Scarborough Borough Council

Filey Bay Coastal Defence Strategy Study

Strategy Report (Final)

October 2002

Halcrow Group Limited

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Scarborough Borough Council

Filey Bay Coastal Defence Strategy Study

Strategy Report (Final)

Contents Amendment Record

This report has been issued and amended as follows:

Issue	Revision	Description	Date	Signed
1	0	Draft (in 3 volumes)	June 2001	
2	0	Revised draft for consultation	Sept 2001	
3	0	Final	Oct 2002	[signature]

Contents

Annexes (in separate volume)

1 Introduction

1.1 *Background & Scope of Study*

Halcrow were commissioned by Scarborough Borough Council to assist in producing a coastal defence strategy study for Filey Bay.

The study covers Coastal Process units 27 to 31 as defined in the Huntcliffe to Flamborough Head Shoreline Management Plan (SMP), see Figure 1.1. The strategy follows on from the SMP, considering the management units within Filey Bay in more detail, reviewing recommended management policies and identifying appropriate options for implementation.

This document presents the coastal strategy study for Filey Bay. It is supported by a series of technical appendices provided in a separate document. A separate Executive Summary presents the key findings of the strategy study together with an action plan for implementation.

1.2 *Objectives of the Study*

The strategy study will:

- provide information on the condition and performance of existing defences;
- identify options to provide cost-effective and efficient coast protection for a strategy duration of 50 years;
- identify a preferred option for each discrete length of coastline
- recommend a preferred programme of work;
- provide information that can be subsequently used in the design of future coast protection.

Key objectives of the strategy are:

- a quantitative risk assessment for existing or potential future coastal defences;
- predictions of cliff recession rates on unprotected lengths of coastline;
- proposed coastal defence and slope stabilisation works, to provide appropriate levels of coastal protection for the next 50 years;
- an assessment of the sediment budget for Filey Bay;

- preservation of property and safety of the public;
- elimination / reduction of landslip / cliff recession risk in defended areas;
- reduction in risk to coastal defences from coastal instability;
- identification and evaluation of assets at risk from coastal erosion.

A key component of the strategy study was a detailed cliff mapping study. This quantified cliff recession rates, allowing zones at risk within the strategy lifetime to be identified. This assisted in the development of the strategy, allowing prioritisation of intervention works and was also used to provide planning guidance for the coastal zone.

1.3 *Format of document*

Following this introduction, Chapter 2 describes the physical features of the Bay, including geology, geomorphology, and features of the foreshore and seabed. Hydrodynamics within the Bay are presented in Chapter 3, including the results of wave modelling studies undertaken as part of the Study.

The detailed cliff assessment studies that were undertaken are presented in Chapter 4, including quantification of the sediment contribution into the Bay from the cliffs and mapping of cliff geomorphology and recession potential. Coastal processes within the Bay are discussed in Chapter 5, including findings from historic map analysis and sediment transport modelling that was undertaken, and an assessment of the sediment budget. The Strategic Environmental Assessment process is summarised in Chapter 6. Environmental Objectives are identified and the implications of the 'do nothing' scenario are discussed. The full Strategic Environmental Assessment is provided in Annex D. The existing defences along the frontage are identified and described in Chapter 7, where an assessment of their condition is made and key issues noted.

Chapter 8 discusses the approach to assessing alternative strategic options for the Bay, with each management unit being considered in more detail in Chapter 9. Reference is made in Chapter 9 to the environmental and economic assessment of the strategic options, which are presented in more detail in Annexes D and E.

Recommendations and conclusions are given in Chapter 10, together with a summary comparison with the Shoreline Management Plan and identification of key differences in recommended policy where appropriate. An Implementation Plan is given in Chapter 11.

During the study, the particular risk to property in the short term at Flat Cliffs was identified. Site Investigation work was therefore undertaken to provide information for a stability analysis of the area, to inform future planning. The Site Investigation and stability analysis is reported in Annex F.

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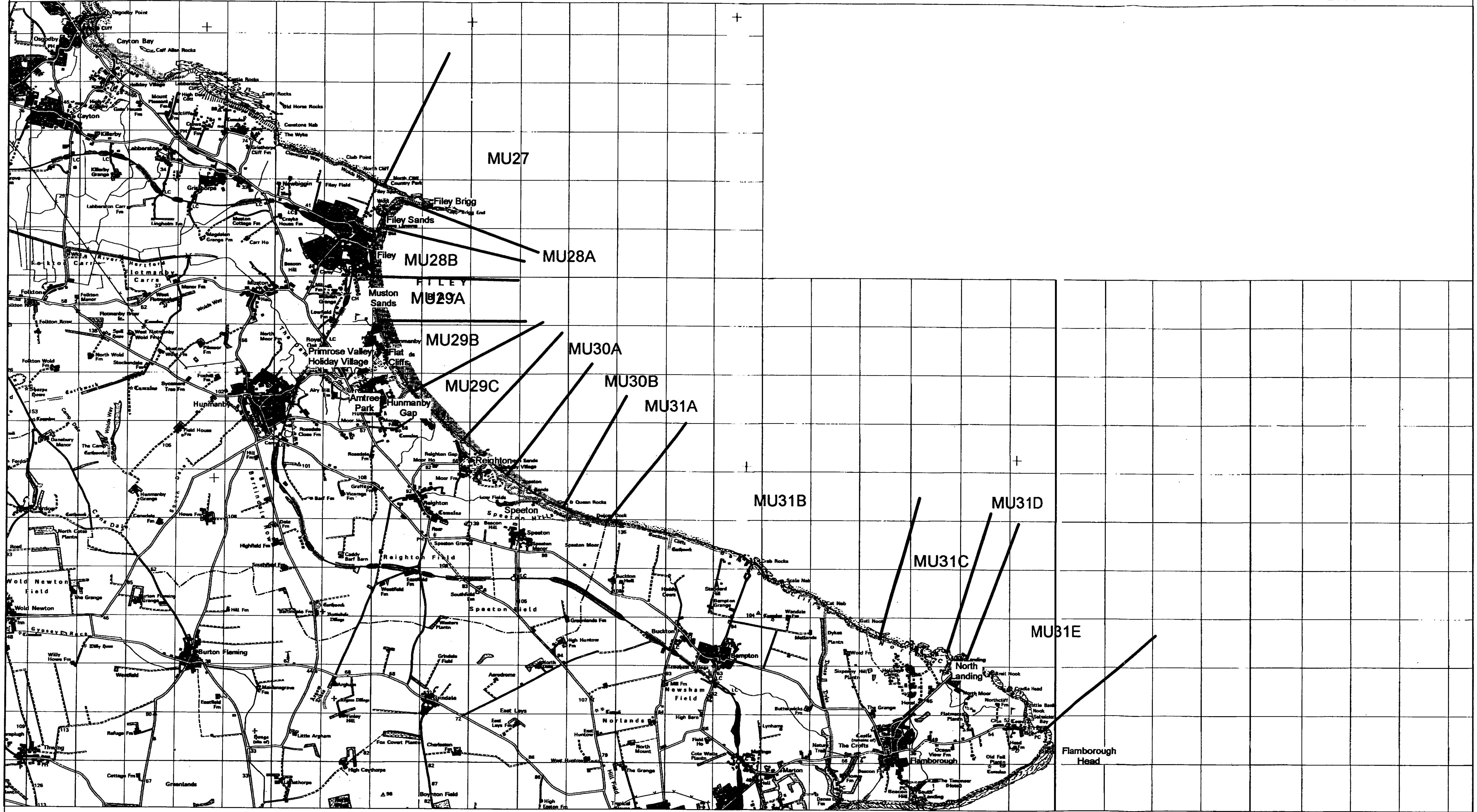

MU31A Management Unit Name

Management Unit Boundary Markers

Map of Study Area Showing Management Units

Figure 1.1

2 Physical Environment

2.1 *Geology & Geomorphology*

2.1.1 *General*

Filey Bay comprises mostly Glacial Till (Boulder Clay) cliffs of varying height, which are underlain by Upper Jurassic rocks to the north of the Bay and as far as Speeton, and Cretaceous rocks south of Speeton. The northern limit of the Bay is marked by Filey Brigg, a natural headland that owes its existence to the more resistant Upper Jurassic limestones and Corallian Grits which outcrop above sea level.

South of Filey Brigg, the coastal cliffs are formed entirely of Glacial Till, with the solid rock formations dipping below sea level. Towards the southern end, at Speeton, the harder geology underlying the glacial till outcrops above sea level. The high Chalk cliffs at Flamborough Head mark the southern limit of the Bay.

Aerial photographs showing the extent of the study are given in Figure 2.1 (6 sheets) at the end of this chapter.

2.1.2 *Solid Geology*

From north to south the sequence is as follows:

- Filey Brigg: Corallian grits and limestones
- Filey Brigg to Hunmanby: Kimmeridge Clay
- Hunmanby to Speeton: Lower Greensand and Speeton Clay
- Speeton to Flamborough Head: Upper Cretaceous Chalk

2.1.3 *Superficial Geology*

Both the one inch to one mile (Sheet 54, reprinted 1967) and the six inch to one mile (Sheet 54, 1873) British Geological Survey maps covering Filey show the area to be covered by superficial "Boulder Clay", now known under modern nomenclature as Glacial Till.

The Glacial Till caps the exposed Jurassic and Cretaceous rocks in the northern and southern extremities of the Bay and where the solid strata dip below sea level, the cliffs are formed entirely of Glacial Till. The Glacial Till deposits comprise a highly variable mixture of clays, silts, sands and gravels. They are easily eroded by wave action, and are highly susceptible to groundwater effects and mass movement.

Other superficial deposits observed during the geomorphological survey include extensive Chalk talus ramps which separate the near-vertical Chalk Cliffs and the Lower Greensand deposits at Speeton. The angular Chalk talus appears very old and probably derives from the Quaternary when the Chalk escarpment would have been broken up by the action of ice and permafrost, resulting in formation of scree. The Chalk talus is currently being eroded and mobilised by wave action, with Chalk debris being deposited on the beaches where it is rapidly broken down into rounded Chalk pebbles.

2.2 *Foreshore Topography and Seabed Bathymetry*

Bathymetry data for the study area was identified from Admiralty Charts as follows:

- Admiralty Chart 1882C which covers the area from Filey Brigg to the King and Queen rocks (scale 1:20,000). The data on Chart 1882C nearest to the coastline was surveyed in 1997, while that further offshore was obtained from a 1893 lead-line survey.
- Admiralty Chart 129 which covers the coastline from Whitby to Flamborough Head (scale 1:75,000). The data on this Chart were considerably older, being taken from lead-line surveys conducted between 1830 and 1932.

As much of the survey data on these charts is from surveys in the late 19th and early 20th Century, a bathymetric survey was commissioned as part of the Strategy Study to provide more up-to date survey information.

Beach profile data was unavailable, so a topographic survey was completed in conjunction with the bathymetric survey. The survey was completed in November 2000 and is documented in Annex A. The bathymetric and topographic survey was completed along profiles covering the extent of the Bay, extending to 2km offshore or to the -10m contour, whichever was closest to shore. Beach sediment samples were taken at some profile locations and sediment grading analyses were completed. The profile locations where samples were taken are shown in Figures 3.1 and 5.1 (these profiles were also used in subsequent sediment modelling). The median sediment sizes established from the grading analyses are given in Table 2.1.

Profile No.	Location	Sample No.	D_{50} (mm)
4	Filey Sands	F1	0.16
5	Filey Town (North)	F2	0.15
6	Filey Town (South)	F4	0.20
7	Flat Cliffs	F6	0.23
8	Reighton	F8	0.26
9	Speeton Sands (south)	F10	0.26
10	Buckton Cliffs	F11	0.24
11	North Landing	F12	1.50

Table 2.1 Profile locations and median beach sediment grain size

Seabed contours are generally parallel to the shoreline, and bed slopes are typically at slopes of 1 in 50 to 1 in 100.

At the north end of the Bay, the seabed comprises sand, increasing in size to gravel further offshore. In the centre of the Bay, the median grain size of beach material increases, while further to the south end of the Bay, rock platforms form the seabed and there is less mobile bed material inshore. Seaward of the rock platform, a band of fine sand extends round Flamborough Head to Bridlington Bay and into Smithic Sands.

Filey Bay - aerial survey, October 1999

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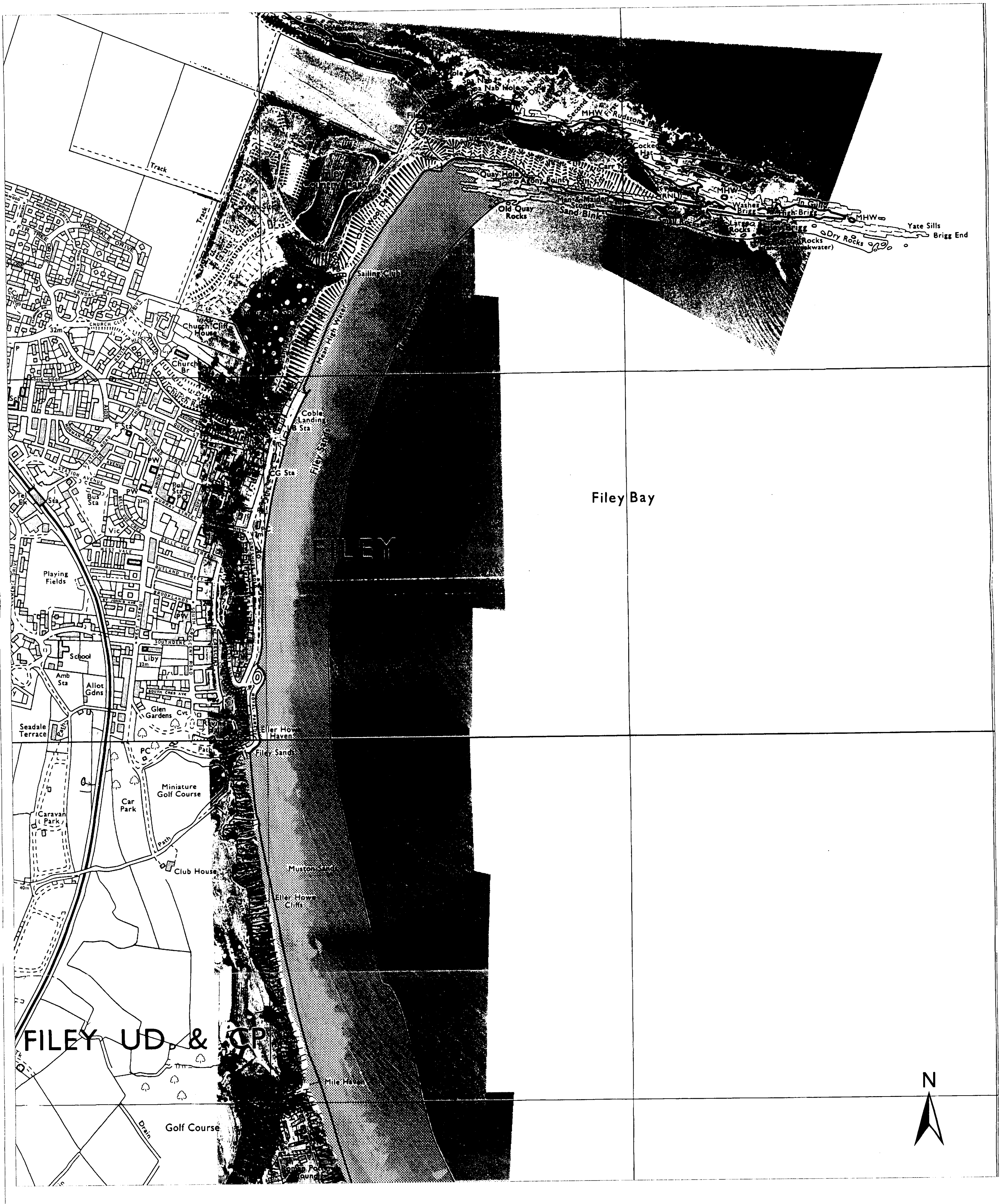

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Filey Bay - aerial survey, October 1999

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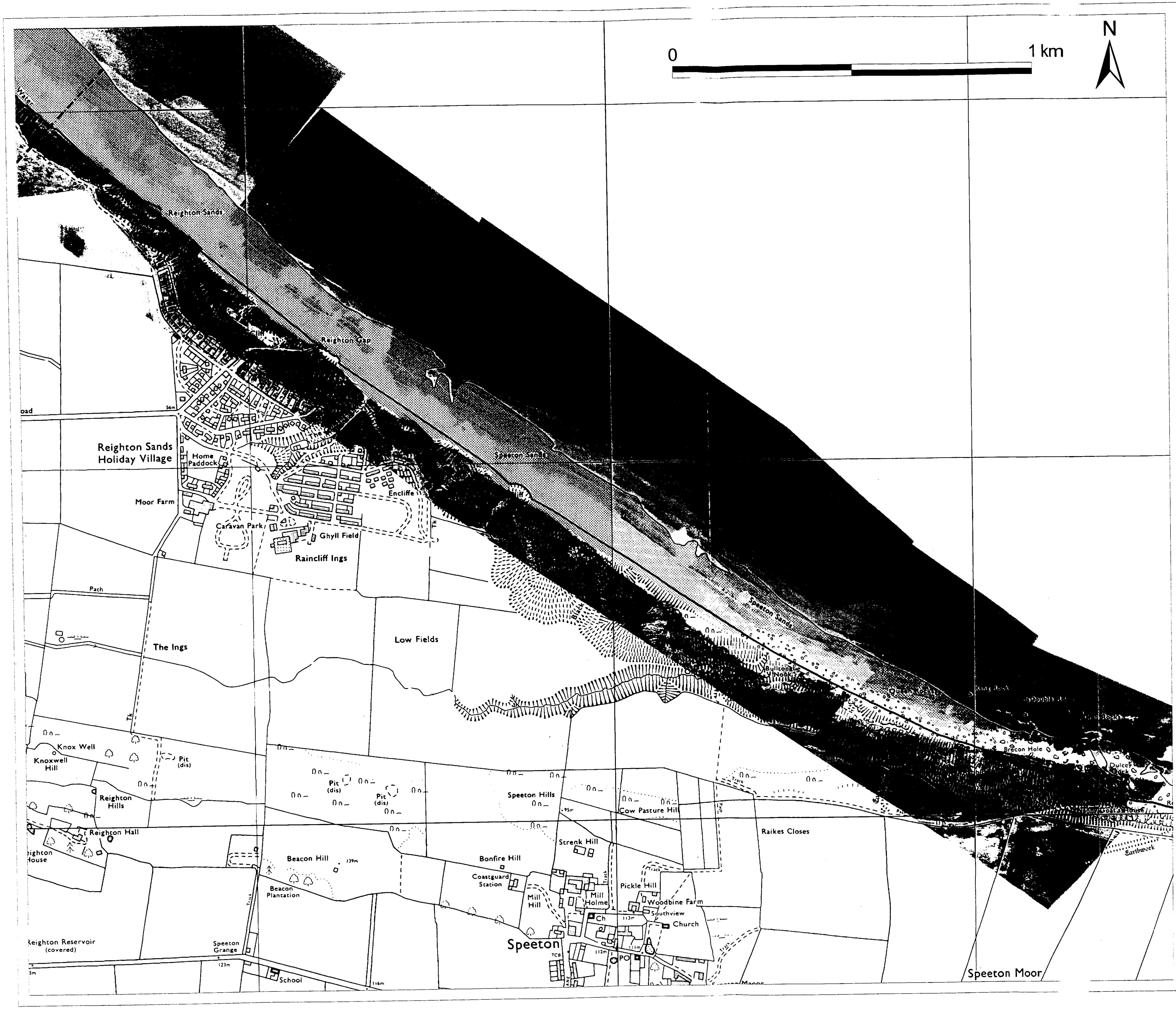

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Filey Bay - aerial survey, October 1999

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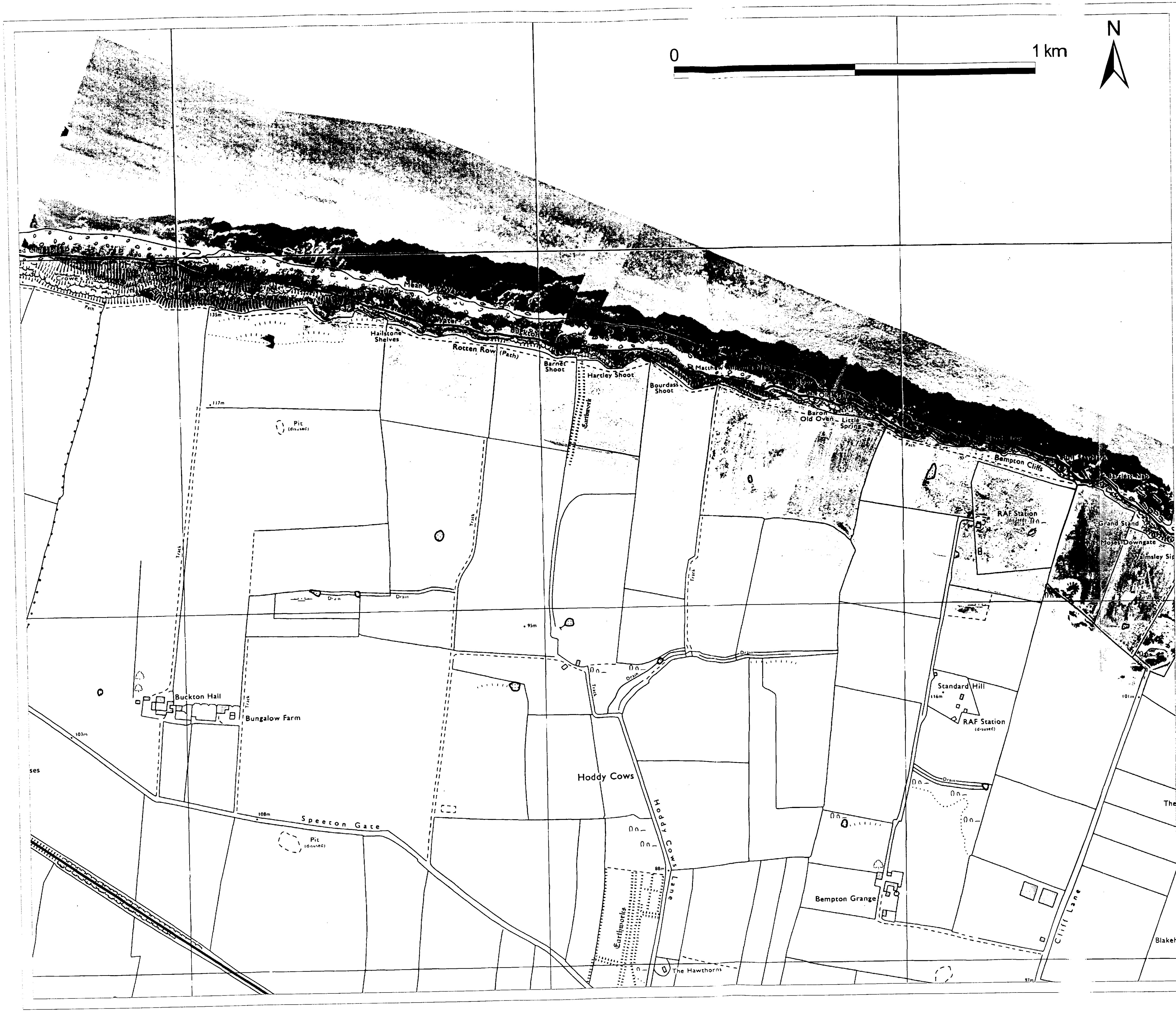

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Filey Bay - aerial survey, October 1999

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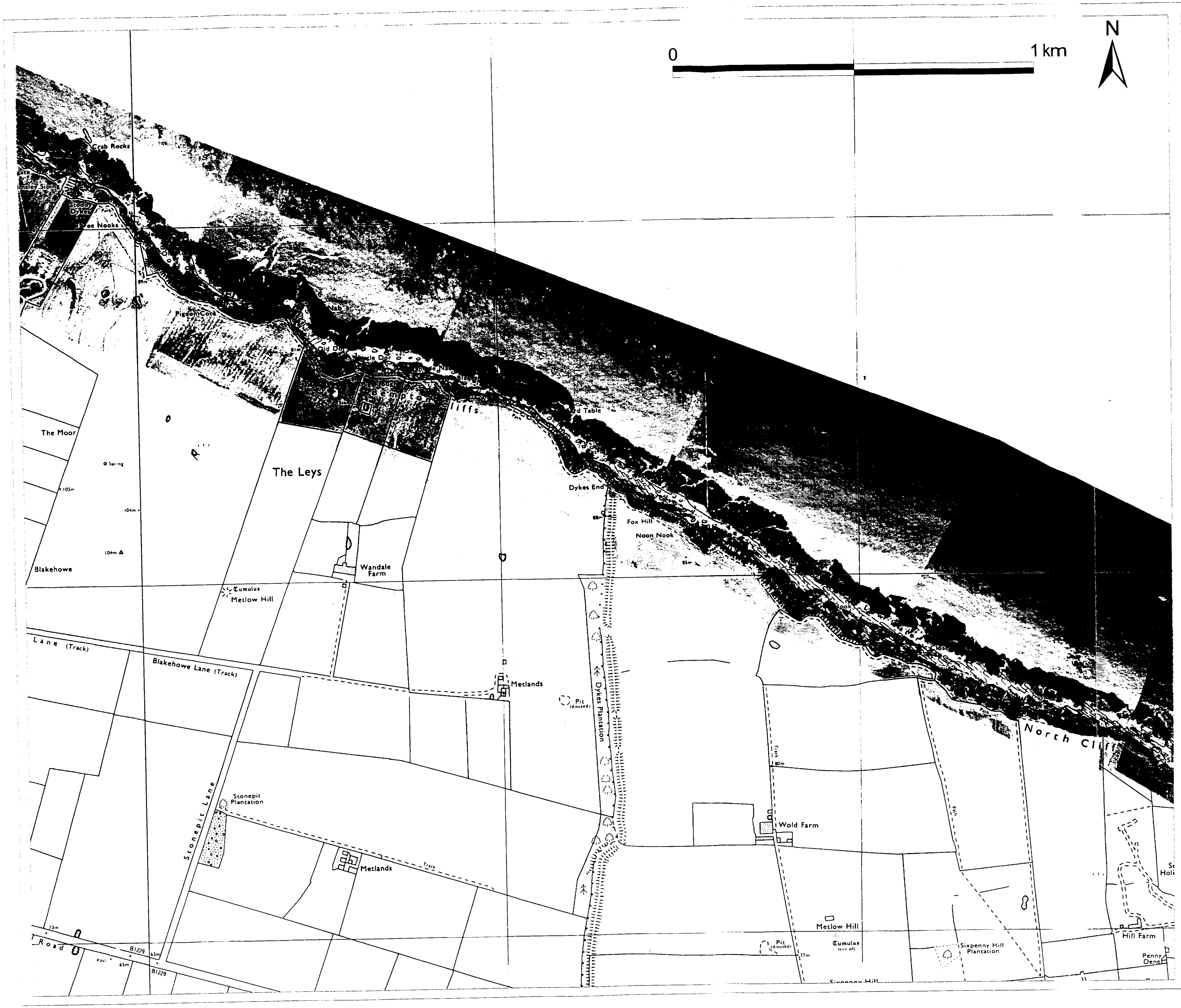

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Filey Bay - aerial survey, October 1999

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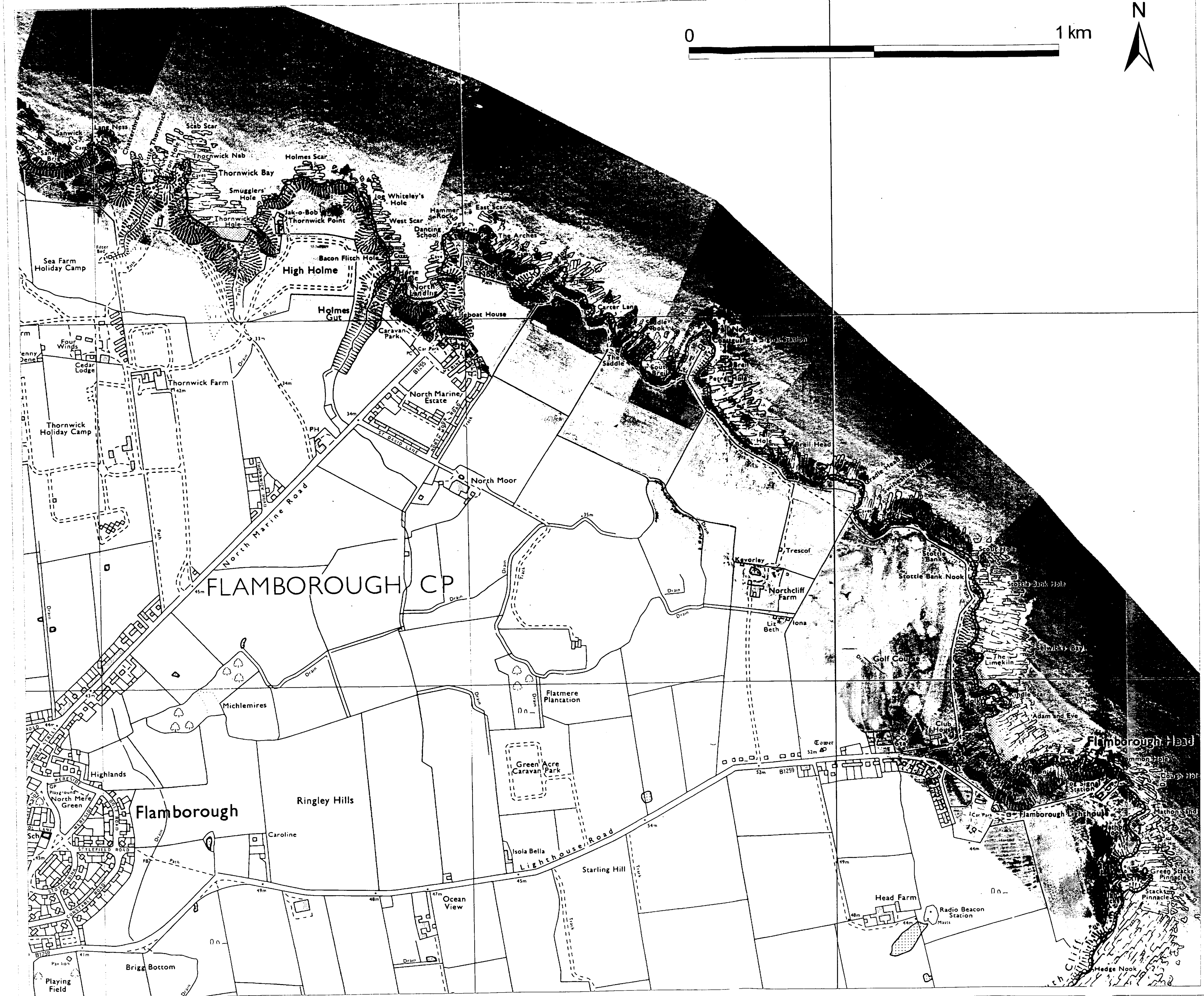

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Filey Bay - aerial survey, October 1999

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3 Hydrodynamics

3.1 *Water Levels*

Water levels within the Bay were obtained from the Admiralty Tide Tables, Table 3.1. No data are available on Mean Sea Level or the relationship between Chart Datum and Ordnance Datum Newlyn, which has been interpolated from information for Scarborough and Bridlington.

