NATIONAL RIVERS AUTHORITY
Anglian Region

MABLETHORPE TO SKEGNESS SEA DEFENCES STRATEGY STUDY

November 1991

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NATIONAL RIVERS AUTHORITY
ANGLIAN REGION

SEA DEFENCES, MABLETHORPE TO SKEGNESS
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CONTENTS

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date 2 December, 1991

Miss Debbie Prigmore
National Rivers Authority
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Peterborough. PE2 0ZR

Dear Miss Prigmore,

MABLETHORPE TO SKEGNESS SEA DEFENCES
PART 30 - STRATEGIC APPROACH STUDY

Please find enclosed a copy of the final report for the above study.

Yours sincerely,

R.S. THOMAS
Director, Coastal and Rivers Division

Encl:

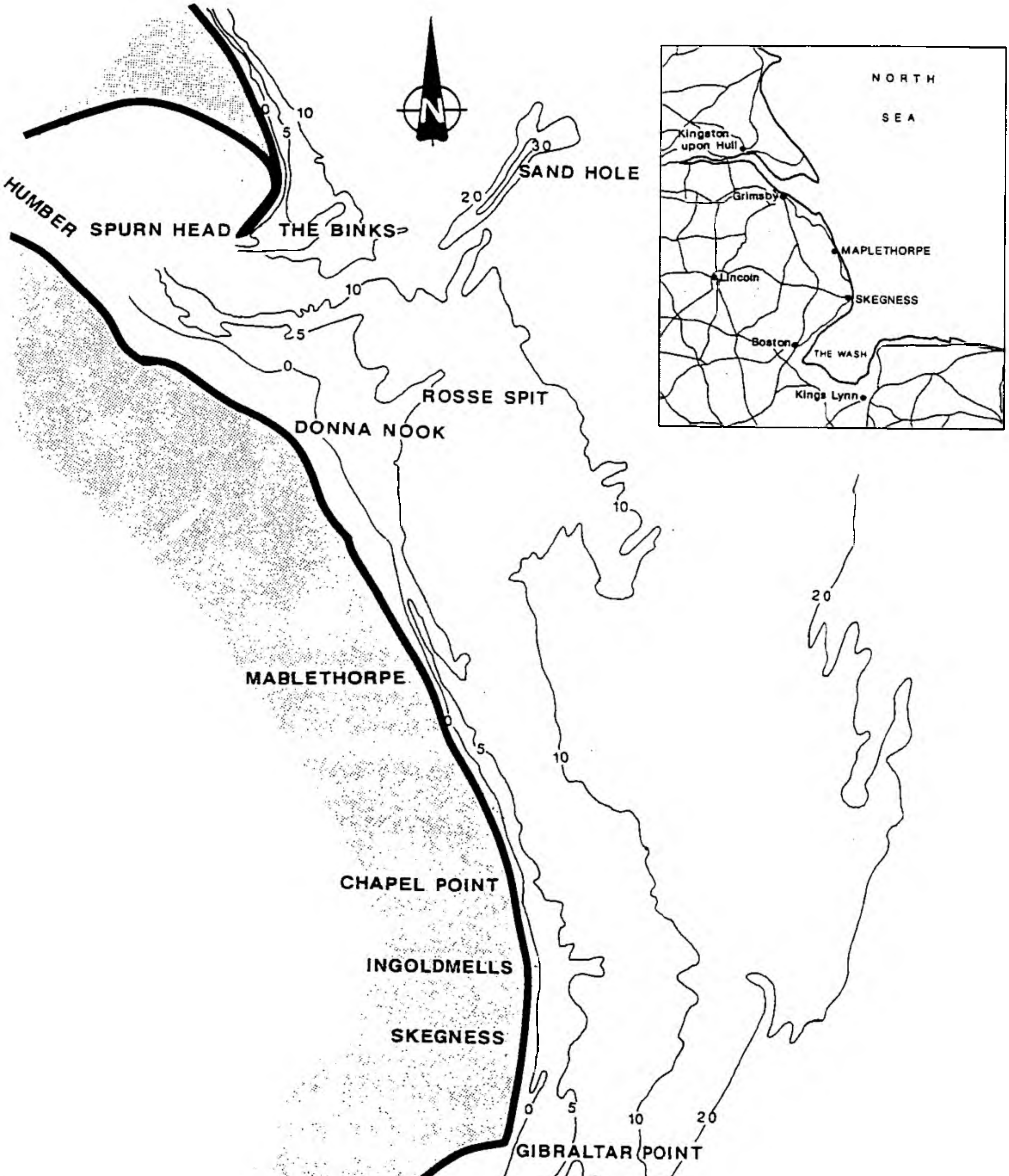
FIGURES

PHOTOGRAPHS

TABLES

SUPPORTING DOCUMENTATION
(Bound Separately)

Appendices



THE STUDY COASTLINE

SUMMARY

Introduction

National Rivers Authority Anglian Region (NRA), are responsible for the 24km of sea defences extending from Mablethorpe to Skegness. They defend an area of some 20,000 hectares of low lying land including in excess of 15,500 residential properties and 18,000 residential caravans as well as extensive agricultural, commercial, industrial and service related activities. In 1953 the defences were breached in several places and, in addition to causing widespread flooding, a total of 41 people died. Many of the defences were built in the aftermath of those floods and have required continuing improvement and rehabilitation ever since. As part of their ongoing committment, the NRA commissioned Posford Duvivier in June 1990 to undertake a Strategy Study to examine the most appropriate coastal strategy for the future.

This report presents the finding of the Study. All background information, data and evaluations are presented in Appendices as detailed in the report contents.

A full and independent environmental assessment, meeting the requirements of Statutory Instrument 1217, is being undertaken in parallel with this engineering assessment, and a consultation document, supported by presentations and meetings, has been circulated to 42 interested parties.

The Coastal System

A coastal system is a complex interaction between the land and the sea. To study such a system requires an understanding of all the factors which act on the coast, both natural and man made. These include the coastline, with the existing defences and beaches, and the marine conditions of winds, waves, tides, surges and currents.

The study covered a length of coast extending from Donna Nook to Gibraltar Point. Within this length it was found that the central (Mablethorpe to Skegness) length was characterised by narrow relatively steep beaches of highly mobile fine sand overlying clay. Marine conditions impinging on this length create considerable potential for movement of the sand offshore, onshore and longshore resulting in the exposure of the clay and subsequent irreversible erosion.

The above factors combine to give increased wave action within the foreshore area and at the sea defences, which results in an increase in the following:

- structural deterioration
- wave overtopping
- breach and flooding risk
- foreshore erosion

Currently the existing defences are at risk of failure due to excessive overtopping from storms with return periods of 1:3 years to in excess of 1:200 years. However, the persistent erosion of the foreshore would progressively reduce these values. In addition it was found that many of the existing sea defence structures are nearing the end of their lives.

Options

In the development of a viable strategy the following alternatives were considered either singly or in various combinations.

- Retreat
- Set back
- Linear Rock Protection (Seawalls)
- Beach Nourishment
- Rock Groynes
- Offshore Breakwaters/Reefs
- Artificial Headlands

A total of six options were selected for detailed consideration as follows:

Seawall Approach:
1. Sustain present standards of service
2. Improve to a 1:100 year standard
3. Improve to a 1:200 year standard

Nourishment Approach*:

4. Nourishment alone
5. Nourishment with rock groynes
6. Nourishment with breakwaters

* The nourishment approach was found to have similar costs for both the 1:100 year and 1:200 year standard of service.

Each of these options was reviewed in terms of its environmental and technical implications and a comparative economic evaluation was prepared.

The benefit/cost ratio and Net Present Value (NPV) (£ million) at April 1993 of the options are as follows:

	Option 1 Sustain	Option 2 1:100yr	Option 3 1:200yr	Option 4 Nourish-ment	Option 5 Groynes	Option 6 Breakwaters
Benefit/ Cost	8.9	9.2	8.5	11.3	9.4	7.7
NPV	612.5	784.0	784.2	826.5	766.5	723.0

Option 4 is preferred for environmental, technical and economic reasons.

Sensitivity tests were performed on a range of criteria, and show no change in the ranking of Option 4 as the most economic. The discounted cost of Option 4 could rise by some 22% (£18 million) before the benefit/cost ratio falls below that of the leading seawall option.

Prior to 1993 some sea defences will have to be reconstructed and these have not been included in this strategy. After 1993 all works required between Mablethorpe and Skegness have been included.

Conclusions

Option 4 involves the construction of a nourished beach profile with a berm width of 15m at +4.5 mOD and a 1:25 beach slope. This would, with adjustments dependant on location, provide a satisfactory technical strategy. In conjunction with this there is a requirement to retain and rehabilitate some seawall structures. The adoption of such a strategy, however, requires the firm commitment to system recharge and renourishment in future years to maintain the necessary level of defence. For this to be effective a similar commitment is required to detailed monitoring (to assess performance), future design modifications and maintenance.

Recommendations

In order to start beach nourishment in 1994 it is necessary to undertake certain actions as a matter of priority.

- submit this report to MAFF for agreement
- obtain extraction licence
    - apply for a prospecting licence for the proposed borrow area
    - implement a prospecting programme
    - apply for an extraction licence for the selected borrow area
    - negotiate extraction royalties with the Crown Estate Commissioners
- prepare a detailed specification for the monitoring of the beach
- implementation and interpretation of baseline monitoring from 1993
- carry out detailed design and prepare specification and contract documentation
- continue consultation with interested and affected parties
- include the following capital expenditure in the Medium Term Plan: (1993 prices)

	£
1993/94	6,506,044
1994/95	12,792,647
1995/96	11,797,312
1996/97	13,528,686

Experience has shown that the total elapsed time required to obtain an extraction licence is of the order of 2 years.

The implementation of this strategy would involve the following non-construction costs over the next 50 years.

Actual Cost	£7,463,080
Discounted Cost	£3,308,214

The expenditure profile, for the incurred costs and the non-construction costs are included for the preferred Option as Appendix C.

SECTION 1

THE NEED FOR A STRATEGY

More than 35,000 people live behind the 24 km of sea defences between Mablethorpe and Skegness in an area of Lincolnshire approaching 20,000 hectares, most of which is below high tide level.

Prior to 1953 the sea defences of this area consisted of revetments of various types, concrete slab or stepwork structures complete with wavewalls etc, many of which were severely damaged and breached during the storm surge of that year in which 41 people lost their lives.

Reconstruction of the defences began immediately after the 1953 flood and has continued ever since. Many of the earlier structures have required rehabilitation and reconstruction and the opportunity was taken to upgrade the standard of the defence where this could be justified.

The basic problem remains and in simple terms means that if any of the defences were to fail the consequences would be:

- loss of life
- structural damage to towns
- economic disruption
- infrastructure and environmental damage

Storm surges in 1976, 1978 and 1983 together with other important aspects such as deterioration of the beach and foreshore, reinforced the need to carry out a comprehensive and detailed review of the way ahead, and in 1990 the NRA Anglian Region commissioned Posford Duvivier to undertake a Strategy Study (i), the particular objectives of which were to:

- Comprehensively investigate strategic works
- Include such mathematical modelling as necessary
- Formulate and evaluate options for the works eg. offshore breakwaters, artificial headlands, beach nourishment etc. or combinations thereof.
- Include an independent Environmental Statement (bound and issued separately)
- Examine the financial worthwhileness
- If necessary include ground investigations, other preliminary investigations, physical model testing and/or site trial works
- Select a preferred scheme

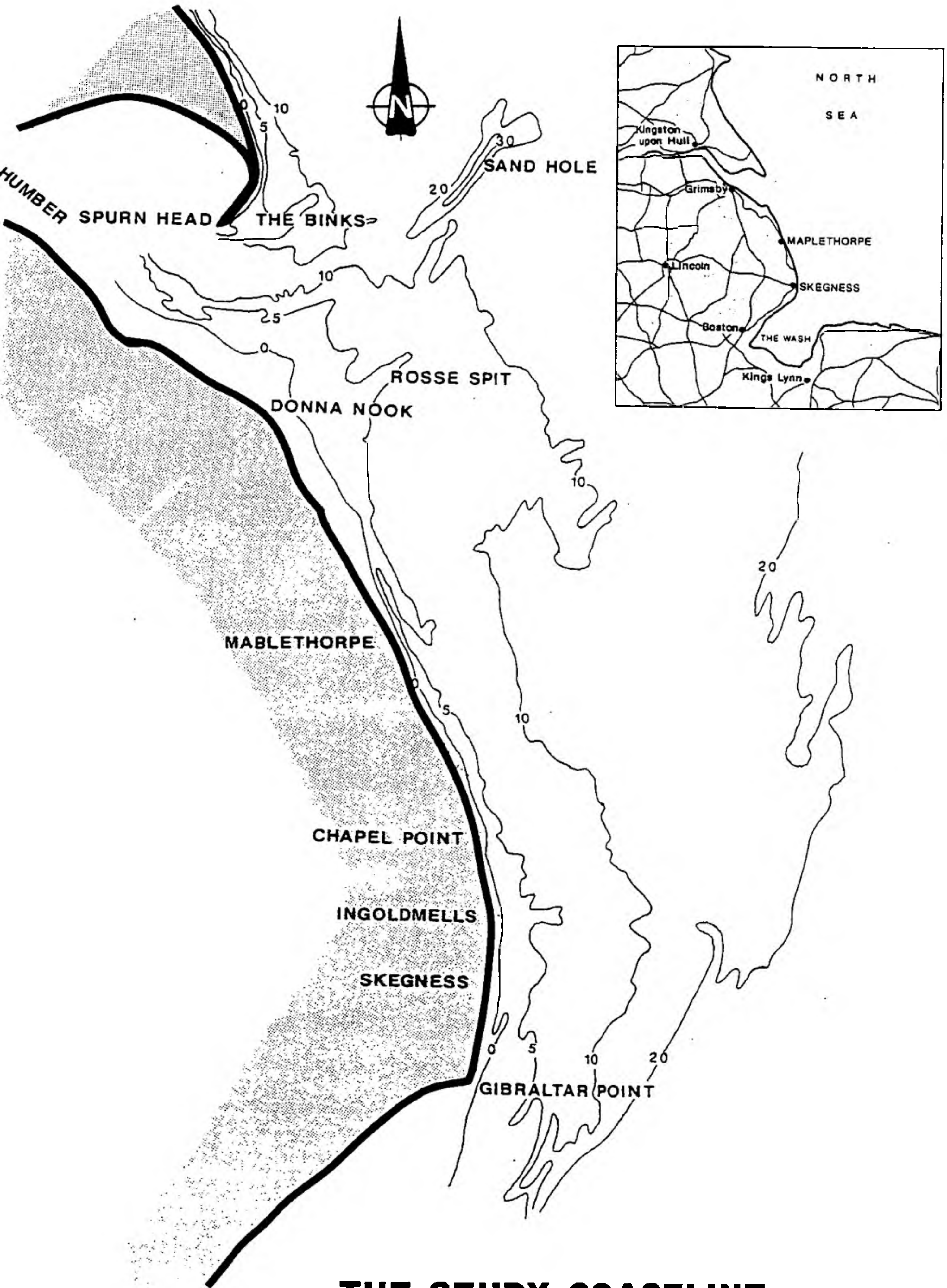
The report which follows describes studies of the existing coastal system, and the use of that knowledge to develope strategy options. Options were then compared both technically, environmentally and economically to arrive at a preferred strategy.

This report is based on a number of separately bound detailed studies listed in the contents as appendices.

References

(i) Appendix A National Rivers Authority, Study Brief, 1990

Figure 2.1



THE STUDY COASTLINE

SECTION 2

DESCRIPTION OF COASTAL SYSTEM

A coastal system is a complex interaction between the land and the sea. To study such a system requires an understanding of all the factors which act on the coast, both natural and man made. These include the coastline, with the existing defences and beaches, and the marine conditions of winds, waves, tides, surges and currents. This is recognised by NRA Anglian Region and much information already exists within the Anglian Sea Defences Management Study (1) (SDMS)

Whilst information was available in the SDMS, much more detailed information was required for this study. This study concentrates on the 24 km of coast between Mablethorpe and Skegness, and also considers, to complete the coastal system, an area from north of Mablethorpe, extending as far south as Gibraltar Point. Information obtained under this study will be fed back into the SDMS.

2.1 The Coastline

The study coastline is shown on Figure 2.1 and generally aligns from north to south between Skegness and Ingoldmells before turning to some 25 deg west of north between Ingoldmells and Mablethorpe. The coastline is exposed to severe wave action originating from the North Sea, albeit reduced to some extent by offshore bank systems. The wave climate is modified further by nearshore banks located to the north of Mablethorpe and to the south of Skegness.

Concrete seawalls exist over some 19 kms of the coastline, in some instances backed by dunes. Over the remainder, the primary defence is provided by a reveted relic dune system. Typical examples of each are shown in Photographs 2.1 and 2.2. There are around 280 timber groynes of varying length and condition along the central 24km of coastline.

The foreshore in front of the defences comprises a thin mobile veneer of sand overlying a clay substratum. At times, due to wave action, the sand cover is removed and the clay layer beneath is exposed and is eroded as shown in Photograph 2.3. Currently only about a quarter of the toe of the defence remains dry at high water (spring tides).

The drainage of 20,000 hectares of low lying land depends upon a drainage system which incorporates a total of six land drainage outfalls which pass through the study coastline. A typical example of an outfall is shown on Photograph 2.4.

Of particular environmental importance are:-

- Gibraltar Point, which lies at the southern limit of the coastline and is a Site of Special Scientific Interest (SSSI) and one of Europe's most important nature reserves in terms of bird populations, provides a range of habitats which are unique in Great Britain. Internationally important populations of breeding and overwintering birds are dependent on mudflats and saltings in the area.

- Tourism which plays a major part in the economy of the region with large numbers of seasonal visitors and around 18,000 static residential caravans.

Photograph 2.1

SEAWALL DEFENCES

Photograph 2.2

DUNE DEFENCES

Photograph 2.3

FORESHORE CLAY EROSION

Photograph 2.4

TYPICAL OUTFALL

2.1.1 The Existing Defences

Because of the continual renewal and reconstruction of the sea defences for more than 30 years, there is now a large variety of different types of construction and profiles along this coast.

Frontage numbers were allocated to individual lengths of defence to identify these different profiles and/or types of construction. These numbers are detailed in Appendix B.

A detailed inspection of the defences was carried out in mid 1990. This established the constructional details of each frontage and its structural condition. Additional information was also collected from existing drawings and documents and all information was stored within Posford Duvivier's Geographical Information System.

2.1.2 The Beaches

Within the length of the coastline considered in this coastal system, there are distinct variations in the type of beach. The coast can be divided up into three sections:

- north of Mablethorpe
- Mablethorpe to Skegness
- Skegness to Gibraltar Point

These sections are considered briefly below.

North of Mablethorpe the beaches are wide and shallow and consist of a thick layer of fine sand backed by dunes. These beaches show long term accretion tendencies.

The central section, Mablethorpe to Skegness has narrow, relatively steep beaches with little sand cover to the clay. The beach material varies in thickness and particle size, from a thin layer of coarse gravel after a storm to in excess of 1m of fine sand in the summer.

The southern section from Skegness to Gibraltar Point is again a wide shallow beach system, with abundant fine sand, and showing long term accretion tendencies. The northern limit of this area appears to be moving southwards.

Existing borehole data was also collated and entered onto the data base. The boreholes indicate sands and gravels overlying clay layers of variable strength and thickness including some boulder clay, except where, in the vicinity of Sandilands, a buried river channel infilled with sand deposits crosses the coastline.

2.2 The Coastal Processes

2.2.1 Marine Climate

The main driving forces in the marine climate are winds, waves, tides, surges and currents. The objective of this element of the study was to determine the marine conditions which both drive the coastal processes and act directly on the sea defences.

Water Level and Wave Conditions

Damage to sea defences is rarely due to high water alone nor is it necessarily due to waves alone but occurs as a result of combinations of the two.

High water levels are not just a function of the natural tidal cycles but are affected by surges. Surges are weather dependent, and a function of winds and variations in atmospheric pressure, and are usually associated with storms.

