and could lead to different rates of longshore sediment transport and cliff top recession to those estimated. It would therefore be prudent to include as part of the coastal management scheme a modest programme of monitoring.

For further information on this study please contact Mr Peter Frew at North Norfolk District Council or Dr Alan Brampton or Mark Morris at HR Wallingford.