Water level	mCD	mODN
Mean High Water Spring (MHWS)	5.8	2.5
Mean high Water Neap (MHWN)	4.9	1.6
Mean Sea Level (MSL)*	3.52	0.22
Mean Low Water Neap (MLWN)	2.4	-0.9
Mean Low Water Spring (MLWS)	1.0	-2.3
CD**	0.0	-3.3

Table 3.1 Water levels in Filey Bay
**No data available – Mean Sea Level at Scarborough given*
*** Interpolated from Bridlington and Scarborough*

3.2 *Waves*

Deep water wave conditions were extracted from the UK Met Office European Wave Model by HR Wallingford (1996) at three locations covering the SMP study area, the most southerly point of which is located offshore of Filey Bay (54.25N 0.33E). A scatter table of offshore wave conditions for the period from January 1987 to December 1995 is given in Table 3.2.

As part of the SMP, extreme wave conditions were derived at two inshore locations within Filey Bay on the –10mCD contour, one seaward of Filey Town and one just north of Flamborough Head.

It had been anticipated at the outset of the Strategy Study that a review of the results of the SMP wave modelling studies would be adequate at the Strategy Study stage. However it became clear upon review, that more detailed wave studies would be required, in particular to:

- investigate processes within the Bay at a higher resolution, taking into account the influence of Filey Brigg;

- derive inshore time series / scatter tables of wave conditions for use in assessing the longshore sediment transport within the Bay.

The scope of the Strategy Study was therefore extended to include more detailed wave modelling.

3.2.1 *Wave Transformation Modelling*

Wave transformation modelling was completed to derive wave conditions at a number of locations on the –10mODN contour, Figure 3.1. These conditions were determined at the beach profile locations, in order that they could be used as input to the sediment transport modelling (see Chapter 5). The wave transformations were completed at Mean Sea Level (+0.22mODN at Scarborough).

The modelling was completed using Halcrow's grid-based MWAVE_REG model (see Annex B). An interpolated bathymetric grid of the study area was produced (Figure 3.1), from the digital information obtained during the recent survey (Annex A) and by digitising the available Admiralty Charts, as discussed in Section 2.2. By using a grid-based model the effect of wave diffraction round Filey Brigg can easily be assessed.

For the extreme wave conditions, only waves between offshore directions 330° and 90° were considered (consistent with the SMP), as these direction sectors have the highest frequency of occurrence of the largest waves. Extreme offshore wave conditions as given in the SMP were transformed to the inshore points using MWAVE_REG for 1:1, 10, 50, 100, 200 and 300 year return periods and the offshore scatter table was transformed to each of the profile locations. The 300 year return period offshore significant wave heights were interpolated from graphs in the SMP as values were not given. A fixed wave steepness, s=0.05 was assumed, in accordance with the offshore wave data extracted from the Huntcliffe to Flamborough Head SMP. The offshore extremes from the SMP are given in Table 3.3, for each direction sector considered. Extremes derived at each location on the -10m contour are given in Table 3.4 for each return period, with significant wave height, H_s, mean wave period, T_m, and wave direction tabulated.

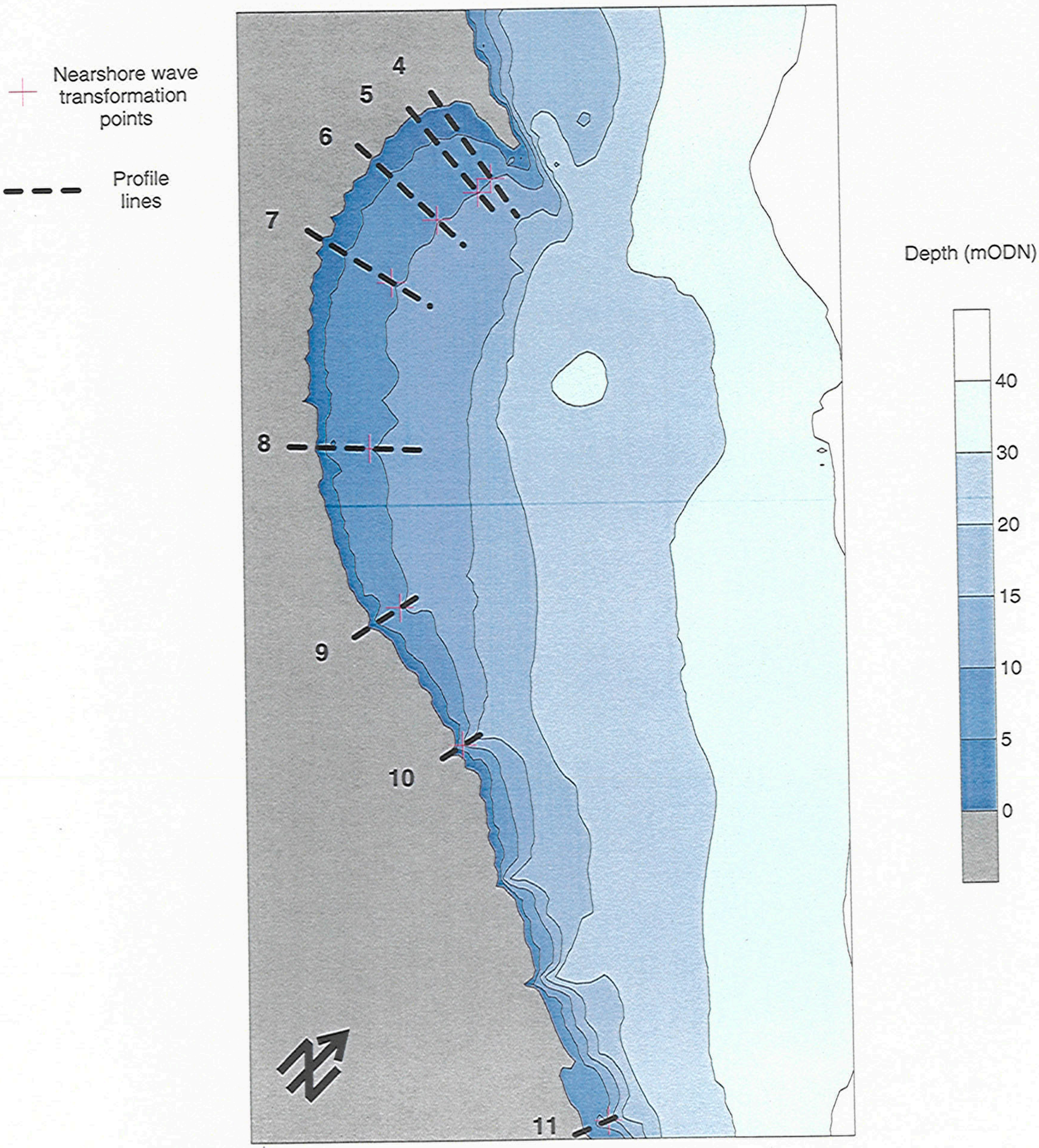
Wave height contours and directions for the 50 year wave conditions are given in Figures 3.2 to 3.5 for each direction sector (330-360°, 0-30°, 30-60° and 60-90° respectively). This shows the clear influence of Filey Brigg in providing shelter to much of the Bay under northerly conditions [note that scale bars vary on these figures due to differing magnitudes of incident wave conditions].

Wave height and direction are also shown for the 75° wave direction (60-90° sector) for a number of return periods (10, 100, 300 years) in Figures 3.6, 3.7 and 3.8 respectively. This direction causes the highest wave heights along most of the frontage.

Figure 3.1

Filey Bay Strategy Study

Bathymetry and profile locations



H1 to H2		P(H > H1)	Wave Direction (degrees true)												Total
			0 - 30	30 - 60	60 - 90	90 - 120	120 - 150	150 - 180	180 - 210	210 - 240	240 - 270	270 - 300	300 - 330	330 - 360	
0.00	0.50	0.99137	2848	1327	1057	688	415	411	323	407	323	300	559	1418	10076
0.50	1.00	0.89059	8180	2978	2263	1476	1460	1167	1152	1384	1533	1669	1685	4138	29085
1.00	1.50	0.59975	4875	1399	1354	1175	1129	1240	1415	1761	1757	1901	1555	4316	23877
1.50	2.00	0.36097	2654	688	856	871	685	901	1221	1171	1198	1323	1088	2118	14774
2.00	2.50	0.21323	1297	388	521	468	494	749	1099	821	620	742	715	1487	9401
2.50	3.00	0.11922	570	255	327	262	312	407	593	437	445	415	403	943	5369
3.00	3.50	0.06552	243	164	205	137	186	361	335	164	95	255	274	563	2982
3.50	4.00	0.03571	106	110	171	65	65	198	106	68	34	84	278	418	1703
4.00	4.50	0.01867	72	80	133	8	42	91	11	8	8	57	64	285	859
4.50	5.00	0.00989	30	27	87	23	8	30	11	19	0	38	42	251	566
5.00	5.50	0.00422	27	4	23	8	4	4	4	4	0	4	19	137	238
5.50	6.00	0.00186	8	0	23	0	4	0	4	0	0	4	8	49	100
6.00	6.50	0.00087	0	0	4	0	0	0	0	0	0	0	0	30	34
6.50	7.00	0.00053	0	0	0	0	0	0	0	0	0	0	0	11	11
7.00	7.50	0.00042	0	0	0	0	0	0	0	0	0	0	0	19	19
7.50	8.00	0.00023	0	0	0	0	0	0	0	0	0	0	0	0	0
8.00	8.50	0.00023	0	0	0	0	0	0	0	0	0	0	0	15	15
8.50	9.00	0.00008	0	0	0	0	0	0	0	0	0	0	0	8	8
Parts per thousand			209	74	70	52	48	56	63	62	60	68	67	162	991

Table 3.2 *Scatter Table of Offshore Wave Conditions at Met Office Wave Model point 54.25N 0.33E*

Notes: *1) Data is in parts per hundred thousand, with wave heights the significant wave heights in metres.*

2) P(H>H1) is the probability of Hs exceeding H1.

3) Total number of hours = 78888

4) Based on UKMO predictions for January 1987 to December 1995.

Direction	345°		015°		045°		075°	
Return Period (years)	H_s (m)	T_m (s)	H_s (m)	T_m (s)	H_s (m)	T_m (s)	H_s (m)	T_m (s)
1	6.7	9.3	4.8	7.9	4.6	7.7	5.4	8.3
10	8.6	10.5	6.3	9.0	6.3	9.0	7.3	9.7
50	9.8	11.2	7.3	9.7	7.5	9.8	8.6	10.5
100	10.4	11.5	7.8	10.0	8.0	10.1	9.1	10.8
200	10.9	11.8	8.2	10.3	8.5	10.4	9.7	11.1
300	11.1	11.9	8.7	10.6	8.7	10.6	9.9	11.3

Table 3.3 *Offshore extreme wave conditions (from SMP)*

Return Period (years)	Filey Sands [4]			Filey Town (North) [5]			Filey Town (South) [6]		
	H_s (m)	T_m (s)	Dirn (°)	H_s (m)	T_m (s)	Dirn (°)	H_s (m)	T_m (s)	Dirn (°)
1	5.1	8.3	76.2	5.1	8.3	75.3	4.9	8.3	73.5
10	6.6	9.7	74.4	7.2	9.7	73.7	7.1	9.7	72.2
50	7.4	10.5	73.5	8.1	10.5	72.9	7.9	10.5	71.6
100	7.6	10.8	73.1	8.1	10.8	72.6	7.9	10.8	71.4
200	7.7	11.1	72.8	8.1	11.1	72.4	7.9	11.1	71.2
300	7.7	11.3	72.6	8.1	11.3	72.2	7.9	11.3	71.0

Return Period (years)	Flat Cliffs [7]			Reighton [8]			Speeton Sands (Sth) [9]		
	H_s (m)	T_m (s)	Dirn (°)	H_s (m)	T_m (s)	Dirn (°)	H_s (m)	T_m (s)	Dirn (°)
1	4.6	8.3	69.2	4.4	8.3	60.4	3.7	8.3	49.2
10	6.6	9.7	67.7	6.4	9.7	58.1	5.3	9.7	47.0
50	7.6	10.5	67.0	7.4	10.5	57.1	6.4	10.5	46.0
100	7.7	10.8	66.8	7.5	10.8	56.8	6.8	10.8	45.7
200	7.7	11.1	66.6	7.5	11.1	56.6	7.2	11.1	45.5
300	7.7	11.3	66.5	7.5	11.3	56.3	7.2	11.3	45.3

Return Period (years)	Buckton Cliffs [10]			North Landing [11]		
	H_s (m)	T_m (s)	Dirn (°)	H_s (m)	T_m (s)	Dirn (°)
1	3.6	8.3	41.6	4.0	8.3	53.7
10	4.9	9.7	39.6	5.1	9.7	51.6
50	5.7	10.5	38.9	6.0	10.5	50.9
100	6.1	10.8	38.7	6.3	10.8	50.6
200	6.4	11.1	38.6	6.6	11.1	50.4
300	6.5	11.3	38.5	6.7	11.3	50.3

Table 3.4 *Inshore extreme wave conditions*

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Wave climate with boundary conditions:
Hs=9.8m, Tm=11.2s, Direction=345 degs (Ret. Per. = 50yrs)
Water level = 0.22mODN

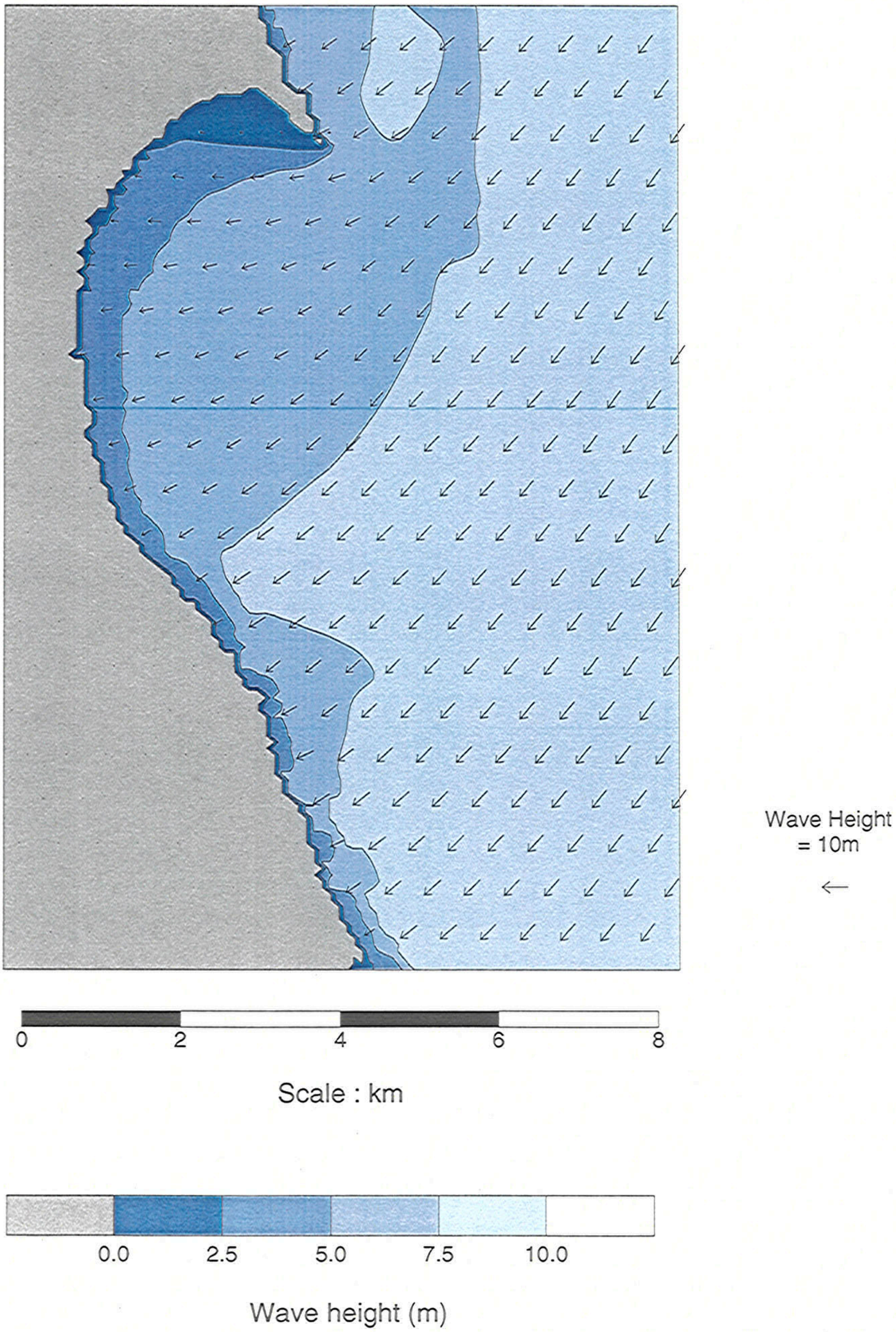


Figure 3.3

Filey Bay Strategy Study

Wave climate with boundary conditions:
Hs=7.3m, Tm=9.7s, Direction=015 degs (Ret. Per. = 50yrs)
Water level = 0.22mODN

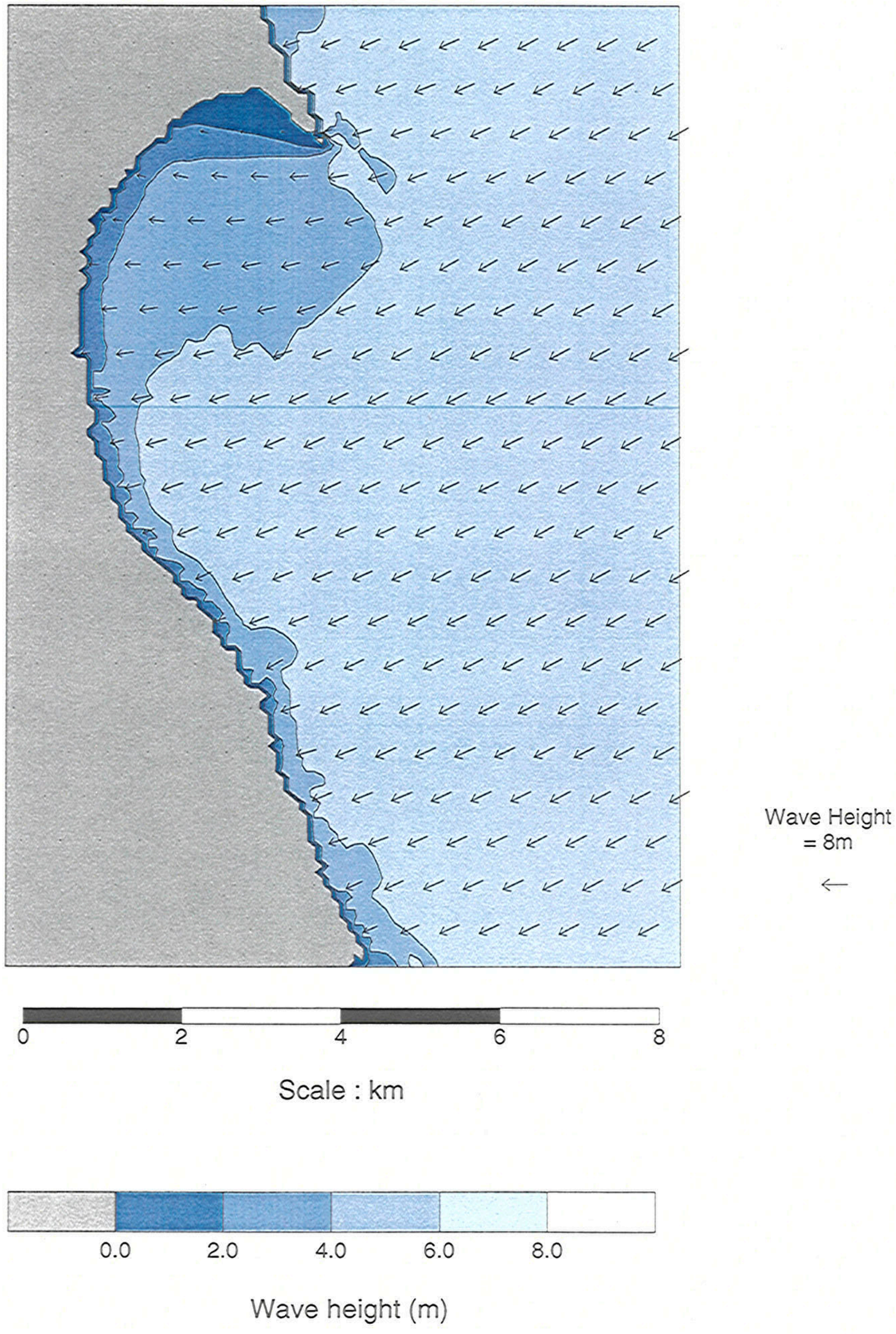
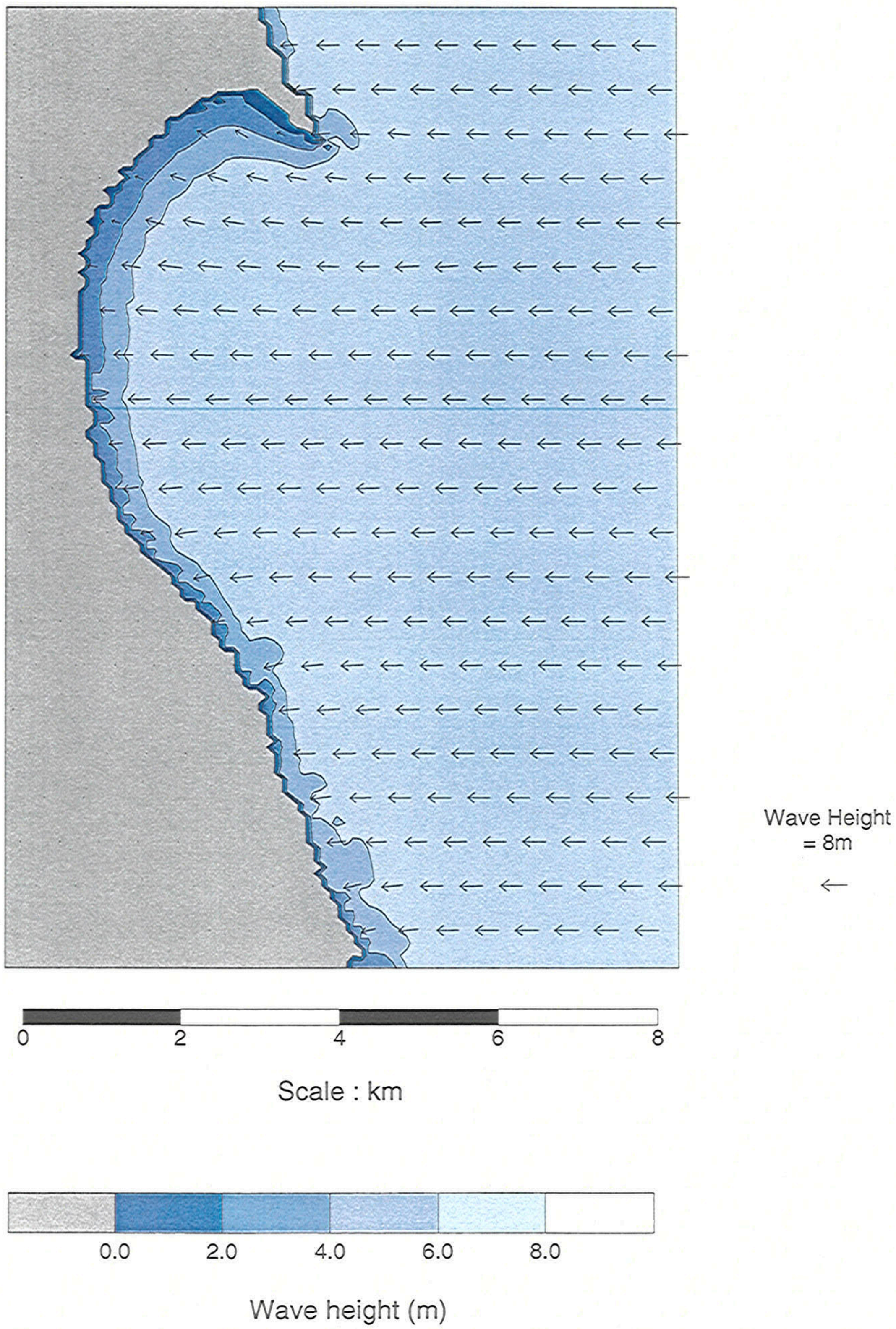


Figure 3.4

Filey Bay Strategy Study

Wave climate with boundary conditions: Hs=7.5m, Tm=9.8s, Direction=045 degs (Ret. Per. = 50yrs) Water level = 0.22mODN



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Wave climate with boundary conditions:
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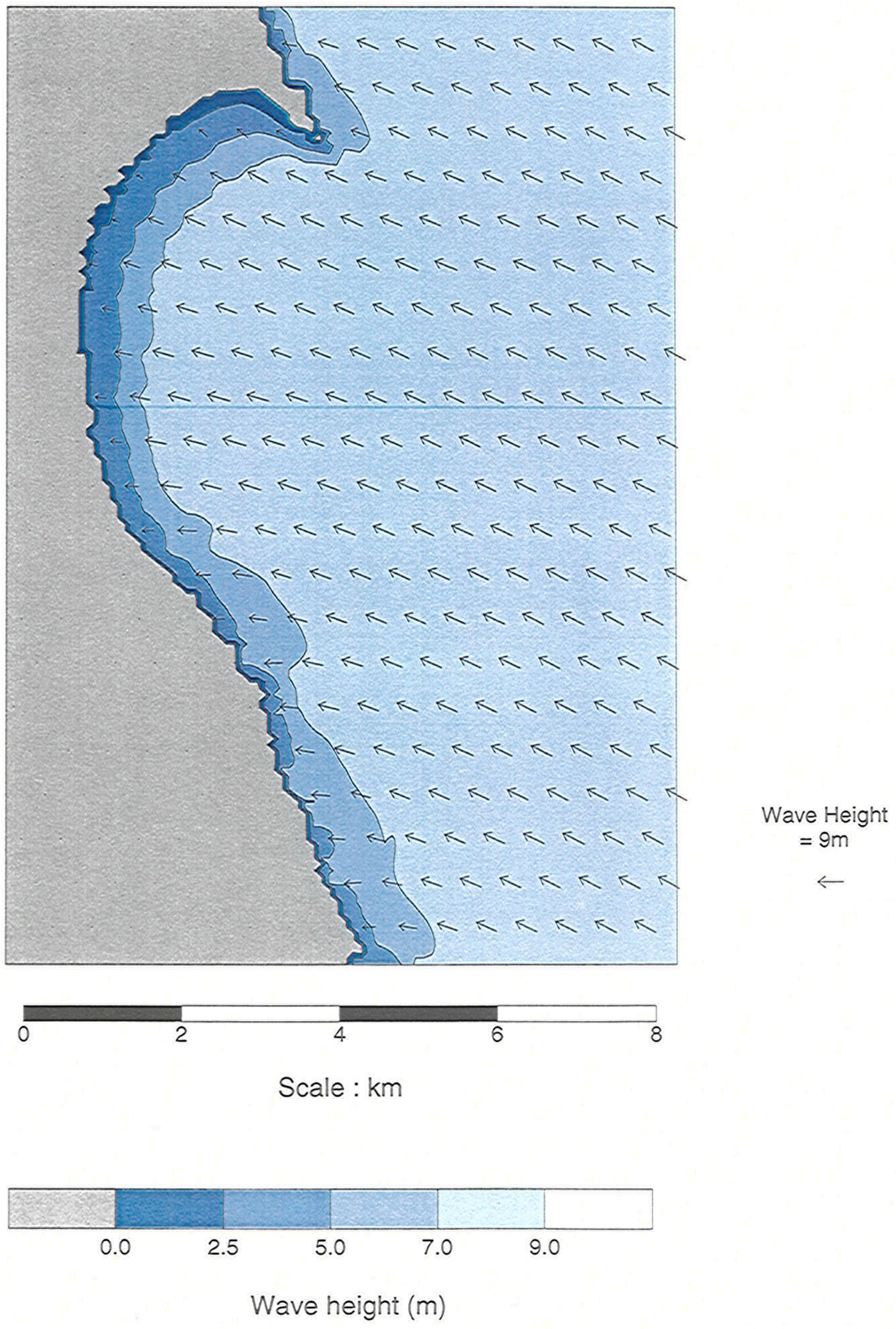
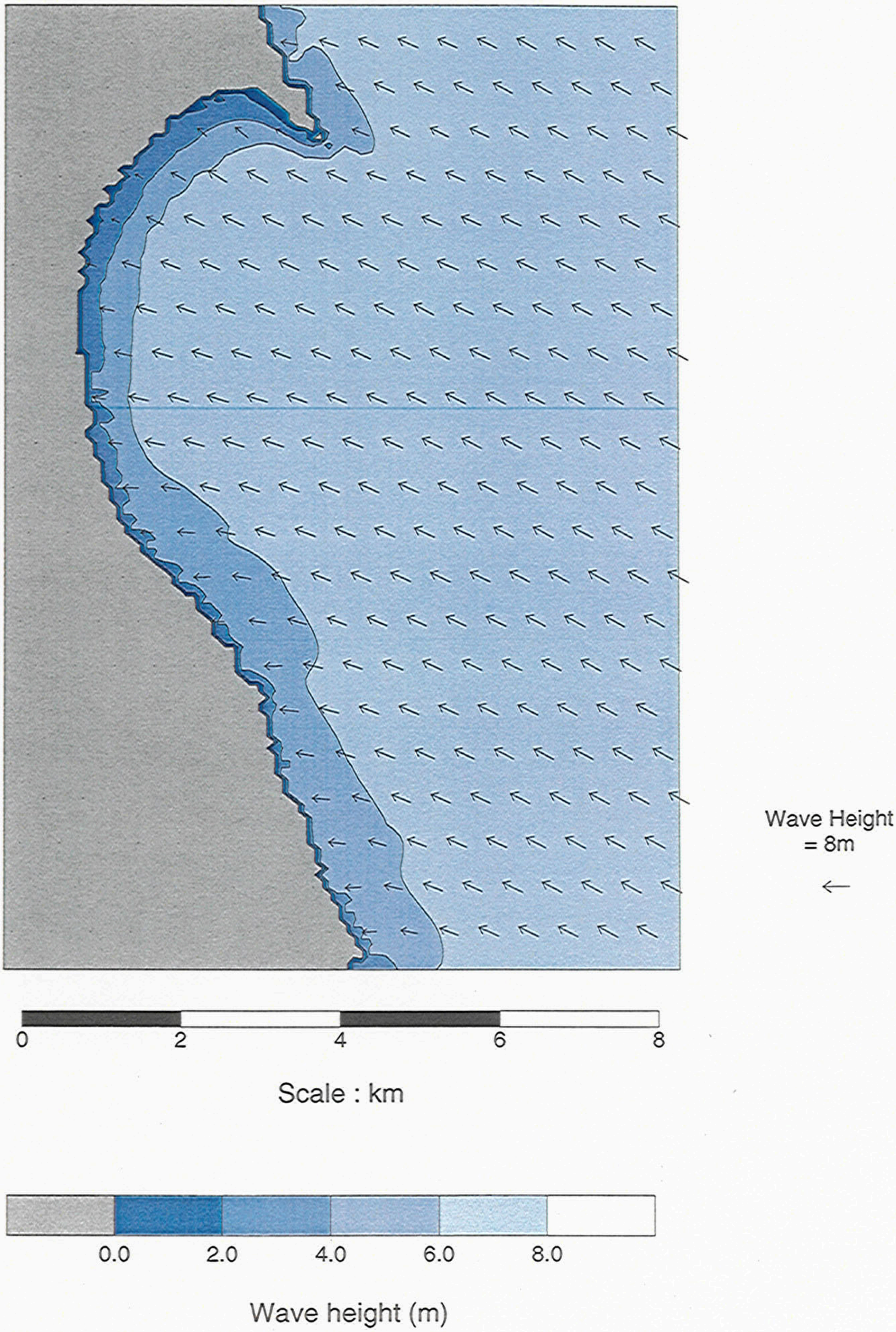
Water level = 0.22mODN