To determine the marine climate Hydraulics Research Limited were commissioned by Posford Duvivier to undertake a study into the interdependence of wave height and water level. In this study, data on wind, waves and water levels for Dowsing Light Vessel over the period 1978 to 1987 were used to produce frequencies of occurrence (return periods) for specific combinations of water levels and wave heights.

To investigate the driving forces in the coastal system, conditions need to be known much closer to the shore than at Dowsing Light Vessel. Reducing water depths cause changes in wave height and direction. The conditions near the shore were modelled in two ways in order to provide inputs into future calculations. These were:

- Combinations of Extreme Wave Height and Extreme Water levels. These are required for different return period storms as driving forces in the overtopping calculations.

- Annual Wave Conditions. These are ranges of wave heights, directions and durations which best represent the annual wave conditions. They can be either average or severe and were used as input data into sediment transport calculations.

Sea Level Rise

The Anglian Region of the National Rivers Authority has adopted a relative rate of rise of 5mm/year to take account of both sea level rise and tectonic changes. An alternative value of 8mm/year has also been considered for sensitivity testing.

2.2.2 Beach Behaviour

The behaviour of the beach and especially the movement of the sand on the beach is a complex and important part of the coastal system.

Sand is transported along the coast (longshore) and on/offshore by waves and currents, both during storms and normal conditions. The transport of sand longshore increases in quantity with distance offshore to a maximum around low water and then tails off to zero in deep water.

To study this behaviour Hydraulics Research and Delft Hydraulics were commissioned, under the direction of Posford Duvivier, to carry out extensive studies which included:

- studies of observed sand movements.
- reviews of studies carried out by other research bodies
- statistical analysis of past beach profiles.
- modelling of longshore and on/offshore transport including clay erosion.

The three sections of the coast, north of Mablethorpe, Mablethorpe to Skegness and Skegness to Gibraltar Point show differing sand processes.

Evidence from more than 30 years shows the northern and southern sections of the coastline were accreting whilst the central section was eroding.

The fundamental reasons behind the difference in these trends is the availability of sediment supply to the shore which is considered to be related to nearshore sand banks which act as sources of supply for foreshore accretion in the northern and southern areas.

The presence and depth of sands within the north and south areas, was confirmed by a geophysical survey undertaken as part of this study (Figure 2.2). The survey also confirmed the absence of sand deposits overlying the clay within the central area. Where the clay becomes exposed because of sand movement some permanent loss of the clay occurs. The beach and seabed sampling survey indicated superficial deposits of gravel within the central area and it is therefore concluded that the clay layer could well be "armoured" to some extent by these deposits. This armouring might well also explain why in the modelling higher rates of offshore clay erosion were predicted than observed. The origin of the gravel is probably from the reworked boulder clay.

North of Mablethorpe

The coastline in this area is characterised by a relatively wide, fine sand beach backed by a dune system. The origin of the sand on the beach system is the offshore bank system centred off Donna Nook and effectively held in position by the main tidal and residual current patterns associated with the Humber Estuary. No evidence was found to show that the offshore bank area receives sand from the Holderness coast, north of the Humber. (see also the SDMS)

Sand is feeding from this bank system to the coastline, but very little feeds to the south due to nearshore tidal currents and wave refraction effects. Modelling shows that this small amount is only some 130,000 m^3/annum of fine sand, moving south under average annual conditions.

Mablethorpe to Skegness

The coastline over this length has a narrow, steep beach with little sand, backed by seawalls or revetments.

The beach consists of a veneer of sand overlying clay of variable consistency, strength and depth. The sand layer is thin. In some places it is only temporarily present in the summer season after favorable wave conditions have accumulated sand on the beach.

In places beach levels can vary by up to 2.5 m. The nature of the beach material is variable and following severe beach loss, the remaining sediment is coarse gravel or shingle. During periods of recovery fine sand ridges are evident which slowly migrate up the beach. Beach sampling was performed during a period of high beaches which indicated a fine sand (mean particle diameter [D_{50}] typically around 0.2mm). The variability of the beach level is attributable to the on/offshore transport of the fine sand fraction; with the coarser fraction, requiring higher energy for transport, remaining on the beach.

Figure 2.2

SAND THICKNESS
(From Geophysical Survey)

Because of the complex nature of the foreshore it has not been possible to model the annual or seasonal transport rates south of Mablethorpe within the current state of mathematical modelling. An estimate was made based on the assumption that the source of sand lies to the north of Mablethorpe and so around 130,000 m^3/yr is assumed to enter this coastal length from the north. To the south of Mablethorpe the potential transport rate increases 2 to 3 fold but clearly because of the lack of available beach material this increased potential cannot be realised. At best, therefore, the average longshore transport towards Skegness will be 130,000 m^3/yr without allowing for any reduction in supply due to minor accretion in the Anderby area.

Short timber groynes exist along the length of this coastline. These groynes, in general, show no consistent signs of beach growth due to longshore transport. However, these groynes do help to hold the head of the beach against the structure.

Skegness to Gibraltar Point

The coastline and offshore sandbanks in this area were extensively studied by researchers from Nottingham University. The following discussion is largely based upon their findings.

The offshore sand banks and in particular the shore-connected "Skegness Middle" are considered to be responsible for sustaining foreshore accretion in the area south of Skegness and Gibraltar Point. Inspection of Admiralty Charts from 1871 suggests that the Skegness Middle has migrated progressively southwards by around 5km. Other evidence, particularly profile surveys, suggests that this movement was accompanied by the migration of the point of maximum accretion on the foreshore. This point has moved from the locality of Skegness Pier to a position just north of Gibraltar Point. The coast to the north has begun to show indications of steepening, coarsening and erosion as the source of sediment was removed. The present erosion and the need for sea defence works to the north of the Pier is a consequence of this migration process.

Along this section of the coast the potential longshore transport rates are relatively uniform and in line with those of the central section.

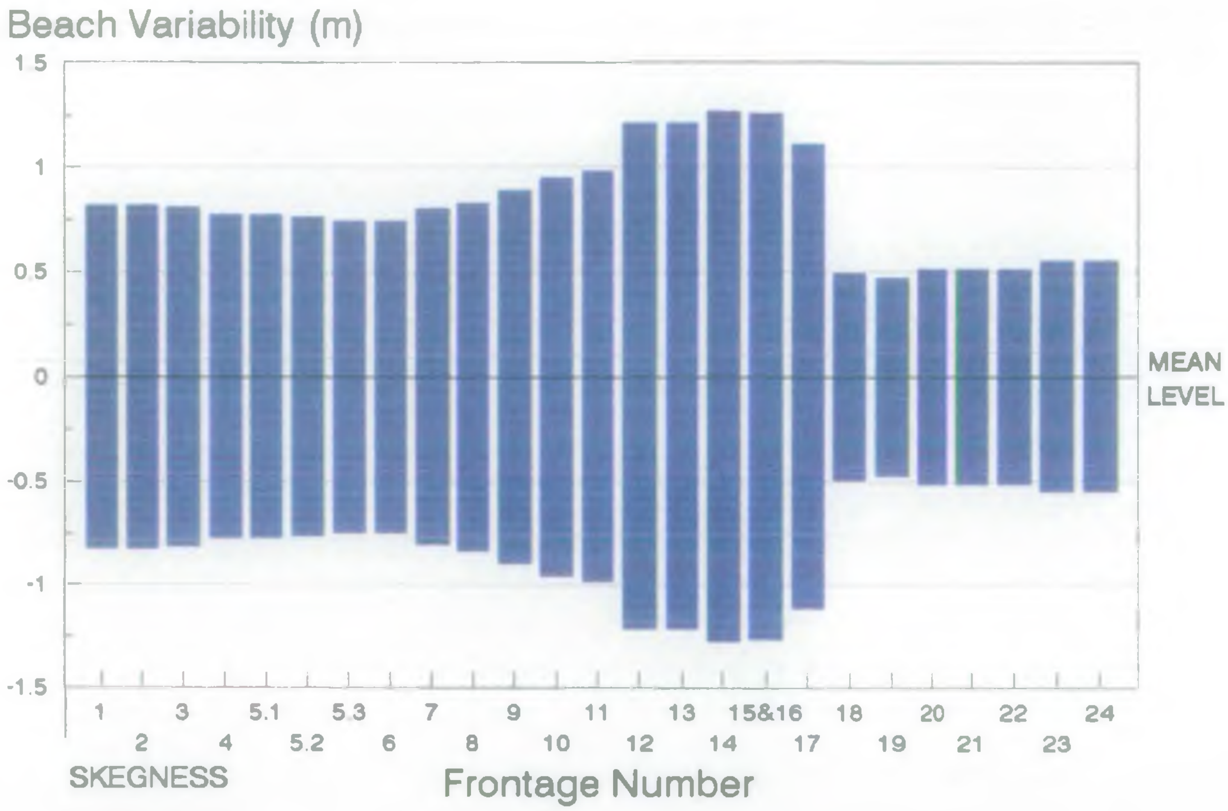
Beach Erosion

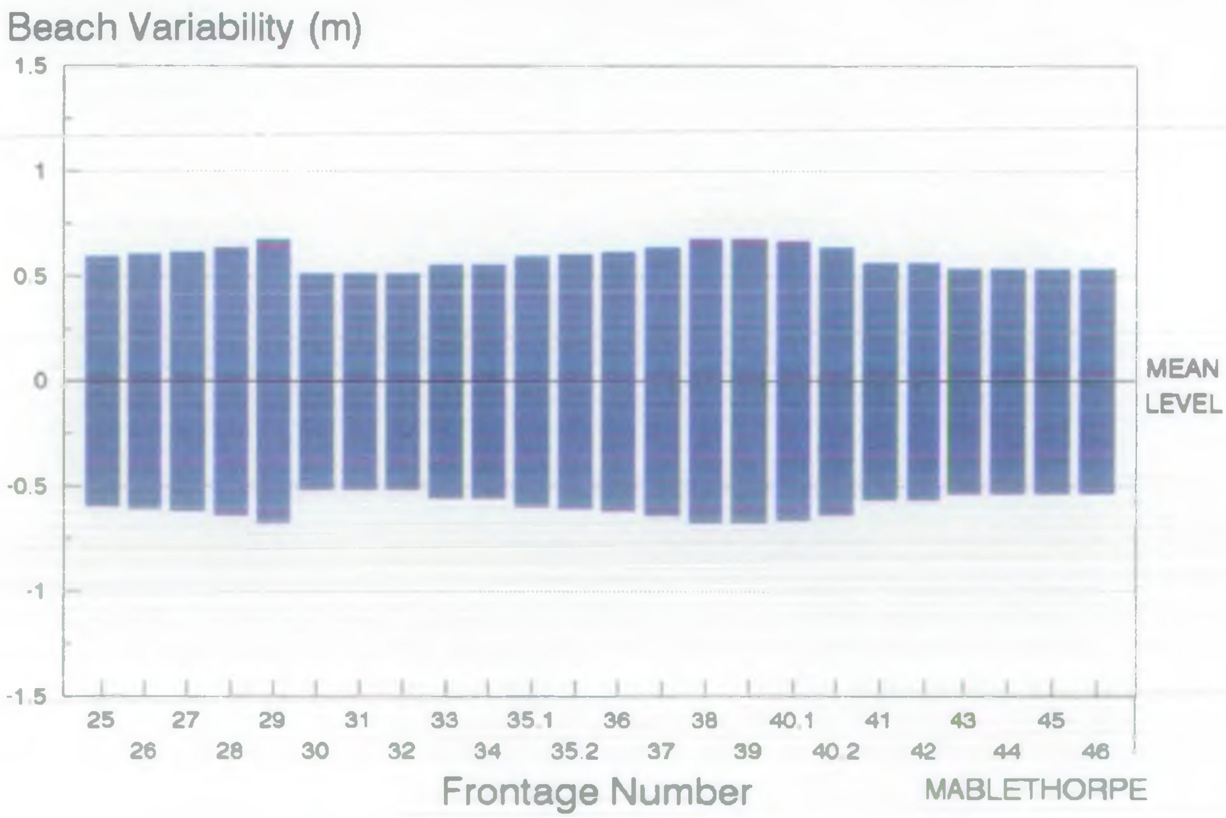
Beach profiles have been taken between Mablethorpe and north of Skegness since 1959 and continue to be taken. Each profile was analysed statistically at three specific points to determine the general trend. The data in Figure 2.3 demonstrates the range of beach levels in relation to the statistical mean. The maximum range is ± 1.25m which occurs in the vicinity of Frontage 14 (Chapel Point).

The results of the trend analysis are shown in Figure 2.4 and represent the historical behaviour of the beach over the last 30 years. This shows the beach to be eroding at between 0.1 cm/yr and 3 cm/yr.

It is considered that this erosion is due to the erosion of the underlying clay rather than any significant sand loss. During storm periods the overlying sand veneer is largely removed from the upper beach area and deposited offshore to form a breaker bar system. Once exposed, or with limited sand protection, the clay is eroded. The fine particle size of the majority of the eroded clay material results in it being retained in suspension and being carried further offshore and effectively lost to the system.

Figure 2.3





VARIABILITY IN BEACH LEVELS

(95% CONFIDENCE LIMITS)

2.3 Interaction with Defences

2.3.1 Mechanisms of Failure

The mechanisms of failure of a sea defence can be complex but are categorised by three fundamental modes:

1. Erosion at the toe of the defence.
2. Failure of the structural elements of the defence, either due to old age or impact from severe storms.
3. Erosion and failure of the backslope by excessive overtopping during storms.

Any of these three modes alone could result in the failure of the defence.

To this end the sea defences on this coast were assessed in two ways. Firstly a residual life was allocated to each frontage which takes into account beach erosion and structural integrity, and secondly an assessment of the return period of storm which would cause a failure due to excessive overtopping.

2.3.2 Toe Erosion

Failure of the toe can be the result of either:

- short term erosion due to storms
- long term erosion due to beach material loss

or a combination of the two.

Short term erosion can be represented by the beach variability identified previously as a maximum of 1.25m below the average beach level.

Long term erosion rates were derived for the present day situation by statistical analysis of past profiles and results in a maximum rate of 3 cm/yr (see p9). For the purpose of assigning residual lives in the future it is important that some prediction of future rates is undertaken.

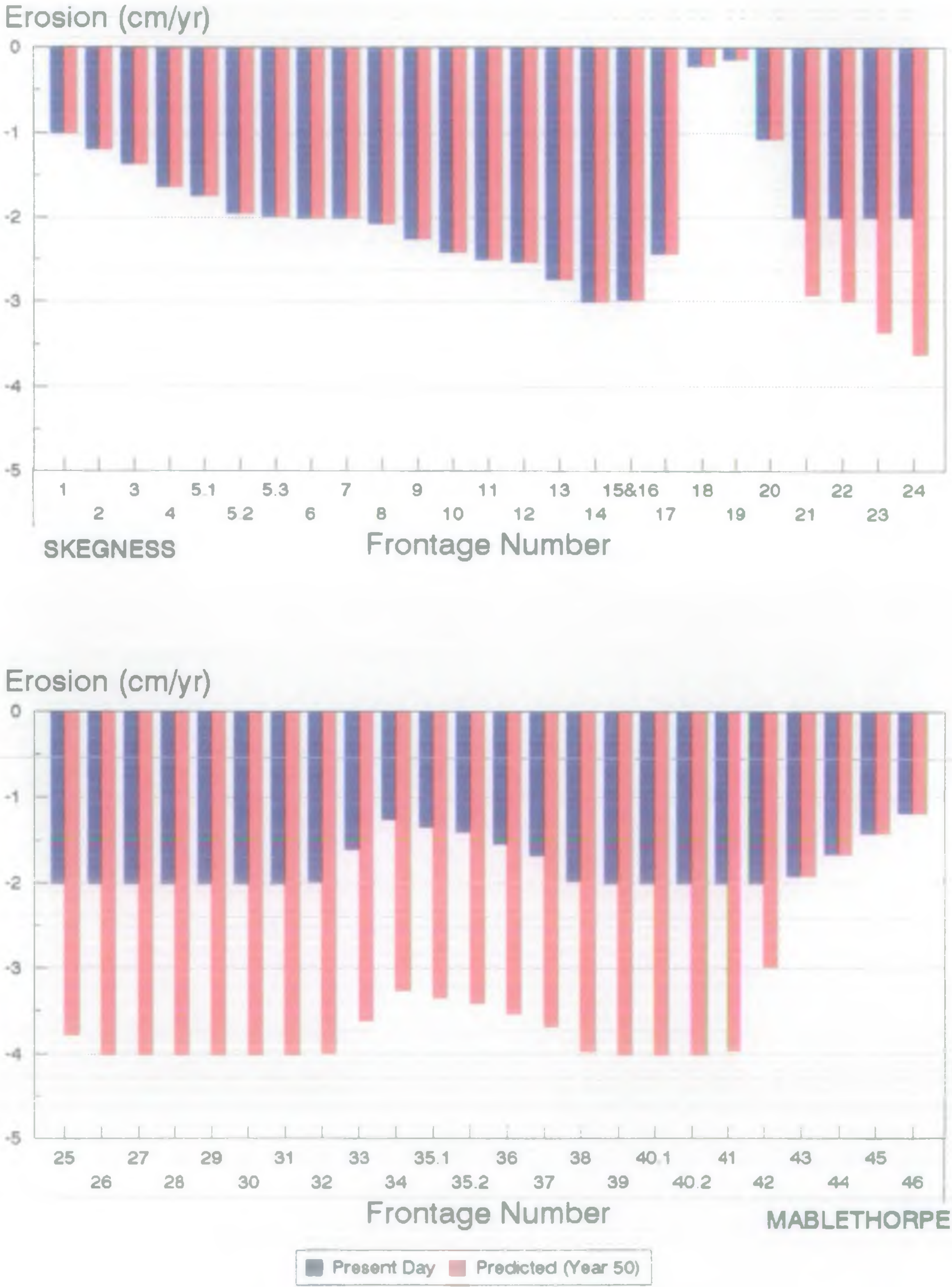
Existing beach trends were extrapolated forwards for 50 years, using a mathematical model at three locations and taking account of both sand transport and clay erosion. The modelling was performed in time steps of 10 years to investigate the effects of future clay erosion and thus identify any acceleration in the general rate of beach erosion. As a result of this analysis erosion rates are predicted to increase by up to 2 cm/yr by year 50 in the northern part of the study coastline as shown in Figure 2.4.

2.3.3 Residual Lives of Structures

The evaluation of structural residual life was based upon overall experience, in turn, based upon past performance and rates of deterioration of similar structures. This is considered to be the only practicable and viable approach.

The various elements that make up the sea defence structures were inspected during the Summer of 1990. The storms of October 1990 resulted in the deterioration of a number of the defences and a further survey was subsequently carried out. The conditions of the wave wall, revetment and toe were surveyed and logged. For the purposes of the study the residual lives were based on a date of April 1993 and due allowance was made within the

Figure 2.4



COMPARISON OF FORESHORE EROSION RATES

assessment for ongoing and committed works up to this date.

Information collected included:

- the nature of the sea defence
- the date of construction
- toe elevation
- the existence or otherwise of toe piling
- crest elevation
- crest protection
- the existence or otherwise of a dune backing
- the nature and degree of backslope protection
- structural condition

The objective of the survey was to assign residual lives to the various elements of the sea defences and thereby establish the likely programme of works necessary over the next 50 years. Account was taken of changes in wave climate brought about by predicted foreshore erosion and sea level rise and the increased risk of failure due to toe erosion.

From this assessment a single value for the residual life of each structure was obtained. For the first 5 years the accuracy of prediction was considered adequate. Beyond 5 years there has to be some doubt as to the accuracy of the assigned value and so ranges of values were used based on ± 0 years for year 5 to ± 10 years for year 50 (thus a 50 year residual life has a range of 40 to 60 years). For comparison purposes within the options the worst estimate (or pessimistic value) was taken. The range of values for each Frontage is shown in Figure 2.5 which indicates the upper and lower limits. The maximum values of 60 to 40 are the result of newly reconstructed schemes with design lives of 50 years.