Filey Bay Strategy Study

Wave climate with boundary conditions:
Hs=7.3m, Tm=9.7s, Direction=075 degs (Ret. Per. = 10yrs)
Water level = 0.22mODN



Filey Bay Strategy Study

Wave climate with boundary conditions:
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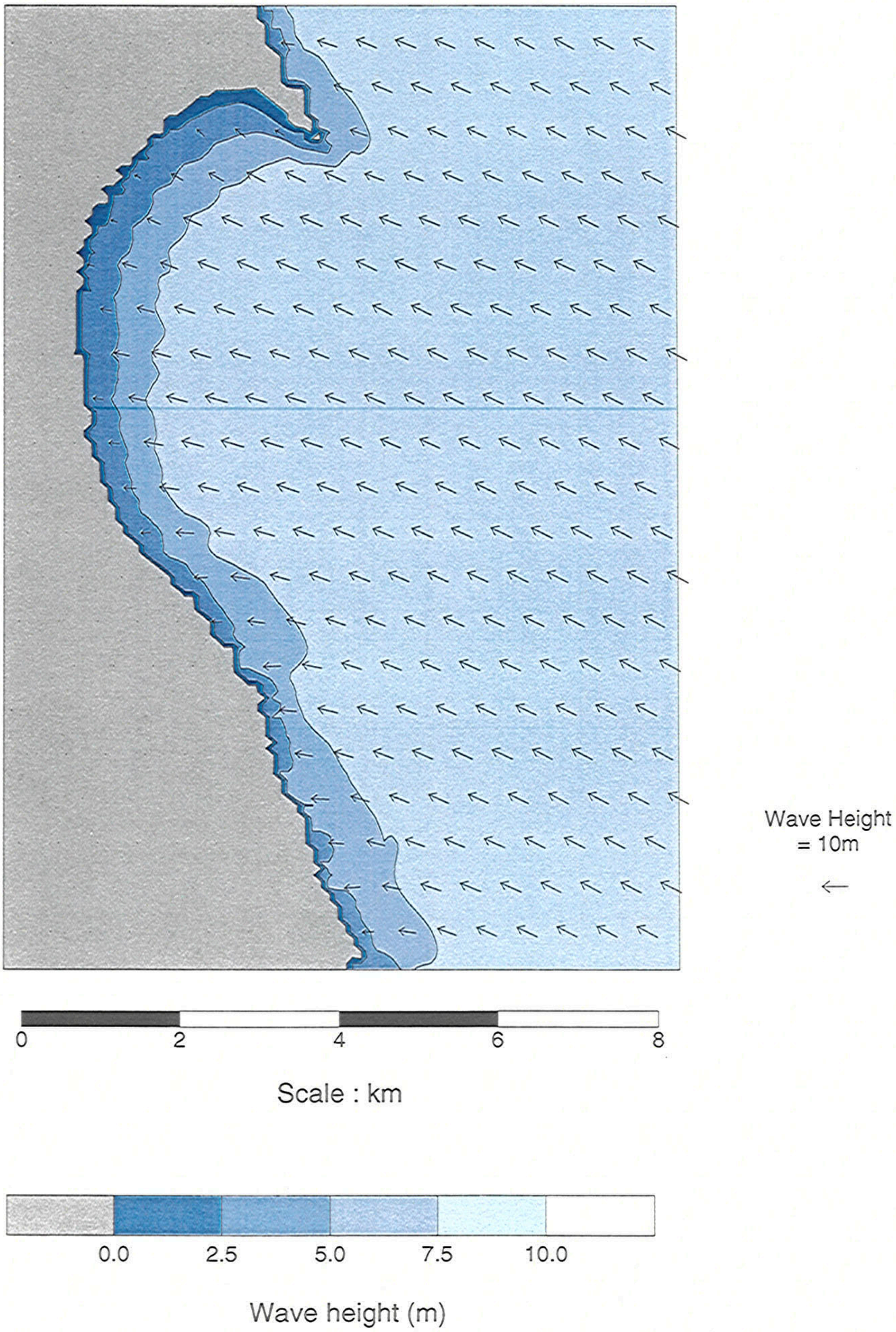
Water level = 0.22mODN



Filey Bay Strategy Study

Wave climate with boundary conditions:
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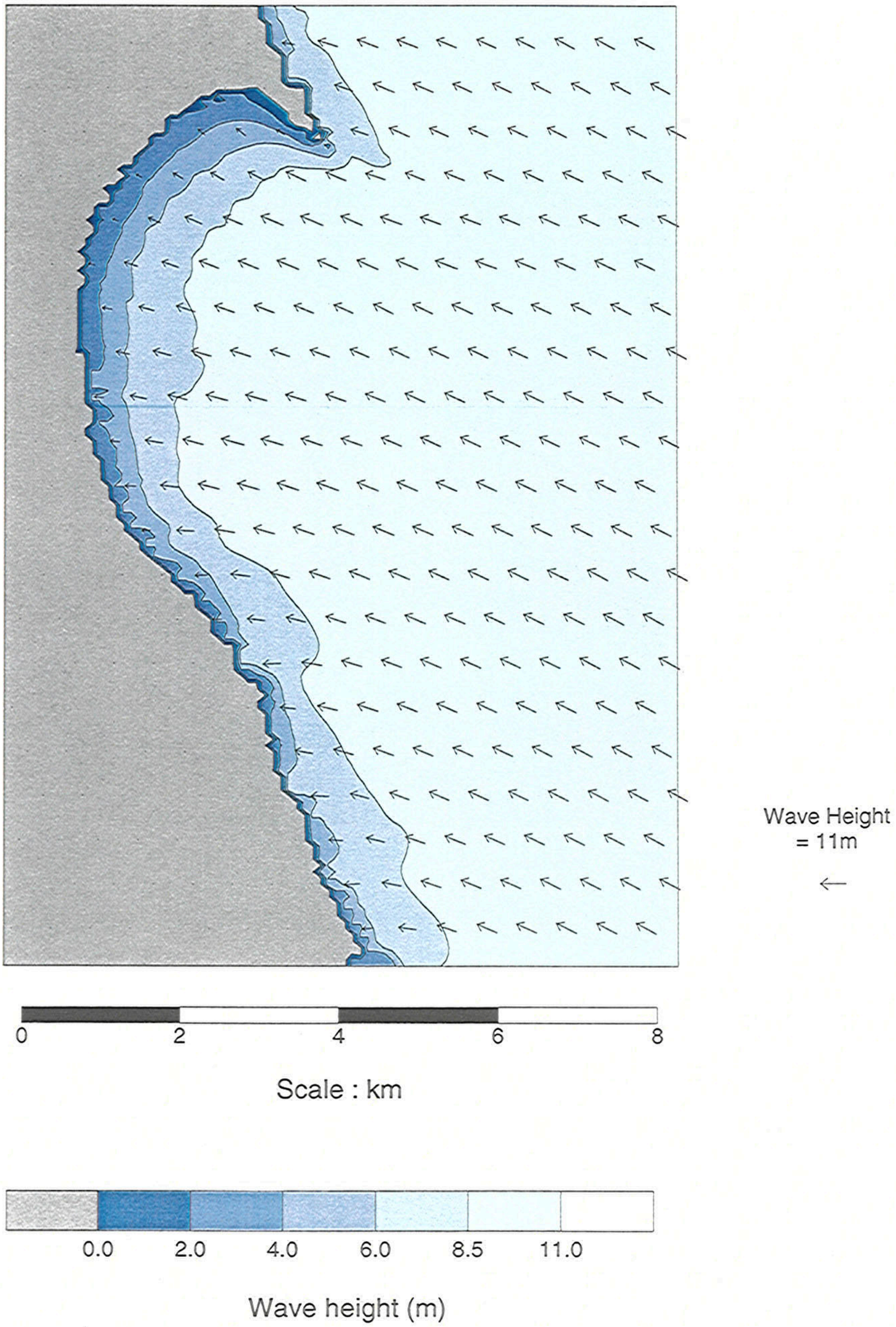
Water level = 0.22mODN



3.3 *Currents*

Information on tidal currents was obtained from Admiralty tidal diamonds within Filey Bay (shown on Admiralty Chart 129). These are located at approx. 2km east of Flamborough Head and approx. 8km north-east of Flamborough Head. A third is located to the south of the Bay, just offshore of Bridlington Harbour.

Tidal currents are strongest immediately offshore of Flamborough Head with magnitudes of up to 1.6m/s during spring tides. IECS (1991) demonstrate that there is a reversal of current offshore, resulting in a clockwise circulation in Filey Bay during both Spring and Neap flood tides.

Residual currents near to the coast flow in a northerly direction during spring tides and in a southerly direction during neap tides. This results in a net residual current to the north of 0.11m/s on spring tides and 0.09m/s to the south on neap tides.

4 Cliff Mapping / Assessment

4.1 *Introduction*

Existing coastal defences within Filey Bay are limited to the coastal frontage of Filey Town, comprising a high sea wall between Coble Landing and Martin's Gill, and toe protection measures at the sailing club to the north of Filey. Evidence of former (wartime) defences and local protection measures are apparent between Filey and Reighton but these generally do not provide much protection to the cliffs from marine erosion.

An important issue to be considered is the need to account for potential cliff instability and recession in future planning and decision-making. Equally important is the need to assess the contribution of cliff erosion in the maintenance and supply of materials to the extensive sandy beach, which is a major feature and asset of Filey Bay.

In fulfilment of the above, detailed assessment of the cliffs has been carried out, comprising collation and review of existing information, and new field surveys. The main objectives of this work were to assess potential cliff instability and recession throughout the Bay, consider the implications of failure of existing defences, and consider the effects of possible future coastal defences on the supply and distribution of sediments to the beaches.

The remaining sections of this Chapter explain the broad approach to this aspect of work, the findings of the cliff behaviour assessment and the conclusions that can be drawn from this with regard to the issues stated above.

4.2 *Approach*

Geomorphological investigations carried out in Filey Bay have comprised a review of information, field observation and mapping, compilation of a database and reporting. These activities are described below.

4.2.1 *Information Sources*

Table 4.1 lists the information sources reviewed as part of the geomorphological investigations. They provide useful background information of a geological and geotechnical nature at a 'broad' strategic scale and for specific sites. The Shoreline Management Plan and 'coastal planning and management' studies for the area consider the nature of cliff recession and coastal processes in broad terms. Various site investigation reports provide data on local ground conditions.

Information	Date	Source
Report on the Inspection of Filey Brigg	2000	High Peak Access Services
Huntcliffe to Flamborough Head SMP, Volume 1	1997	Mouchel Consulting Ltd.
Fellsway, Sandhill Lane, Filey: Site Report	1995	Robert T. Horne & Partners
Coastal Planning and Management: Applied Earth Science Mapping – Filey to Scarborough, North Yorkshire	1995	High Point Rendel
Church Ravine, Filey: Slope Stability Review	1994	High Point Rendel
Further Report on Investigation of Ground Conditions for Proposed Family Club at Primrose Valley, near Filey	1993	Patrick Parsons Ltd
Flat Cliffs Sewer Diversion Primrose Valley, Filey: Part 3 Inclinometer Monitoring Report	1992	Yorkshire Water Services Plc
Flat Cliffs Sewer Diversion Primrose Valley, Filey: Part 2 Geotechnical Assessment	1991	Yorkshire Water Enterprises Ltd
Flat Cliffs Sewer Diversion Primrose Valley, Filey: Part 1 Factual Report	1991	Yorkshire Water Enterprises Ltd
The Pastures, Filey: Ground Investigation Report	1991	Norwest Holst Soil Engineering Ltd
Church Ravine, Filey: Ground Investigation Report	1985	Soils Engineering Services

Table 4.1 Information Sources

4.2.2 *Geomorphological Mapping and Cliff Behaviour Assessment*

A geomorphological survey of the coastal cliffs at Filey Bay was carried out in two visits, during September and November 2000. The survey extends from Filey Brigg in the north, to the Chalk cliffs south of Reighton.

The geomorphological survey comprised observation and mapping of cliff morphology, landslides, geology, materials, current cliff activity and recession potential. The field mapping used base maps at 1:1,250 scale. Field measurements of distance and cliff angles were made using a 30m tape and a compass clinometer, respectively. A photographic record of salient cliff and beach features was also obtained during the survey (see CD inside back cover).

Given the nature of geomorphological mapping, the accuracy of the information shown on the resulting maps should be regarded as approximate, with an 'on-the-ground' accuracy no better than 2m. The cliff angles are accurate to 1 or 2 degrees.

The field observations and measurements have been supplemented by additional information, most notably scaled measurements of distance from the base maps, interpretation of colour vertical aerial photography, and the available geological and geotechnical records (summarised in Table 4.1).

Using the field observations and supporting information, a geomorphological interpretation of cliff instability mechanisms and processes has been made (hereafter termed Cliff Behaviour Assessment). The approach provides an important spatial framework and vital clues as to the likely mechanisms, causes and consequences of cliff instability. The findings also provide an important context within which any future decisions on coastal management should be considered. The Cliff Behaviour Assessment provides the first detailed systematic evaluation of cliff instability and recession in Filey Bay. The approach combines factual data with 'best judgement' (i.e. interpretation of landslide mechanisms and depth of cliff failure) to derive semi-quantitative estimates of cliff erosion and sediment supply to the beaches. As such the results should be regarded as preliminary pending further detailed investigation and monitoring which should be used to validate the findings.

4.2.3 Database Compilation and Reporting

The outputs of the geomorphological investigations comprise a series of maps, and a database included in Annex C of this report.

Map Series A (comprising 6 sheets) provides a summary of the main observations from the geomorphological survey and the spatial distribution of 'Cliff Behaviour Units'. Each cliff behaviour unit is coded and cross-referenced to the database and photographic record.

The database provides detailed information on each cliff behaviour unit, which includes both factual and interpretative data. Further explanation of the data entries is given in Section 4.3, which includes the following main parameters:

- Cliff Behaviour Unit types
- Geology
- Sediment Storage on Cliffs
- Cliff Recession Potential
- Cliff Sediment Input to Beaches

The database presents semi-quantitative estimates of cliff recession potential, sediment storage and supply from cliff erosion and landslides. It is recognised there are many uncertainties in estimating these parameters, as described further below (Section 4.3). Accounting for such uncertainties, the database includes upper and lower bound estimates for these parameters, which represent credible worst-case (i.e. high erosion) and best-case (low erosion) scenarios, respectively. In reality, it is considered the more likely scenario falls somewhere between the upper and lower bound estimates.

4.3 Cliff Behaviour Assessment

4.3.1 Cliff Behaviour Unit Types

To understand cliff recession something must be known of the conditions and processes operating on the foreshore and on the cliff (and, in many cases, behind the cliff). It was for this reason that the concept of a 'cliff behaviour unit' (CBU) was developed for MAFF (1997), as it provides an important framework for cliff management.

The MAFF (1997) study identified a range of CBU types that reflect different mechanisms and rates of sediment inputs, throughputs and outputs (see Figure 4.1). Those that apply to Filey Bay are described in the following sections along with any variations of these that were observed during the geomorphological survey.

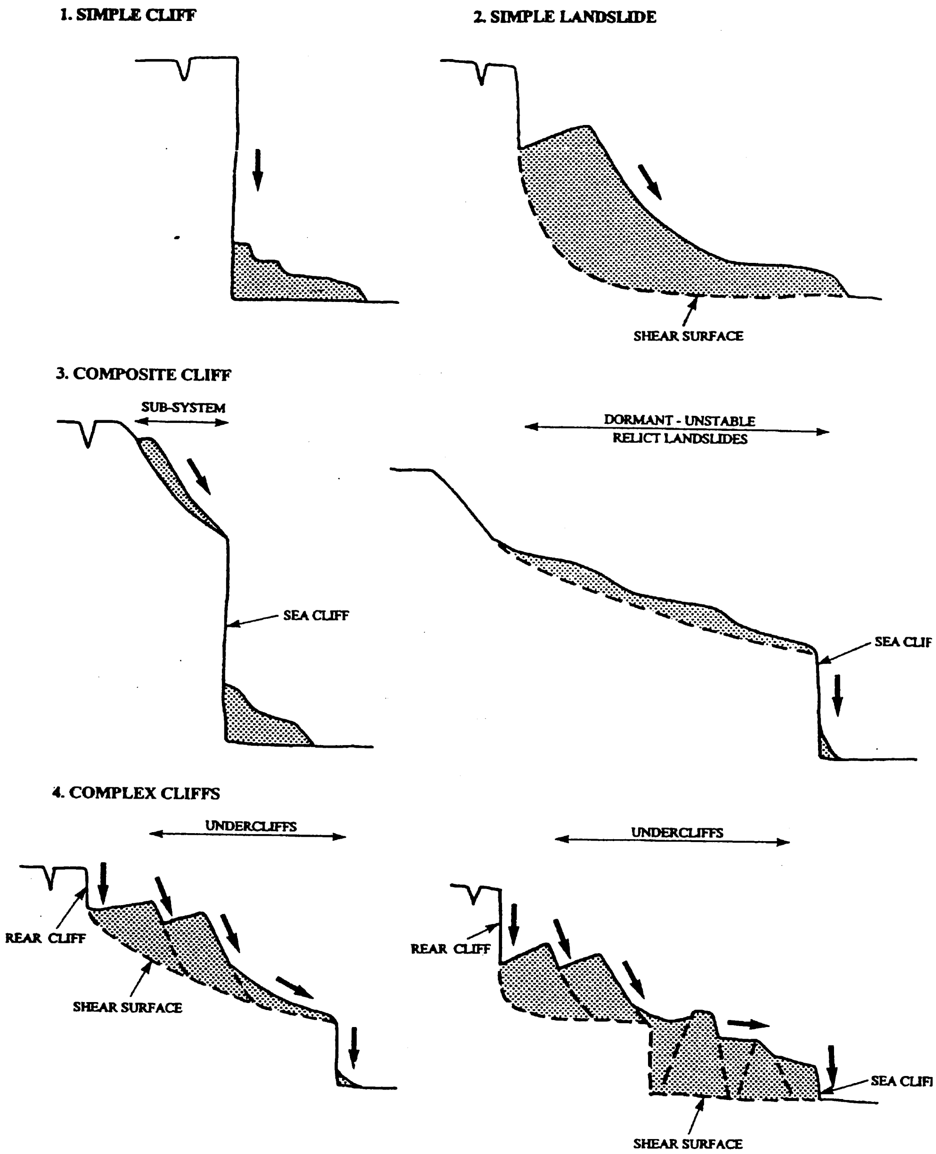


Figure 4.1 *Cliff Behaviour Unit Types*

In the assessment of cliff storage for CBU's, account is made of potential 3D effects in subsurface geometry. For shallow planar mechanisms of cliff failure (i.e. simple and composite cliffs), subsurface edge effects are minimal and a small reduction in volume (10% upper bound; 20% lower bound) has been applied. For simple and complex landslides, which may comprise deep-seated rotational failure mechanisms, 3D subsurface edge effects can be significant and a large reduction in volume (30% upper bound; 50% lower bound) has been applied.

(a) Simple Cliffs

These comprise a single sequence of inputs and outputs with limited storage. They are typically characterised by steep cliff faces and shallow erosion.

In Filey Bay, simple cliff CBU's are developed on the Glacial Till cliffs in localised places. They are also developed on outcrops of *in situ* Kimmeridge and Speeton Clays, Lower Greensand and relic Chalk talus south of Reighton. The cliffs are in places, prone to gullying caused by surface water run-off from above the cliffs. Such gullies cause localised washout and form significant conduits supplying fine and coarse sediments to the foreshore.

(b) Simple Landslides

These comprise a single sequence of inputs and outputs with variable amounts of storage within the failed mass. The occurrence of simple landslides is episodic and depends on the removal of the failed mass in order to initiate further landslides.

In Filey Bay, the Glacial Till cliffs are highly susceptible to simple landslides. Deep-seated rotational and shallow translational (mudslide) mechanisms are common. The distribution of the various landslide types appears to be random and probably reflects the inherent lithological variability within the Glacial Till.

(c) Composite Cliffs

These comprise partly coupled sequences of contrasting simple sub-systems. They are often formed where different bedrock or lithological sequences introduce variations in the shear strength or erodibility of the parent materials. An example of a composite cliff would be a simple cliff (i.e. formed in resistant strata) overlain by a simple landslide (i.e. a mudslide in weak clays).

In Filey Bay, composite cliffs are developed in the Glacial Till and bedrock sequences at Filey Brigg. The more resistant Upper Jurassic rocks, which outcrop above sea level, form low vertical rock cliffs, while the weaker overlying Glacial Till is susceptible to high rates of erosion and landsliding.

(d) Complex Landslides

These comprise strongly coupled sequences of sub-systems, each with their own inputs, throughputs and outputs of sediment. The output from one sub-system forms the input for the next. Such systems are characterised by complex spatial and temporal feedback mechanisms. Examples of complex landslides would include a successive, multi-tiered rotational landslide, or cascading mudslide complex.

In Filey Bay, complex landslides are present at Flat Cliffs and Reighton. At these sites large-scale deep-seated mass failure of the Glacial Till cliffs has occurred. Little is known about the origins, subsurface geology and mechanisms of failure. At Flat Cliffs (north), the surface morphology indicates rotational failure of the Glacial Till has occurred. At Flat Cliffs (south) and Reighton, large 'undercliffs' have formed, which appear from the surface morphology to be formed by translational failure of the Glacial Till, possibly founded upon or within weathered bedrock.

4.3.2 *Geology*

The geology of Filey Bay is discussed in detail in Section 2.1.

4.3.3 *Sediment Storage on Cliffs*

An estimate of the volume of sediment stored within each CBU has been calculated based on measured and estimated parameters. These are described below with the numerical formula for estimating the volume of sediment stored.

(a) Cliff Morphology

Field measurements of cliff gradient were obtained for each CBU using a hand-held compass clinometer and by sighting from the cliff toe to cliff top, or vice versa. For composite CBU's (i.e. Filey Brigg), the cliff gradient was measured from the crest of the lower rock cliff to the cliff top. The height of the lower near-vertical rock cliff was estimated from field observation.

The plan length (in section) and width (longshore) of each CBU was scaled from the base maps. These dimensions and the cliff gradient have been used to estimate the cliff height, as follows:

$$\textit{Cliff height} = \textit{plan length} * \textit{Sin}\ \theta + \textit{height of rock cliff (if applicable)}$$

where, θ is the cliff gradient.

(b) Depth of Cliff Failure

The depth of cliff failure has been estimated from field observation. For simple and composite cliffs, depths of failed sediments were typically shallow ranging between 0.1m and 3.5m. For simple landslides, depths of landslide deposits ranged between 1m (i.e. for mudslides) and 6m (i.e. for rotational slips) and for complex landslides depths of 6m and 18m were estimated. Estimates were made from direct observation of exposed debris mantle or from an appreciation of the 3D geometry of the CBU.

To account for uncertainty with this parameter, two estimates of the most credible minimum and maximum depth of cliff failure were recorded.

(c) Sediment Storage Estimation

A numerical estimation of the volume of sediment stored on the cliffs has been calculated from the cliff morphology and estimated depth of cliff failure, as follows:

*Sediment storage = slope length * width * failure depth * 3D correction*

where, 3D correction accounts for subsurface geometrical edge effects (see Section 4.3.1).

4.3.4 *Cliff Recession Potential*

The recession potential for each CBU was assessed from field observation and supporting information. This included classification of the current activity status of the cliffs, the recession potential (i.e. cliff top retreat) and estimated frequency of occurrence.

(a) Cliff Activity

Cliff activity was classified based on field evidence of active landslides or erosion. A distinction has been made between simple and composite cliffs subject to surface erosion processes, and simple and complex landslides subject to deep-seated ground movements. Vegetation density (i.e. % cover) was used as an indicator of activity for cliffs subject to surface erosion processes, whereas evidence of relic or active rotational and differential shear movements and toe heave were used for the latter. In this way, the activity for each CBU was rated according to the following classification (Table 4.2):

Activity Status	Activity %
Dormant (defended shoreline)	0
Inactive	25
Marginally Stable	50
Active	75
Very Active	100

Table 4.2 Cliff Activity Rating

(b) Cliff Recession Potential

The cliff recession potential (or potential cliff-top retreat) has been estimated from historical records and field observation. As for cliff activity, a distinction has been made between cliffs and landslides as the magnitude and frequency of recession events are dependent on the mechanism of cliff failure. For example, simple cliffs are generally in dynamic equilibrium, with the rate of erosion at the cliff toe in balance with the rate of retreat at the cliff top, with only minimal time-lag response. Landslides, on the other hand are rarely at equilibrium, as the presence of landslide blocks or debris storage on cliffs provides a temporary buffer (or natural protection) against the de-stabilising effects of toe erosion. Only when a significant portion of debris has been removed through toe erosion will cliff top land be subject to mass failure once more. For large-scale landslides this cyclical response can take many years, decades or even centuries.

It is important to note that displaced landslide debris (i.e. the sediment stored on cliffs) will be subject to creep and/or occasional ground movement throughout this cycle in response to groundwater and erosion at the toe of the cliff.

Based on historical records and field observation, the recession potential for each CBU has been rated according to the following classification. To account for uncertainty with this parameter, two estimates of the most credible minimum and maximum cliff top recession events have been recorded (Table 4.3). The upper bound estimates also account for potential increases in sea level rise (5mm / year) and seasonal rainfall and groundwater levels, due to the possible effects of climate change.

Cliff-Top Recession Event	Upper Bound	Lower Bound
Low erosion	0.5m	0.1m
Moderate erosion	1m	0.5m
High erosion	2m	1m
Landslip (small <0.2ha)	20m	10m
Landslip (moderate <1ha)	50m	20m
Landslip (large >1ha)	100m	50m

Table 4.3 Cliff Recession Potential Rating

(c) Frequency of Recession Events

The frequency of cliff top recession events ranges from annual losses from ongoing erosion to infrequent losses due to landslides. There are few records from which reliable estimates of landslide frequency on the cliffs at Filey Bay can be made. Field observation and anecdotal reports of recent large-scale landslides at Reighton provides some evidence that such events may not be that rare. During the period of geomorphological survey (i.e. a period of days during a wet period), three mudslide surges onto the beach were observed.

Given the uncertainties with this parameter, it has been assumed that the recession of cliffs due to erosion is realised on an annual basis, whilst recession caused by infrequent landslide events of various size will be realised over a 50 year period from now, except where coastal defences are in place. For the latter it has been assumed the probability of occurrence of landslide events is significantly reduced (i.e. 10%).