It has to be accepted that any assessment of the residual life of a coastal structure is primarily a matter of experience, knowledge of the coastline and a visual inspection of the outside fabric. There is no satisfactory economic method of establishing with any degree of certainty the conditions which may exist within the structure, such as voids etc.

2.3.4 Overtopping

Wave run up and spray during storm conditions can cause water to overtop the defence. Overtopping can be tolerated up to a certain limit, beyond which damage will occur and this may eventually result in a breach.

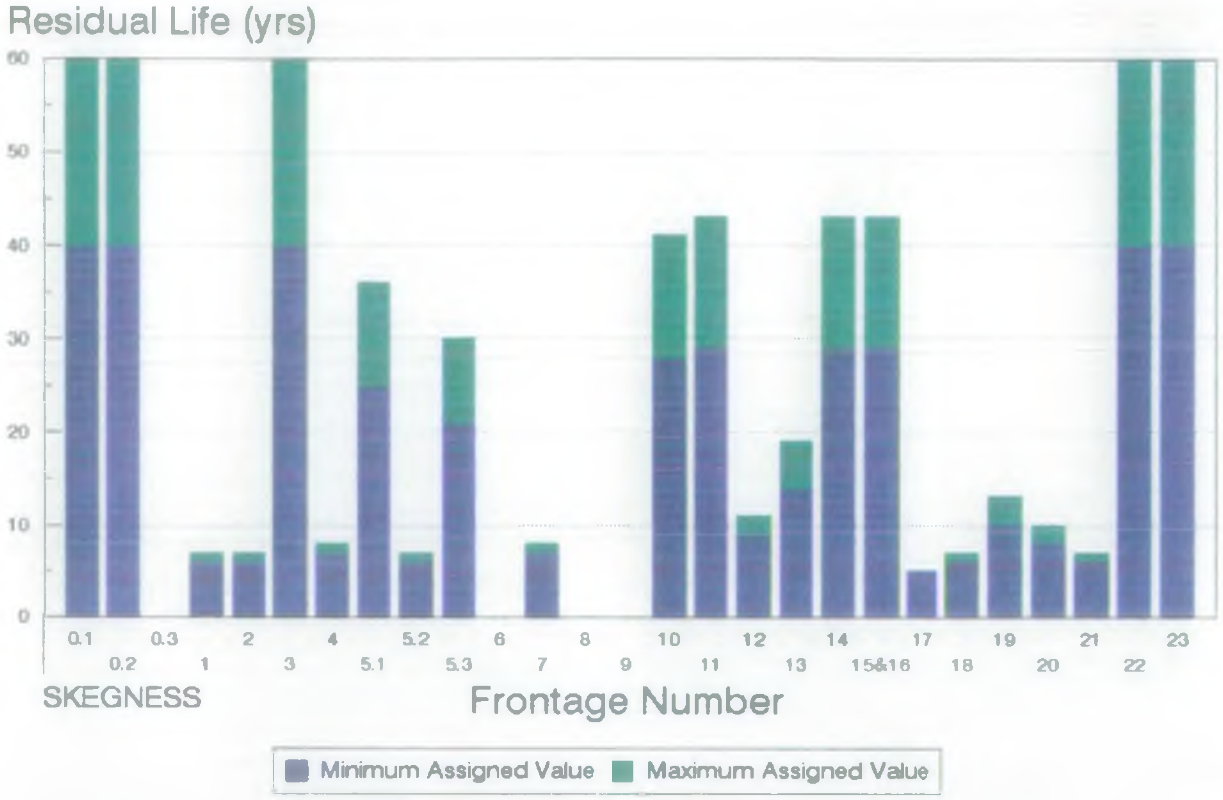
The assignment of limits for allowable overtopping over any given sea wall or defence is a site specific evaluation which must take into account:

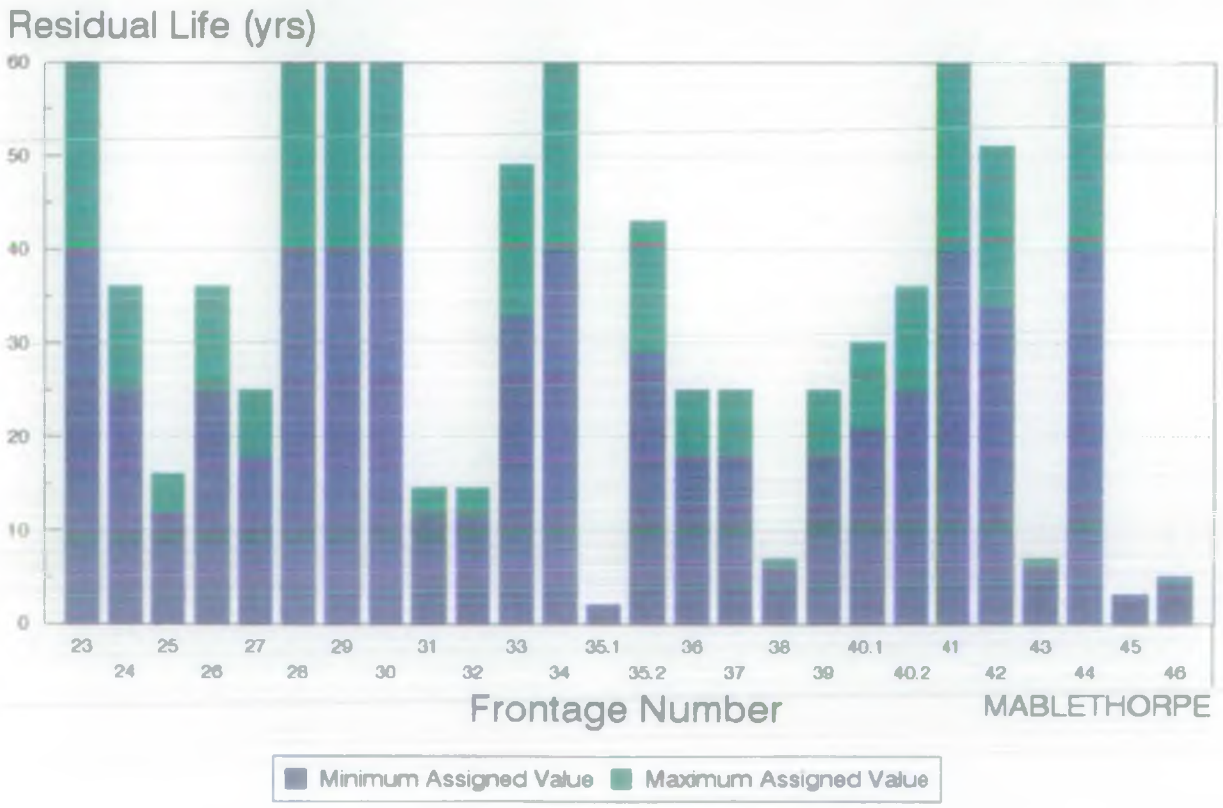
- the existence and nature of the backface
- the type of protection to the crest
- the likelihood of flow concentration on the backface
- the extent of acceptable damage

On the basis of Hydraulic Research Report EX 924[2] and other published data the following limits were selected to define the likely onset of damage due to overtopping:

- 20 litres/m/sec. for frontages comprising a seawall embankment with grass/bush protection to the back slope but without a dune backing

Figure 2.5





STRUCTURAL RESIDUAL LIVES

- 50 litres/m/sec. for frontages comprising a seawall embankment with dune backing
- 200 litres/m/sec. for frontages with well developed/protected back slope areas or frontages effectively designated as seawalls rather than embankments as defined in EX 924.

These limits were tested against past known events, as a part of this study, and it is considered that they represent the onset of significant damage which, without intervention, would result in failure on a subsequent lesser event (ie the Do Nothing condition).

However, in reality, NRA repairs its defences when damaged, so in considering sustaining or improving the existing defences, it can be argued that the limits underestimate the amount of overtopping required to create a breach during a single storm event. Following careful consideration, the overtopping limits, for these cases, were revised by a factor of four up to a maximum of 200 litres/m/sec (ie the Repair Condition).

The existing defences were analysed for overtopping for various different wave and water level conditions. This has allowed the derivation of the return period of the storm event which would cause overtopping in excess of the assigned overtopping limits, for both the Do Nothing and Repair conditions.

The return periods of events reaching the Do Nothing and Repair limits were calculated assuming that beaches are at their minimum levels. This is a reasonable assumption on the basis that the storm conditions which lead to overtopping are likely also to lead to beach drawdown. The results are presented in Figure 2.6. with the minimum return period events for the Do Nothing and Repair conditions being 1:3 and 1:7 respectively.

2.4 Conclusions

In coming to an understanding of the coastal system on this coastline a number of conclusions can be drawn:

- The majority of the beaches in the central study area are narrow, relatively steep and with a lack of beach material. (Section 2.1.2)
- The potential for longshore transport along the coastline is considerable and not at present fully realised. (Section 2.2)
- There is long term erosion of the clay which in some places is likely to increase. (Section 2.2)
- The wave attack on the structures will increase due to lowering of the beaches and sea level rise. (Section 2.2.1 and 2.3.2)
- Many of the existing structures are nearing the end of their lives. (Section 2.3.3)
- Risk of failure due to excessive overtopping is high for many structures. (Section 2.3.4)

Figure 2.6

OVERTOPPING

References

1	-	The Anglian Sea Defence Management Study, National Rivers Authority, 1988 to 1991
2	-	'Design of Seawalls allowing for Wave Overtopping', Report No. EX924, Hydraulics Research, June 1990
Appendix B	-	Frontage Numbers
Appendix 1	-	Existing Structures
Appendix 2	-	Joint Probability Analysis
Appendix 3	-	Existing Beach Morphology
Appendix 4	-	Beach and Seabed Sampling
Appendix 5	-	Geophysical Survey
Appendix 6	-	Beach Trends
Appendix 7	-	Evaluation of Existing Structures

SECTION 3

OPTIONS

3.1 Introduction

The fundamental issues associated with the formation of a viable strategy for sea defences in the future are:

- the lack of sand and the high potential for longshore transport on the foreshore.
- the continued and, in some locations, accelerating erosion of the foreshore
- the effects of sea level rise.
- the short residual lives of many of the structures

Two diverse philosophies of approach can be adopted:

- the condition of the structures and the foreshore are allowed to deteriorate and action taken as and when the defences are threatened.
- measures are taken to minimise the erosion and prolong the lives of the existing defences.

In the development of a viable strategy the following alternatives were considered either singly or in various combinations.

- Retreat
- Set back
- Linear Rock Protection (Seawalls)
- Beach Nourishment
- Rock Groynes
- Offshore Breakwaters/Reefs
- Artificial Headlands

When considering the above alternatives due account had to be taken of the following:-

(a) Practical limits on yearly expenditure.
(b) A start date for the implementation of the strategic works of April 1993. As such all works up to this start date were assumed to be sunk costs and consequently not included in the economic analysis.
(c) Linear rock protection is effectively a continuation of the present strategy and for this reason was well documented as being cost effective. As such it became a yardstick on costing, against which other strategies had to match to warrant further 'in depth' study.

An initial review was carried out on the basic alternatives above and a brief description is set out below.

- Retreat

  Unmanaged retreat in its most literal definition equates to doing nothing on the coast. Nowhere was it considered to be a viable approach but was studied in detail to provide the base line for comparisons.

- Set Back

  Set back is here defined as 'managed' retreat or setting back the defences to a new line. This approach could only be considered as viable over short sections of the coastline. NRA has evaluated this alternative on several schemes on this coast in the past and in every case it was rejected on economic grounds.

- Linear Rock Protection

  This alternative, as stated earlier, is effectively a 'continue as you are' approach. It is a well established cost effective approach and strongly influenced the development of the other strategies.

- Beach Nourishment

  This alternative was studied firstly as an overall strategy in its own right and also in conjunction with other alternatives such as rock groynes and/or offshore breakwaters.

- Rock Groynes

  The introduction of major structures such as long rock groynes, by themselves, would lead to significant but adverse changes in the local rates of erosion and accretion because of the limited supply of beach material available at present. They could not therefore be considered as a viable approach without the inclusion of major beach nourishment measures. It should also be borne in mind that the very severe wave climates on this coastline would require these to be very substantial structures.

- Offshore Breakwaters/Reefs

  Much of the comments on Rock Groynes above also apply to the use of offshore breakwaters and/or reefs.

- Headlands

  The introduction of the artificial headland type of structure on a coast whose oritentation is already fixed by massive concrete seawalls prevents this alternative operating effectively. This alternative could only be affective by the introduction of major beach nourishment.

The above outline serves as an introduction to the more detailed development of strategies which follows.

3.2 Standards

For the development of different options two further criteria were used:

- that the strategy should last or be sustained for the next 50 years.
- that a defined standard be reached for each option.

Standard in this case means the return period of the storm event which would cause failure of the defence (i.e. 1:100 yr means that a storm with a return period of 100 yrs is likely to be equalled or exceeded, on average, once in 100 years).

For the seawall options it is relatively easy to define the standard of the structure since it is a function of the performance of the particular structure against wave attack, and to raise the standard is only a question of improving the structure shape. For seawalls three different levels of standard were used.

For the nourishment options the assessment of standards is less straight forward. The addition of material to the beach represents an improvement in standard. Two different levels of standard were initially adopted; 1:100 year and 1:200 year and these were equated to berm levels of +2.5 mOD and +3.5 mOD respectively.

When modelling to establish the minimum nourishment quantity required to withstand a storm, it was found that the 1:100 year option required a wider berm than the 1:200 year options. This increase in berm width meant that the volume of sand required for each option was similar and so with the costs being roughly equal for both options the 1:200 year standard clearly represents the more cost effective solution.

3.3 Do Nothing

Do Nothing assumes that all maintenance and rehabilitation works cease at April 1993. No emergency intervention works would be undertaken to make good any storm or flooding damage.

Table 3.1 identifies the lowest standard frontages in terms of both residual life and overtopping.

Table 3.1

Do Nothing Breach Scenario Frontages

Frontage No.	Residual Life	Overtopping Return Periods *
9	0 years	1:8
35.1	2 years	1:20

* Return Period associated with minimum beach levels

The consequences of Do Nothing are:

- the flooding of the entire area within a short time.
- the abandonment of all residential, commercial and industrial properties and activities.
- the loss of most existing recreational and environmental interests in the area.

Clearly this does not represent a viable approach. However, the associated damages are developed in Section 4.2.2 for evaluation purposes.

3.4 Seawall Options (Options 1-3)

The seawall options are in effect a continuation of the existing approach to the provision of sea defences. Three options were selected for development, however, the implications of the adoption of each would be similar and include the construction of short timber groynes.

Option 1	**Sustain** -	The existing standard of the defences would be allowed to fall as a result of beach erosion and sea level rise. Rehabilitation works would be programmed in accordance with the assigned residual lives with the works designed to provide the present day standard at year 50.
Option 2	**1:100 yr - Standard**	The existing defences would be upgraded to 1:100 yr standard in line with priority (existing low standard) and residual lives. Rehabilitation works would be designed to have a minimum 1:100 yr standard at the end of their design life.
Option 3	**1:200 yr - Standard**	The existing defences would be upgraded to 1:200 yr standard in line with priority (existing low standard) and residual lives. Rehabilitation works would be designed to have a minimum 1:200 yr standard at the end of their design life.

3.4.1 Implications

The retention of seawalls would not prevent the erosion prevalent over much of this coastline. Reflected waves from the structures increase the wave agitation within the foreshore area, thus bringing more material into suspension and increasing the potential for sediment transport and loss.

Differing types of seawalls have been constructed in the past, including solid and voided stepwork, smooth revetment slopes, concrete armour units and rock. The rock solutions provide the highest degree of wave absorption and the lowest level of wave reflection. They therefore reduce the amount of wave agitation in the foreshore area to the lowest practicable limit and hence help to reduce the rate of foreshore loss. Even if this solution were employed along all lengths of eroding foreshore, it is considered that the general pattern and rates of erosion would persist; primarily since the rock solutions have little impact on the on/offshore transport mechanism.

The variability of the beach would remain with the seasonal exposure of the underlying clay. Presently some 22% of the upper beaches remain dry at mean high water springs (MHWS). By the year 50, with foreshore lowering of some 1.5m in some places, the corresponding figure would reduce to some 11% and hence the recreational use of the beaches would become increasingly restricted with an associated impact on the local economy.

Reconstruction of the seawalls in this manner would not interrupt or affect the existing longshore transport situation. Therefore the existing supply of 130,000 m^3 per annum from the north to Gibraltar Point would continue.

The archaeological interests associated with the clay exposures would be progressively eroded and effectively lost.

Concerns have been raised over the safety access and aesthetic properties of the seawall option particularly those associated with the rock solution. These would be mitigated by the provision of appropriate handrailings, access steps within each groyne bay and sympathetic design.

Rehabilitation works through necessity would occur during the summer period. The complexity and extent of the rehabilitation works would increase as structures are founded at progressively lower levels to account for the falling beach levels. It may therefore be anticipated that the current level of disruption and construction traffic would increase proportionally.

Finally, it has to be acknowledged that the seawall option, in allowing foreshore erosion to persist, may preclude, on financial grounds, the adoption of an alternative approach, such as beach nourishment, in future years even if this proves desirable.

3.4.2 Constructional Aspects

The continuation of the sea wall option for the next 50 years represents a viable engineering approach. The necessary technical and design knowledge exists to provide appropriate solutions. However, the cost of construction would increase for the following reasons.

As beach levels reduce, lower foundation levels for the rock toe would be required. This would reduce the time available for work during the low tide period of the tidal cycle and would eventually lead to extensive de-watering. Both of these items would significantly increase the cost of construction.

Further more, falling beach levels would also lead to an increase in the wave attack on the structures and to counteract this more robust construction solutions would be required. There is an upper limit on the size of rock armour of around 15 tonnes, above which more expensive concrete armour units would have to be used. As a example, the current project at Sandilands is already using rock armour up to 9 tonnes because of the existing low beach levels at this position.

The frontages were initially programmed for reconstruction at the end of their residual lives. For Option 1 the programme was smoothed to a uniform expenditure level to meet the practical organisational and financial limits and prevent excessive variations in expenditure in adjacent years. For Options 2 and 3 the remaining frontages were programmed to be reconstructed as soon as possible to raise the level of standard along the coast. In theory this could be achieved by performing all the reconstructions in the first year. However to be practicable the same organisational and financial constraints were applied to these options, and the programmes were adjusted accordingly.

3.4.3 Costs

Unit rates were developed, at a September 1990 price base, for each element of construction including general and preliminary items as follows:

Rock revetment	Above OD	£50/m^3
	Below OD	£80/m^3
Concrete berm		£180/m^3
Upper stepwork		£80/m^2
Wave wall		£250/m
Decking		£35/m^2
Access works		£250/m
Groyne construction	Each	£20,000

The unit rates were applied to the measured scheme quantities with construction dates in accordance with the appropriate option. No account was taken of the additional cost of larger rock or concrete armour units.

The resulting discounted costs inflated to 1993 (19%) are detailed in Table 3.2.

Table 3.2

SEAWALL COSTS £ MILLION

	Option 1 Sustain	Option 2 1:100 yr	Option 3 1:200 yr
Construction Cost	147.9	157.5	163.6
Discounted Cost	77.7	95.4	104.4

3.5 Nourishment Options (Options 4-6)

The nourishment options are directed towards providing, through artificial means, higher beach levels. The benefit of this approach would be:

- eliminating the inevitable, eventual loss of the existing beach
- prolonging the lives of seawalls
- increasing the standard of existing defences
- mitigating the effects of sea level rise

Clearly such benefits can only be achieved if the higher beach levels can be retained or the losses minimised. This can be achieved, to varying degrees, through the adoption of one or a combination of the following:

- reducing the variations in beach level by employing a less readily transportable material
- introducing controlling structures such as groynes or offshore breakwaters

Each of the above have specific implications, particularly on coastal processes and these are dealt with under the discussion of each option. However common to each option is the need to provide additional beach material.