4.3.5 *Cliff Sediment Input to Beaches*

Estimation of the effective annual supply of sediment to the beaches from each CBU has been based on the estimated cliff sediment storage, the magnitude and frequency of erosion and cliff recession events, current cliff activity and estimated sediment grading of the various soil and rock types.

(a) Cliff Sediment Loss Estimation

Numerical estimation of the average annual sediment loss (erosion) from cliffs was calculated as follows:

*Cliff loss = Storage * Recession potential/ (slope length * recession frequency) * Activity*

For the composite cliffs at Filey Brigg, account is taken of the potential sediment loss from the erosion of the lower rock cliff.

(b) Cliff Sediment Grading

Not all sediment eroded from the cliffs provides material suitable for retention on the beaches at Filey Bay. The Glacial Till deposits provide the main source of material, other than localised outcrops of Jurassic sandy limestones at Filey Brigg, and the argillaceous Kimmeridge and Speeton Clays, Lower Greensand and Chalk talus deposits south of Reighton. Little is known of the sediment gradings of the various sediments other than visual observation, which was recorded during the geomorphological survey. From observation of materials exposed in each CBU, an estimate of the proportion of the coarse, medium and fine sediments was recorded. It is noted that considerable variability in the composition of the Glacial Till exposed in Filey Bay is apparent from visual observation. In order to reduce uncertainties regarding beach inputs, a small number of sediment samples were taken from the cliffs and grading analyses undertaken, to refine the estimates of coarse, medium and fine sediments.

(c) Effective Supply of Sediment to Beaches

An estimate of the volume of sediment likely to be retained as beach material has been calculated based on the estimated annual sediment loss from cliffs and the cliff sediment gradings. It is assumed that all coarse and medium sediment gradings are retained in the beach and that only fine sediment is lost to the sea. In this way, the cliff sediment contribution to the beaches at Filey Bay is calculated as follows:

*Input to Beach = Cliff loss * (Coarse % + Medium%)*

4.4 *Discussion*

The Filey Cliff Database and cliff mapping are included in Annex C. The maps are divided into three series (each comprising 6 sheets):

A – Cliff Behaviour Units
B -- Cliff Recession Potential
C – Planning Guidance

A detailed breakdown of each Cliff Behaviour Unit is shown on Maps A.1-A.6. The length of coast covered by the assessment is approximately 10km, between Filey Brigg and Speeton, where the geology changes.

As outlined in Section 4.3, the database includes lower and upper bound estimates of cliff storage, annual erosion and effective supply of sediment to the beaches.

The upper and lower bound estimates represent credible worst-case (i.e. high erosion) and best-case (low erosion) scenarios, respectively. The results are summarised below.

Cliff inputs	A. Inputs from cliff erosion per year (m^3/yr)	B. Total inputs due to episodic failure over strategy duration (m^3)	C. Effective annual inputs averaged over strategy duration ($m^3/year$)
lower bound	1,354	141,273	4,179
upper bound	5,597	878,964	23,176

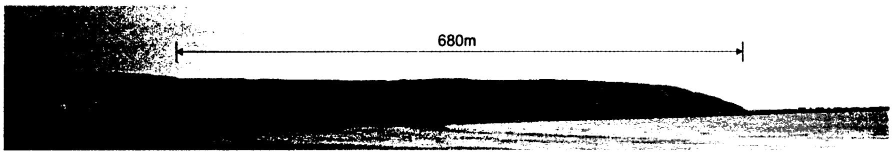
Table 4.4 Estimated sediment input to Filey Bay from cliffs
Notes: $C = A + B/50$

The effective annual sediment input includes the inputs due to cliff erosion and a proportion of the total input from episodic failure due to landslides that may feed into the Bay at any time over the strategy lifetime.

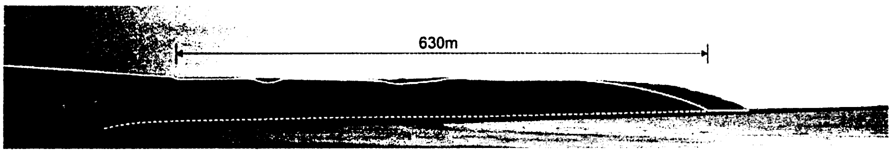
The distribution of erosion and sediment inputs to the beach within Filey Bay indicates that inputs from the cliff section north of Coble Landing are mainly due to cliff erosion. From south of Filey Town to Speeton, where the geology changes, inputs are mainly as a result of landslides and are therefore episodic in nature.

Maps B.1 to B.6 (in Annex C) show the recession potential of the various cliff units, together with the worst case scenario 50-year recession potential. These maps should be considered in conjunction with Figure 4.2, which shows a prediction of the evolution of Filey Brigg over the strategy lifetime.

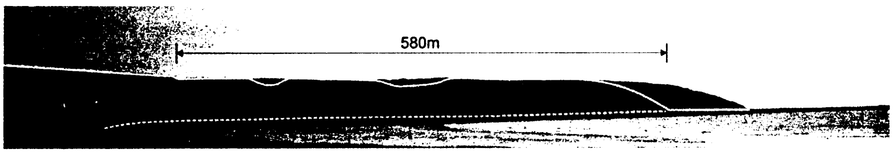
The information given on these maps, and on Maps A.1 to A.6 has been used to provide future planning guidance for the Bay. This gives recommendations on appropriate planning and development controls that should be applied in zones of varying risk of recession along the coastal frontage. The four planning guidance zones are identified in Table 4.5 and the information is presented on maps C.1 to C.6.



Filey Brigg Profile 2000



Possible Profile 2025



Possible Profile 2050

Figure 4.2 Predicted Evolution of Filey Brigg over Strategy Lifetime

Setting	Development Recommendations	Development Control
Coastal Cliffs	Area most unsuitable for development due to ongoing active coastal erosion. Development proposals subject to major constraints.	Should development be considered, a detailed Stability Report by a competent person would normally be required prior to any planning application. Many planning applications in this area may have to be refused due to the potential impacts of coastal erosion.
Coastal Landslides	Area most unsuitable for development due to ongoing active landslides. Development proposals subject to major constraints.	Should development be considered, a detailed Stability Report by a competent person would normally be required prior to any planning application. Many planning applications in this area may have to be refused due to the potential impacts of coastal landslides.
Degraded Coastal Slopes	Area likely to be subject to significant constraints due to potential ground movement. Development proposals should take account of the potential for ground movement and the requirements for slope stabilisation measures to safeguard the site and development proposals.	A detailed Stability Report prepared by a competent person would normally be required prior to any planning application. The stability of the site and adjacent land should be evaluated with regard to the design-life of the development proposals and strategy for maintaining the coastal defences.
Cliff-top Consideration Zone	Area which may or may not be suitable for development due to potential cliff-top recession and instability. Site investigation and monitoring may be required prior to proposals being made.	A detailed Stability Report prepared by a competent person would normally be required prior to any planning application. The stability of the site and adjacent land should be evaluated with regard to the design-life of the development proposals and the potential impacts of cliff-top recession and instability.

Table 4.5 *Planning guidance*

5 Coastal Processes

5.1 *Historic Map Analysis*

5.1.1 *Methodology*

Analysis of historic maps for the frontage was undertaken in conjunction with studies being carried out for the DEFRA-funded Futurecoast project, with some further analysis being undertaken to assess the changes in Filey Bay in more detail. Current and historic Ordnance Survey 1:10,000 (or equivalent) scale mapping was reviewed to identify the extent and nature of historic shoreline change. Four positions were recorded for each map year along pre-defined profile lines:
Mean Low Water (MLW);
Mean High Water (MHW);
Cliff toe; and,
Cliff top.

The profiles considered for the study area are shown in Figure 5.1. The 1:10,000 maps available for the frontage at the locations considered are listed in Table 5.1. These allowed an assessment of changes over approximately 150 years to be made.

Futurecoast profile ref.	Location	Maps available
116	North of Filey Town	1853, 1913, 1938, 1958, 1971, 1992, 2000
117	Flat Cliffs	1853, 1893, 1912, 1945, 1958, 1973, 2000
118	Reighton	1893, 1912, 1945, 1958, 1973, 2000
119	Speeton	1853, 1893, 1912, 1953, 1958, 1974, 2000

Table 5.1 Historic map analysis profiles

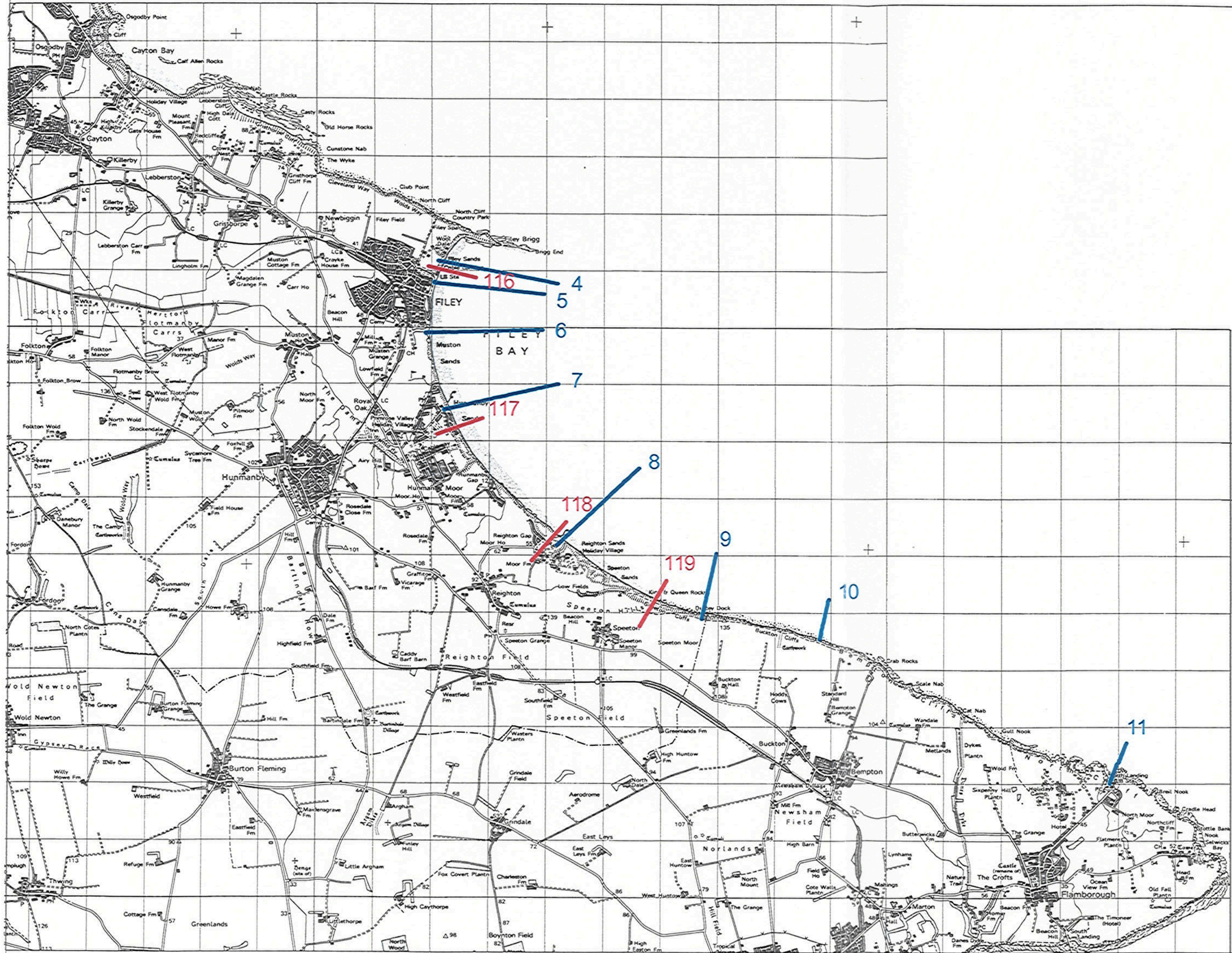
The cross-shore profiles, along which historic shoreline movements are measured, were identified based on the methodology derived for the Futurecoast project:

- Selection of locations that are geomorphologically representative of the length of coast (not the most active/highest rates).
- Locations at a maximum of 5km apart, and a minimum of 1km apart.
- Confirmation that lines do not cross the edge of historic mapping tiles (as adjacent tiles may not have the same survey dates).
- Alignment of profile 'normal' to the trend of the coast to ensure correct distances are measured).

Scarborough Borough Council

FILEY BAY
COASTAL STRATEGY STUDY

Halcrow
2001



Profiles used for historic map analysis

Survey profiles used in sediment transport modelling

Profiles Used in Coastal Processes Analysis

Figure 5.1

N

0 2 4 6 Kilometres

The historic movement data has been filtered to remove near-zero values based upon the known accuracy of OS mapping, i.e. points closer than 4.2m (between map editions) are filtered out as they are more likely to be due to mapping error than actual change. This process removes the data that indicates a level of accuracy greater than can actually be achieved with the mapping. In addition to this it is important to identify data which is incorrectly positioned due to errors in the warping etc of the historic maps.

It is not possible to automate this process, as movements due to map shifts are not detectable above natural shoreline movement. Therefore it is necessary to attempt to identify the erroneous maps and define the error. The following qualitative checks have been carried out to identify those maps (and hence data) which are not correctly positioned due to errors in their warping etc.

- Whilst identifying the historic point locations, digitisers overlay and compare map editions. From this, any significant difference between the maps is immediately obvious as the displacement makes the image appear blurred.
- Identification of any data that appears to show a seaward migration of the cliff-top position. This is very unlikely to occur in reality, therefore it is highly likely that such data are indicative of incorrect mapping.
- Identification of any data that appears to indicate movement of hard defence structures. Again, this is not likely to happen (except where a defence has been rebuilt on a new alignment) and the data are likely to represent mapping error.
- Identification of data indicating a single reversal in the overall movement trend of a feature, e.g. if the MLW position has shown retreat on all but one map editions. Although it is quite reasonable for a feature to display non-linear behaviour, it is more likely that a trend would continue over time, and therefore this may be due to mapping error.

The first test is carried out whilst the data is being captured whereas the others are based upon analysis of the gathered data.

Having identified those maps that may not be correctly spatially located, it was then necessary to quantify the error through measurement of the movement of known fixed features (e.g. churches, houses, etc). Where possible, three measurements within the vicinity of the profile are taken and the average of these is used to define the error for that profile (in metres). Where this error is in excess of acceptable tolerances, a correction was applied to 'shift' the value determined from the map.

Relative positions of cliff top, base of cliff, high and low water are represented in Figures 5.2 to 5.5 for each of the profiles. The changes observed at each location are discussed below.

5.1.2 *Filey (Figure 5.2)*

To the north of Filey Town, the mapping analysis suggests cliff recession. There are intervals where the cliff toe recession appears to be greater than cliff top recession, indicating cliff steepening. This is generally followed by some advance of the base of the cliff. This might be the result of slips as the over-steepened cliff becomes unstable, although clearly it is difficult to identify such processes at the map scale used.

There has been some fluctuation of the high and low water positions at this location although there is no long-term change. While there was some historic steepening of the beach, particularly 1920 –1940, there is no apparent trend of a reduction in beach width in recent years. Since 1940, a back of beach is present, which was non-existent in the earlier mapping, suggesting the high water line met the cliff. These changes may well be due to difference in the position of high and low water at the time of survey, so may not actually indicate any real changes.

5.1.3 *Flat Cliffs – Primrose Valley (Figure 5.3)*

At the centre of the Bay, at Flat Cliffs / Primrose Valley, the cliffs and beach are steeper. There is a clear trend of cliff and high water recession, with cliff top, cliff toe and high water retreat occurring at similar rates. There is some fluctuation in the position of low water, with the beach reaching its narrowest around 1945. From 1945 to 1958 the beach appears to have increased in width, with negligible change in width since then.

5.1.4 *Reighton (Figure 5.4)*

At Reighton, there seems to have been some retreat of the low water mark until 1940, since when the position has been relatively constant. This retreat may have coincided with the commercial extraction of material from the foreshore, which reportedly took place at Reighton between 1939-69. This may have triggered the retreat of the high water line and cliff toe, which has resulted in a wider beach. There is no indication of significant change in the cliff top position over the period considered.

Figure 5.2

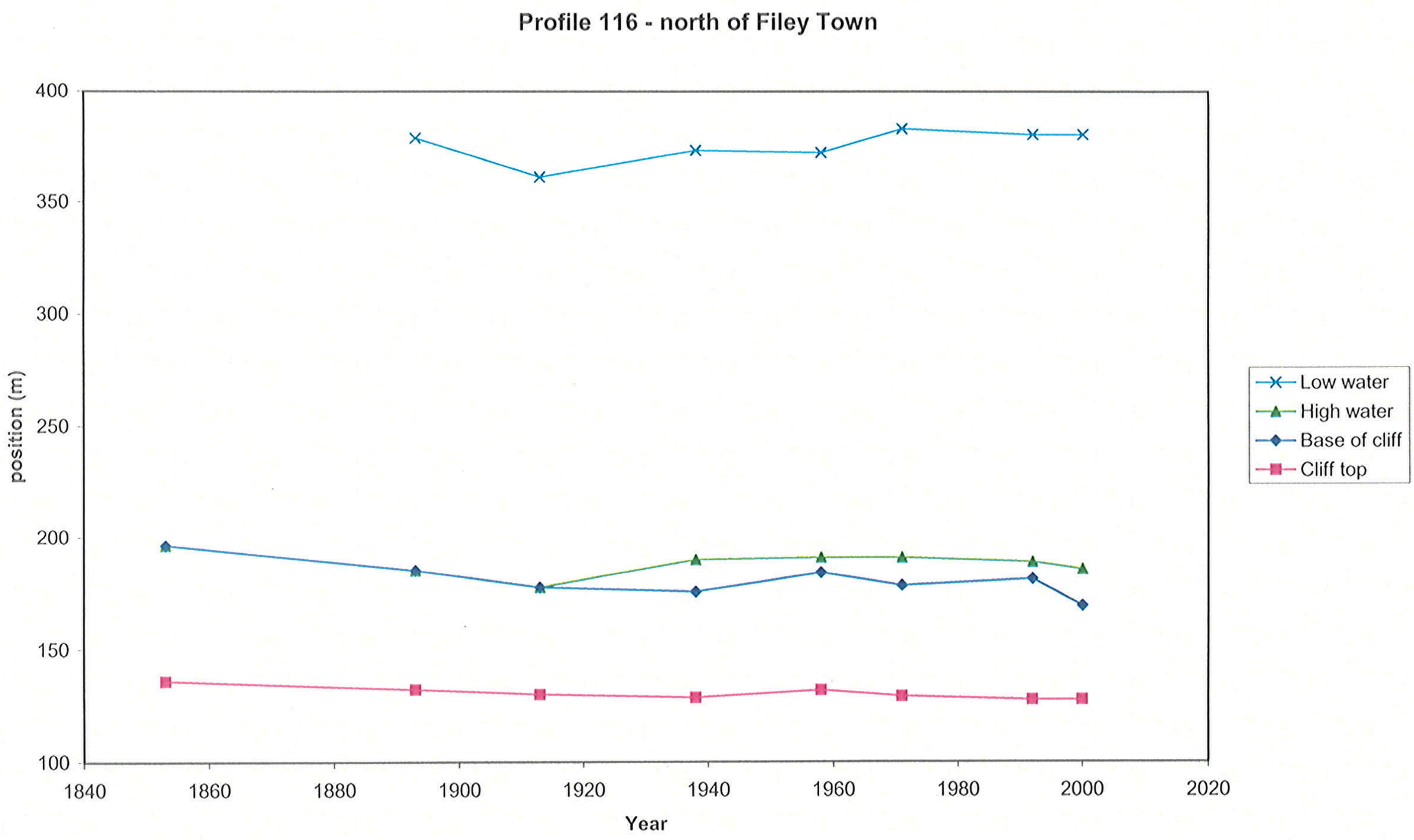
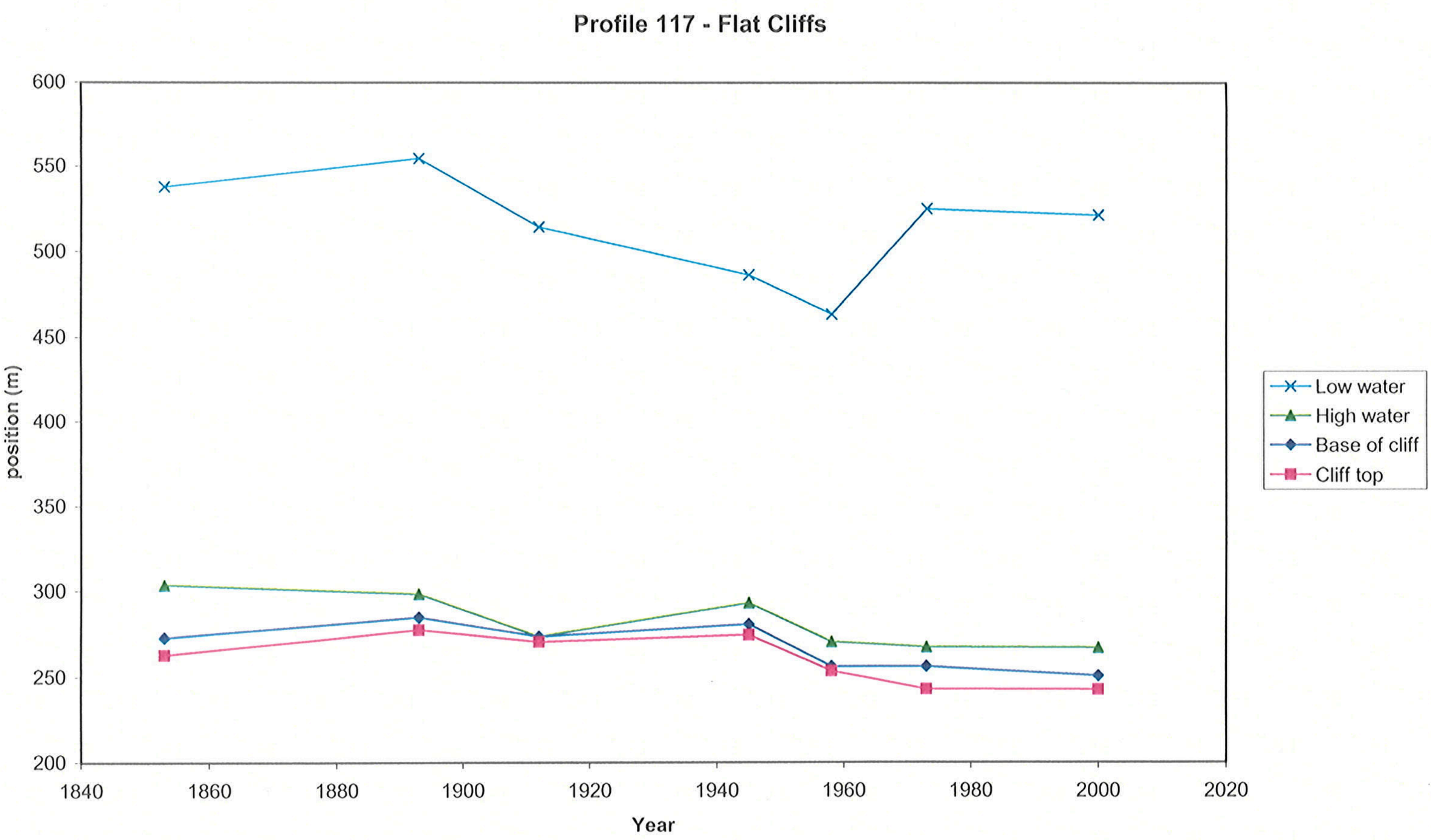

Profile 116 - north of Filey Town
400
350
300
250
200
150
100
position (m)
1840
1860
1880
1900
1920
1940
1960
1980
2000
2020
Year
Low water
High water
Base of cliff
Cliff top

Figure 5.3



Profile 117 - Flat Cliffs
600
550
500
450
400
350
300
250
200
position (m)
1840
1860
1880
1900
1920
1940
1960
1980
2000
2020
Year
Low water
High water
Base of cliff
Cliff top

Figure 5.4

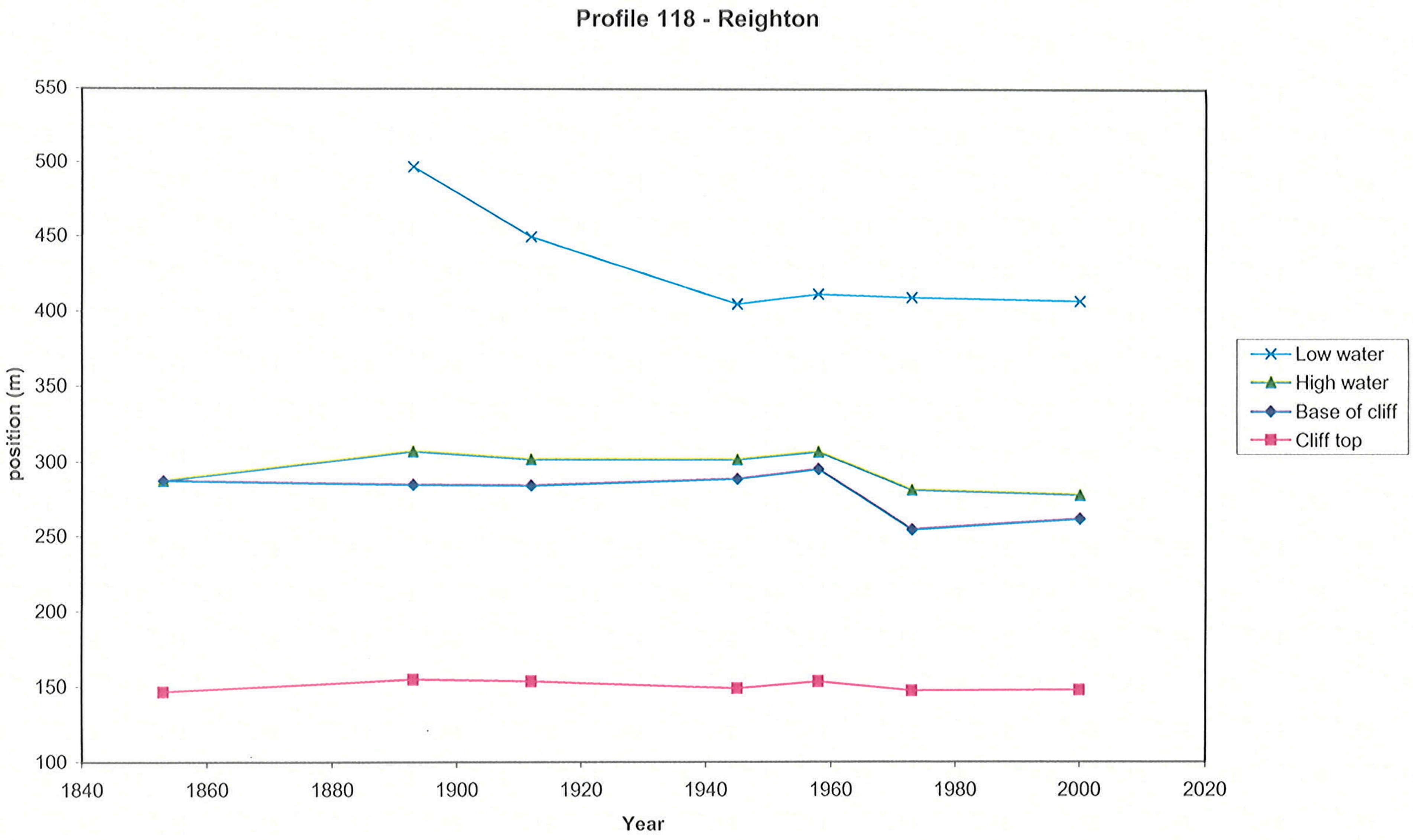
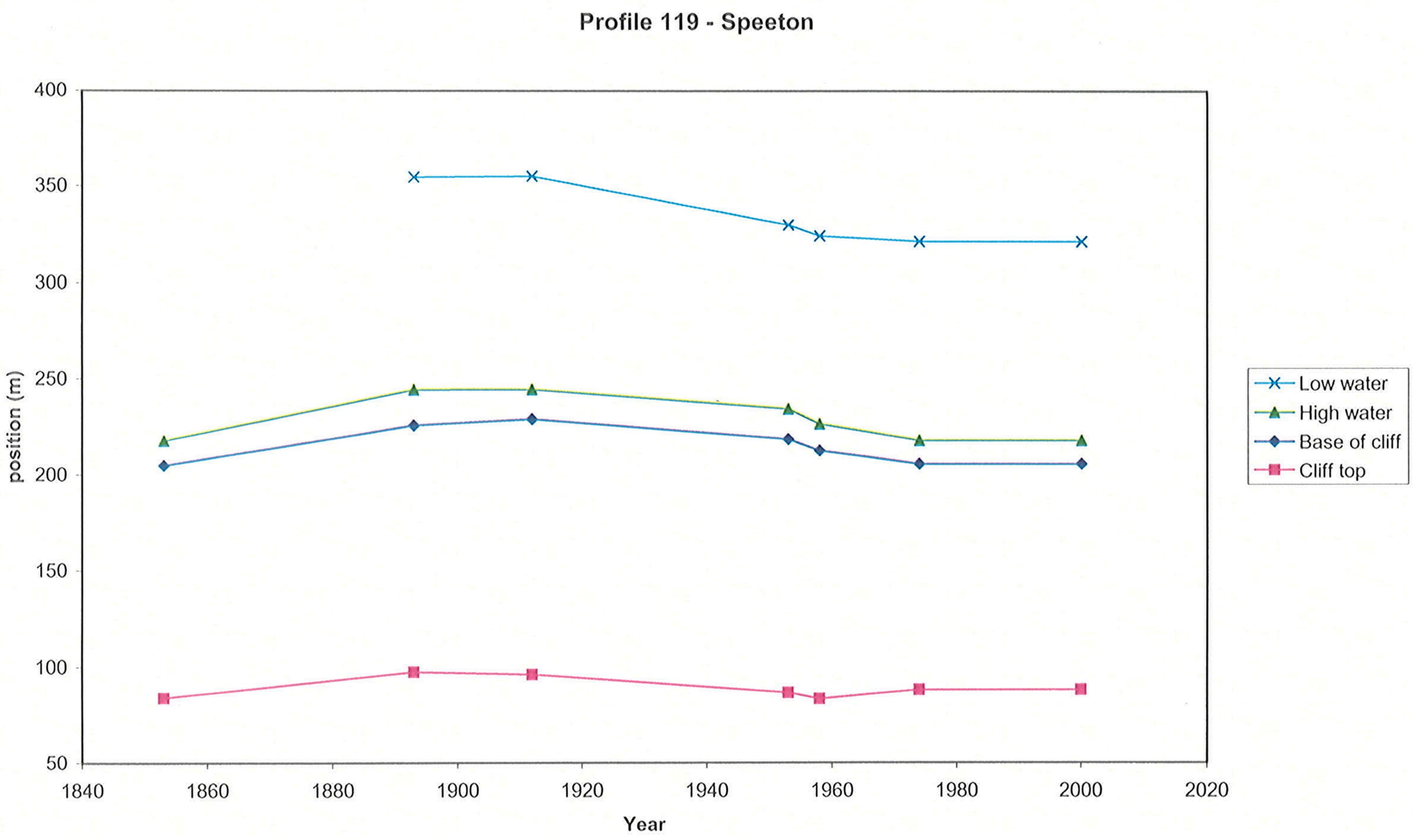

Profile 118 - Reighton
550
500
450
400
350
300
250
200
150
100
position (m)
1840
1860
1880
1900
1920
1940
1960
1980
2000
2020
Year
Low water
High water
Base of cliff
Cliff top

Figure 5.5


Profile 119 - Speeton
400
350
300
250
200
150
100
50
position (m)
1840
1860
1880
1900
1920
1940
1960
1980
2000
2020
Year
Low water
High water
Base of cliff
Cliff top

5.1.5 *Speeton (Figure 5.5)*

To the south, at Speeton, low water, high water and the base of the cliff have retreated at a similar rate. Cliff top recession has been slower, resulting in some steepening of the cliff, although some fluctuation in the cliff toe position has meant there is no net change in cliff toe (and high water) position over the mapping period considered.

There is clearly a fluctuation in the cliff top position over the time frame considered, resulting in no net change in position over the time frame considered, while it is clear from site observations that this is not the case. This is clearly a shortcoming of the data set considered and is likely to be as a result of the errors resulting from using maps at such a scale to identify small changes.

Typical cliff recession rates calculated from the historical mapping area as follows:

Futurecoast profile ref.	Location	Cliff top recession (m/year)	Cliff toe recession (m/year)
116	North of Filey Town	0.06	0.18
117	Flat Cliffs	0.16	0.14
118	Reighton	0.17	0.17
119	Speeton	No discernible change from maps (see discussion above)	

Table 5.2 Cliff recession rates from historic mapping analysis

These give average recession rates over approximately 150 years, and as a result mask any short term trends, such as accelerated recession rates. These rates are of use in assessing historic changes, however care should be exercised in using these average rates to determine likely future recession. The more detailed cliff behaviour studies, discussed in Chapter 4 have identified individual cliff behaviour units and have quantified their likely recession over the strategy lifetime. For much of the glacial till cliffs within the Bay, the key failure mechanism is episodic in nature, due to landslips that result in several metres of cliff top being lost in a single event. The historic recession rates derived from the mapping will not identify this recession mechanism. Where erosion is the dominant mechanism, then historic recession rates are more readily comparable with the predictions made during the site inspection. Of the profiles considered, the only one where erosion dominates is immediately to the north of Filey Town (profile 116). The lower bound recession rate for this profile was estimated as 0.1m/year (see database in Annex C) which compares well with the rates derived from the historic mapping, given in Table 5.2.

Key features the historic mapping analysis has identified are:

- a widening of the back of beach north of Filey Town;
- an increase in beach width at Flat Cliffs since 1960, due to cliff retreat and advance of the low water mark;
- an increase in beach width at Reighton since 1960, mainly due to cliff recession, rather than advance of the low water line.

The historic recession rates do not take account of future rises in sea level due to climate change and the resulting potential for increase in cliff recession, which has been considered in the upper bound estimate made in the cliff recession studies (see upper bound database table in Annex C).

5.2 Sediment Transport Modelling

5.2.1 *Introduction*

A review of previous studies of sediment transport in Filey Bay was undertaken. In order to improve understanding of sediment movements within Filey Bay, this was supplemented by sediment transport modelling. The modelling addressed two key aims:

- to establish annual potential longshore drift rates, to improve understanding of sediment movements within the Bay;
- to assess cross-shore response of the beach under storm conditions, to identify whether the stability of defences may be compromised or erosion of the cliff toe may occur.

5.2.2 *Previous studies*

A detailed study of Filey Bay was undertaken by the Institute of Estuarine & Coastal Sciences at the University of Hull (IECS, 1991), to assess sediment movements within the Bay and the likely impacts of dredging on the sediment budget for the Bay.

The IECS study assessed the likely sediment movements under waves from different directions, using the 50-year return period wave conditions to develop a model of the processes within the Bay, which concurs with the wave studies undertaken as part of this strategy. The studies indicated that the most extreme wave conditions came from the north to north east. Under storm conditions of low return period, Filey Brigg shadows the northern end of the Bay, however, for the 1 in 50 year event and above, the longer period waves diffract round the headland.

Studies identified that waves caused sediment movement in depths of up to 20m. Coarse sediments are deposited around the -10m contour as deepwater waves begin to break, and finer material is moved onshore. This is confirmed by sediment mapping, which indicates coarser material offshore. Given the limit of sediment movement at depths of around 20m, IECS suggest there is no significant cross-shore transfer of material via shore-normal pathways. This also suggests that there is not likely to be any input of sediment to the Bay from offshore of the 20m depth contour.

Modelling undertaken by IECS suggests that under northerly wave conditions, sediment transport is in a southerly direction, increasing from Coble Landing to Reighton. There is some deposition of material south of Reighton, and some loss of material out of the Bay as it is transported round Flamborough Head. Under north-easterly wave conditions, trends are similar, but there is no apparent loss of sediment out of the Bay, to the south.

IECS suggest that northerly residual currents around Flamborough Head result in a sediment input to the Bay of approximately 30,000m^3/year, most likely from Smithic Sands, offshore of Bridlington, immediately to the south of the Head. The sediment budget proposed by IECS appears to rely on this assumption of input for the sediment budget to be in equilibrium. A simplified estimate of sediment inputs from the cliffs was made, based on average erosion rates and the assumption that less that 10% of the debris deposited on the beach would be large enough to be retained on the beach. This gave an estimate of 10,000m^3/year of sand being input from the cliffs to the beach.

5.2.3 *Longshore Modelling*

In order to further develop an understanding of sediment movement within the Bay, the COSMOS2D model was used to quantify potential longshore drift rates at various locations within the Bay. COSMOS2D is a 2-dimensional beach profile model for fine sediments (see Annex B).

Beach profile and bathymetry information, obtained during the survey completed as part of the Strategy, was used to set up the COSMOS2D model at 8 locations within Filey Bay, see Figure 5.1. Information on sediment grain size, obtained from grading analysis of beach samples collected during the survey work, was used as input to the modelling (see Table 2.1).

COSMOS2D was run for each of the wave conditions in the scatter table, given in Table 3.2 (after transformation to the -10m contour), with each condition weighted to represent its probability of occurrence. The outputs for all of the discrete conditions were then summed to produce a potential annual longshore drift rate at each profile location.

COSMOS2D transforms the offshore wave conditions inshore, taking into account refraction, shoaling, bottom friction and wave breaking, assuming shore parallel contours.

Initially the modelling only used those wave conditions from the 330-90° sectors, as these were the wave direction sectors that had been used in the modelling completed as part of the SMP studies. It was recognised that there was some wave energy from the south-easterly sector that may have an influence on sediment transport, particularly at the northern end of the Bay. Further runs were therefore completed that included wave conditions from additional sectors 90-130°, allowing for waves from the south-east that would diffract round Flamborough Head.

The general drift trend was the same for both wave data sets, with only a slight reduction in the southerly drift rate due to the south-easterly waves, suggesting that the wave energy from the south east does not have a significant effect on sediment transport within the Bay.

At the northern end of the Bay, from Filey to Reighton, net drift is in a southerly direction, towards Flamborough Head (which agrees with the findings of IECS for northerly / north-easterly waves), however at Speeton, the net drift direction reverses, towards Filey Brigg. The results suggest some potential for erosion at the northern end of the Bay, at Filey Town. From Filey Town to Flat Cliffs, the drift rates suggest that the shoreline is accreting, while from Flat Cliffs to Reighton, the shoreline generally appears to be in equilibrium. The drift appears to converge just south of Reighton. It is therefore likely that some accretion is occurring. The historic map analysis shows that the low water mark here is not retreating at the same rate as the cliffs, suggesting an accumulation of material. Some of this material may also be lost offshore or may be carried northwards within the Bay by the northerly residual tidal currents. The bathymetry shows relatively shore-parallel contours suggesting that sea bed features, such as offshore bars are not being formed by this material. The change in drift direction coincides with a change in orientation of the coastline, in particular relative to the most extreme incident waves (from 75°).

Moving east, along Buckton Cliffs, the drift reverses once again towards Flamborough Head, resulting in a drift divide. The drift rate is however significantly reduced, due to the change in geology, the resulting increase in sediment size, and the change in orientation of the shoreline.

The information on longshore drift derived from this modelling is the net drift resulting from those wave conditions in the offshore scatter table given in Table 3.2, comprising 9 years of data (January 1987 to December 1995). The results do not however show the variability in either drift rate or direction resulting from different wave directions and can therefore only be taken as indicative of sediment processes within the Bay.

5.2.4 *Cross-shore Modelling*

Cross-shore modelling was carried out to assess the effect of extreme storm conditions on draw-down of beach levels. For the majority of the Bay, where there is no form of defence, this assists in identifying whether the drawdown might cause increased erosion of the toe of the cliff, leading to accelerated cliff erosion and instability. For Filey Town, the modelling allowed an assessment of the likelihood of undermining of the seawall to be made. The locations considered were:

- North of Filey Town (profile 4)
- Filey Town, in front of the seawall (profile 5)
- Flat Cliffs (profile 7)
- North Landing (profile 11)

The COSMOS2D model was used, assuming that an extreme wave event lasted for 24 hours. Tidal levels, from a typical spring tide curve, were derived at hourly intervals, giving 24 wave/water level events, each with a duration of one hour.

The quantity of mobile beach material is limited in places by the presence of the glacial till extending beneath the sand, forming a less erodible cohesive layer. There is anecdotal evidence of the clay layer being exposed during storm conditions, with the sand returning some days later. The COSMOS2D model allows a cohesive layer to be included. In order to establish the depth of mobile material, hand augering was undertaken at various locations on the beach, at Flat Cliffs and Filey Town.

The field measurements suggested that the sand depth at Flat Cliffs was typically 2m on the upper beach, reducing to 0.25m at approximately 20m further seaward.

At Filey Town, augering at each end of the seawall, to a depth of approximately 1m, yielded only sand and gravel material, indicating that the presence of the clay layer is at a depth of greater than 1m. Later trial pit investigations confirmed sand and gravel depths of 1.2m to 1.4m overlying the clay.

Profile changes arising from the 1-year return period storm, from 4 direction sectors (330-360°, 0-30°, 30-60° and 60-90°) were assessed, to establish the wave direction which caused the worst draw-down in beach levels. For each profile, various sensitivity analyses were then carried out, to further assess beach response.

It is clear from the modelling results (discussed in more detail below) that there is a risk of erosion of the cliff toe along the unprotected frontage as the beach, which provides a degree of natural protection to the cliffs, is drawn down under extreme conditions. Clearly there are resulting benefits, as this ensures a continued supply of sediment to the Bay. It does not appear that there are long-term problems due to loss of beach material in the Bay, with the losses at least balanced, if not less than, the supply from the eroding cliffs. It is also likely that the beach will be built up at the toe of the cliff under milder wave conditions. Material deposited as a result of cliff falls and landslips will provide additional temporary protection. Of more concern, however, are cases where the cohesive layer beneath is exposed, particularly as this may occur with increasing frequency as a result of increasing storminess, due to climate change. Increased exposure is likely to lead to abrasion and erosion of the cohesive layer, which is not so easily replaced. This could ultimately result in lowering beach levels as the strata beneath erodes, leading to increased toe erosion and an acceleration of the resulting cliff recession. At Filey Town this scenario could eventually lead to undermining of the wall, which may result in failure. Where cliffs are unprotected this effect is likely to be balanced by the increase in sediment supply from the cliffs.

Each of the locations is discussed in further detail in the following sections.

(a) North of Filey Town (profile 4)

To the north of Filey Town the beach is backed by unstable coastal slopes. The key purpose of cross-shore response modelling at this location was to identify whether beach levels will draw down to such a degree that the stability of the toe of the slopes is compromised.

Assessment of the 1-year return period waves from various directions indicated that waves from the 60-90° sector caused the greatest draw-down in beach levels (Figure 5.6). The offshore wave height is highest from this sector. The beach draw-down was limited by the presence of the less erodible cohesive layer, which was assumed to be 1m below the sand profile. The beach level dropped to +2.0mODN, suggesting that the toe of the cliffs might be exposed to some wave attack at high water (MHWS = +2.5mODN), during storm conditions.

(b) Filey Town (profile 5)

Profile 5 is located at Filey Town, in front of the near-vertical seawall. Assessment of short term changes in beach levels at this location is important as it will allow an estimate of the potential for undermining of the seawall during storm conditions to be made.

As profile 5 is relatively close to profile 4, it was assumed that the greatest changes in beach level would occur under the same wave conditions. The effect of waves from the 60-90° sector for various return periods (T_R = 1, 50 and 300 years) was therefore assessed.

As the draw-down of beach levels had been shown to be very sensitive to the location of the cohesive layer, the model was run both with a cohesive layer 1m below the sand profile (Figure 5.7) and with no cohesive layer (Figure 5.8). Trial pits later confirmed that 1.2m to 1.4m of mobile material (sand and gravel) overlies the clay horizon (located at approx +0.6mODN). Without the cohesive layer, beach levels immediately in front of the seawall dropped further, to 0mODN under the 300-year condition. [Note that the 50 year condition showed almost identical response – the inshore wave heights for the two conditions are the same, although there is a slight increase in wave period for the more extreme condition.]

The effect of Sea Level Rise (SLR) was also considered, in conjunction with the 50 year wave conditions, Figure 5.9. An allowance of 50 years SLR, at 5mm per year, was included, raising water levels by 0.25m. This showed a small increase in the depth of beach draw-down at the seawall for the case with no cohesive layer, although the resultant beach level was still approximately 0mODN.

There is limited information on the existing seawall (see Chapter 7), however historic drawings suggest that the toe of the seawall is at approximately -2.0m to -3.0mODN, well below predicted storm beach levels. The seawall stability is discussed further in Chapter 7.

(c) Flat Cliffs (location 7)

At Flat Cliffs, wave conditions from a number of wave directions were assessed. This showed that waves from the 60-90° sector (75° mean direction) resulted in the greatest draw-down in beach levels, for the 1-year return period condition, Figure 5.10. A cohesive layer was included, based on field observations. There was some localised cut down of beach levels at the cliff toe, as far as the cohesive layer, with the rest of the profile dropping to a beach level of approx. +2.3mODN, just below MHWS (+2.5mODN).

A number of sensitivity tests were completed at this location, to assess the influence of wave period and of tidal currents on beach levels. The 1-year return period wave condition, from offshore direction 75 degrees, was used for these tests.

Wave period was varied by ±1 second, Figure 5.11. This showed that the longer wave period resulted in greater retreat of the crest of the beach, however, the shorter waves caused the greatest draw-down in beach levels.

The introduction of a tidal current of constant magnitude 1.3m/s, in both northerly and southerly directions (Figure 5.12), showed that neither current had a significant effect on beach levels. Again, the presence of the cohesive layer appears to control the drop in beach level.

Profile changes under extreme conditions with return periods, T_R, of 50 and 300 years were then considered for the worst case offshore wave direction (75°), Figure 5.13. This showed that beach levels cut down to the cohesive layer at the cliff toe, but that seaward of this beach levels were typically +2mODN, slightly below MHWS.

Figure 5.6

Filey Bay Strategy Study : Profile 4 - Comparison of profile changes under 1 year return period waves from different offshore directions over a spring tide event

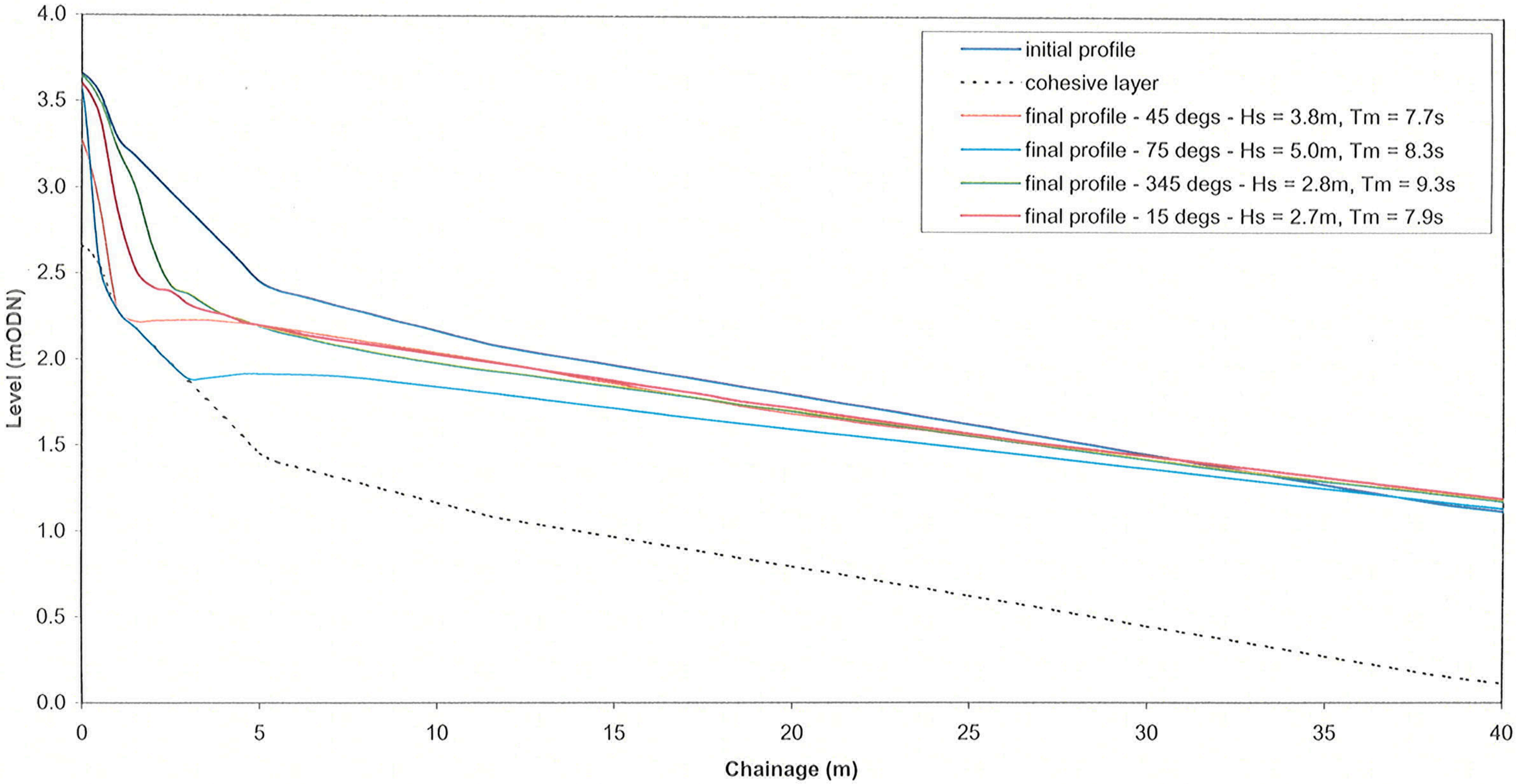


Figure 5.7

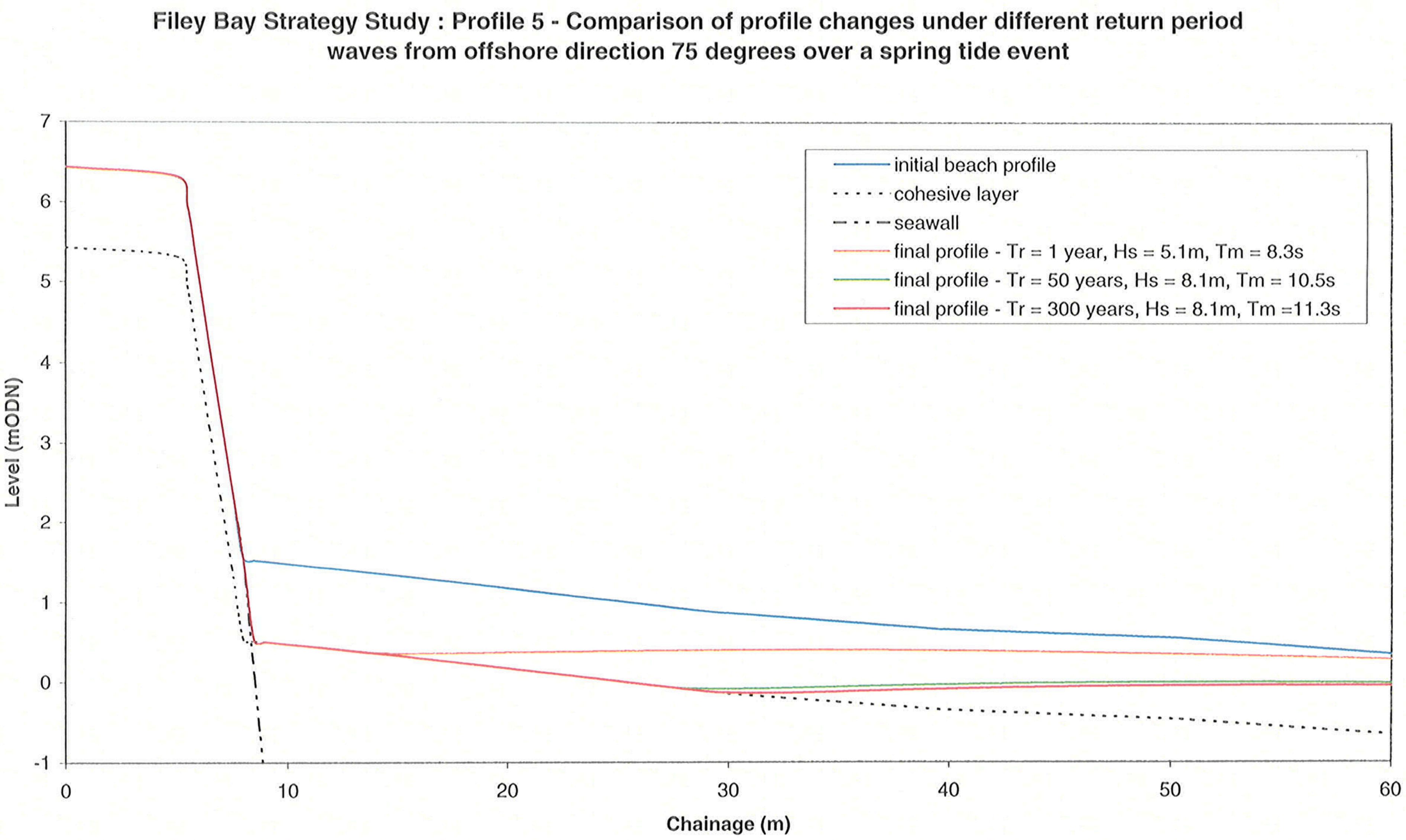

Filey Bay Strategy Study : Profile 5 - Comparison of profile changes under different return period waves from offshore direction 75 degrees over a spring tide event
initial beach profile
cohesive layer
seawall
final profile - Tr = 1 year, Hs = 5.1m, Tm = 8.3s
final profile - Tr = 50 years, Hs = 8.1m, Tm = 10.5s
final profile - Tr = 300 years, Hs = 8.1m, Tm =11.3s
Level (mODN)
7
6
5
4
3
2
1
0
-1
0
10
20
30
40
50
60
Chainage (m)

Figure 5.8

Filey Bay Strategy Study : Profile 5 - Comparison of profile changes under different return period waves from offshore direction 75 degrees over a spring tide event with no cohesive layer

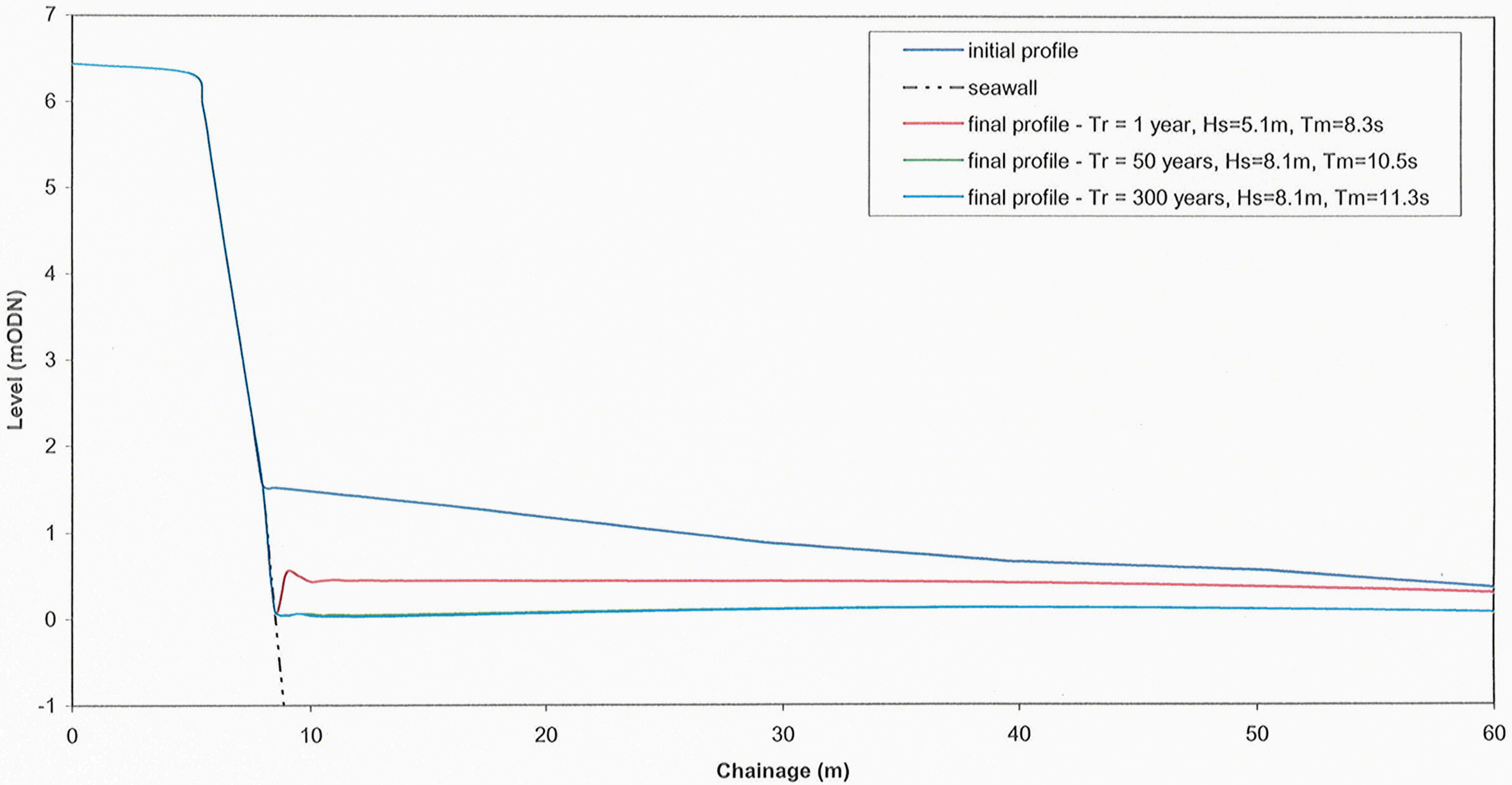


Figure 5.9

Filey Bay Strategy Study : Profile 5 - Comparison of profile changes (with no cohesive layer) under 50 year return period waves from offshore direction 75 degrees over a spring tide event with and without an allowance for sea level rise (=5mm/year)