The three options considered are

Option 4	**Beach Nourishment**	-	To raise the level of the beach to +4.5 mOD, after rehabilitating the seawalls where necessary and to recharge the nourishment in the future when the beach levels fall by 1m.
Option 5	**Nourishment with Rock Groynes**	-	As Option 4 but with the provision of rock groynes along part of the coast.
Option 6	**Nourishment with Breakwaters**	-	As Option 4 but with the provision of offshore rock breakwaters.

3.5.1 Implications

Beach nourishment would provide protection to the underlying clay substrate. The erosion of the clay within the upper foreshore area would, therefore, be significantly reduced if not eliminated. The archeological interests associated with the clay layer would be buried, but retained for future examination. Some element of consolidation may occur within the deposits due to the additional overburden, although a similar overburden would have existed prior to the retreat of the coastline.

Safety and access to the beach would be improved through higher beach levels and the aesthetic properties of the defences and beach would also be improved.

The nourishment operations would largely occur in the summer period. The operation would be largely a sea based one and thus increased road traffic would be minimal.

The increased beach levels would increase the tourist attraction of the area. A contingent valuation survey was performed to assess the perceived benefit to beach users of the existing beach and this benefit was included in the economic evaluation within Section 4.

The six land drainage outfalls within the nourishment area would need to be extended beyond the seaward limit of the nourishment profile.

3.5.2 Constructional Aspects

Beach nourishment would involve standard dredging and reclamation processes. Preliminary enquiries indicate a potential source of material some 30 kms offshore. Certain areas close to the shore have been eliminated because of environmental and technical grounds and include the sand banks to the north of Mablethorpe.

A licence application would be made to the Crown Estates Commissioners for beach nourishment purposes which would be followed by prospecting, analysis and trial dredging to confirm the suitability of the source. The licence application would be subject to statutory approvals.

Typically, material would be won from a borrow area using a trailer suction dredger and hauled to a discharge point located approximately 1km offshore. The discharge point would comprise a buoyed and anchored floating pipeline connected to a sinker line, laid on the sea bed. The sinker line would run to the existing sea defences and there be fitted with a "T" to allow distribution in both directions.

The distribution pipe would be extended as the beach feed is progressed and a total of 2 kms of beach feed should be achievable from a single sinker line position. It is anticipated that two sinkers would be deployed at any one time with a third being located in readiness.

The natural outwash from the discharge pipe would be employed to distribute the material to a natural profile with some mechanical reworking.

The general implications of the above operations would be as follows:

- Sinker fabrication. A suitable coastal site would be required for the fabrication of the sinker line. This can normally be performed in a drying beach area with the pipe rolled out at high water in 250m lengths and jointed whilst afloat to form a 1km line for tow-out and sinking.

- Offshore Discharge Point. The offshore discharge point would be subject to a Notice to Mariners and marked with appropriate navigation aids.

- Sinker line. Each sinker line would be in position for a period of some 12 weeks.

- Placement line. Up to a maximum of 2 kms of shore parallel pipe of some 0.75m diameter would be laid at the toe of the existing defences. The line would be laid on previously placed material to ensure that it is above the tide and wave action level. Access points across the pipeline would be needed at appropriate intervals.

- Discharge Point. During discharge operations it would be necessary to prohibit public access within 200m of the discharge point. The quantity of excessively fine (silt) sediment should be small, but would require monitoring.

- Working. The dredging and pumping operation would be performed on a 24 hour, 7 days week basis. The operation of any mechanical plant on the foreshore would be restricted to daylight hours.

- Rate of Progress. The typical rate of advance of the pipeline along the beach would be 24 m per day.

3.5.3 Option 4, Beach Nourishment

The development of a strategy involving beach nourishment involves many factors. Extensive mathematical modelling was undertaken in conjunction with Delft Hydraulics to study the potential sand movement of a nourished beach. The following items were considered in detail:

- Selection of sediment size
- Development of a minimum profile/volume
- Analysis of Sediment Budgets
- Cross shore Transport
- Longshore Transport
- Storm Losses

From these basic factors the whole coastline was analysed and features on a global scale studied such as:

- Mixing of existing and new sediments.
- Effects of short timber groynes.
- Discontinuitities in the coastline (points).
- Renourishment of the beaches.

Selection of Sediment Size

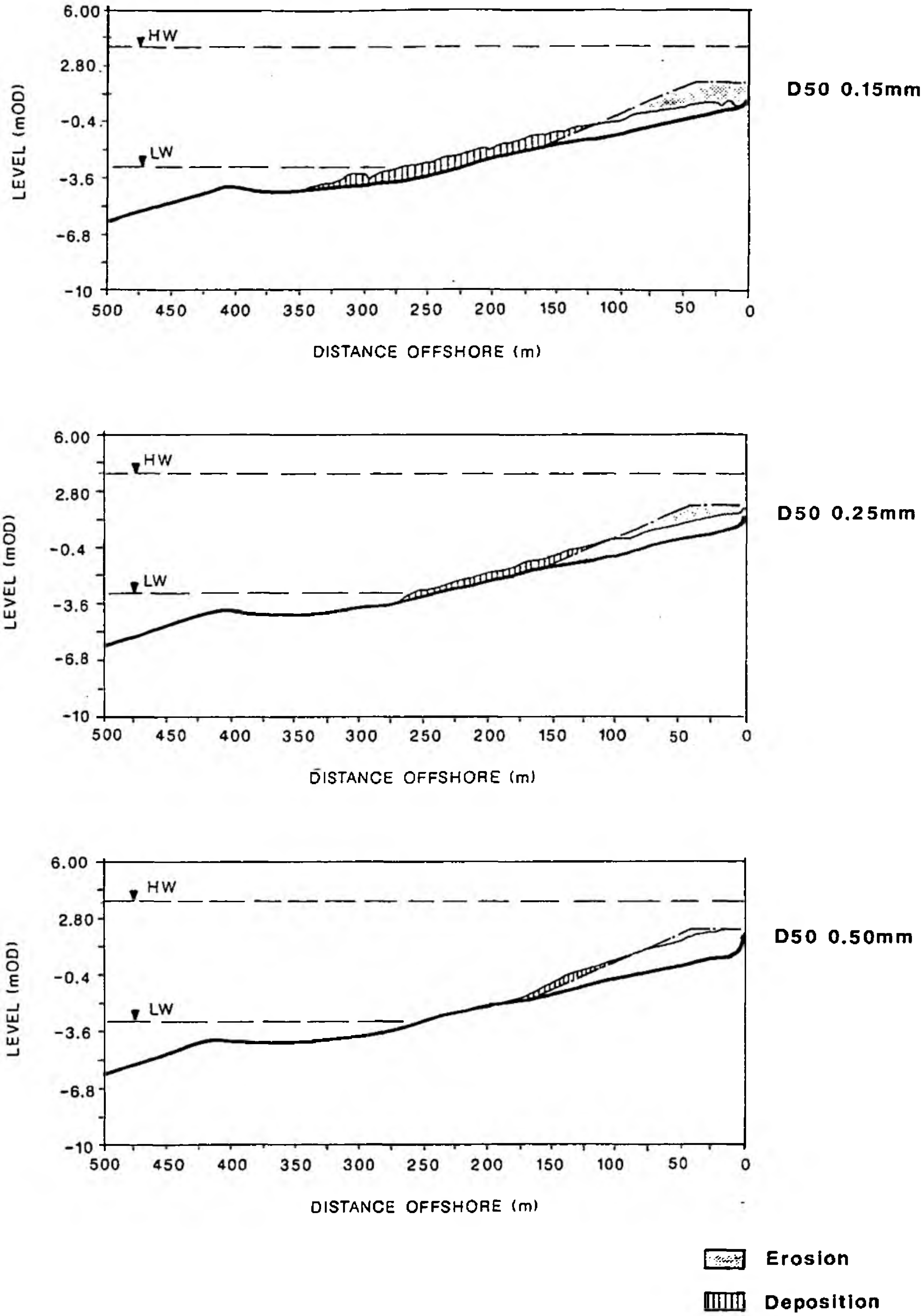
The variability of the existing foreshore can be attributed to the existing sediment size. The beach sediment was sampled during the summer of 1990 when the beaches were high and shown to have relatively consistent D_{50} size of 0.12 to 0.2mm. Sediment of this size is easily moved.

Nourishment with sand of the same size would increase the beach levels but would still be very mobile which is undesirable. Figure 3.1 demonstrates for an existing beach profile that an increase in particle size leads to significantly less change in the beach profile. An improvement would be achieved by using a sand with a D_{50} of 0.5mm for nourishment and this would have little or no ecological or recreational impact.

Minimum Profile/Volume

The minimum volume requirements for the beach nourishment were calculated assuming a variety of beach slopes. The modelling work undertaken has shown the beach slope to vary and slacken as a function of the severity of the wave climate. During periods of draw down the lower part of the profile is supplied by sediment from the upper drying beach area and a wave cut "cliff" could develop. If the magnitude of such a feature presents a restriction to access

Figure 3.1



BEACH LEVEL VARIABILITY

WITH SEDIMENT SIZE

then it would need to be removed and levelled out by mechanical plant.

Having calculated the minimum volume required this was equated to a realistic minimum profile with a beach slope of 1:25 and a berm width of 15 m at a crest level of + 4.5 mOD. The proposed nourishment profile, for a typical location, is shown on Figure 3.2. Beach nourishment would cover up the existing revetments inc rock armour toes, seabees etc.

Severe storm modelling (up to 1:200 yr event) with nourished profiles confirmed the relative stability of sediment with D_{50} = 0.5mm and this material was adopted for detailed consideration.

Sediment Budget

For the beach to be in equilibrium (ie. stable) the net input of sediment has to equal the net loss of sediment. If this basic equation does not balance then erosion or accretion takes place on the coast. This equation is called the 'Sediment Budget' and is the means of equating beach material losses to erosion or accretion.

To apply this principle to the coastline as a whole would be a very coarse approach and so to get a better picture of the sediment movement the coastline was split up into 'cells', shorter lengths of around 1km, and the equation applied to these individually.

A typical sediment budget cell is shown in Figure 3.3. The cell has a fixed width and this was developed for each cell by the cross shore transport modelling. From this the longshore transport across this area can be calculated and also any storm losses over the boundary in a cross shore direction.

Cross-shore Transport

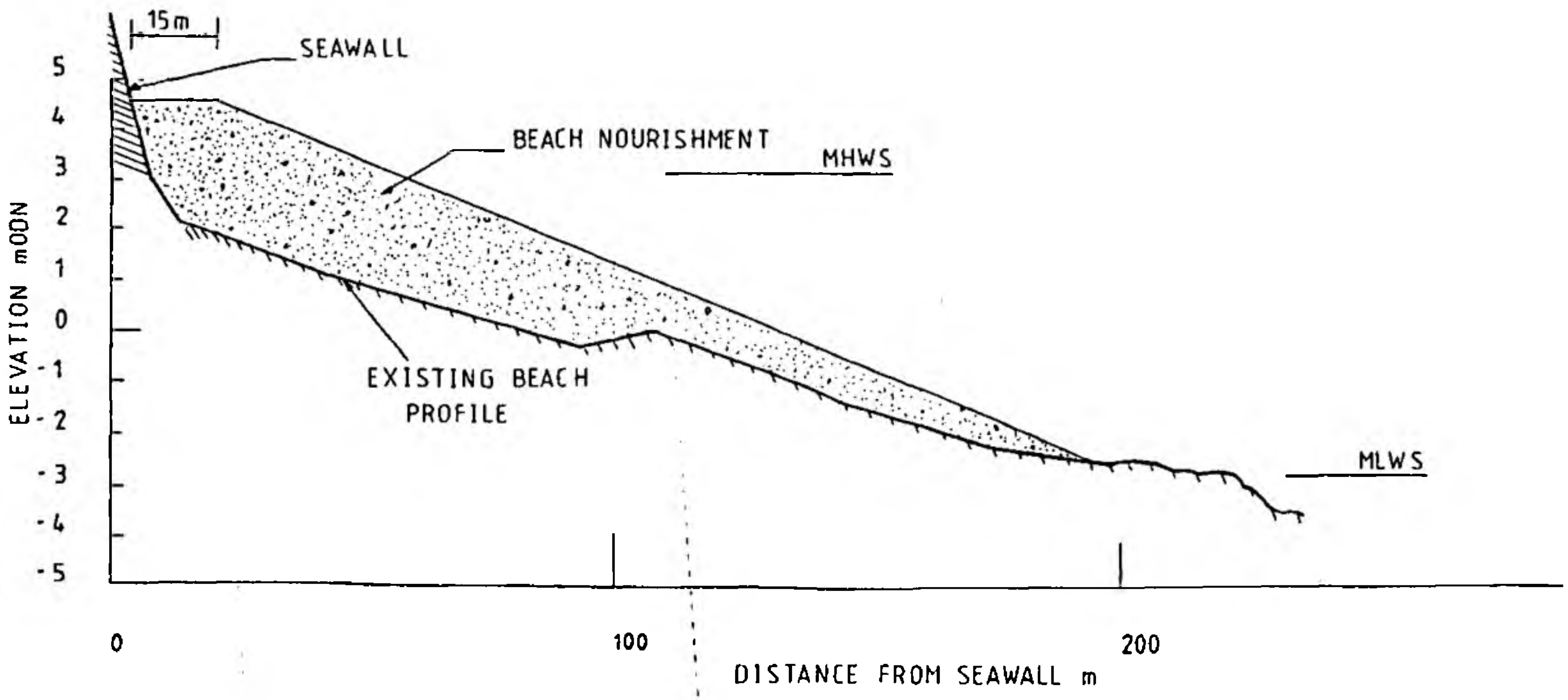
Severe and average nearshore wave conditions were identified following a detailed wave refraction study. This data was used to establish the width of beach over which material was drawn down and subsequently recovered. This in turn was employed to define the width of the sediment budget cell over which the longshore transport can be calculated due to the presence of an adequate sediment supply.

Longshore Transport

The results of the longshore transport modelling over an average year are presented as Figure 3.4. This indicates a relatively uniform net transport rate with the only significant increase being in the vicinity of Sutton, profiles 26 to 24, when the shelter of the nearshore banks off Mablethorpe is lost. Sediment budget cells were used to establish areas of net annual erosion and accretion. Under a severe annual wave climate the rates of longshore transport were shown to increase by around 45%. Longshore transport rates were significantly reduced by using a coarser sand.

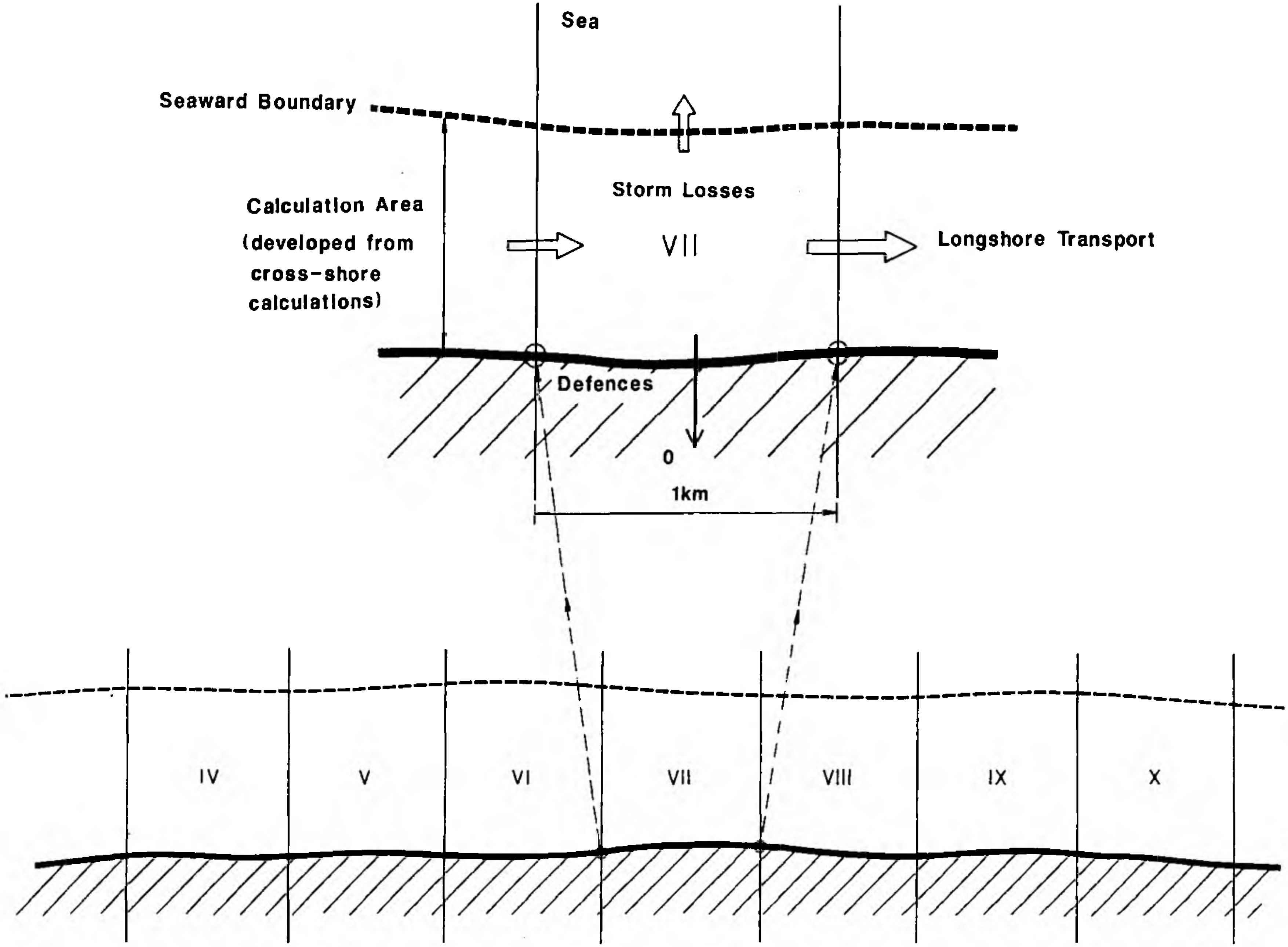
Storm Losses

The nourished profile was developed under an average year's wave action and then re-analysed under extreme storm conditions with any material carried over the offshore boundary of the sediment cell assumed to be lost.



BEACH NOURISHMENT PROFILE
(Frontage 43)
(exagerated vertical scale)

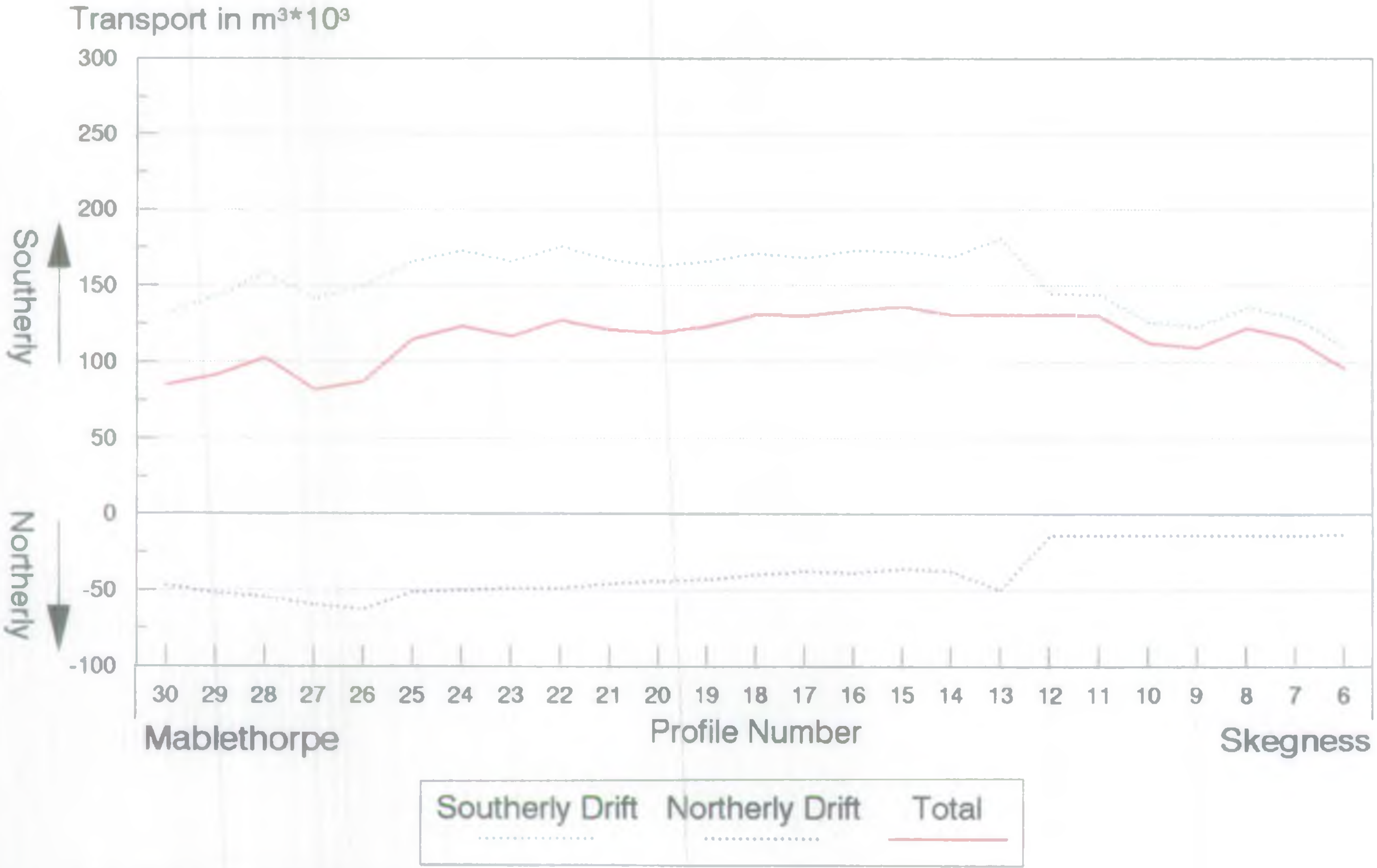
Figure 3.2



TYPICAL SEDIMENT BUDGET CELL

Figure 3.3

LONGSHORE SEDIMENT TRANSPORT



This graph shows transport over the landward 500m of the beach profile.

Figure 3.4

Sediment Mixing

The existing sediment supply (D_{50} = 0.2mm) is believed to be of the order of 130,000m^3 per annum from north of Mablethorpe, see Section 2.2.2. Accretion tendencies along certain lengths of the coastline could well reduce this value.

In the long term it is considered that the fine sediment feed would re-establish itself. Inevitably there would be some mixing of the imported and indigenous materials, however the extent to which mixing would occur cannot be predicted.

The implications of mixing (or lack of it), on the cost of beach nourishment as a whole is also equally difficult to quantify. In the costings a pessimistic view has been taken that there would be no contribution from the existing transport to the maintenance of the beach. To compensate for this a recharge of the system was allowed for.

In the short term the supply to the south of Skegness and Gibraltar Point would be maintained by the nourished material, albeit with a minor increase in sediment size.

The long term implications for Gibraltar Point can be considered in terms of the possible range of mixing. If full mixing does occur it would continue to be fed by a coastal contribution, as opposed to the offshore banks, at around 100,000 m^3/yr of slightly coarser material. The degree of coarseness would diminish throughout the strategy life.

If no mixing occurs then the coastal contribution to Gibraltar Point would effectively double. Controlling structures could be implemented to moderate the rate of supply if this was found to be necessary.

Short Timber Groynes

The monitoring of the performance of the beach profile and in particular the beach head would be an important element of this option. Monitoring would be carried out in conjunction with that required under the SDMS. The existing short (40m) timber groynes play an important part in the present situation in that they tend to "hold" the beach head against the sea defences. Additional support to the beach nourishment from new short timber groynes installed after nourishment, may represent an effective measure should the monitoring demonstrate a requirement. Groynes of this length have little or no effect on the longshore transport after nourishment.

Coastline Discontinuities

This coastline has some notable and abrupt changes in orientation such as at Vickers Point. The existing coastline shows a consistent low water line across such features, a pattern which would be likely to persist after nourishment. As such, the higher beach levels would not be retained across such features. The option therefore includes allowance for the continued maintenance and rehabilitation of such features as sea walls, albeit with improved foreshore levels.

Renourishment

A key feature of nourishment options would the need to compensate for longshore and offshore losses by periodically feeding new material to the nourished beach. Wind and wave action would eventually reduce the beach level, and when the berm level reached +3.5m OD re-nourishment would be required. Thus programmes of monitoring beach levels and re-nourishment would be required to return beaches to design levels and so maintain their effectiveness. An indicative programme of renourishment is shown in Figure 3.5. The programme could be phased to take into account any additional constraints and the costs have been included in the economic evaluation.

3.5.4 Option 5, Nourishment with Rock Groynes

The introduction of a groyne field into the nourished area would have the effect of reducing the longshore transport potential. This is achieved by a local re-orientation of the shoreline within the groyne bays. If the groynes were long enough and sufficient material was provided, the groyne bay shoreline would adjust to an equilibrium angle, dictated by the dominant wave direction, and hence the longshore transport would be eliminated until the groyne bay is filled.

The adoption of shorter groynes would result in a proportion of the longshore transport being located outside the influence of the groynes. This would not only effect the overall efficiency of the groyne field but also the degree of response of the shoreline within the groyne bays.

The objective of the groyne field would be to modify the longshore transport to a uniform level. Its reduction to a uniform, zero level, would require extensive groynes of the order of 350m long and would result in downdrift erosion requiring, effectively, continual replenishment and thus negate the objective. A more practicable approach would be to restrict the longshore transport rate to one compatible with the existing situation.

It is proposed that the longshore transport should be reduced to a uniform level compatible with the predicted transport rate in the north. The achievement of this would require groynes of some 175m length at a provisional spacing of 250m for the coastal length between Sutton and Ingoldmells point. It is anticipated that the berm width would need to be increased by some 20m over this length to accommodate changes in shoreline orientations and still provide the necessary buffer of material against the existing seawalls during storm events.

The designed uniformity of the longshore transport rate would effectively eliminate erosion and accretion tendencies. However, on/offshore losses would persist with due allowance required.

This option would retain the sea wall approach for the marked discontinuities of the coastline but to a lesser extent than those associated with the pure nourishment option.

The construction of groynes of this length would restrict the existing longshore sediment supply to Gibraltar Point in the short term. Thus it would be necessary for the implementation to commence with the nourishment of the beaches to the south of the proposed groyne field (Ingoldmells Point) to provide a reservoir of material to feed Gibraltar Point, again with a slightly coarser material.

In the long term the natural bypassing processes would be re-established for both the nourishment and indigenous materials. Again the degree of mixing of the two materials would dictate the nature and volume of sediment transported to Gibraltar Point. As for the pure nourishment option, it is predicted that the existing coastline supply rate would not reduce.

The groynes would be constructed to suit the existing beach levels and prior to the nourishment. As such a considerable height of groynes would be exposed during the intervening period and, for stability as well as performance reasons, it is proposed that rock groynes should be employed.

It is proposed that the groynes should be orientated some 10° south of the shoreline normal to benefit from diffraction effects of the dominant north east wave direction.

3.5.5 Option 6, Nourishment with Breakwaters

Offshore breakwaters provide a solution whereby the sediment driving forces can be controlled before they reach the nourished beach. In so doing the solution would also have the benefit of controlling both longshore transport and on/offshore transport.

The approach to the development of an offshore breakwater solution was similar to that adopted for the groyne option; namely the achievement of the uniform longshore transport rate of around $100{,}000m^3/yr$ rather than a total elimination in the short term.

The control of the highwater beach plan shape is crucial to the primary purpose of the nourishment option in retaining high beach levels at the sea defences. The large tidal range has a considerable influence on the selection of the preferred location of the structures.

A scheme was examined based upon the following parameters.

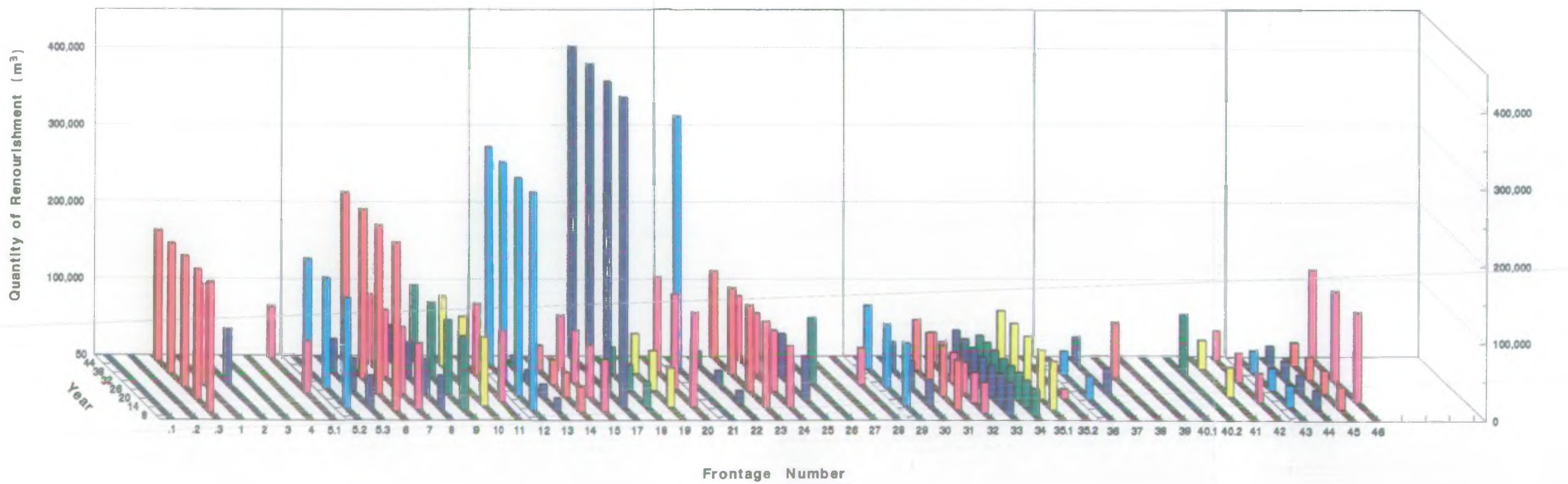
- structures located at -4.0m OD
- length of structure 200m
- gap between structures 300m
- efficiency 30%
- crest elevation +3.5m

The construction of the proposed breakwaters would severely restrict the longshore movement of sediment and impose strong, local, shoreline effects. An additional 20m of berm width would be allowed to accommodate shoreline changes between the breakwaters. Implementation would again commence with nourishment to the south of the breakwaters to maintain the supply to Gibraltar Point.

Similarly the long term, by-passing of the system would occur when the salient features have developed to their equilibrium state. The complexity of the shoreline processes effectively dictates that full mixing of the materials would occur. The prediction of the time required to re-establish bypassing is not considered possible and therefore the conservative estimate was made that continual feed to the south of the breakwaters would be required.

3.5.6 Costs

An appropriate programme of works was developed for the three alternative nourishment options. Each required the establishment of an offshore licence area and it is considered that the earliest date of implementation would be 1994. There is thus a common element of ongoing and committed works that



RENOURISHMENT PROGRAMME

would be required to secure the defences in the intervening years and to provide the required structural integrity of the defence and a minimum residual life of two years before nourishment. In many cases minor stepwork renewal works may be all that is required, although in some cases more extensive work may be required. In addition there would be a number of frontages which would be retained as sea walls throughout the course of the nourishment strategy. The indicative programmes for each option are shown on Figure 3.6.

To obtain the best estimate of costs for dredging several operational factors have to be considered. Firstly a major part of the dredging cost is related to the mobilisation of plant and sinker pipelines. This cost is split up over the unit rate of dredged material. Therefore, if the quantity of material increases then the amount of mobilisation included in each m^3 of material decreases. If the quantity of material required in any one year exceeds a certain value then more plant will be needed to complete the work in a season / year. If this is the case then the cost of plant will rise dramatically and the rate for material will rise. Therefore a practical balance is required between enough material to spread the mobilisation costs over and not to much so as to require excessive amounts of plant. This practical limit equates to an annual expenditure of around £10 million and has been used in the development of programmes and costs for the nourishment options.

The development of the programme has included a degree of optimisation. This optimisation represents a fine balance between early expenditure on nourishment and its deferment, thereby requiring additional expenditure on seawall rehabilitation. Following trials it was found that the least cost approach for Option 4 would be the implementation of nourishment as early as practicable (ie. 1994).

The increased scale and costs of Options 5 and 6 meant that works would have to be phased over a longer time period. Because of this delay in completion many more of the seawalls with short residual lives would have to be rehabilitated. Having reconstructed these walls, it would then be possible to delay the remainder of the nourishment programme since further walls would not need rehabilitating for several years.

Detailed discussions were held with two dredging companies to establish unit rates for nourishment. A higher rate for renourishment and recharge costs was adopted due to the more piecemeal nature of the operation. The basic unit rates employed in the evaluation (at September 1990 prices) are:

Beach nourishment		
Skegness to Chapel St Leonards		£5.50/m^3
Chapel St Leonards to Mablethorpe		£4.20/m^3
Crown Estate Royalties (estimated)		£0.75/m^3
Renourishment and Recharge costs		£8.00/m^3
Groyne construction		£500/m
Offshore breakwaters		£7,000/m
Outfall extension		£3000/m
Stepwork Renewal	above +3.0 mOD	£80/m^2
	below +3.0 mOD	£160/m^2

The resulting discounted costs, inflated to 1993 (19%) are detailed in Table 3.3.

Table 3.3

NOURISHMENT COSTS £ Million

	Option 4 Nourishment Alone	Option 5 Nourishment + Groynes	Option 6 Nourishment + Breakwaters
Constructional Cost	203.4	219.8	196.0
Discounted Cost	80.3	91.6	107.8

3.6 Environmental Consultation

As part of the full and independent environmental assessment, a consultation document was prepared covering the background to the factors influencing the study and the nature of the engineering options under consideration. This document was circulated to 42 interested parties and comments invited. This second round of consultations has been supported with presentations and meetings. Particular attention was paid throughout the investigations to keeping interested parties fully informed of the nature and extent of the modelling performed. This process ensured that all concerns were correctly interpreted and investigated.

An over-riding concern of all parties is the maintenance of NRA's committment to provide secure defences to ensure the continued livelihood of this extensive area. The particular areas of concern are presented in Table 3.4.

Overall, the beach nourishment option was shown to be the preferred approach whenever an opinion was expressed. The approach is preferred on aesthetic, tourism, recreation and nature conservation grounds.

The major residual impacts associated with the beach nourishment option are:

- A possible small increase in sedimentation may occur at Gibraltar Point. Investigations and consultations have indicated that this is not likely to be significant although monitoring will be required. Chemical composition will also be monitored and any changes will be taken into consideration.
- The foreshore archaeological and geological interests will be covered by beach nourishment. It is, however, felt beneficial that the interests will be preserved, albeit under cover.

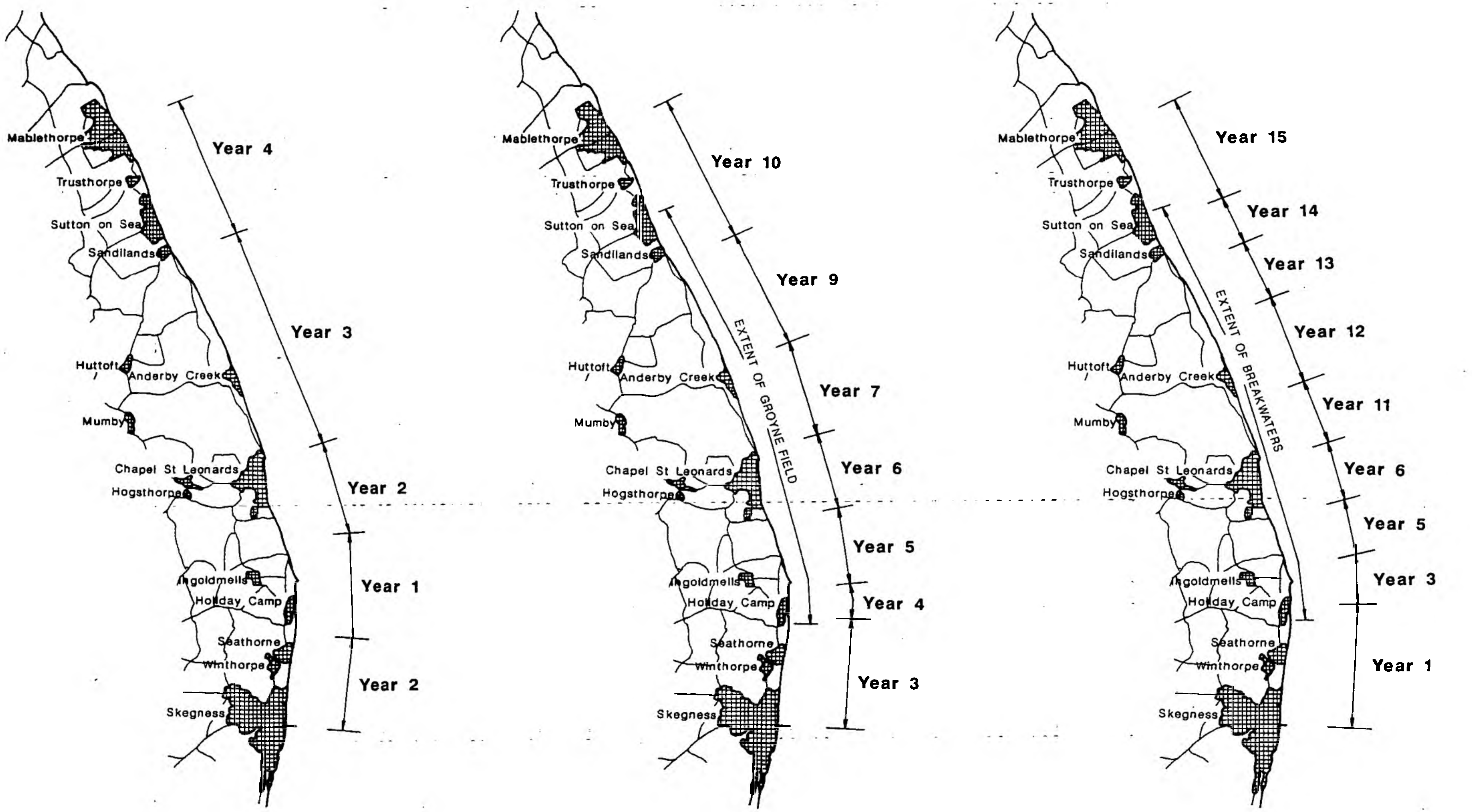
3.7 Conclusions

A total of 6 strategy options were considered and each was subjected to in depth assessment under the following headings

- Engineering viability
- Implications - particularly on coastal processes
- Constructional aspects
- Cost
- Environmental considerations, including consultation

It is considered that viable engineering solutions have been found for both the sea wall and nourishment options.