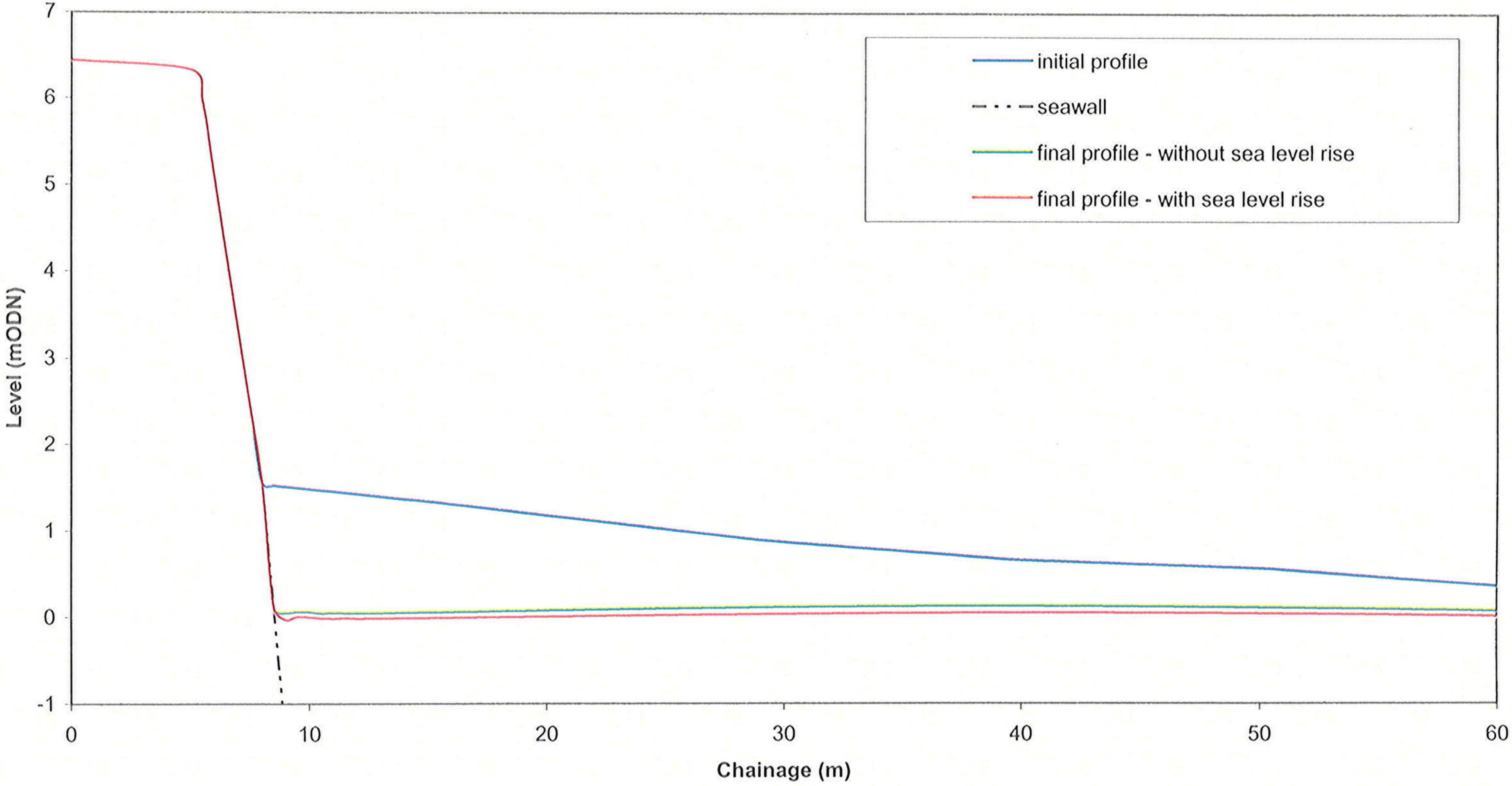


Figure 5.10

Filey Bay Strategy Study : Profile 7 - Comparison of profile changes under 1 year return period waves from different offshore directions over a spring tide event

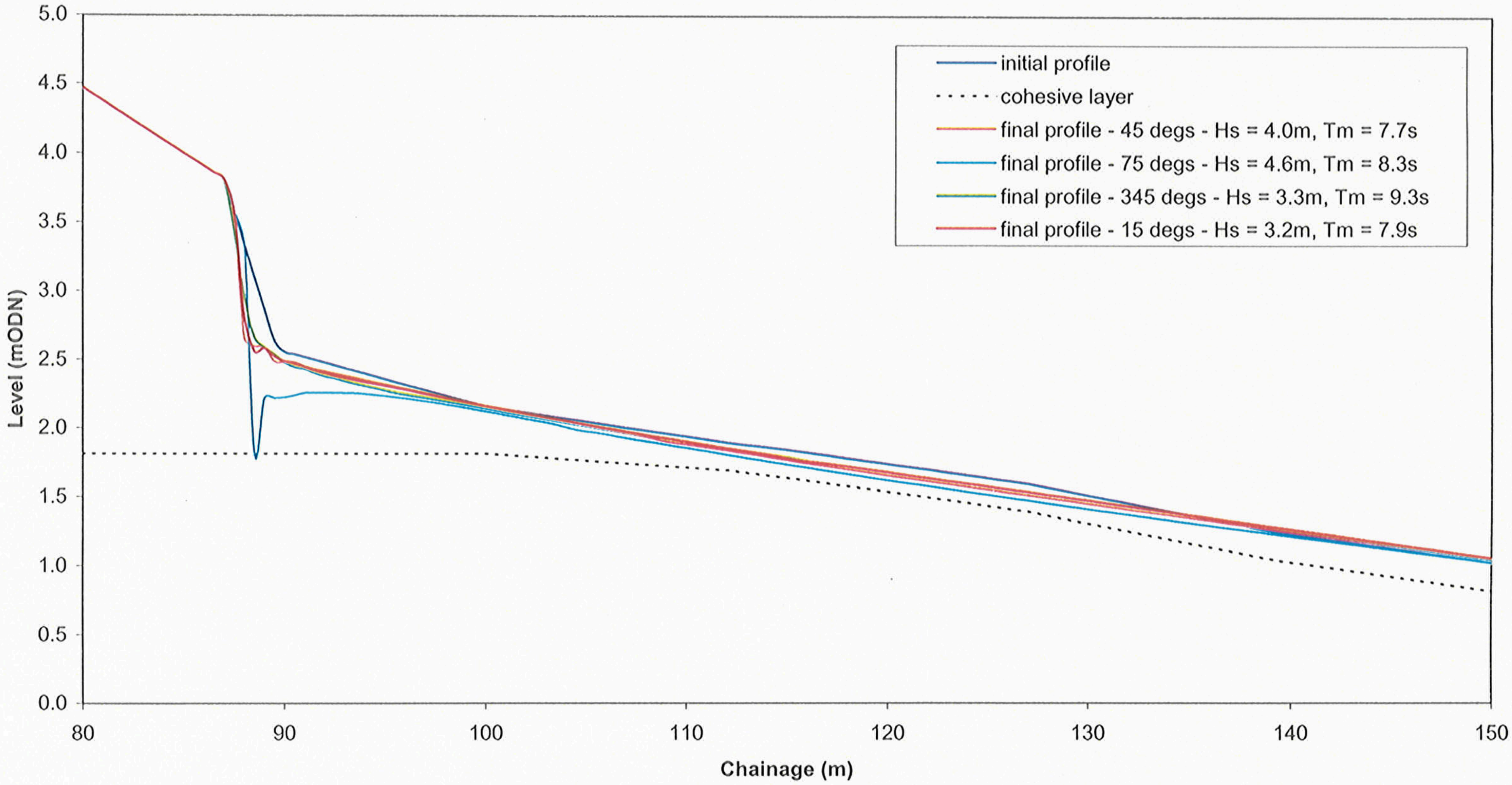


Figure 5.11

Filey Bay Strategy Study : Profile 7 - Comparison of profile changes (with modified cohesive layer) with different wave periods and 1year return period waves from offshore direction 75 degrees over a spring tide event

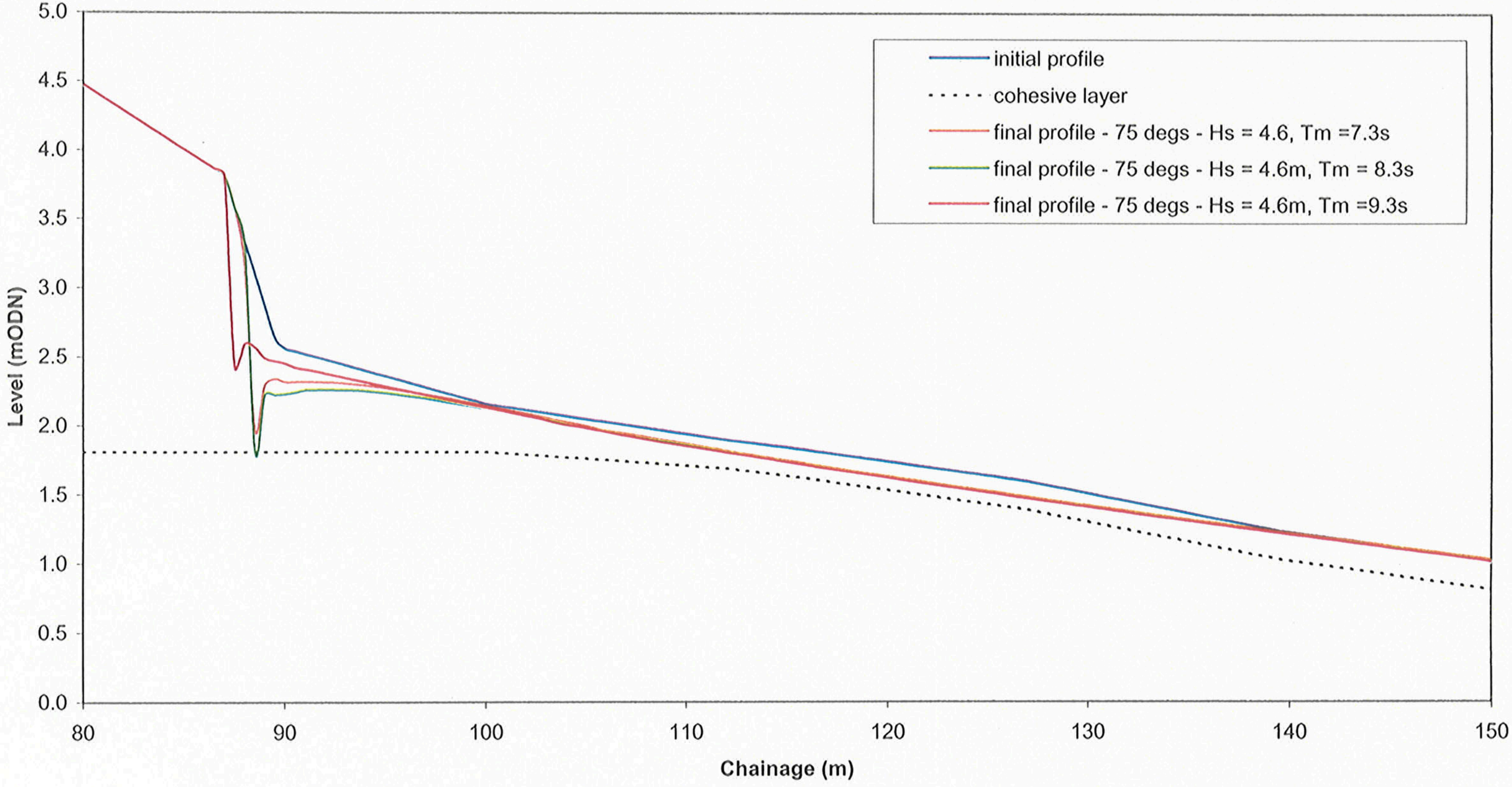


Figure 5.12

Filey Bay Strategy Study : Profile 7 - Comparison of profile changes (with modified cohesive layer) with different magnitudes and directions of tidal currents and 1year return period waves from offshore direction 75 degrees over a spring tide event

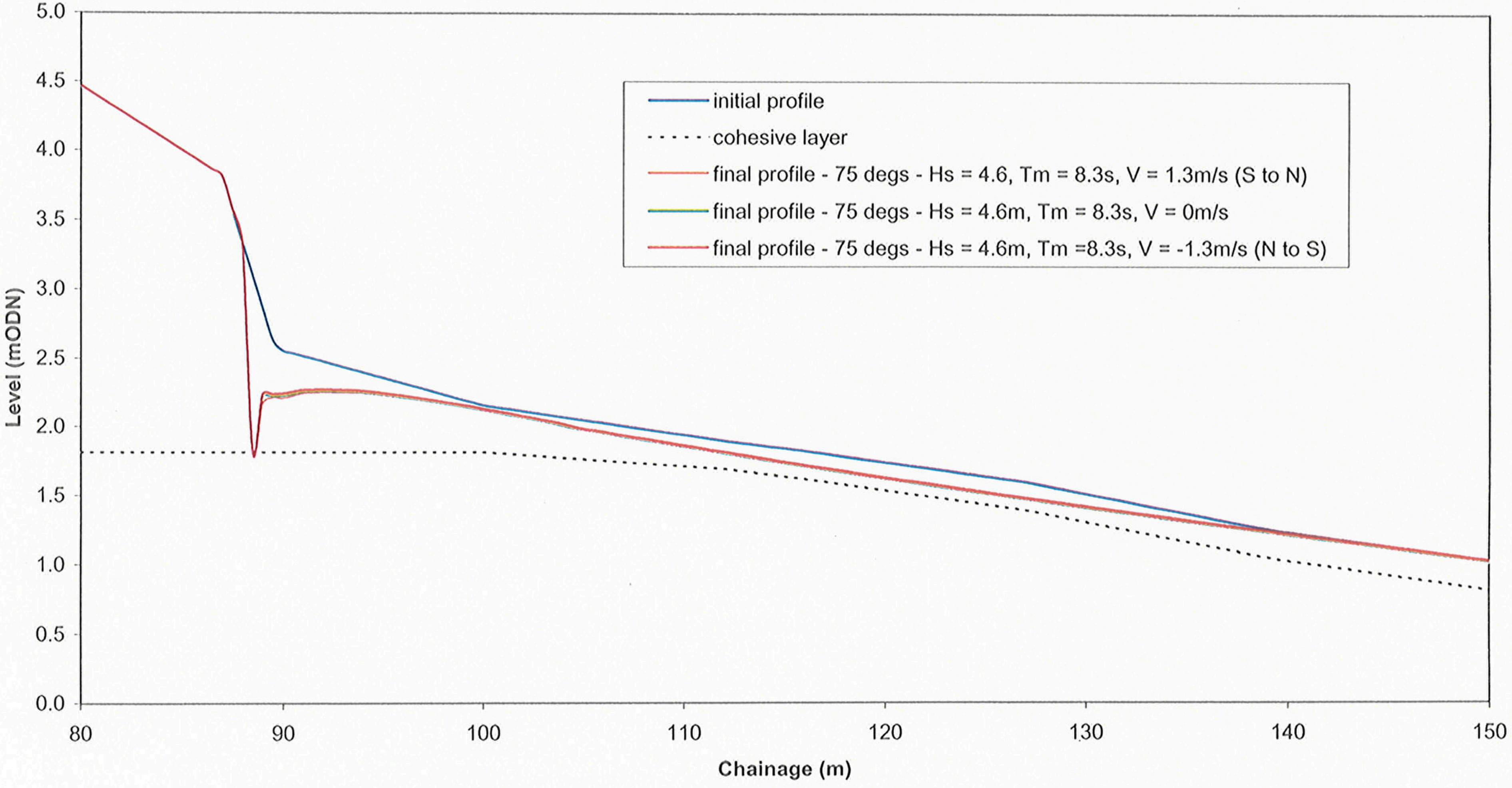


Figure 5.13

Filey Bay Strategy Study : Profile 7 - Comparison of profile changes (with modified cohesive layer) under different return period waves from offshore direction 75 degrees over a spring tide event

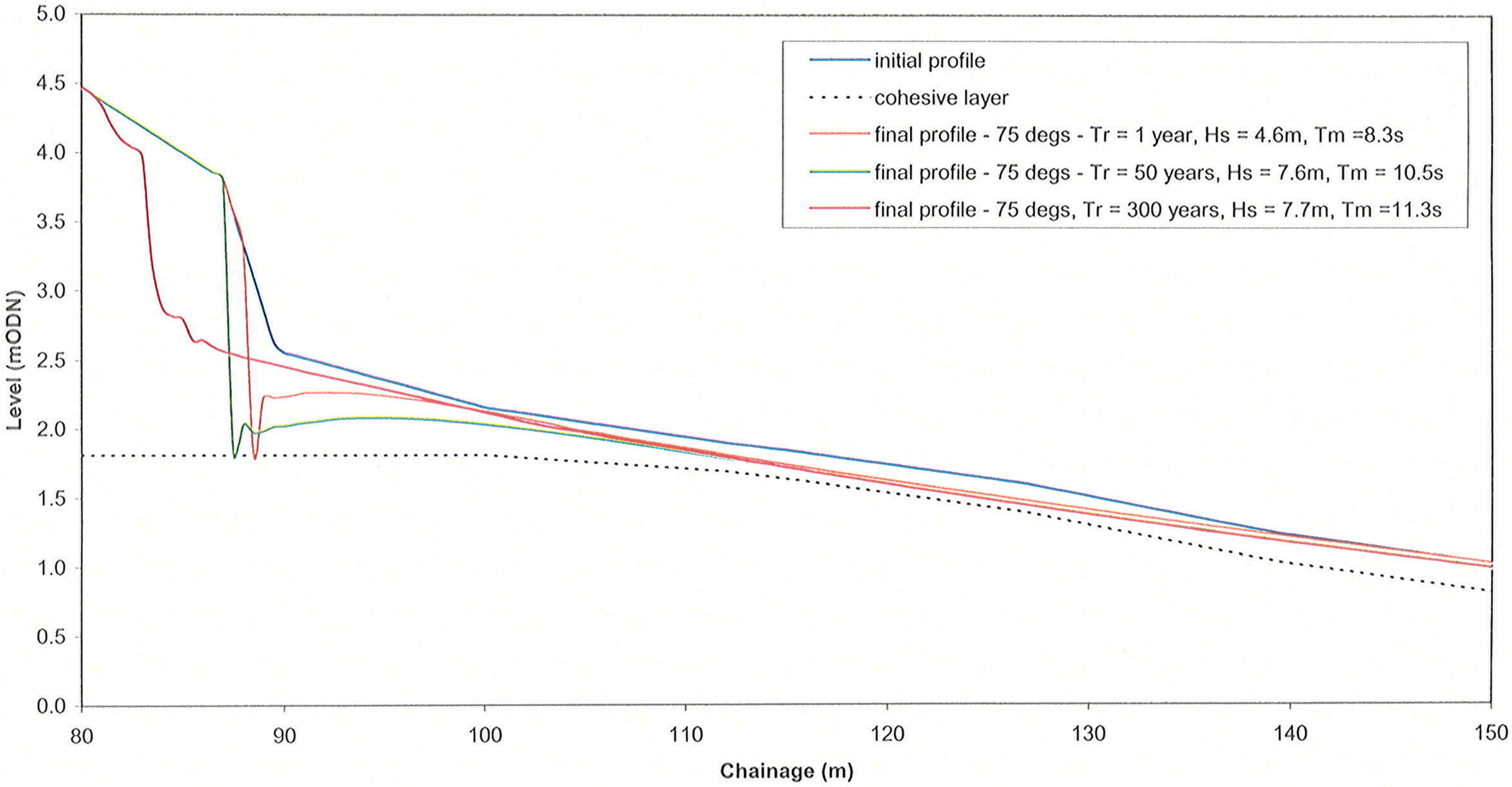
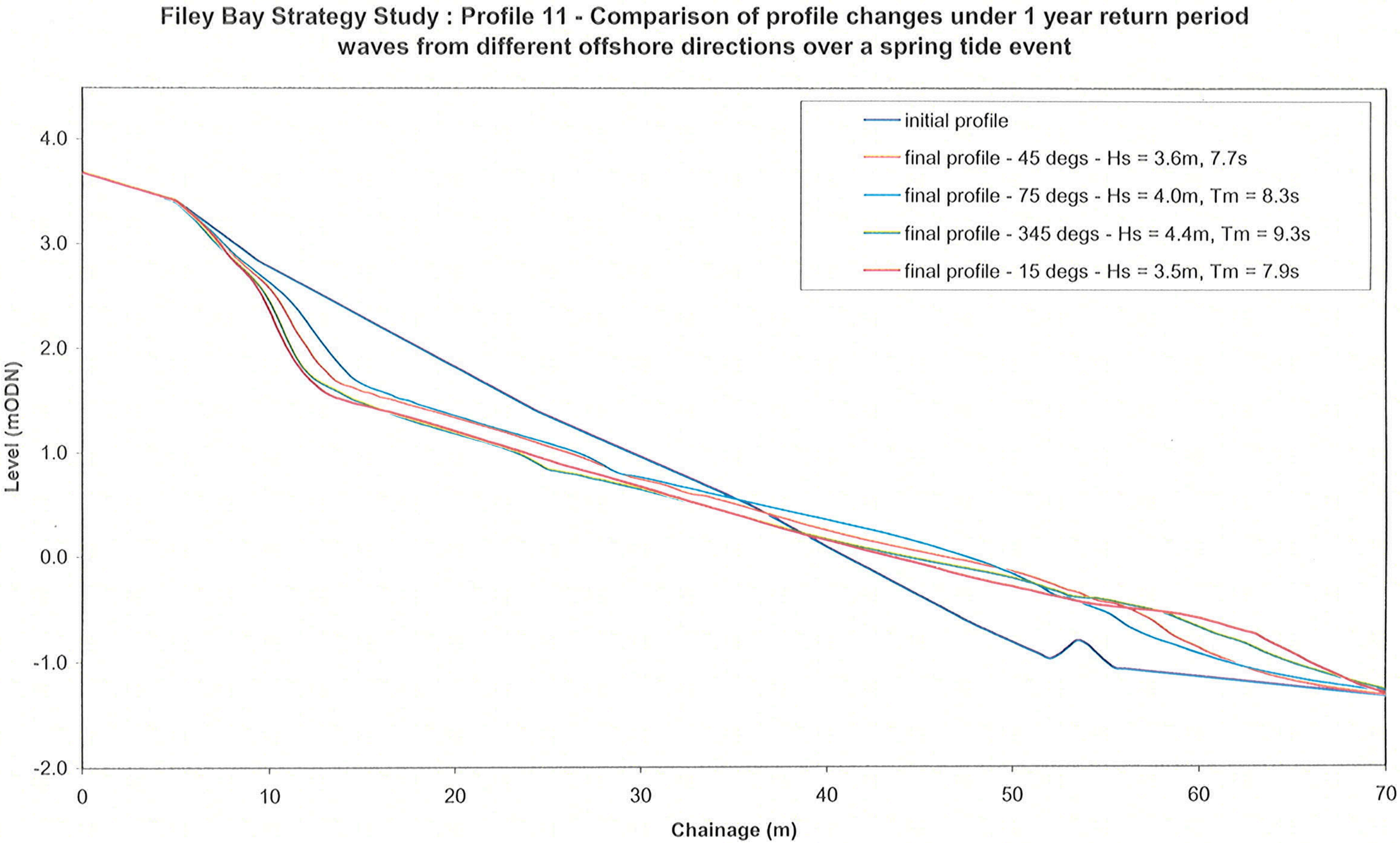


Figure 5.14


Filey Bay Strategy Study : Profile 11 - Comparison of profile changes under 1 year return period waves from different offshore directions over a spring tide event
initial profile
final profile - 45 degs - Hs = 3.6m, 7.7s
final profile - 75 degs - Hs = 4.0m, Tm = 8.3s
final profile - 345 degs - Hs = 4.4m, Tm = 9.3s
final profile - 15 degs - Hs = 3.5m, Tm = 7.9s
Level (mODN)
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
0
10
20
30
40
50
60
70
Chainage (m)

(d) North Landing (location 11)

North Landing is a relatively enclosed Bay. The main concern at this location will be loss of the amenity beach as a result of storms, and possible undermining of the slipway. Modelling shows that the worst case erosion is produced by the waves from offshore direction 15 degrees, (Figure 5.14), when beach levels drop to +1.5mODN near the crest.

5.3 *Sediment Budget*

In order to develop an understanding of the sediment budget for Filey Bay, an assessment must be made of inputs, losses and storage within the Bay.

(a) Inputs

The key sediment input into the Bay is from the eroding cliffs, as discussed in Chapter 4. It has been assumed that only the medium and coarse sediment will remain within the Bay and contribute to the sediment supply, with finer cliff material being carried offshore. These inputs occur by means of two processes: inputs may be due to erosion resulting in smaller frequent inputs of sediment, or due to the occurrence of landslides, where larger inputs of sediment occur on an episodic basis. There will therefore be an average input of sediment to the Bay, with further larger quantities of material input as a result of landslides, although the timing of these inputs is not certain. The cliff assessment that was undertaken made an assessment of likely inputs over the strategy lifetime as a result of erosion and episodic failures. For convenience, these inputs have been averaged over the strategy lifetime in order to make an assessment of the sediment budget. Lower and upper bound estimates of inputs were made as part of the cliff behaviour assessment, estimated at between 4,000 and 23,000m^3 per year. The majority of the input from north of Filey Town is due to erosion, while in the centre of the Bay, from south of Filey Town to the southern limit of the glacial till at Speeton, inputs from landslides dominate. There will therefore be a small but relatively continuous supply from the northern end of the Bay, with larger episodic inputs of material occurring throughout the central part of the Bay.

This assessment of likely inputs of sediment from the cliffs is comparable with the estimate of 10,000m^3, made by IECS (1991). This earlier estimate was based on limited data on average cliff recession rates. These latest studies have however considered in some detail the modes of failure of the cliff and the three-dimensional nature of recession, which can result in significant quantities of material being fed into the beach during episodic events.

IECS (1991) suggest no significant input of sediment from offshore as material does not move in depths greater than 22m, which would appear reasonable. Their report does however suggest a net northerly movement of material around Flamborough Head as a result of tidal currents.

(b) Losses

An assessment of losses from the Bay can be made from the longshore transport modelling. At Reighton, there is evidence of a change in drift direction, with the drift converging. Historic map analysis suggests some accretion here as the low water line is not retreating at the same rate as the cliffs, however it is likely that there is also some loss of material offshore. This material may either be transported south round Flamborough Head, as proposed by IECS (1991), or may be recirculated within the Bay, as a result of the residual northerly tidal currents.

Studies of historic maps (see Section 5.1) have shown no significant movement of the Low Water Mark in recent years. There has been some retreat of the high water mark in conjunction with cliff recession, at Flat Cliffs and Reighton, resulting in widening of the beach, most likely fed by material from the eroding cliffs.

IECS (1991) suggest limited loss of sediment by shore normal movement of material under storm conditions as material does not move beyond depths of 22m. This suggests that any material moved offshore is more likely to be moved parallel to the shoreline, most likely round Flamborough Head. The estimate of losses of $40,000m^3$ as a result of this mechanism, as made by IECS (1991) would appear reasonable. Based on longshore drift modelling, it is assumed that much of this material is lost at the southern end of the Bay, between Reighton and Speeton.

Dredging

There are currently no dredging activities within Filey Bay, although there are historic records of extraction of material from the foreshore until the late 1960's. Clearly this extraction of material will have an adverse effect on beach levels, and this appears to be supported by historic map analysis at Reighton which shows a reduction in beach width together with cliff toe recession around the time of extraction activities.

The impacts of offshore dredging, particularly in deep water are less clear, and any future proposals would require to be assessed on the basis of the likely impact to the sediment transport within the Bay and the nearshore wave regime.

(c) Storage

There is limited information on sediment depths within the Bay, however crude hand-auger measurements suggest that mobile sediment depths might typically be 0.2m to 0.5m over the inter-tidal zone, increasing to 2m at the base of the eroding cliffs. At Filey Town, trial pits indicated 1.2m to 1.4m of mobile material overlying the clay. On the basis of this limited information, that the assumption made by IECS (1991) that the Bay stores 12 million m^3 of sediment appears reasonable. This was based on the assumption that the average sediment depth was typically 1m in water depths up to 5 m, while seaward of this, out to water depths of 15m, sediment depths of 0.25m were assumed.

	m^3/year
Inputs from cliffs	4,000 to 23,000
Losses	40,000[1]
Other inputs from south of Flamborough Head	45,000[1]
SEDIMENT BUDGET (inputs less outputs)	9,000 to 28,000

Table 5.1 Indicative sediment budget

[1]Estimated by IECS (1991)

Table 5.1 demonstrates that there is a surplus of sediment into the Bay. However it is important to note that a significant proportion of the sediment input to the Bay is as a result of landslides and as a result there is likely to be a significant fluctuation in inputs, year by year. This highlights the importance of continued natural recession of the cliffs, without intervention measures to protect the coastline, to ensure that this sediment supply to the Bay is maintained. While there is an apparent surplus of material into the Bay as a result of cliff recession, much of this material will form beach to replace the eroded cliff, thus adding to the volume of material stored within the Bay.

Assumptions on other inputs and losses to the Bay have been based on previous studies. An improved understanding of pathways for these sediment movements may be derived from more detailed studies that are recommended below.

5.4 *Future studies*

The assessment of sediment processes within the Bay has been based on limited modelling, due to the lack of data available and on desk study and literature review. While it would appear that there is no shortage of sediment within the Bay, future studies and strategy reviews would clearly benefit from a more detailed understanding of hydrodynamic processes within the Bay. This would allow a more thorough understanding of offshore and nearshore sediment movement and likely sources and sinks of material. It would also allow detailed assessment of any impacts of dredging activities on sediment transport within the Bay, should such activities need to be considered in the future. Such a study would clearly benefit from future bathymetric surveys and monitoring data as recommended by the strategy.

6 Strategic Environmental Appraisal

6.1 *General*

Strategic Environmental Assessment (SEA) is the formalised, systematic process of evaluating the environmental impact of a policy, plan, strategy or programme. It provides an environmental overview and establishes environmental objectives at the strategic level, identifying generic approaches. Consultation is undertaken with the aim of agreeing objectives with a wide variety of stakeholders, and ensuring an environmentally sustainable strategy. By identifying and considering the most important environmental issues at this stage, it is intended to prevent a situation in which detailed schemes are developed that subsequently have to be rejected or fundamentally re-designed to comply with legislation or other environmental requirements. By identifying strategic level issues that can be carried through to several projects or schemes, SEA also aims to minimise duplication of work later on. Hence, SEA occupies a central position in an hierarchy of studies, between shoreline management planning and project environmental assessment.

The specific objectives of the Strategic Environmental Assessment for Filey Bay are:

- Identification of nature conservation assets that may be lost or significantly affected by erosion or flooding, and an initial estimate to quantify the habitat changes expected;
- Identification of archaeological or other cultural heritage sites that may be affected by erosion or flooding, and recommendation of measures for recording them;
- Identification of any other environmental assets, including those relating to recreation and tourism, that may be affected by erosion or flooding;
- Development of environmental objectives for each unit of the frontage, to be used in developing and appraising strategy options;
- Review of Shoreline Management Plan policies, in relation to environmental assets, and identification of specific strategy options;
- Identification of legal issues and other constraints relating to strategy options (including the "do nothing" option), such as the need to meet obligations under the Habitats Directive relating to SPAs and SACs;
- Contributing to the development of preferred strategic options for each unit of the frontage;

- Identification of significant environmental issues that are expected to arise in relation to the development of individual coastal defence or flood protection schemes, including recommending approaches to their assessment and mitigation.