Figure 3.6



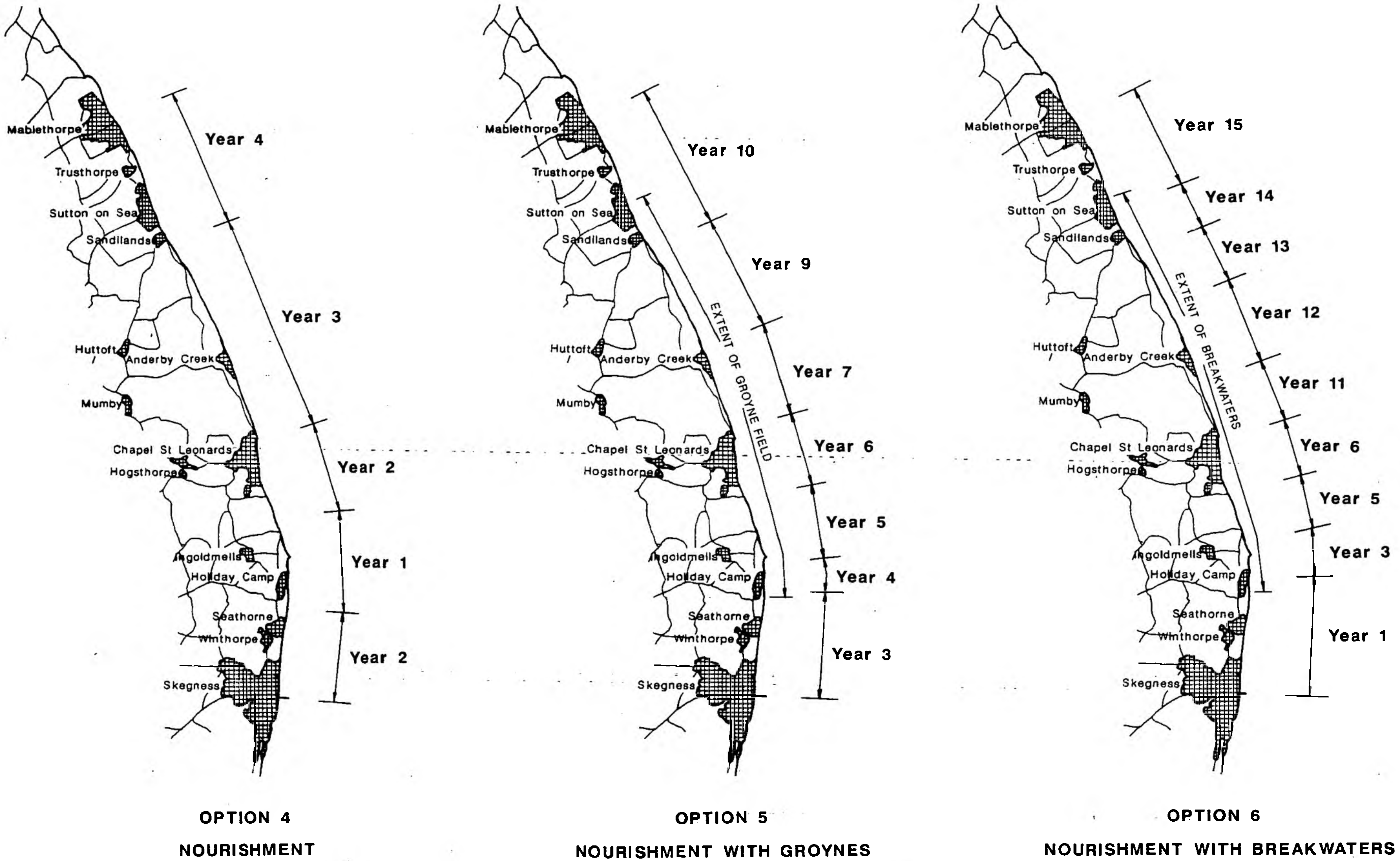
OPTION 4
NOURISHMENT

OPTION 5
NOURISHMENT WITH GROYNES

OPTION 6
NOURISHMENT WITH BREAKWATERS

NOURISHMENT IMPLEMENTATION PROGRAMMES

Figure 3.6



NOURISHMENT IMPLEMENTATION PROGRAMMES

Table 3.4

PRIMARY CONCERNS EXPRESSED DURING THE ENVIRONMENTAL CONSULTATION EXERCISE

	Aesthetics	Recognised Need For Sea Defences	Tourism/ Amenity	Turbity Resulting from Recharge Operations	Timing	Impact on Gibraltar Point	Rock Armour	Effect on N. Norfolk Coast	CaCo2 content of sediment	Dune Preservation	Preferred Approach Where Stated	
											Seawall Option	Nourishment Option
East Lindsey District Council		■	■		■							■
Lincs County Council		■				■						■
Skegness Town Council		■										
County Archaeologist/ Lindsey Archaeological Services												■
Mab & Sutton Town Council		■	■				■					■
English Nature										■		■
Lincolnshire Trust for Nature Conservation						■			■	■		■
Anderby Parish Council		■										
National Federation of Fisherman's Organisation												
East Midlands Tourist Board		■	■									■
Eastern Sea Fisheries		■		■							■	
Countryside Commission		■						■		■		■
CPRE	■	■										■
Ingoldmells Parish Council												

The sea wall options would become increasingly costly and require heavier elements to combat increasing wave forces in the future. It has also to be acknowledged that any strategy which allows foreshore erosion to persist would ultimately restrict the recreational use of the beach and therefore would have an impact on the local economy.

Under the nourishment options the existing mobility of the beach could be reduced by the introduction of a coarser graded material with longshore and on/offshore losses further reduced by groynes and breakwaters. The modelling has shown however that the degree of losses sustained by the nourishment alone does not justify the implementation of groynes or breakwaters.

The implementation of the nourishment schemes would be a largely sea based operation and as such any increase in road traffic would be minimal. There is a significant and important committment, inherent in such schemes to long term monitoring and periodic recharge of the beach.

All 6 options were therefore evaluated for economic worthwhileness related to the base line case of "Doing Nothing", details of which are set out in Section 4.2.2.

References

Appendix	9	-	Seawall Options
	9.1	-	Development of Cost Estimates
Appendix	10	-	Beach Nourishment Options
	10.1	-	Development of Unit Costs
	10.2	-	Assessment of Minimum Profile
	10.3	-	Wave Climate Study
	10.4	-	Sediment Budgets
	10.5	-	Controlling Structures
	10.6	-	Development of Cost Estimates
Appendix	11	-	Sensitivity Assessment
	11.1	-	Sea Level Rise
	11.2	-	Overtopping Limits
	11.3	-	Structural Residual Life
	11.4	-	Accelerating Beach Trends/Increased Nourishment Losses

SECTION 4

ECONOMIC EVALUATION OF OPTIONS

4.1 Introduction

The base line for the economic evaluation of all options was taken as "Doing Nothing". The potential damages associated with this are developed in Section 4.2.2. Similarly the residual damages associated with the adoption of differing seawall standards and the nourishment options (1:200 year standard) were assessed in Section 4.2.3. The benefits of each solution were derived as being the difference between the Do Nothing damages and the residual damages associated with the solution under consideration. In addition the nourishment options have the increased benefit associated with the prevention of further loss of the beaches as presented in Section 4.2.4.

4.2 Benefits

4.2.1 Data Collection

The objective of the data collection was to identify sufficient benefits, in terms of damage avoided, to justify the likely range of expenditure associated with the proposed strategies.

Accordingly, data collection was limited to some 15,000 residential properties in the immediate coastal strip. Each property was classified and coded with the full four figure reference as given in the "The Benefits of Flood Alleviation" (1). Floor levels of all properties were assessed and data used in conjunction with the "Detailed Standard Residential Depth/Damage Data" in the Penning Rowsell "Major Update 1988"(2). The main urban conurbations were subdivided into polygons and depth related damages compiled. The data was adjusted for inflation from 1987 to 1993 and for salt water damage.

The write-off or relocation costs were obtained for average values for each classification through discussion with the local manager of one of the largest estate agents in the area.

4.2.2 Do Nothing Damages

It can be argued that for a true Do Nothing approach, the failure of any one frontage on the coastline would lead to the flooding of the entire protected area. However, to be more realistic, a breach scenario was developed involving the failure of two frontages with short residual lines, Frontage 9 and Frontage 35.1 and the idealised flood areas are shown in Figure 4.1.

The damages have been calculated by looking at the risk of failure of these frontages, in the first and subsequent years, by excessive overtopping, upto the end of their residual lives, at which time they are assumed to have failed and the area flooded.

The damage values are based on the write-off values of the residential properties within the coastal margin. No allowance was made for business and commercial properties.

The damages to properties caused by overtopping without failure are insignificant compared with the write off values associated with the breach scenario.

The present day value of the resulting damages, based upon a discount factor of 6% amount to some £943 million.

4.2.3 Residual Damages

The construction of a sea defence of any given standard does not eliminate all risk of flooding. For example a 200 year defence standard leaves a risk of flooding of the order of 1/200 in any one year. This remaining risk of damage is quantified as the Residual Damage.

The calculation of the residual damages for the differing standards of the seawall and nourishment options is compounded by the continual change in standard of each frontage due to:

- falling beach levels
- rising sea levels
- rehabilitation works

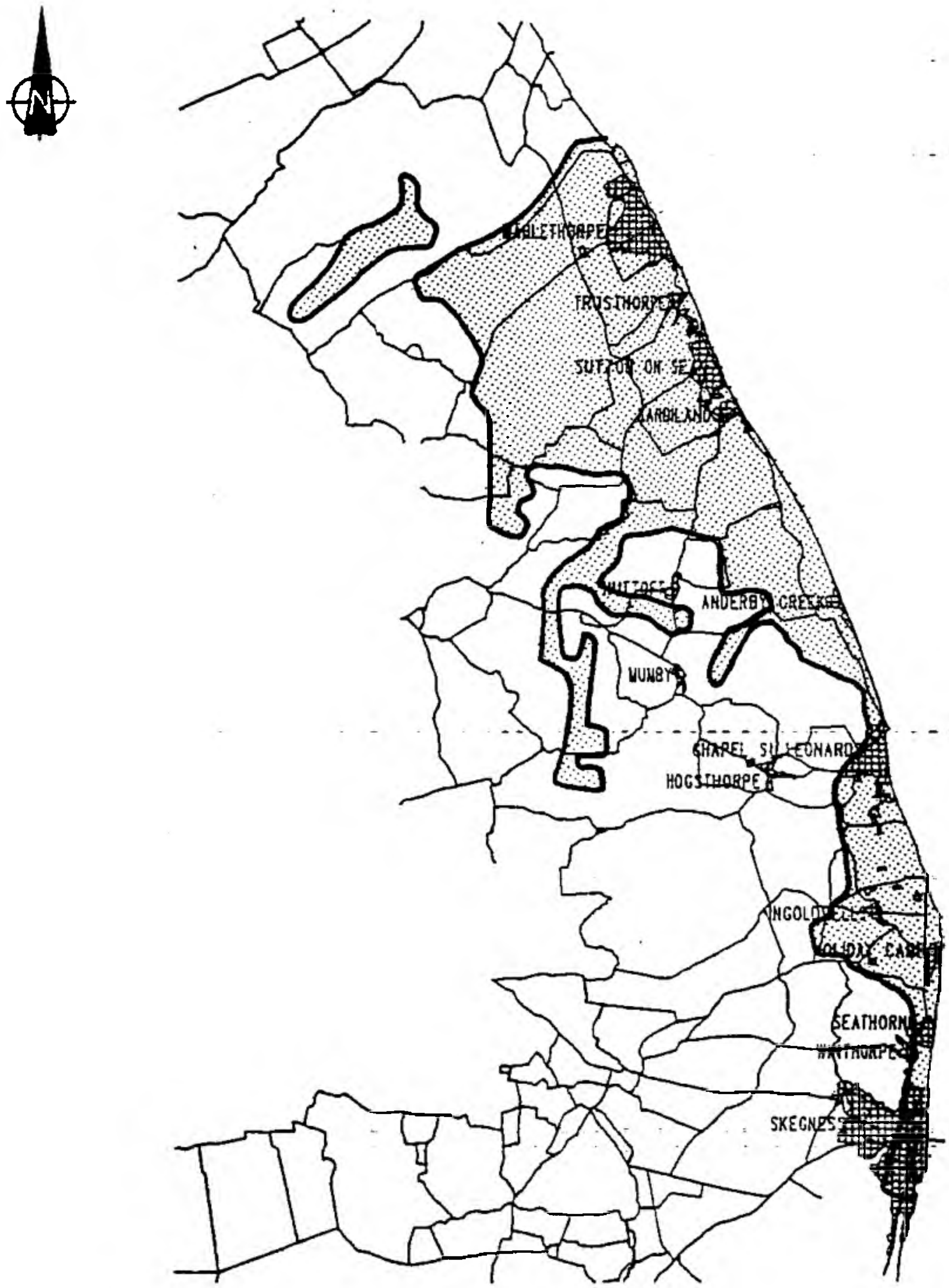
Declining standards have therefore been calculated for each year of the 50 year evaluation period with improvements linked to the programmed rehabilitation works or nourishment, as appropriate.

The coastline was divided into sections with corresponding frontages assumed to control the flooding within each section. The frontage with the lowest standard in each section, in any given year, provides the probability of a breach occurrence and the damages within that section being realised. Clearly this represents an element of approximation since the breaching of a frontage would typically result in the area of flooding being centered on the breach rather than a pre-determined section length. A more rigorous probability / damage assessment could be performed for each year of the evaluation period but it is considered that the procedure as outlined is sufficiently robust for the comparative evaluation of alternatives given the underlying viability of providing sea defences.

Detailed consideration was given to the number of sections to be adopted in the assessment. This has drawn heavily upon the flooding extent in 1953 (Figure 4.1) and the more recent occurrence at Towyn. At Towyn it was noticeable that the extent of flooding was severely compounded by the subsequent high tides with only a small residual surge element. In line with this, a flooding level approximately equal to mean high water spring tides was adopted, which when combined with an assumed storm tide profile (based on the 1953 event), results in the following coastal lengths being flooded per breach:

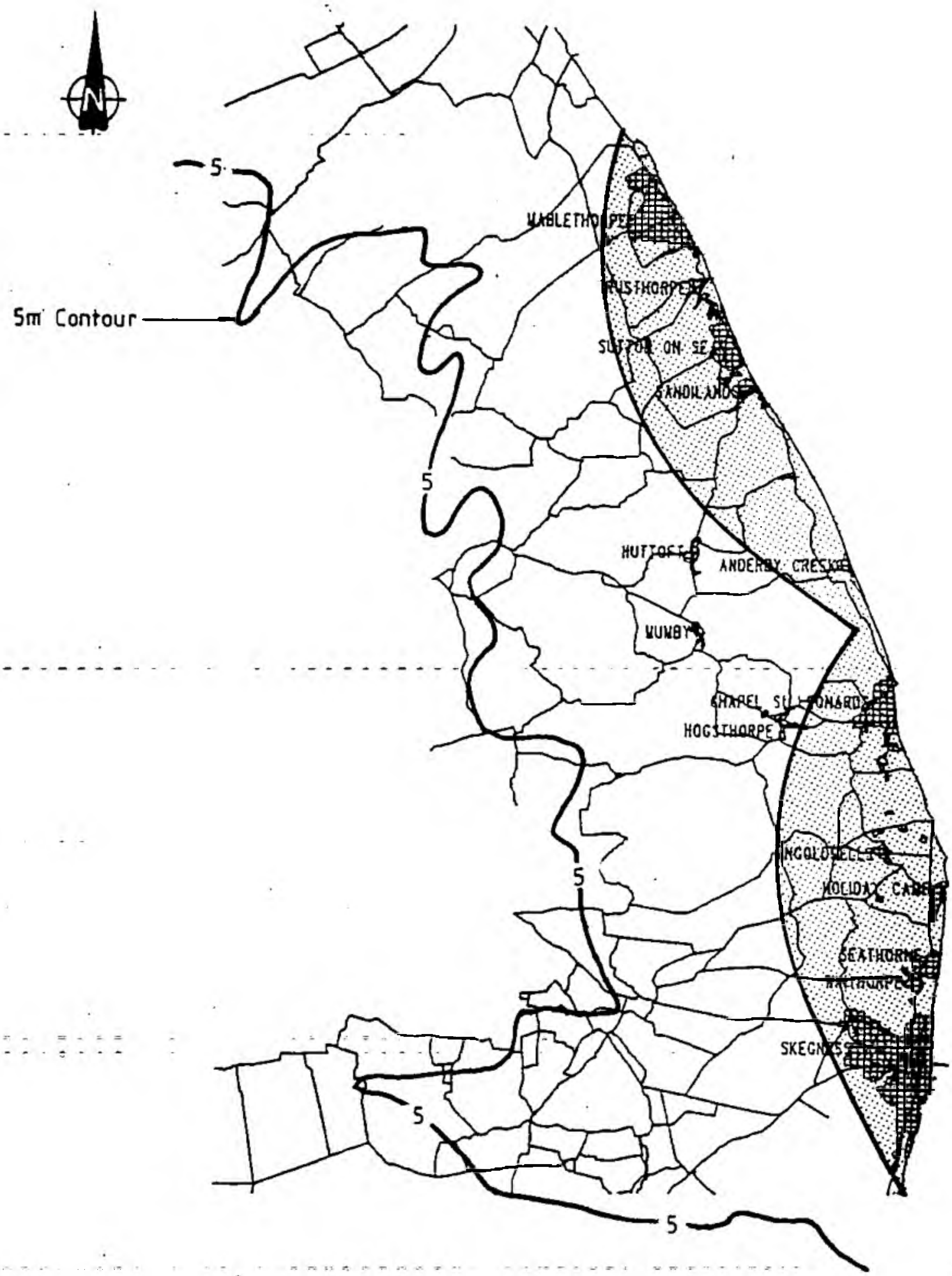
1:20 year event	8.4 kms
1:100 year event	9.0 kms
1:200 year event	10.0 kms

These lengths refer to a specific storm duration of some 4 hours. Inevitably there would be a delay in the implementation of emergency repair works which, with persistent wave action and subsequent highwaters could well extend these limits. Given a coastal frontage length of some 24kms it is considered appropriate to divide the coastline into three sections with similar damages assigned to each event.



FLOOD AREA IN 1953

Figure 4.1



IDEALISED FLOOD AREAS FOR DO NOTHING DAMAGES

The resulting residual damages associated with the proposed option were discounted at 6% per annum to give present day values as detailed in Table 4.1.

Table 4.1

DISCOUNTED DAMAGES

	Damages £ million
Do Nothing Damages	944
Sea Wall Options (Residual Damages)	
Sustain	253
1:100 year	64
1:200 year	55
Nourishment Options* (Residual Damages)	
Nourishment	58
Groynes	106
Breakwaters	134

* Although all nourishment options result in an equivalent 1:200 year standard differing residual damages occur due to programming differences within the expenditure constraints (see section 3.1).

4.2.4 Contingent Valuation of the Beach

The beach nourishment options carry a benefit in addition to the damage avoided value, namely the prevention of the further long term deterioration of the beaches. A contingent valuation survey was undertaken to assess the level of the willingness to pay to retain the amenity value of the beaches at their current level.

A detailed questionnaire was prepared covering local residents, holidaymakers and day trippers and a total of 840 surveys were completed by interview between 22nd July and 21st August. The questionnaire, interview procedures and subsequent analysis was checked and approved by Risk & Policy Analysts Limited of Loddon, Norfolk.

Beach counts were performed during the interview period and logged in relation to the weather conditions on each day. Summer beach use was assessed in accordance with average weather conditions as supplied by the Meteorological Office, Bracknell. The daily average beach use for the peak summer season was assessed at 3,600. This information enabled the study team to calculate the percentage of users interviewed and, using interview data on the average number of visits made per year, to estimate a total annual number of beach visits. This exercise produced a total present value benefit of retaining the existing beach levels of £20.9 million.

4.2.5 Sensitivity Tests

Sensitivity tests were performed for five selected frontages to examine the effects of:

- lower overtopping limits (reduced from 4 to 3 times Do Nothing limits)
- reduced residual lives (sliding scale of zero reduction at year 5 to a

reduction of 10 years at year 50)
- a higher rate of sea level rise (increased from 5mm/yr to 8mm/year)
- higher rates of foreshore erosion (2 times predicted rate at year 50)-seawall options only
- increased rates of nourishment losses (1.5 times predicted rates)-nourishment options only

The results of the sensitivity analyses were applied to adjacent frontages on a proportional basis.

4.3 Costs

4.3.1 Option Costs

The individual option costs were developed in Section 3. They are listed below. The programmes for Options 1, 2 and 3 are derived from the residual lives of the structures adjusted to give a practicable programme of works with a reasonable rate of expenditure. Options 4, 5 and 6 were developed by using a practicable rate of expenditure for dredging.

Seawall Options	1	2	3
Constructional costs (£million)	147.9	157.5	163.6
Discounted costs (£million)	77.7	95.4	104.4

Nourishment Options	4	5	6
Constructional costs (£million)	203.4	219.8	196.0
Discounted Costs (£million)	80.3	91.6	107.8

4.3.2 Sensitivities

The same sensitivity tests were applied to the costs as were used in the residual damages (section 4.2.5) so that comparisons of benefit cost ratios could be made.

	Discounted Costs in £ million		
Seawall Options Sensitivity to	1	2	3
■ Overtopping limits *	77.7	95.6	104.6
■ Residual lives	84.0	99.4	106.4
■ Sea level rise	80.2	97.6	108.6
■ Foreshore erosion	82.3	104.1	113.4

* minimal increases in cost were found but are within the overall accuracy of the cost estimates.

Nourishment Options Sensitivity to	Discounted Costs in £ million 4	5	6
■ Overtopping limits	80.3	91.6	107.8
■ Residual Lives	81.3	94.0	112.1
■ Sea Level Rise	80.7	93.7	111.8
■ Increased Losses	99.3	109.3	116.8

4.4 Economic Evaluation

Table 4.2 summarises the total discounted costs and benefits of each of the strategy options evaluated.

Option 4, beach nourishment alone, is shown to be the most economic on both benefit/cost and NPV grounds. The discounted costs of Option 4 could rise by some 22% (£18 million) before the benefit/cost ratio falls below that of the leading (1:100yr) sea wall option.

The programming of works is a critical feature in the development of options. Deferring works would improve the discounted costs, but can lead to an increase in the residual damages by allowing lower standards to exist for longer. For reasons previously explained practical limits on expenditure were used in all options to various degrees. This practical limit for both sets of options was around £10 million per annum.

In developing the discounted costs for the sensitivity tests the expenditure constraint was relaxed to enable the same option programmes to be used and so give a better base for comparison. It is evident that the seawall options are more sensitive to the various criteria adopted. Although not strictly comparable, Option 4 is shown to retain a higher benefit/cost ratio than Option 2 for the nourishment loss and foreshore erosion criteria, respectively.

References

1 - 'The Benefits of Flood Alleviation: - A Manual of Assessment Techniques'. E.C. Penning-Rowsell & J.B. Chatterton, Saxon House, 1977

2 - 'Potential Flood Damage Date: - A Major Update', Flood Hazard Research Centre, MIddlesex Polytechnic, 1988

Appendix 8 - Benefit Assessment
8.1 - Property Survey
8.2 - Do Nothing Damage Assessment
Appendix 9 - Seawall Options
9.1 - Development of Cost Estimates
9.2 - Assessment of Damages
Appendix 10 - Beach Nourishment Option
10.6 - Development of Cost Estimates
10.7 - Assessment of Damage
10.8 - Contingent Valuation Assessment
Appendix 11 - Sensitivity Assessment
11.1 - Sea Level Rise
11.2 - Overtopping Limits
11.3 - Structural Residual Life
11.4 - Accelerating Beach Trends/Increased Nourishment Losses

Table 4.2

ECONOMIC EVALUATION *

	SEAWALL OPTIONS			NOURISHMENT OPTIONS		
	Option 1 Sustain	Option 2 1:100yr	Option 3 1:200yr	Option 4 Nourish-ment alone	Option 5 plus Rock Groynes	Option 6 plus Breakwaters
Base Scheme						
Cost	77.7	95.4	104.4	80.3	91.6	107.8
Residual Damages	253.3	64.2	55.0	57.6	106.3	133.6
Nourishment Benefit	---	---	---	20.9	20.9	20.9
Benefits	690.2	879.4	888.6	906.8	858.1	830.8
Benefit/Cost (B/C)	8.9	9.2	8.5	11.3	9.4	7.7
NPV	612.5	784.0	784.2	826.5	766.5	723.0
Sensitivity (B/C) to						
Overtopping limits	7.3	9.0	8.4	11.0	8.9	7.3
Residual lives	8.3	8.8	8.3	11.1	9.1	7.4
Sea level rise	8.3	8.9	8.2	11.2	9.1	7.3
Foreshore erosion	8.3	8.4	7.8	---	---	---
Increased Losses	---	---	---	9.1	7.9	7.1

* All monetary values in £ million

SECTION 5

CONCLUSIONS

5.1 Introduction

The objective of the study was to determine the most appropriate longterm strategy for the provision of secure sea defences, considering environmental, technical and economic aspects. The following sub-sections present the conclusions drawn under each aspect and develop the recommended strategy.

5.2 Environmental

The over-riding concern of all parties is the committment to provide secure defences to ensure the continued livelihood of this extensive area.

Considerable concern remains over the aesthetic, access, and safety aspects of the seawall options. Some resistance is still evident to the preferred rock option in general, with growing concern over the use of increasingly larger rock. The use of increasing rock sizes would continue as the beaches continue to fall allowing higher waves reach the sea defences. Disruption during construction would also increase in relation to the size and scope of the future schemes.

The continued loss of the foreshore would increasingly limit their recreational use with associated impacts on the local economy. The beaches play a prominent role in the advertising of the area and are considered to be a vital element in the attraction of holidaymakers to the area.

The nourishment approach is preferred on aesthetic, tourism, recreation and nature conservation grounds. Clearly its adoption would have a greater impact on the existing coastal processes, but mitigating measures would have to be adopted to ensure the maintenance of the coastal sediment feed to Gibraltar Point.

Whilst the nourishment option cannot be strictly classed as a sustainable development, in that it requires replenishment from offshore sources, it does provide a solution which meets the needs of the present without compromising the ability of future generations to meet their own needs.

The seawall approach fails to achieve this because the consequent continuing erosion of the clay is irreversible and would provide future generations with an ever increasing burden of providing secure sea defences on an eroding foreshore.

5.3 Technical

It is considered that viable engineering solutions can be found for both the seawall and nourishment options.

The seawall options would in the future become increasingly costly and require heavier elements to combat the increasing wave forces. The use of larger rock could become unacceptable on environmental grounds in future years.

Under the nourishment options, the existing variability in beach levels could be reduced by the introduction of coarser sand.

Modelling has shown that the degree of losses sustained by the nourishment alone option does not justify the implementation of effective groynes or breakwaters. However, it is considered necessary to retain and rehabilitate certain seawalls where the likelihood of retaining an effective berm width in front of the defences is low.

Option 4 takes account of this, and together with a nourished beach with a berm width of 15 m at +4.5 mOD and a 1:25 slope would, with adjustments dependant on location, provide a satisfactory technical strategy. The adoption of such a strategy, however, requires the firm commitment to renourishment in future years to maintain the necessary level of defence. For this to be effective, detailed monitoring, (to assess performance) future design modifications and maintenance requirements also involve a similar commitment.

5.4 Economic

The economic evaluation reviewed six options and has shown the nourishment option, without controlling structures (Option 4), to be the most cost effective on benefit/cost and NPV grounds. The standard of service of this option is 1:200 yr, although the same values would also apply to a 1:100 yr standard. The second ranked option is the 1:100 yr seawall approach (Option 2). The sensitivity criteria considered demonstrate this order of ranking to be effectively maintained, with an approximate 22% cushion on the discounted costs of Option 4.

5.5 Preferred Strategy

Environmental, technical and economic considerations favour the adoption of nourishment. Of these Option 4 was shown to be the most cost effective as well as being robust to sensitivity criteria.

The preferred strategy is therefore to adopt Option 4, nourishment alone as set out above, which includes the commitment to monitoring and recharge.

SECTION 6

RECOMMENDATIONS FOR IMPLEMENTATION

6.1 Strategy Details

The proposed nourishment programme in relation to the residual lives of the existing sea defences is presented in Figure 6.1. By inspection it is apparent that certain frontages would require rehabilitation prior to the nourishment to ensure the desired ultimate defence line. Some of these frontages would require reconstruction prior to 1993. These have not been included in the strategy. All works after 1993 between Mablethorpe and Skegness have been included. Table 6.1 summarises all frontages requiring rehabilitation and those which would require further capital expenditure to accommodate abrupt changes in the coastline:

Table 6.1

SEAWALL FRONTAGES

Requiring Rehabilitation (yrs 1993-95)	Requiring Future Capital Expenditure (yrs 2013-33)
0.3	5.1
6	5.3
7	7
8	10
9	14
35.1	34
45	41
46	

The nourishment works are programmed to occur in the years 1994 to 1997 inclusive, commencing in the first year between Frontages 3 and 9 with subsequent stages as shown in Figure 3.6. The adoption of this initial frontage length would permit the performance of the nourishment to be more accurately monitored under the influence of the predicted net southerly longshore transport because the southern end of the nourishment will be allowed to 'run free'. After the first year the southern end would be nourished and constrained by the ample sand at Skegness. Local Planning Permission for beach nourishment is not required.

An indicative renourishment programme has been detailed in Figure 3.5 and shows the years when renourishment would be required and where. However these results were developed for use in the economic evaluation and are likely to change after the results of monitoring are known. Also to continue to maintain a realistic dredging cost some rationalisation of renourishment may have to take place.

6.2 Recommendations

In order to start nourishment in 1994 it is necessary to undertake certain actions as a matter of priority.

- submit this report to MAFF for agreement
- obtain extraction licence
  - apply for a prospecting licence for the proposed borrow area
  - implement a prospecting programme

INITIAL NOURISHMENT PROGRAMME

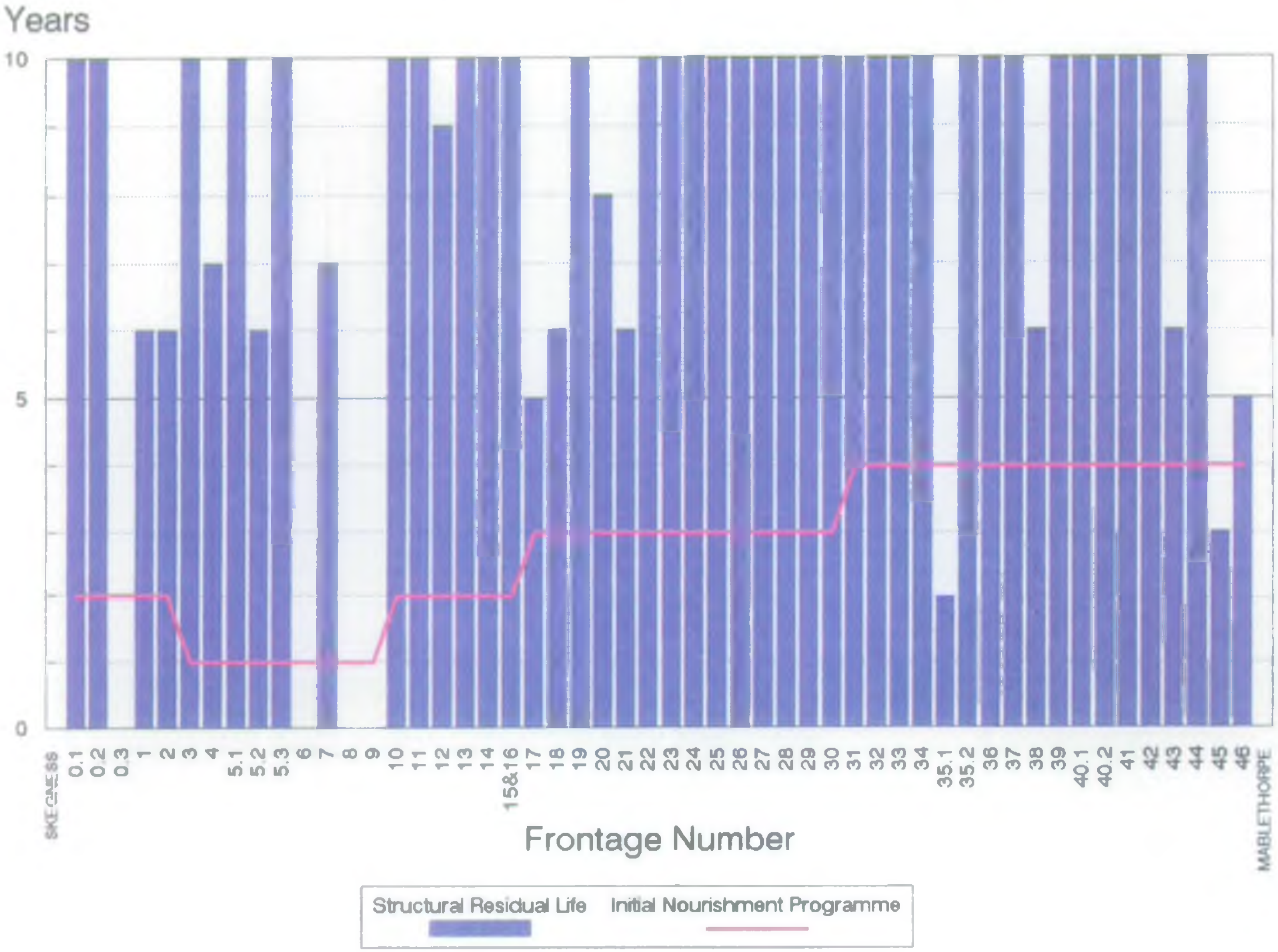


Figure 6.1

- apply for an extraction licence for the selected borrow area
- negotiate extraction royalties with the Crown Estate Commissioners

- prepare a detailed specification for the monitoring of the beach
- implementation and interpretation of baseline monitoring from 1993
- carry out detailed design and prepare specification and contract documentation
- continue consultation with interested and affected parties
- include the following capital expenditure in the Medium Term Plan: (1993 prices)

	£
1993/94	6,506,044
1994/95	12,792,647
1995/96	11,797,312
1996/97	13,528,686

Experience has shown that the total elapsed time required to obtain an extraction licence is of the order of 2 years.

The implementation of this strategy would involve the following non-construction costs over the next 50 years.

Actual Cost	£7,468,080
Discounted Cost	£3,308,214

The expenditure profile, incurred costs and the non-construction costs are included for the preferred option as Appendix C.

Appendix A

MABLETHORPE TO SKEGNESS SEA DEFENCES SCHEME

STRATEGIC APPROACH STUDY

AUTHORITY BRIEF

1. The Mablethorpe to Skegness Sea Defences Scheme is a series of works intended to provide an adequate standard of sea defence along the 24km coastal frontage between Mablethorpe and Skegness. (see attached 1:50000 scale plan).

2. The existing sea defence consists of alternate lengths of revetment (of various types) and concrete slab or stepwork structures complete with wavewalls etc. The defence was breached in several places and generally extensively damaged during the 1953 flood and the existing construction dates largely from the rebuilding thereafter (although some lengths did survive the flood).

3. Additionally, after 1953, groyne construction works were carried out resulting in a system of approximately 270 no groynes (260 timber, 10 asphalt). The system is now dilapidated over many parts of the frontage.

4. Since 1953, a programme of works has been in progress to reconstruct and, where necessary, improve the sea defences.

5. The reconstruction has consisted generally of a new facing of concrete stepwork although some current and planned schemes include the use of rock armour and "Seabee" concrete armour units. The need for this work is due to the general deterioration of the sea defence structure and ongoing beach erosion.

6. Improvements have involved the construction of splash walls/embankments and decking together with the provision of gated walls across access pullovers where the need was identified as a result of the 1976 and 1978 storm surge events.

7. Due mainly to limited funding, works to date have not addressed the problem of beach erosion. Attention and expenditure have been concentrated on providing a secure sea defence that would not breach or be substantially overtopped during storm events. The current use of rock armour and Seabee units (together with the reinstatement of the groynes over a length of 40 metres at their landward ends) is intended to both provide a secure sea defence and, by reducing wave reflection, avoid worsening the beach erosion.

8. It is anticipated that the ongoing major programme of reconstruction works will be largely completed within the next few years. (Although there will always be a need for some reconstruction works thereafter). It is therefore proposed to institute a series of "strategic works" which will be directed at providing higher beach levels along the whole 24km frontage. From the sea defence point of view, such higher beach levels will have the benefit of reducing the frequency and severity of wave attack on the sea defence structures, thereby:-

   (i) prolonging the lives of lengths recently reconstructed

   (ii) delaying the need to reconstruct other lengths

   (iii) reducing the amount of overtopping

(iv) mitigating the effects of rises in sea level.

In addition there are likely to be other benefits, eg to amenity.

9. Consulting Engineers are required to comprehensively investigate the feasibility of strategic works and in particular the study shall:-

(i) take the form of a Stage B Project Appraisal

(ii) include such mathematical modelling as is necessary

(iii) formulate and evaluate options for the works, eg offshore breakwaters, artificial headlands, beach nourishment etc or combinations thereof

(iv) include an Environmental Statement

(v) examine the financial worthwhileness

(vi) if necessary, include ground investigations, other preliminary investigations, physical model testing and/or site trial works

(vii) select a preferred scheme

(viii) compile a design brief and the data necessary for design and construction of the preferred scheme.

More details are given below.

10. (i) Formal minuted Project Group meetings will be held in accordance with the attached procedural note "Project Groups and Project Appraisal Panel". The Consulting Engineers shall provide the Project Engineer in the Group and shall be responsible for minuting the Group Meetings.

(ii) The Feasibility Report shall be prepared in accordance with the attached Format for Stage B Detailed Appraisal Reports.

(iii) The Consulting Engineers shall assist the Authority's Project Manager in presenting the Report to the Project Appraisal Panel (Section 6 of the Project Groups procedural note).

11. (i) Options shall take account of a secular rise in sea level of 5mm/annum.

(ii) The height and adequacy of the existing sea defences shall be investigated and if necessary options shall include defence raising and/or strengthening measures to minimise overtopping (having regard to the recommendations of the Flood Protection Research Committee and Report No. EX924 as published by Hydraulics Research Limited) and ensure that the defences could be reasonably expected to withstand greater than design conditions without undue risk of breaching.

(iii) Options shall include defence raising and/or strengthening measures necessary if, for whatever reason, strategic works are not implemented.

(iv) Options shall include any works necessary to protect legitimate safety, amenity, access, conservation and other environmental interests including those identified in the Environmental Statement.

12. (i) The Environmental Statement shall be prepared in accordance with the letter dated 18th July 1988 from the Ministry of Agriculture, Fisheries and Food and as described in the Schedule to S I no 1217 (copies attached). (The Ministry letter refers to "Assessment" rather than "Statement").

(ii) The Environmental Statement shall, where relevant, encompass means of carrying out the works (eg. transportation to and from site) and sources of material (eg. sand for beach nourishment, timber for groynes etc).

(iii) The Environment Statement shall take account of the views of interested/affected parties including those on the list attached. The beaches and sea defences are used extensively by the public; the District and Parish Councils, local population, visitors, and holiday makers are very sensitive about coastal works including their appearance, access arrangements, safety aspects and timing of construction.

(iv) The Environmental Statement shall as far as practicable be an independent report and shall be bound as a separate document. It shall be prepared by a team with the necessary experience and expertise. Subject to the Authority's approval to the composition of the team, the Consulting Engineers may use their own staff (if appropriate, supplemented by sub-consultants) or they may employ an outside organisation. On Conservation aspects the teams shall liaise closely with the conservation Officer of the Authority's Anglian Region.

13. (i) The worthwhileness of retaining the existing sea defence alignment between Mablethorpe and Skegness has been investigated and confirmed. (See attached benefit/cost calculation dated 7th August 1989). For reasons of simplicity (not because they are unimportant or of low value), loss of life, structural damage, flood damage to caravans and indirect and intangible benefits have not been included.

(ii) Based therefore on avoidance of flood damage to residential properties alone, the capitalised benefit is approximately £1,455 million.

Construction cost of the necessary work (ignoring the possibility of strategic works) along the whole frontage has been assessed section by section and, by taking account of the likely phasing, the present day value has been estimated at some £57 million. The benefit/cost ratio is therefore about 25.

(iii) The current planned expenditure (taking account of the construction phasing used in the above benefit/cost calculation and present priorities) is set out in the attached table.