6.2 *Contents of Strategic Environmental Appraisal*

The SEA Report, which is included as Annex D to this Strategy, comprises:

- An account of existing environmental conditions that are relevant to coastal management in the study;
- A summary of consultation responses from interested organisations, together with comments;
- Environmental objectives;
- Evaluation of options;
- Proposed approaches to mitigation and compensation;
- Conclusions.

The SEA deals with matters relating to the physical environment, such as geology, geomorphology and water, with the biological environment and with the human environment. However, these are not rigid categories as a number of topics are cross-cutting in nature, for example landscape incorporates aspects of the physical, biological and human environment, whilst fisheries deals with aspects of both the biological and human environment.

6.3 *Environmental Objectives*

On the basis of the environmental baseline information and the views expressed by consultees, environmental objectives have been defined for the frontage. These provide a basis for the evaluation of strategic options put forward. The inclusion of a particular objective does not mean that it will necessarily be met by the strategy; indeed a number of objectives conflict with each other.

Objectives have been divided into General (those applying to all or much of the study area) and Specific (those applying to individual coastal sections). These are reproduced in Tables 4.1 and 4.2, respectively, of Annex D. Where there may be a conflict between objectives this has been identified in the Tables.

In formulating the objectives, account has been taken of the recommended policies in the adopted Shoreline Management Plan (SMP). However, the present study is much more detailed than the SMP. Hence the SMP policies have been re-visited to take account of new information.

Objectives for nature conservation assets generally have been framed in terms of habitats, rather than species. This is because, as a coastal defence strategy, the study is concerned with defining areas of land for management with respect to coastal and flood defences.

Objectives have been formulated to take account of practical as well as legal constraints. Objectives are only put forward where an initial screening indicates that the types of actions required to meet them are likely to be technically feasible and environmentally sustainable, which as a minimum is taken to mean that:

- interventions would have a reasonable chance of being successful over a fifty year time scale;
- interventions would not interfere with natural processes in such a way as to bring about loss or damage to other European sites or other internationally important features;
- there would not be a requirement for continued, excessive and increasing input of natural and financial resources.

It is considered that any actions that did not pass these tests would be very unlikely to be implemented, even if there were a *prima facie* requirement.

In the case of some objectives, an additional criterion is applied that they should only be implemented if an economic case can be made. This means at a minimum that there should be a cost-benefit ratio exceeding 1, but in practice a scheme would have to pass DEFRA priority scoring to be implemented. The criterion of economic acceptability is not applied to objectives that relate to protecting nature conservation sites covered by the European Union Habitats Directive, since DEFRA has announced grant aid in such cases will not be dependent on economic criteria being met.

6.4 Implications of do-nothing policy

The main implication of a "do nothing" policy is continued, unmanaged retreat of the soft cliff coastal sections between Filey Brigg and Speeton Sands. This would lead to:

- Risk to property estimated as follows: 63 properties at Flat Cliffs & Primrose Valley, 27 properties at Reighton and 3 properties at Hunmanby Gap, lifeboat station, cafes and other amenities on Coble Landing and several Yorkshire Water pumping stations;
- No significant effects on statutory protected nature conservation sites (SSSIs, SPA and cSAC);
- Loss of vegetated cliff, cliff-top and associated habitats in the SNCI, with no provision for set-back or recreation, leading to squeeze between the eroding cliff and existing land uses;
- Serious adverse effects on landscape and visual amenity from deteriorating and collapsing defences and derelict properties, together with increasingly visual exposure of existing landscape elements such as caravan parks;
- Significant losses of recreational amenity, including some lengths of coastal footpath, beach access points, Filey Sailing Club and any tourism amenities at risk due to outflanking of Filey seawall;
- Deterioration of the seawall protecting Filey Town, possibly leading to failure of sections of the seawall;
- Possible loss of access for launching fishing boats at North Landing and Filey;
- Loss of one Scheduled Monument and up to fifteen non-scheduled known archaeological sites.

7 Coastal Defences

7.1 *Overview*

Much of the frontage of Filey Bay is in its natural state with no man-made coastal defence structures. There are a few notable exceptions to this, discussed in further detail in the following Sections.

The defences for the Bay, as recorded in the most recent update (1997) of the 1993 Coast Protection Survey of England (CPSE) are summarised in Table 7.1, with the assessment of condition and residual life updated where considered necessary.

This table also includes defences not recorded in the CPSE, where these have been observed during site inspection (denoted * in the Defence Length Code column).

For each defence length, a recommended action during the strategy is identified in the Table, whether continued maintenance, abandonment or removal.

Defence Code	Location	Defence Length (km)	Asset Type	Crest Level (mODN)	Degree of exposure	Defence condition	Residual life (years)	Required action
240/6562	Filey	0.30	Cliff / scarp	35	Medium	n/a	n/a	-
240/6563	Filey Sailing Club	0.07	Timber breastwork / rock armour	5.3	Medium	4	5-10**	To be abandoned during strategy
240/6564	Filey Sailing Club	0.04	Piling	5.1	Medium	3	5-10	
240/6565	Filey	0.28	Cliff / scarp	35	Medium	n/a	n/a	-
240/6566	Filey	0.07	Seawall	5.1	Low	3	>10	Continued maintenance
240/6567	Filey	0.99	Seawall	6.3	High	3**	>10	
*	Martin's Ravine, Filey		Gabions		Medium	3	5-10	To be replaced by rock protection
240/6568	Hunmanby Sands	4.94	Cliff / scarp	42	High	n/a	n/a	-
240/6568	Hunmanby Sands	0.02	Gabions		High	3**	5-10	To be abandoned / removed
240/6401	North Landing	0.3	Revetment	9.5	High	2	>10	Continued maintenance

Table 7.1 *Filey Bay Defences*

Note: Defence condition classes:

1 Condition as built
2 Some signs of wear, needs to be kept under observation; returnable to condition as built with simple maintenance, i.e. work advisable in order to prevent undue deterioration
3 Moderate works required; probably limited to a maintenance operation to return to satisfactory condition. i.e. work necessary to sustain adequate performance
4 Significant works needed; capital works probably required within 5 years
* Not included in CPSE
** Values updated from site inspection

7.1.1 *Filey Sailing Club (Unit 28A)*

Figure 7.1 Filey Sailing Club

The Sailing Club to the north of Filey Town is located within the cliffs. It is protected by sheet piles and rock contained by timber breastwork. These defences have an estimated residual life of 5-10 years. Beyond that time it is likely that the defences will be outflanked as erosion and land slippage continues on both sides.

It is anticipated that the Sailing Club will not be sustainable during the lifetime of the strategy, and will require to be relocated, and it is therefore unlikely that these defences will require significant maintenance.

7.1.2 *Filey Town Seawall (Unit 28B)*

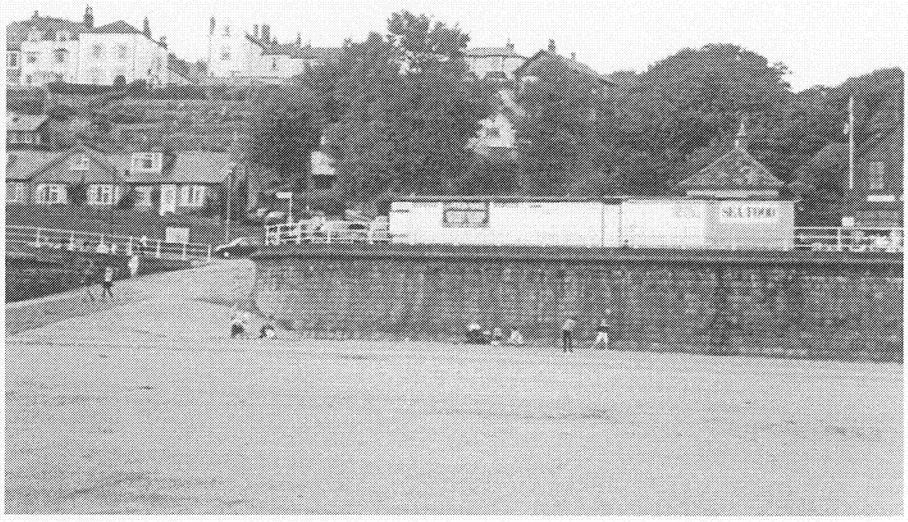


Figure 7.2 *Filey Town seawall*

A near-vertical concrete seawall extends along the developed frontage at Filey (Figure 7.2). The wall, faced with stone, incorporates a wave recurve section at its crest to deflect overtopping waves seaward. At the northern end, the seawall incorporates the Coble Landing slipway, used by local fishing boats and the lifeboat. A second slipway exists at the southern end of the seawall, at Royal Parade.

There is evidence of outflanking at both the northern and southern ends of the seawall. Rock protection has been placed immediately to the south of the seawall (Figure 7.3), at Martin's Ravine, to protect against this outflanking. Gabions were initially used, reinforced later by small pieces of granite gabbro rock (less than 1 tonne). These have been placed in front and on top of the gabion baskets at a very steep slope. It is doubtful that this structure would be effective during a significant storm event. The section may present a safety hazard to beach users, particularly if the landslip behind is reactivated. It is assumed that the gabions and rock were placed to limit outflanking of Royal Parade and the access way through Martin's Ravine. There is also an active landslip on the cliffs immediately behind the gabion/ rock wall, adjacent to the access way. This slip is partly resisted by the rock defence, but any further slope movement could overwhelm the gabion structure.

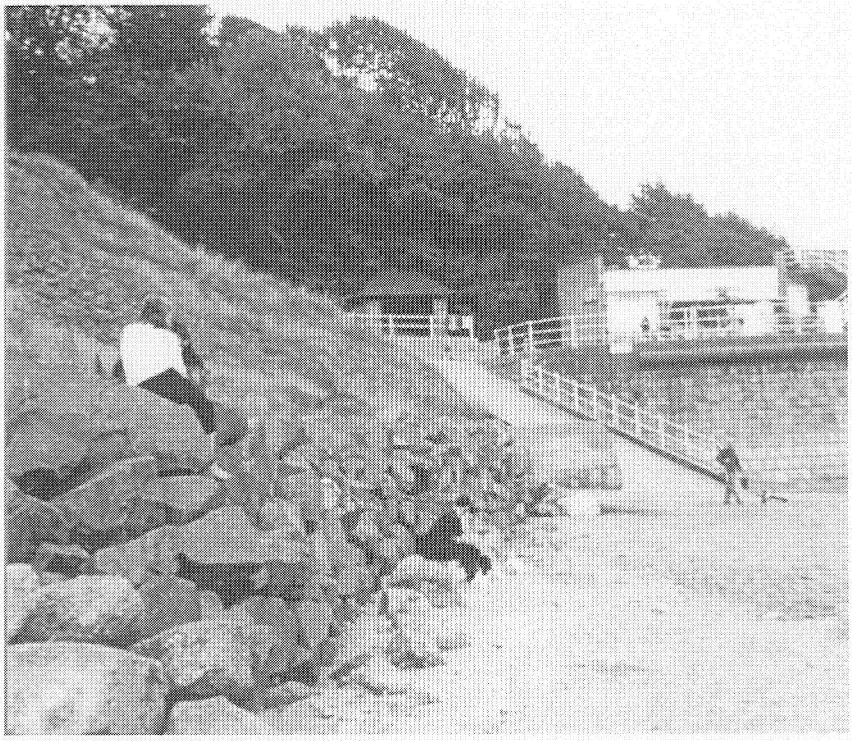


Figure 7.3 *Rock protection adjacent to Martin's Ravine to south of Filey Town*

The seawall is in fair condition, though there are certain aspects that should be monitored and maintained to prolong the asset life of the structure. Some wave return copings are suffering from calcitic crystalline expansion which causes the coping to crack and parts of the overhang to break off. These should be periodically inspected and replaced. There are definite movement cracks evident in numerous places along the wall. These could be caused by a change in pore water pressure behind the seawall.

Scour is evident in places along the base of the seawall. Exposure of the lower wall blocks is greater at changes of alignment and at the slipway interfaces. Scour effects are particularly evident on the northern roundhead of Royal Parade, where exposure of the top of the foundation block was observed during inspection (Figure 7.4). Along the length of the wall the variations in beach levels could be seen during walkover inspection, although these variations were of no more than 150mm, based on the block dimensions. On occasions, following storm conditions, beach levels have dropped significantly at the wall, exposing a concrete apron that forms the toe, Figure 7.5. This is considered in more detail in Chapter 5, where the effects of storm conditions and sea level rise on beach levels are discussed.

Figure 7.4 *Scour at base of Filey seawall*

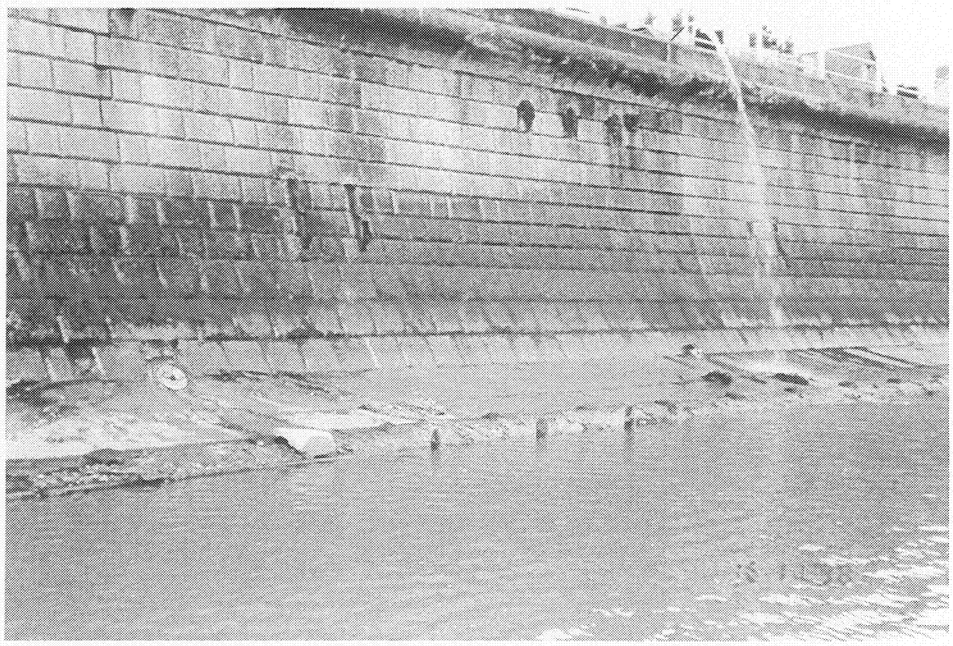


Figure 7.5 *Filey Town seawall following extreme conditions, 16 November 1998 [note exposed toe apron]*

7.1.3 *Hunmanby Gap (Unit 29C)*

Figure 7.7 Gabions at Hunmanby Gap

There are some gabions protecting the toe of the cliff at Hunmanby Gap (Figure 7.7). These appear to have originally been placed to protect beach access, which has since been relocated. The gabions therefore currently have limited function and are gradually being outflanked as erosion and land slippage continues on both sides.

It is likely that this defence will fail as cliff recession continues. Intervention will only be required if this were to present a safety hazard to beach users.

7.1.4 *Reighton (Unit 30A)*

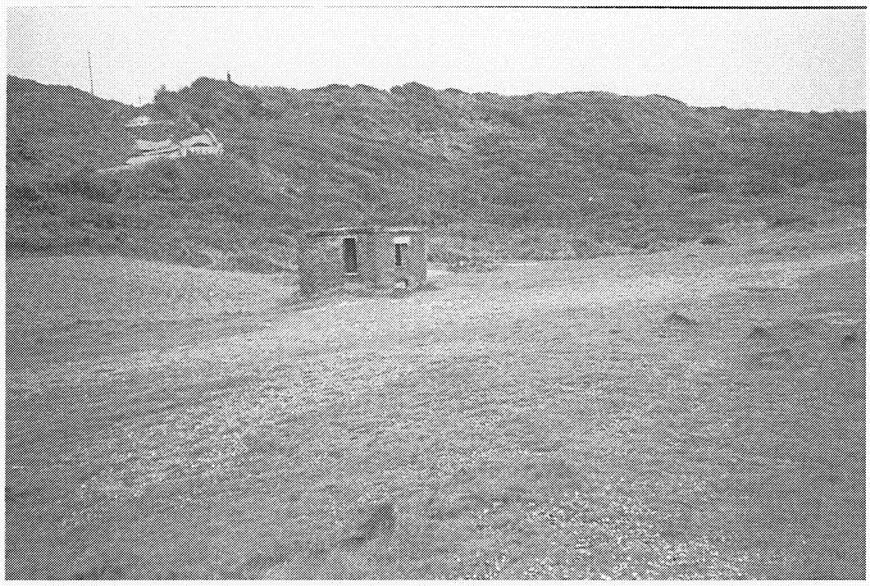


Figure 7.8 Cliffs at Reighton [note damaged access at top left of photo]

While there are no formal defences at Reighton, public access down to the beach is by means of a concrete track that is badly damaged (Figure 7.8), and in its present state poses a safety hazard to beach users. Along the beach, there is concrete debris, presumably from structures that have collapsed as the cliff has eroded (Figure 7.8).

Figure 7.9 Concrete debris at Reighton

7.1.5 *North Landing (Unit 31D)*

At North Landing, a concrete slipway provides boat access. The slipway appears to be in reasonable condition, with an estimated residual life of greater than 10 years.

7.2 *Key issues*

The key area where the existing defences require attention is at Filey Town. Where there are signs of damage to the coping and face of the wall, patch repairs should be carried out as necessary, as part of a continuing maintenance programme.

Outflanking is a problem, due to continued erosion and land slippage to the north and south. This is given careful consideration in the development of options in Chapter 9. Stability analysis suggests that the wall is vulnerable to reductions in the level of the clay horizon and it is recommended that this be monitored as this is critical to the long term stability of the wall. There are uncertainties regarding the wall dimensions and foundation levels of the wall and the retained material. Given the importance of the wall in protecting Filey Town, it is recommended that a structural survey is completed to establish foundation levels and properties of the retained material to refine assessments of the wall's factor of safety and inform future the development of future intervention options.

8 Assessment of Strategic Options

8.1 *Overview*

The management units proposed in the Shoreline Management Plan have been considered in turn to identify preferred management policies and options, taking into account environmental, technical and economic constraints. The methodology is outlined in this chapter, with the detailed assessment of each unit being discussed in Chapter 9.

8.2 *Strategic Options*

The policy recommendations made in the SMP were based on guidance for completion of Shoreline Management Plans published in 1995 (MAFF, 1995). Definitions were further developed for the purpose of completion of the SMP as follows:

(i) Do Nothing

Carry out no coastal defence activities except for safety measures.

(ii) Retreat the existing defence line

By intervention to move the existing defence landward. It is necessary for each length of coast subject to this option, to define the position of the existing defence. This policy allows natural processes to continue but with active management. This policy may include the provision of structures to control the rate of erosion or possibly the removal of existing linear defences. Where a policy of retreat the existing defence line is adopted this should be periodically reviewed to confirm its continued applicability as assets become threatened.

(iii) Hold the existing defence line

By intervention, hold the existing defence where it is. This may include replacing the existing defence on the present alignment or enhancements such as abutting rock armour. It is necessary for each length of coast subject to this option, to define the position of the existing defence.

(iv) Advance the existing defence line

By intervention to move the existing defence seaward. It is necessary for each length of coast subject to this option, to define the position of the existing defence.

Following completion of the Shoreline Management Plans, and as a result of the experience gained in their implementation, the guidance has been revised. A consultation draft is currently in circulation (MAFF, 2000a), due for formal publication later this year.

The guidance has evolved since the earlier publication and revised definitions of strategic policies have been produced. The options developed in this strategy are based on the new MAFF guidance, but reference is made to the SMP policy recommendations and where alternative policies are proposed, this is highlighted. For clarity the policy options from the two sets of guidance are compared in Table 8.1, to allow easy cross-reference with the Shoreline Management Plan.

The policies from the latest guidance are:

- **Hold the existing defence line** by maintaining or enhancing the standard of protection.
- **Advance the existing defence line** by constructing new defences seaward of the existing defences.
- **Managed realignment** by identifying a new line of defence and where appropriate constructing new defences landward of the original defences.
- **Limited intervention**, by working with natural processes to reduce risks, whilst allowing natural coastal change. This may range from measures which attempt to slow down rather than stop coastal erosion and cliff recession to measures that address public safety issues e.g. promoting the build-up of beach material in front of unstable cliffs, or improving drainage of unstable coastal slopes.
- **No active intervention**, where there is no investment in coastal defence assets or operations.

<table>
<tr><th>SMP
(based on MAFF, 1995)</th><th>Strategy
(based on MAFF, 2000)</th></tr>
<tr><td colspan="2">hold the existing defence line</td></tr>
<tr><td colspan="2">advance the existing defence line</td></tr>
<tr><td>retreat the existing defence line</td><td>managed realignment</td></tr>
<tr><td rowspan="2">do nothing</td><td>limited intervention</td></tr>
<tr><td>no active intervention</td></tr>
</table>

Table 8.1 Comparison of policy definitions

For each unit, the preferred management policy is identified, taking into consideration environmental, technical and economic constraints. As a first step in this process, the policy recommendations made in the Shoreline Management Plan are reviewed and modified as seen to be appropriate.

Any particular management policy may be achieved in a number of ways. A number of alternative options are therefore identified where appropriate, with each one being assessed on its technical, environmental and economic merits, in order to identify the preferred option.

8.3 *Assessment of present situation*

Key features have been identified, together with specific environmental objectives for the frontage (full details are presented in Table 4.1 of the Strategic Environmental Assessment, Annex D).

At Filey Town, maintenance work to repair localised damage to the seawall is undertaken and some ad-hoc works have been carried out to delay the effects of outflanking to the south of the seawall.

For much of the Bay, the environmental value of the coastline lies in its natural eroding state, therefore it is likely that intervention will not be appropriate, unless there is key infrastructure of value.

An assessment of the do-nothing scenario is presented to indicate the level of damage that would result from no implementation of the strategy.

8.4 *Technical assessment*

Having identified a preferred strategic policy for each management unit, alternative intervention options are identified. A technical assessment of each of these intervention options is then made. This includes, but is not limited to:

- impact of option on littoral drift;
- likely performance of option given local conditions;
- availability of raw materials;
- sustainability of option.

8.5 *Environmental assessment*

Each of the various options is assessed on the basis of the environmental objectives derived as part of the Strategic Environmental Assessment (see Chapter

6 and Annex D). For each unit, options are then ranked by their acceptability in environmental terms.

It is not anticipated that any one option will meet all environmental objectives, as there are conflicts that arise within the objectives themselves, so a judgement is made on which options are the least onerous in environmental terms.

8.6 *Economic assessment*

Economic assessment of technically and environmentally acceptable options is completed in accordance with DEFRA Project Appraisal Guidance (MAFF, 1999) and is included in Annex E. The maps derived during the cliff behaviour assessment (see Chapter 4) are used to identify assets at risk under the "do nothing" scenario in order to assess the benefits of intervention options. These benefits might be delays in erosion or landslipping or, for the case of monitoring / warning systems, the benefits gained from advance warning of the need to evacuate properties, allowing residents to remove possessions, thereby reducing the losses.

9 Detailed Strategy Development

9.1 *Filey Brigg (Management Unit 27)*

Figure 9.1 Filey Brigg

9.1.1 *Description*

Filey Brigg and Carr Naze form an important SSSI located at the northern end of Filey Bay. The feature comprises glacial till over bedrock of Jurassic age and is eroding. The Brigg has been quarried over the years which has influenced current rates of erosion. The Brigg has a key influence on the coastal system within the Bay and is an essential component of the defences which together protect Filey Town.

Assessment of cliff recession (see Chapter 4) has identified that there is a probability of continued erosion and landslips that will cut through the Carr Naze within 50 years. Potential breaches at the crest of the Brigg are likely as material erodes and slumps on both sides of the ridge. In time the crest of the Brigg will become irregular, with low points coinciding with areas of high rates of retreat, illustrated in Figure 4.2. The harder Jurassic rocks forming the base of the cliffs will provide levels of protection for many years to come, similar to Brigg Point.

A key issue is public safety as the coastline erodes within this unit as there is a public footpath along the Naze.

The proposed environmental objectives for this management unit are:

Proposed Objectives (see Annex D)	
27.1	Avoid interference with natural landscape of Filey Brigg and Carr Naze
27.2	Avoid interference with intertidal habitat and characteristic biotopes of Filey Brigg (SSSI)
27.3	Avoid interference with geological exposures of Filey Brigg (SSSI)
27.4	Maintain pedestrian access to Carr Naze
27.5	Protect site of Roman Signal Station (SM) if feasible and sustainable
27.6	Maintain Brigg to provide protection to Filey and its beach from erosion under northerly storms

9.1.2 Options

The SMP recommends a policy of **retreat** of the coastline for this management unit. Based on the revised MAFF guidelines, an alternative policy of **limited intervention** is recommended, thus allowing natural coastal change, while reducing any risks that may arise.

Management of erosion of the Brigg will need to take into account the public footpath along the cliff top. Intervention will be required to manage this public access as its becomes unsafe due to cliff top recession.

Construction of a footbridge may be considered if landslips cause a breach of the footpath, to maintain access to the eastern end of Carr Naze. This is likely to be an expensive option and would introduce an artificial structure into the presently natural environment. In addition, it is likely that if such a footbridge were constructed, it would become threatened as landslips progress. Relocation of the footpath to a position west of its current location, with the eastern end of the Naze closed to formal public access is likely to be preferred.

The future evolution of Filey Brigg was considered as part of the cliff assessment exercise (see Chapter 4). This showed that Filey Brigg would continue to provide protection to the Bay for the strategy duration. The outer 100m of the glacial till is likely to erode in this time, however the harder rock strata seaward of this will continue to provide shelter.

9.2 *Filey Sands (Management Unit 28A)*

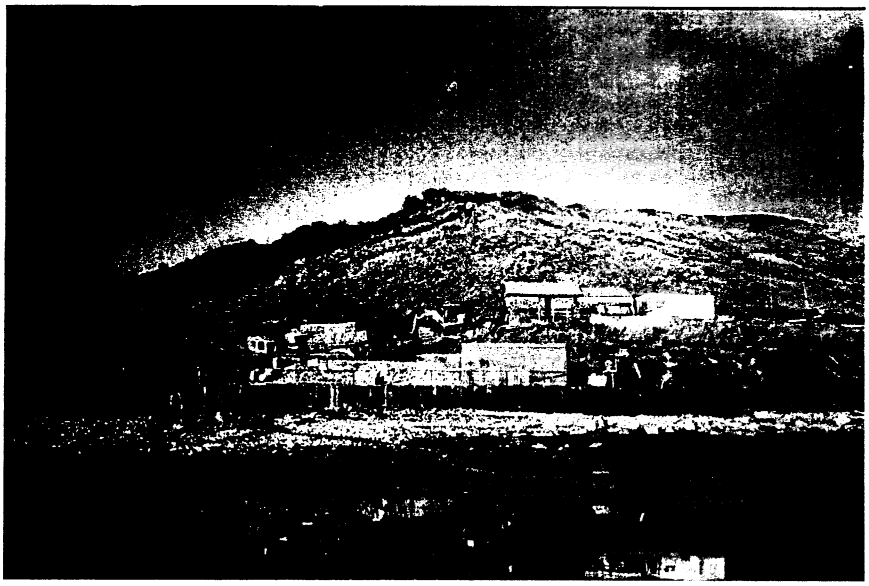


Figure 9.2 *Filey Sailing Club*

9.2.1 *General*

Filey Sands management unit, which includes Filey Country Park is located north of Filey Town. Actively unstable coastal slopes form the seaward boundary of the Country Park. In addition to the coastal erosion of the lower part of the cliffs, ongoing incipient landslipping is evident. Anecdotal reports suggest that the presence of clay, from cliff falls and mudslide run-outs, on the beach foreshore has presented a hazard to beach users in summer months. There is minimal infrastructure at the cliff edge, with the exception of Filey Sailing Club which is located on the cliffs, upon a pre-existing landslide. Noted damage to the slipway access used by the Club is not unexpected, given the exposure of the Club to the prevailing conditions. The clubhouse itself is also exposed and is unsustainable. It is considered that the Sailing Club will need to be relocated within the lifetime of the strategy.

The proposed environmental objectives for this management unit are:

Proposed Objectives (see Annex D)	
28A.1	Maintain open sandy beach
28A.2	Maintain vegetated soft cliffs and allow natural erosion to continue
28A.3	Avoid interference with intertidal and subtidal sandy and rocky habitat
28A.4	Protect cliff top property threatened by erosion and cliff slumping, if feasible, economic and sustainable

9.2.2 *Options*

A revised policy of **limited intervention** is recommended, rather than the **do nothing** policy as proposed in the SMP. This change in policy is recommended due to the presence of public access along the top of the cliff, which will require to be managed and possibly relocated as the cliff retreats, and management of cliff falls and mudslide run-outs, a potential hazard to beach users, to ensure safe beach access.

The Sailing Club is unlikely to be sustainable as it is located in an area of landslip. This should be taken into consideration when planning the long term future of the club premises. The Club may need to be relocated within the lifetime of the strategy, and there is a high likelihood of this being required within the next 10 to 15 years.

It should be noted that the continued erosion in this unit may lead to outflanking of the seawall in the next management unit (28B). The transition between the two units will require careful consideration. This will be addressed under the consideration of options for unit 28B.

There are limited defences protecting the Sailing Club. The Sailing Club is not likely to be sustainable beyond the strategy lifetime, so continued maintenance of the defences is not considered necessary. These should be abandoned, or alternatively removed as necessary through the strategy lifetime if they present a hazard.