(iv) Examination of the financial worthwhileness of strategic works shall have regard to the Ministry's "Investment Appraisal of Arterial Drainage, Flood Protection and Sea Defence Schemes - Guidance for Drainage Authorities" as attached. (NB Treasury Discount rate is now 6%).

14. Ground investigations, other preliminary investigations, physical model testing and/or site trial works may be necessary inter alia to verify the performance of strategic works, quantify overtopping of the sea defences, resolve potential design and construction problems, determine realistic coast etc. They shall be ordered and carried out in accordance with NRA and Ministry procedures (see para 18 below.

15. (i) If the preferred scheme is not financially worthwhile on sea defence grounds alone, tenable reasons shall be given for

a. its selection and/or
b. seeking contributions

(ii) If strategic works cannot be substantiated because of unacceptable environmental impact (despite accommodation works - see para 11(iv) above) the preferred scheme shall relate solely to any necessary defence raising and/or strengthening measures.

(iii) Timing and phasing of the preferred scheme shall:

a. include locations and details of work together with annual expenditures

b. recognise the likely constraints on funding works expenditure on the Mablethorpe to Skegness Sea Defences Scheme significantly greater than the totals given in the table referred to in para 13(iii) viz:-

Year	1990/91	1991/92	1992/93	1993/94 et seq
£ million	6	6	5	11

16. Detailed design and supervision of construction of the preferred scheme will be carried out by Authority staff and/or by Consulting Engineers under appointment(s) separate from and additional to the Strategic Approach Study. The Strategic Approach Study shall include a design brief and the data necessary to enable design and construction of the preferred scheme.

17. (i) The attached 1:50000 plans (3 sheets) show the locations of beach sections which have been surveyed at generally monthly intervals as follows:-

Stations 1 to 3 from 1986
Station 4 from 1968
Station 5 from 1959
Station 6 not known
Stations 7 and 8 from 1975
Stations 9 to 26 from 1959
Station 27 to 30 from 1989

(ii) In 1986 a study was carried out to review the historical performance of the groynes on the Lincolnshire coast and a copy of the study report forms part of this Brief and is enclosed with the Tender Documents.

(iii) The Anglian Regional Sea Defence Management Study is at present being carried out by Sir William Halcrow & Partners Limited and an Information Summary is attached. Stage 2 has been completed and copies of the Strategy Report and Supplementary Studies Report form part of this Brief and are enclosed with the Tender Documents. The Atlas is available for inspection.

(iv) Since 1986 many discrete lengths of sea defence have been reconstructed and reports of Project Appraisal, Ground Investigations and Physical Model Testing are available as set out in the attached schedule. A typical Project Appraisal Report (Part 24: South of Trunch Lane) is enclosed with the Tender Documents.

18. (i) Attention is drawn to Clause 12 of the Form of Appointment (as included with the Tender Documents) that the Consulting Engineers shall observe and comply with the provisions and requirements of the Authority's rules and procedures and shall implement and use standard documents and forms etc.

(ii) The Authority wishes to maximise the amount of grant aid from the Ministry of Agriculture, Fisheries and Food and the Consulting Engineers shall therefore have regard to the grant regulations of the Ministry in respect of ground investigations, other preliminary investigations, model testing, site trial works and any other part of the Strategic Approach Study which may be eligible for grant aid.

19. Appendix A gives details of documents forming part of this Brief.

APPENDIX A

Documents

Paragraph No.

1	1:50,000 scale plan
10(i)	Project Groups and Project Appraisal Panel
10(ii)	Stage B - Detailed Appraisal Report Format
12(i)	Ministry of Agriculture, Fisheries and Food letter dated 18th July 1988
	Schedule to Statutory Instrument no. 1217
12(iii)	Interested/affected parties
13(i)	Benefit/cost calculation dated 7th August 1989
13(iii)	Current planned expenditure
13(iv)	Investment Appraisal of Arterial Drainage, Flood Protection and Sea Defence Schemes - Guidance for Drainage Authorities
17(i)	1:50,000 scale plans (3 No.) showing locations of beach sections
17(ii)	A Review of the Historical Performance of the Lincolnshire Groynes
17(iii)	Sea Defence Management Study: Information Summary
	Sea Defence Management Study: Stage 2 Strategy Report and Supplementary Studies Report
17(iv)	Schedule of reports of Project Appraisal, Ground Investigations and Physical Model Testing
	Project Appraisal Report of Part 24: South of Trunch Lane

Appendix B

Study Frontages

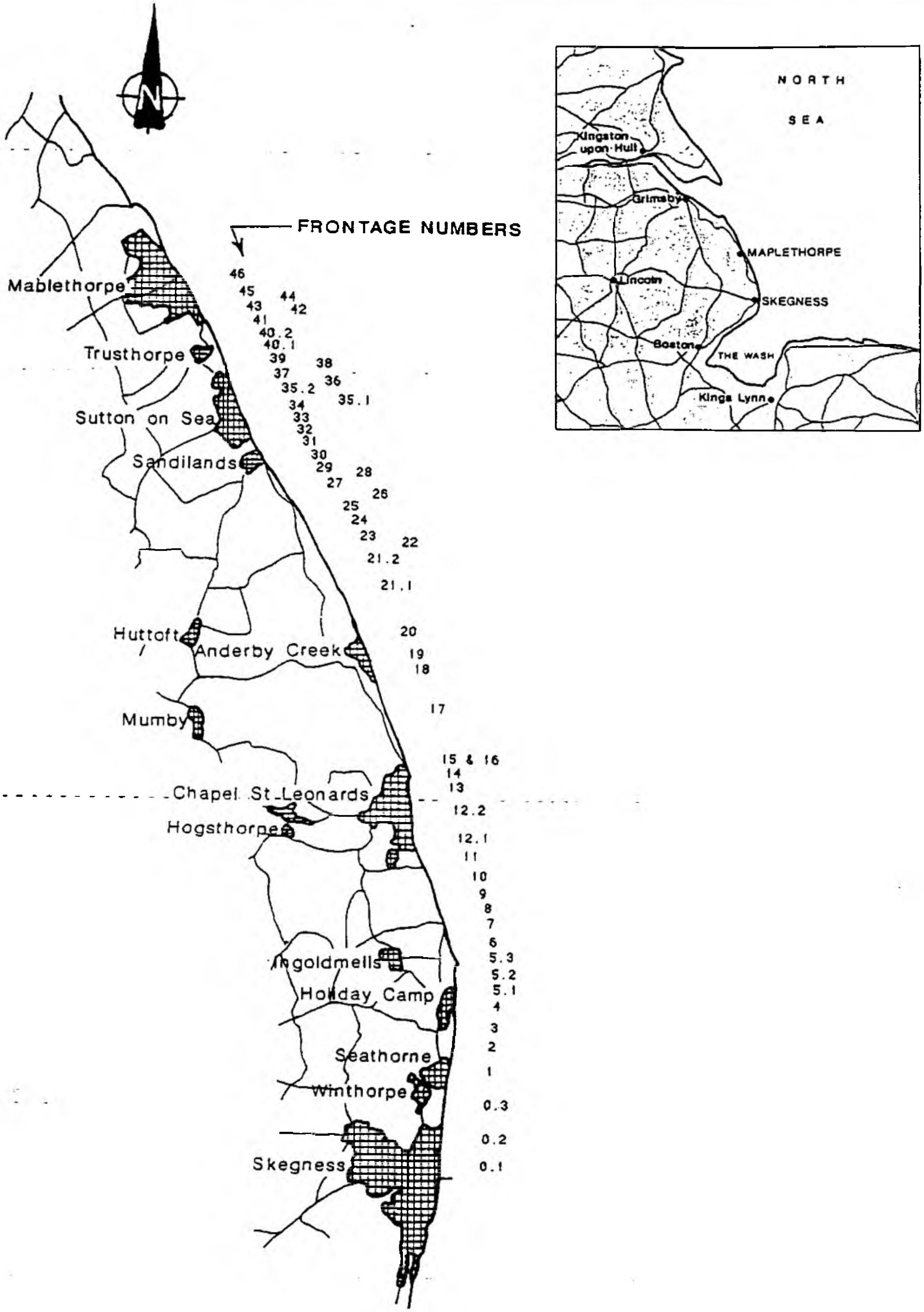
Frontage No.	Length (m)	Existing type of Construction as at 1st April 1993	Location
0.1	590	Seabee Armour Units	Skegness Pier to Sea View Pullover.
0.2	870	Seabee/Rock Armour *	Sea View Pullover to North Shore.
0.3	700	Reveted Dunes	North Shore to Winthorpe Avenue.
1	830	Concrete Stepwork	Winthorpe to Carey House.
2	450	Concrete Stepwork	Carey House to N of Jacksons Corner.
3	450	Concrete Stepwork	N of Jacksons Corner to Midpoint Butlins.
4	710	Concrete Stepwork	Midpoint Butlins to Whitehouse Corner.
5.1	300	Concrete Stepwork	Whitehouse Corner.
5.2	500	Concrete Stepwork	Whitehouse Corner to Ingoldmells Point.
5.3	150	Concrete Stepwork	Ingoldmells Point.
6	740	Grouted Stone Revetment	Ingoldmells Pt to access S of Vickers Pt.
7	390	Seabee Armour Units	Access S of Vickers to N of Vickers Point.
8	210	Concrete Stepwork	N of Vickers Point.
9	450	Concrete Stepwork	S of Chapel Lake.
10	440	Rock Armour Toe	N of Chapel Lake.
11	510	Rock Armour Toe	Trunch Lane.
12.1	570	Rock Armour Toe	North of Trunch Lane.
12.2	1230	Grouted Stone Revetment	Trunch Lane to Chapel Basin.
13	100	Concrete Stepwork	Chapel Basin.
14	190	Rock Armour Toe	Chapel Point.
15 & 16	380	Concrete Stepwork	North of Chapel Point.
17	2030	Grouted Stone Revetment	Foxholes to S of Anderby Outfall.
18	190	Reveted Sand Dunes	Anderby Sewage Works.
19	360	Reveted Sand Dunes	Anderby Creek.
20	790	Reveted Sand Dunes	Anderby Creek to Moggs Eye.
21.1	1910	Grouted Stone Revetment	Moggs Eye to Huttoft Boat Ramp.
21.2		Seabee Armour Units *	Huttoft Car Terrace
22 & 23	590	Rock Armour Toe	N of Huttoft Car Terrace.
24	350	Concrete Stepwork	S of Fairway Cottage.
25	200	Concrete Stepwork	Fairway Cottage.
26	370	Seabee Armour Units	Fairway Cottage to Boygrift Outfall.
27	350	Concrete Stepwork	Boygrift Outfall.

* Proposed Construction

Study Frontages Cont/...

Frontage No.	Length (m)	Existing type of Construction as at 1st April 1993	Location
28	210	Rock Armour Toe	Sandilands Club House.
29	480	Rock Armour Toe	Sandilands.
30	220	Rock Armour Toe	Sandilands Pullover to Acre Gap.
31	460	Concrete Slab Revetment	Acre Gap to Church Lane Pullover.
32	280	Concrete Stepwork	N of Church Lane Pullover.
33	260	Concrete Stepwork	S of Garden Cafe.
34	220	Voided Stepwork	Garden Cafe to Sutton Pullover.
35.1	400	Concrete Slab Revetment	Sutton Pullover to Bohemia Point
35.2	70	Concrete Stepwork	Sutton Pullover to Bohemia Point
36	160	Concrete Stepwork	Bohemia Point
37	160	Concrete Stepwork	N of Bohemia Point
38	370	Concrete Stepwork	N of Bohemia Point
39	170	Concrete Stepwork	Trusthorpe
40.1	350	Voided Stepwork	S of Trusthorpe Outfall
40.2	405	Concrete Stepwork	S of Trusthorpe Outfall
41	200	Rock Armour Toe *	N of Trusthorpe Outfall
42	230	Concrete stepwork	S of Gibraltar Road
43	170	Concrete stepwork	Convalescent Home
44	150	Rock Armour Toe *	N of Convalescent Home
45	180	Concrete Stepwork	Mablethorpe
46	830	Concrete Stepwork	Mablethorpe

* Proposed Construction



THE STUDY FRONTAGES

Appendix C

OPTION 4
EXPENDITURE STREAM

(Price base = 1990)

(Year 0 = 1993/4)

Actual Costs

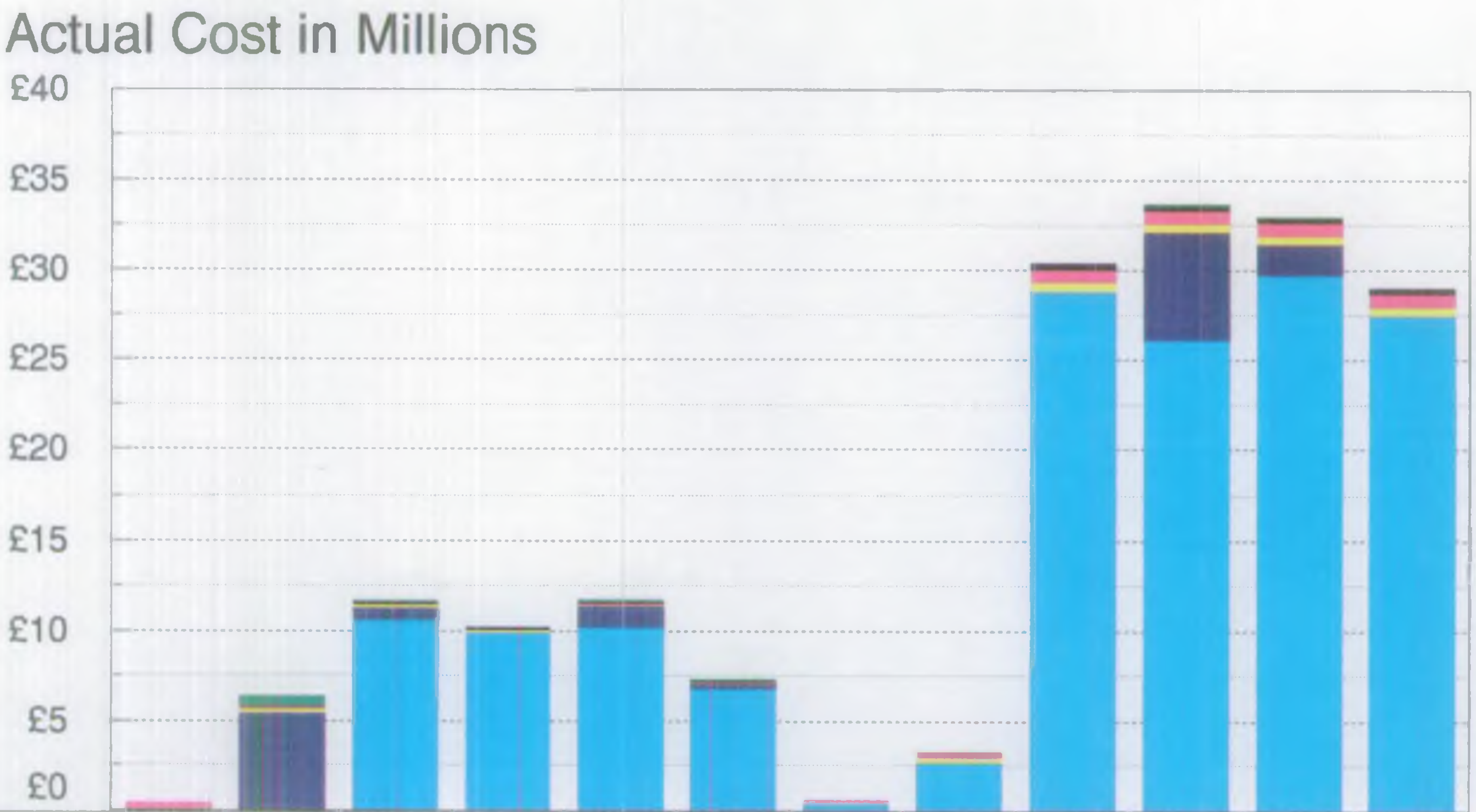
Year	Initial Nourishment	Re-Nourishment	System Recharge	Seawall Rehabilitation	Outfalls	Maintenance	Total
0				£5,462,600		£190,640	£5,653,240
1	£10,577,934			£162,500	£519,000	£167,600	£11,427,034
2	£9,905,251					£126,440	£10,031,691
3	£10,220,746			£196,200	£942,000	£78,140	£11,437,086
4	£5,098,851		£1,663,200		£285,000	£47,660	£7,094,711
5			£415,800			£47,660	£463,460
6-10		£607,827	£2,079,000			£238,300	£2,925,127
11-20		£24,694,959	£4,158,000			£476,600	£29,329,559
21-30		£21,968,203	£4,158,000	£5,963,192		£476,600	£32,565,995
31-40		£25,570,453	£4,158,000	£1,690,500		£476,600	£31,895,553
41-50		£23,329,758	£4,158,000			£476,600	£27,964,358
						TOTAL	£170,787,814

Discounted Costs

Year	Initial Nourishment	Re-Nourishment	System Recharge	Seawall Rehabilitation	Outfalls	Maintenance	Total
0				£5,462,600		£190,640	£5,653,240
1	£9,979,183			£153,302	£489,623	£158,113	£10,780,221
2	£8,815,638					£112,531	£8,928,169
3	£8,581,536			£164,733	£790,921	£65,608	£9,602,798
4	£4,038,768		£1,317,410		£225,747	£37,751	£5,619,676
5			£310,710			£35,614	£346,324
6-10		£348,741	£1,308,823			£150,020	£1,807,584
11-20		£10,542,527	£1,708,869			£195,875	£12,447,271
21-30		£5,165,374	£954,224	£1,322,216		£109,375	£7,551,189
31-40		£3,111,480	£532,833	£271,508		£61,075	£3,976,896
41-50		£1,622,716	£297,531			£34,104	£1,954,351
						Residual Value	(£1,219,035)
						TOTAL	£67,448,684
						Inflated to 1993	£80,332,462

Non–Construction Costs Associated with Option 4

	Actual	Discounted @ 6% /annum
Pre–Dredging Costs (inc Extraction Licence, Prospecting and Negotiation of Royalties)	£300,000	£300,000
Beach Monitoring Initial Set Up Costs (inc Specification and Models)	£68,000	£68,000
Annual Costs (inc Surveying and administration)	£3,900,000	£1,332,140
Beach Nourishment Initial Costs (inc Design and Documentation)	£60,000	£60,000
Annual Costs (inc Design, Head Office costs and Site supervision)	£460,000	£399,971
Beach Recharge and Re–Nourishment (Design, Supervision and Head Office at 1% of Capital Cost)	£1,152,981	£259,038
Seawall Rehabilitation (Design, Supervision and Head Office. at 10% of Capital Cost)	£1,347,499	£738,436
Outfall Reconstruction (Design, Supervision and Head Office. at 10% of Capital Cost)	£174,600	£150,629
TOTAL	£7,463,080	£3,308,214



Years	-1	0	1	2	3	4	5	6-10	11-20	21-30	31-40	41-50
Nourishment			£10,577,934	£9,905,251	£10,220,746	£6,762,051	£415,800	£2,686,827	£28,852,959	£26,126,203	£29,728,453	£27,487,758
Seawalls		£5,462,600	£681,500		£1,138,200	£285,000				£5,963,192	£1,890,500	
Maintenance		£190,640	£167,600	£126,440	£79,140	£47,660	£47,660	£238,300	£476,600	£476,600	£476,600	£476,600
Monitoring	£413,000	£105,000	£75,000	£75,000	£75,000	£75,000	£75,000	£300,000	£750,000	£750,000	£750,000	£750,000
Design Nour			£105,779	£99,053	£102,207	£87,621	£4,158	£26,868	£288,530	£261,262	£297,285	£274,878
Design Seawalls		£546,260	£68,150		£113,820	£28,500				£58,632	£16,905	
Year Totals	£413,000	£6,304,500	£11,675,963	£10,205,744	£11,728,113	£7,285,832	£542,618	£3,251,995	£30,368,089	£33,636,889	£32,959,743	£28,989,236

COSTS INCURRED FOR OPTION 4

(Including non-construction & maintenance)

(Year 0 = 1993)