9.3 *Filey Town (Management Unit 28B)*

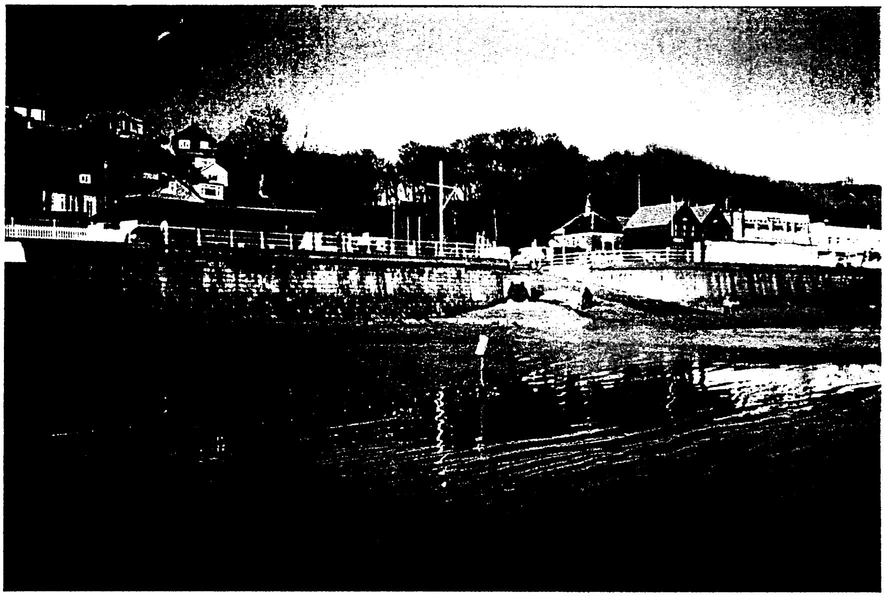


Figure 9.3 Filey Town seawall

9.3.1 *General*

Filey Town is the main residential area of the Bay. A seawall extending from Coble Landing to Martin's Gill protects the Town (see Section 3.1.2). The wall is in fair condition, though there are certain aspects that will require monitoring and maintenance to prolong the asset life of the structure. There is evidence of outflanking of the wall to the north at the Coble Landing slipway. Outflanking is also evident to the south of the seawall, counteracted to some extent by rock scour protection, comprising gabions and small rock. While this provides some protection, the gabions are unlikely to be effective during a significant event. An active landslip is immediately behind the gabions, and it is likely that further slope movements could overwhelm them.

There is also some evidence of drops in beach level in front of the wall, particularly under storm conditions. This is supported by the beach profile modelling (see Chapter 5) and by photographic records from storms which show a concrete toe apron being exposed (see Section 7.1.2). Trial pit investigations were undertaken which established the level of the clay profile at approximately +0.6m to +0.7mODN, however the foundation level of the wall could not be established. Historic drawings were therefore used to establish indicative toe levels for use in a stability analysis (see Section 7.1.2) and a number of (conservative) assumptions were made regarding the retained material. This indicated that the wall is dependent on the clay on its seawards side for stability. Continued drops in beach level, possibly increasing in frequency due to increased storminess could lead to degradation and removal of the clay layer which is not easily replaced. This could result in an overall lowering of beach levels and lead to a cyclical worsening of conditions that may ultimately result in failure of the seawall at Filey. It is believed from the cliff assessment that was undertaken, that the seawall provides protection to the degraded coastal slopes and relict landslips behind the wall. If the wall were to fail, then the consequence in terms of property and infrastructure being compromised due to renewed landslip and ground movement would be significant.

Any options to protect the seawall will require to be carefully designed to prevent edge effects causing outflanking of the wall. Continued monitoring of the beach will also be important together with further studies of the stability of the coastal slopes behind the wall.

The proposed environmental objectives for this unit are:

Proposed Objectives (see Annex D)	
28B.1	Protect property in Filey (including listed buildings and Conservation Area) from erosion, cliff slumping and flooding for cultural, economic, social and tourism reasons
28B.2	Maintain access for launching fishing and pleasure boats at Coble Landing
28B.3	Maintain open sandy beach
28B.4	Sustain recreational and tourist facilities at Filey Seafront

9.3.2 *Options*

A policy of **hold the existing defence line** is recommended for this unit, in accordance with the SMP. The following options are identified:

(a) Rock scour protection

Rock armour protection along the toe of the seawall will provide protection during drops in beach level that could compromise wall stability. The ends of the rock protection should be extended beyond the seawall, to form a berm in front of the cliffs to delay erosion, helping to control outflanking effects.

Stability analysis has identified that the wall has a low factor of safety. Rock armour protection would assist in providing a restraining force to the wall and will also prevent drops in foreshore level. Given the uncertainties regarding the coastal slopes behind the seawall, it is recommended that more detailed studies of the seawall and slopes are undertaken before such an option is implemented. This will allow refinement of the estimates of wall stability and establish the extent of the coastal slopes, in particular whether failure planes extend beneath the wall. Design of such an option could then be based on the findings from stability studies and associated ground investigation. This option is not therefore recommended for immediate implementation, although it is recognised that it is likely to be required within the strategy lifetime. Interim monitoring of beach and clay profile levels will identify if the need for more urgent intervention arises, before more detailed studies are complete.

(b) Rock protection at northern and southern limits of seawall
Construction of rock protection structures at the northern and southern ends of Filey seawall will assist in delaying erosion of the adjacent cliffs, thus delaying outflanking of the wall. Care would be required in the design to ensure that the structures did not interfere with use of the slipway. Some re-grading of the coastal slopes protected by these structures would assist in improving stability.

It should be noted that such structures will provide added protection to the areas currently at risk due to outflanking, but will not completely stop erosion from occurring. Thus a flexible approach should be adopted, with the requirement for management of the defence as outflanking continues, possibly with extension or realignment. The construction of rock structures should assist in delaying the erosion, as they will provide greater energy dissipation than the ends of the vertical wall do at present. Use of rock will allow modifications to such structures to be easily made.

(c) Groynes
Groynes, whether rock or timber, can in some cases be used to control beach levels in front of the seawall, to reduce the risk of undermining. They may be constructed in conjunction with a beach recharge scheme to ensure adequate material to maintain a healthy beach at Filey, while not starving beaches elsewhere within the Bay of sediment. Groynes would require to be carefully designed in terms of efficiency, to ensure supply of material to the south continues.

The selection of groynes as an appropriate option is dependent on sediment transport within the Bay. There is evidence of longshore drift within this area of the Bay, with drift net from north to south (see Chapter 5), and most of the transport occurring between Mean Sea Level and Mean Low Water Springs. This would suggest that the groynes would have to be of substantial length, typically 100-150m (similar to those to the south of Flamborough Head at Bridlington), in

Installation of tell-tale scour sensors on buried sections of seawall will allow assessment of the depth of beach draw-down during storm conditions, as the full extent of scour is often not apparent during post-storm inspections. This will help identify minimum beach levels during storms and hence any increased risk to the wall. The monitors may be linked to a simple logging system that identifies if sensors have been exposed due to drops in beach level. The system can be reset once the response has been logged following storms. This monitoring data will also assist in future analysis of beach processes, in conjunction with the strategic monitoring recommended as part of the strategy.

(g) Coastal Stability Management

Slope stabilisation measures such as drainage, reprofiling, toe-weighting and soil strengthening could be used to improve stability of the coastal slopes, but given the dense nature of existing development, accessibility, technical and economic feasibility would be restricted.

The most pragmatic approach will involve the management and control of planning, development and engineering works in the area, so that potential high risk sites can be avoided and ground movement related problems mitigated. Monitoring and early warning of key sites would be integral to such 'coastal slope management'. In order to set the framework for this it is recommended that a detailed coastal stability study including mapping of the coastal slopes and Ground Investigation be carried out, so that objective guidance for planning, development and slope management can be prepared, and to inform future strategy reviews. This should include more detailed assessment of the seawall to inform stability analysis and allow design of intervention options. Such an approach is supported by the DTLR and Planning Policy Guidance Note PPG14. General ongoing maintenance recommendations for the seawall are discussed in Section 3.2.

9.3.3 *The do-nothing scenario*

In order to complete the economic assessment for this management unit, the do-nothing scenario must be assessed in order to identify assets at risk. There is a risk to assets and infrastructure at the northern and southern limits of Filey town due to outflanking of the seawall. There is a further risk to the seawall of ground movements on the coastal slopes leading to its failure. In order to assess these risks in greater depth, more detailed studies of seawall and slope stability will be required.

	Option	Environmental	Technical	Economic	Conclusions
A	Rock scour protection	Relatively low impact on recreation / amenity value of beach.	Will protect seawall toe against undermining / sliding. Further studies required, to inform stability analysis.	Direct benefit as reduces risk to assets	Need for implementation to be considered, following detailed coastal slope stability studies
B	Rock protection at ends of seawall	Relatively low impact on recreation / amenity value of beach.	Will help control outflanking effects	Direct benefit as reduces risk to assets	Considered in economic assessment.
C	Groynes	Will result in loss of open sandy beach and may cause difficulties for fishing access	Will not stop cross-shore movement of sand during storms	-	Not considered further
D	Beach recharge	No adverse environmental impact	Unlikely to be sustainable without groynes	-	Not considered further
E	Replacement of seawall	No adverse environmental impact	Probability of failure of existing wall to be confirmed by further studies. Likely to be expensive option to implement compared to protecting existing wall.	High level of investment; Probability of failure of existing wall to be confirmed by more detailed field studies	Not considered further at this stage
F	Beach level monitoring	No adverse environmental impact	Will identify if critical beach levels reached and help inform future strategy reviews	Will assist in anticipating increased risk of wall failure and avoid resulting loss of assets	To be recommended in conjunction with any coast protection works
G	Coastal stability management	No adverse environmental impact	Will inform future strategy development and planning guidance	Will help to control future development in risk areas	To be recommended in conjunction with any coast protection works

Table 9.1 *Summary of options appraisal – Filey Town*

Filey Town	Costs and benefits £k	
	Do Nothing	Rock armour protection at ends of seawall
PV costs		62.5
PV damage	239.79	13.02
PV benefits		226.77
NPV		164.28
Benefit/cost ratio		3.63
Incremental b/c ratio		

Table 9.2 Economic assessment – Filey Town: protection against outflanking

Filey Town	Costs and benefits £k	
	Do Nothing	Rock armour protection to seawall in yr 5*
PV costs		752.49
PV damage	4,791.37	260.12*
PV benefits		4,531.26
NPV		3,778.77
Benefit/cost ratio		6.02
Incremental b/c ratio		

Table 9.3 Economic assessment – Filey Town: full protection of seawall
**Assumes highest probability of wall failure in yr 15*

9.4 Muston Sands (Management Unit 29A)

9.4.1 *General*

The frontage to the south of Filey Town is fairly undeveloped and comprises glacial till overlying Jurassic bedrock. There is evidence of active coastal erosion and landsliding and of outflanking at the southern end of Filey Town Wall.

Figure 9.4 Muston Sands

A golf club is located on the cliff top here and could suffer some land loss. However, the sediment supply to the Filey frontage is inherent to its stability and the ongoing natural processes should be allowed to prevail as far as is practical.

The proposed environmental objectives for this management unit are:

Proposed Objectives (see Annex D)	
29A.1	Maintain vegetated and non-vegetated soft cliffs and allow natural erosion to continue
29A.2	Create or maintain vegetated cliff tops, allowing for landward migration as cliff recedes
29A.3	Avoid interference with intertidal and subtidal sandy and rocky habitat
29A.4	Maintain open sandy beach
29A.5	Maintain existing cliff top and beach access routes. Seek to create new Public Rights of Way if feasible and appropriate.

9.4.2 *Options*

A policy of **no active intervention** should be adopted for this unit. This is in accordance with the policy proposed in the SMP of **do nothing**.

9.5 *Primrose Valley - Amtree Park (Management Unit 29B)*

9.5.1 *General*

This length of frontage, though similar to Filey Bay in geological composition, does support infrastructure considered to be of particular value to the tourist industry. This unit includes Primrose Valley, comprising a caravan and holiday park with associated residential area, a disused Butlins camp at Amtree Park, currently the subject of a planning application for redevelopment, and the residential community of Flat Cliffs. Along this frontage there is evidence of active erosion, cliff-top recession and slope instability. Slope instability is particularly apparent at Flat Cliffs where an active landslip threatens to breach the only vehicle access route into the area.

Early field observations as part of the strategy study identified the potential risk to the Flat Cliffs properties due to land instability. Ground investigation works were therefore undertaken to inform stability analysis of the coastal slopes (see Annex F). This gives an indication of the sensitivity of the coastal landslides to basal erosion and ground water level, suggesting failure of the slopes upon which the properties are located within 10 to 20 years.

Figure 9.5 *Flat Cliffs*

It is not considered that the Flat Cliffs community will be sustainable beyond 50 years. Any intervention to prevent erosion of the cliffs will have some effect on processes within the Bay as the cliffs contribute material into the system.

The proposed environmental objectives for this unit are:

Proposed Objectives (see Annex D)	
29B.1	Protect cliff top property at Flat Cliffs threatened by erosion and cliff slumping, if feasible, economic and sustainable
29B.2	Maintain vegetated and non-vegetated soft cliffs and allow natural erosion to continue
29B.3	Create or maintain vegetated cliff tops, allowing for landward migration as cliff recedes
29B.4	Avoid interference with intertidal and subtidal sandy and rocky habitat
29.B.5	Facilitate conservation or, if lost to cliff erosion, the re-creation of freshwater pool supporting breeding population of great crested newts
29B.6	Maintain existing cliff top and beach access routes. Seek to create new Public Rights of Way if feasible and appropriate.

9.5.2 *Options*

The SMP policy of **retreat the line**, while ensuring the continued supply of sediment to the Bay, does compromise the viability of the cliff edge properties. This policy requires identification of a new more sustainable line of defence. Such an alternative line would be located on stable cliff top land, leaving a buffer zone that may be lost due to cliff recession. Given the location of the properties at Flat Cliffs on the coastal slopes, it is clear that they would lie seaward of any proposed new defence line that would be more sustainable. There may be future difficulties in maintaining a retreated defence line due continuing cliff recession and failure of the coastal slopes and the location of the new line of defence may therefore require to be moved landward at intervals as part of the managed retreat process.

An alternative policy is therefore recommended for this frontage.

A revised policy of **limited intervention** is recommended. The key area of concern in this management unit is Flat Cliffs, due to the large number of residential properties. In order to provide protection to the properties of Flat Cliffs, options to delay erosion along this part of the unit are considered, as well as options to provide warning of movement of the coastal slopes. For the rest of the unit, intervention should comprise removal of any structures that become dangerous and management of beach access points as the cliffs erode. A number of the most seaward properties at the Fold and in Primrose Valley Road and Primrose Avenue may be at risk from landslip within 50 years, however the assets at risk are significantly less than at Flat Cliffs and intervention is not likely to be economically viable. Continued monitoring of the cliffs to identify any increase in risk to these properties is recommended.

Options to delay erosion in front of the Flat Cliffs properties are discussed below. As the long term protection of these properties is unsustainable, the options outlined are soft engineering options that will delay cliff recession along this length of frontage, but will not stop it completely. This will allow property owners to relocate within the strategy lifetime.

Should such works be undertaken, the local community will need to be informed of the long term strategic plan regarding the sustainability of the community, and it should be ensured that future generations understand the limited lifespan of the properties.

(a) Rock revetment

Construction of a rock revetment along the Flat Cliffs area of this frontage would provide some erosion protection to the cliffs, and delay recession, thus extending the life of the cliff top properties. It is anticipated that the revetment would typically require to be constructed over a 600m length, from just south of the pumping station to the beach access north of Flat Cliffs, extending over the three cliff behaviour units that encompass the Flat Cliffs properties (see cliff mapping in Annex C). The structure would serve to provide toe protection to the cliffs, reducing erosion, and would also act as a counterweight. Some re-grading of the coastal slopes might be carried out in conjunction with these works. It is recommended that such a structure be designed to reduce erosion, but not limit it completely, as erosion will continue on either side of the protected section, which may result in outflanking of the defence. Construction of a revetment with a relatively low crest level will ensure that natural erosion continues, but to a lesser degree. This will assist in delaying the risk to properties, but will not fully prevent the cliffs from acting as a sediment input to the Bay. It should also provide a more sustainable defence option, within the context of the eroding frontage surrounding Flat Cliffs.

Such a scheme is likely to be an effective option in engineering terms, however will compromise environmental and management (i.e. medium-term occupation) objectives. Long term sustainability of such coastal defences is not viable as the cliff will continue to recede on either side of the defences. Ideally implementation would include removal of the defences at a later date at the end of their useful life in order to prevent longer term impacts on the evolution of the Bay. It is possible that provision of such temporary defences may give a false sense of security regarding the lifespan of the properties.

(b) Groynes

Construction of groynes along the frontage at Flat Cliffs could be considered in order to help maintain healthy beach levels in front of the unstable coastal slopes, reducing erosion at the toe that promotes failure of the pre-existing coastal landslides above. These groynes might be either timber or rock.

Construction of groynes will trap sediment along the frontage, preventing supply of material to other parts of the frontage. In addition, this will reduce cliff erosion, thus reducing the sediment input into the Bay. Groynes might be constructed in conjunction with a beach recharge scheme, to counteract any adverse effect on the sediment budget within the Bay.

As discussed for Filey Town, groynes will provide limited protection during storms, suggesting that groynes would not be a preferred option for this unit.

(c) Beach recharge

For sand beach recharge to be sustainable, given the longshore drift, it is recommended that it be carried out in conjunction with the construction of groynes or other control structures, which have previously been eliminated as viable options for Filey Bay.

As an alternative, shingle recharge to the upper beach, around the high water mark, would provide enhanced erosion protection to the cliff toe. A shingle fraction is already evident on the upper beach, most likely derived from the eroding glacial till cliffs, making this an option that would blend in well with the natural environment. The majority of longshore transport appears to take place below Mean Water Level, with smaller sediment sizes being moved, suggesting that there will be limited movement of the shingle. It may however be necessary to contain the shingle with some form of defence, or to repeat shingle placement at intervals as necessary. Such an intervention would require that an adequate volume of shingle was used to provide protection to the cliff toe, as a small volume may exacerbate erosion by causing abrasion of the toe of the cliff if mobilised under extreme conditions.

Such protection may typically be provided seaward of the coastal slopes containing the access road. This is clearly the most vulnerable part of Flat Cliffs and the consequences of losing the only access route would be significant in terms of the safety of the residents, particularly if urgent evacuation was required. Stability analysis has identified that this zone of the coastal slopes has a very low factor of safety and estimates predict failure within 15 to 30 years. Intervention to provide relatively short term protection to the road may not therefore prove effective.

(d) Slope reinforcement

Ground anchoring or other slope stabilisation techniques could be contemplated at the Flat Cliffs frontage, however given the difficult ground conditions and the deep-seated nature of the landslips, design of such a scheme is likely to present technical difficulties and in terms of cost is not viable.

(e) Rapid response monitoring system

A rapid response monitoring system could be considered, which would allow warning of ground movements that might lead to dangerous conditions or compromise property. Management and operation of such a system should be carefully planned, in conjunction with an evacuation procedure for properties in the risk area.

The piezometers and inclinometers, installed during the Site Investigation might be built in to the design of such a system. Such a system should be implemented in conjunction with a management and evacuation plan, involving the local community in its implementation.

(f) Drainage improvement

Improvements in drainage may be carried out to varying degrees of sophistication. At its simplest, this may comprise improvements in the surface drainage network, controlling run off from properties and paved areas. More sophisticated drainage solutions might include installation of vertical and horizontal drains within the coastal slopes to reduce ground water levels and improve stability.

(g) Monitoring of beach levels and of cliff recession rates

Monitoring of beach levels and cliff recession rates will provide useful data for future modelling of behaviour. While this will not delay the risk to property, it will help to quantify the rate at which the coastline is retreating and help with future management and strategy reviews. Monitoring recommendations are discussed further in Chapter 11.

(h) Provision of alternative access

There is currently a single access road to Flat Cliffs, located on a zone of instability. Stability analysis (see Annex F) has indicated that this zone has a low factor of safety and that ground movements are likely, particularly during periods of prolonged wet weather. Future movement may lead to severance of access as well as loss of a small number of properties in its vicinity early in the strategy lifetime, preventing evacuation of the residents. The road also provides access to Yorkshire Water's pumping station. Provision of alternative access should be considered by the residents and landowners to ensure an evacuation route and to provide continued access to the pumping station, although it is not expected that any of the properties or the pumping station at Flat Cliffs will survive the strategy lifetime.

9.5.3 *Do-nothing scenario*

The do-nothing scenario for this management unit will result in recession as coastal erosion leads to reactivation of the various landslips. From the cliff recession mapping (see Annex C, Map Series B), this is expected to result in significant risk to the properties at Flat Cliffs within the strategy lifetime. Some properties at the Fold, on Primrose Valley Road, Primrose Avenue, some of the Haven Holidays infrastructure and land and some Amtree Park land may also be compromised. In the short term (within 15 years) it is likely that the Flat Cliffs access road will be severed and the properties at the northern end of Flat Cliffs will be lost.

While none of the options outlined will totally eliminate these risks, some of them will assist in delaying erosion and hence reduce the associated risk.

9.5.4 *Recommended option*

The various options and their assessments against environmental, technical and economic criteria are summarised in Table 9.4. From the results of the various assessments, the preferred option for this management unit is installation of a rapid response monitoring system. The results of the cost benefit analysis are presented in Table 9.5. This should be undertaken in conjunction with strategic monitoring of the beach and cliffs, outlined for the full Bay in Chapter 11. The Council will require to develop and implement an evacuation plan for properties anticipated to be at risk, discussed further in Chapter 11.

Provision of alternative access to Flat Cliffs should be considered by residents and landowners to ensure an evacuation route, given the location of the existing road and the risk of it being compromised due to cliff movement. There may be scope for contributions from Yorkshire Water and possibly Haven Holidays in undertaking these works.

Groundwater clearly contributes to cliff instability, so the existing surface drainage network should be well maintained by residents.

Flat Cliffs	Costs and benefits £k		
	Do Nothing	Rock Revetment	Rapid Response Monitoring System
PV costs		703.0	45.61
PV damage	1,730.62	966.37	1,566.77
PV benefits		764.25	163.85
NPV		61.25	118.24
Benefit/cost ratio		1.09	3.59
Incremental b/c ratio			0.91

Table 9.4 Economic assessment – Primrose Valley - Amtree Park: options for Flat Cliffs

Table 9.5 Summary of options appraisal – Primrose Valley - Amtree Park: options for Flat Cliffs

	Option	Environmental	Technical	Economic	Conclusions
A	Rock revetment – Flat Cliffs frontage	Minimal adverse impact	Will prolong property life, but will be unsustainable for strategy lifetime as erosion will continue either side.	Likely to be expensive	Considered in economic assessment
B	Groynes	Minimal adverse impact	Will not stop cross-shore movement of sand during storms	Not considered further	Not considered further
C1	Sand recharge	Minimal adverse impact	Unlikely to be sustainable without groynes	Not considered further	Not considered further
C2	Shingle recharge	Minimal adverse impact	Shingle placement on upper beach will provide some protection to cliff toe, repeat placement is likely to be required. May exacerbate erosion by abrasion of cliff toe.	Relatively inexpensive, some benefits by delaying risk.	Not considered further
D	Slope reinforcement	Some impact on value of vegetated cliffs	Inappropriate due to difficult ground conditions and deep-seated nature of landslips.	Expensive	Not considered further
E	Rapid response monitoring system	No significant adverse impact	Will provide advance warning of risk of movement, providing appropriate thresholds set. Management will require careful consideration.	Some reduction in risk as provides opportunity for evacuation and removal of belongings, but will not prevent properties and pumping station being compromised.	Considered in economic assessment
F1	Surface drainage improvement	No significant adverse impact	Will help to control groundwater levels, but will not delay wave erosion of toe.	Inexpensive options may be considered and may result in some small delay in recession.	Keep existing surface drainage in good repair
F2	Drainage of coastal slopes	May adversely affect wetland features	Installation likely to be difficult given nature of slopes.	Likely to be expensive given access difficulties.	Not considered further
G	Monitoring	No significant adverse impact	Will inform understanding of processes and feed into future strategy reviews	No direct economic benefit, will reduce uncertainties in process understanding.	Recommended
H	Provision of alternative access	Minimal adverse impact	Will ensure an evacuation route should the current access be lost due to landslip	Will ensure evacuation once existing road is lost.	Recommendation to consider further

As part of the site investigation work, piezometers and inclinometers were installed and baseline readings taken (see Annex F). These should be monitored at regular intervals during the interim period before a full monitoring system is implemented to identify any changes that might suggest ground movement.

9.6 *Hunmanby Gap (Management Unit 29C)*

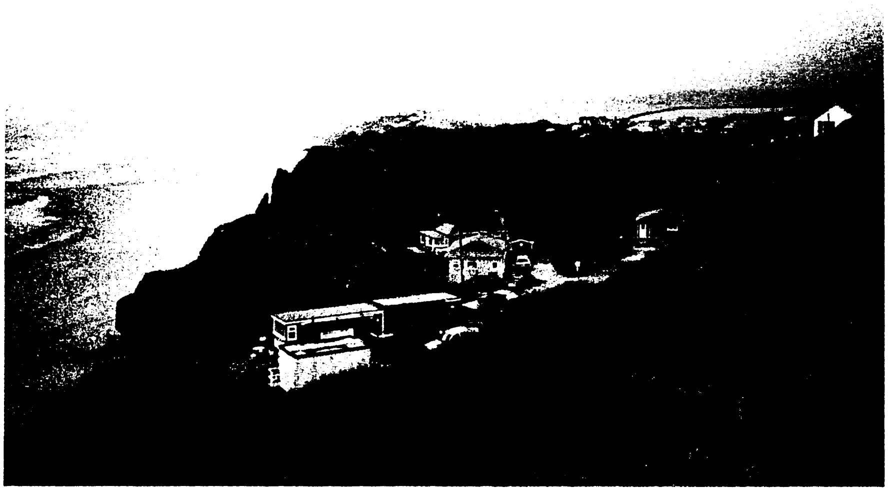


Figure 9.6 Hunmanby Gap

9.6.1 *General*

This length of frontage is similar to the Primrose Valley – Amtree Park Frontage (Management Unit 29B) with evidence of incipient cliff instability and cliff retreat. A small number of residential properties are at risk at the Gap within the lifetime of the strategy as well as a pumping station and its associated pipework. Reighton Gill discharges at Hunmanby Gap.

A new development landward of existing properties has been approved. It is considered that any increase in discharge in Reighton Gill as a result of runoff from this development will be negligible relative to the natural discharges and groundwater conditions.

The proposed environmental objectives for this unit are:

Proposed Objectives (see Annex D)	
29C.1	Protect cliff top property threatened by erosion and cliff slumping, if feasible, economic and sustainable
29C.2	Maintain vegetated and non-vegetated soft cliffs and allow natural erosion to continue
29C.3	Create or maintain vegetated cliff tops, allowing for landward migration as cliff recedes
29C.4	Avoid interference with intertidal and subtidal sandy and rocky habitat
29C.5	Maintain existing cliff top and beach access routes. Seek to create new Public Rights of Way if feasible and appropriate.

9.6.2 *Options*

The SMP recommends a strategy of **retreat the existing defence line**. On review an alternative policy of **limited intervention** is recommended, based on the latest guidance (see Chapter 8). Alternative options that may be considered are:

(a) Slope reinforcement

Ground anchoring or other slope stabilisation techniques might be considered, however given the difficult ground conditions and the deep-seated nature of the landslips, design of such a scheme is likely to present technical difficulties and in terms of cost is not viable.

(b) Rapid response monitoring system

A monitoring / warning system could be installed to inform of ground movement by means of inclinometers. Management and operation of such a system should be carefully planned, in conjunction with an evacuation procedure for properties in the risk area. Dangerous structures should be removed as and when required. An evacuation plan will be required to address properties at risk.

(c) Monitoring of beach levels and rates of cliff recession

Monitoring of beach levels and cliff recession rates will provide useful data for future modelling of behaviour. While this will not eliminate risk to property, it will allow refinement of quantification of the rate at which the coastline is retreating and will help with future management. Monitoring recommendations for all of Filey Bay are discussed further in Chapter 11.

9.6.3 *Do-nothing scenario*

The do-nothing scenario for Hunmanby Gap will result in a small number of the most seaward properties being at risk due to coastal erosion, by the end of the strategy lifetime, based on the mapping of cliff recession potential (see Annex C, Map Series B). At this stage it is not considered that the properties on Gap Road are at risk. The opening of Reighton Gill onto the beach is likely to widen as result of coastal erosion.

Option		Environmental	Technical	Economic	Conclusions
A	Slope reinforcement		Not practical, given the deep seated nature of landslips; installation difficulties given the topography of the slopes	Likely to be expensive as a result of technical difficulties.	Not considered further.
B	Rapid response monitoring system	No adverse impact	Will provide advance warning of risk of land slip, provided appropriate thresholds set. No adverse effect on processes within the Bay.	Will help reduce risk by allowing evacuation and removal of belongings. Will have no effect on risk to pumping station.	Considered in economic assessment.
C	Monitoring	No adverse impact	Data collection will improve process understanding and inform future strategy reviews.	No direct economic benefit.	To be recommended as part of monitoring / management strategy for Bay.

Table 9.6 Summary of options appraisal - Hunmanby Gap

9.6.4 *Recommended option*

From the results of the various assessments (see Tables 9.6 and 9.7), the preferred option for this management unit is continued monitoring. The number of properties at risk in the short term is limited and does not justify protection works or installation of a rapid response monitoring system. Residents of these properties should be made aware of the risks and likely lifetime of their properties in order that provision may be made for relocation. The council will require to develop and implement an evacuation plan for properties at risk. Coastal change in the vicinity of these properties is generally as a result of erosion rather than landslides and is therefore expected to be more gradual. This should be reassessed at strategy review intervals, should there be indications of the properties on Gap Road coming under threat.

Hunmanby Gap	Costs and benefits £k	
	Do Nothing	Early Warning System
PV costs		45.61
PV damage	18.58	16.72
PV benefits		1.86
NPV		43.75
Benefit/cost ratio		0.04
Incremental b/c ratio		-

Table 9.7 Economic assessment – Hunmanby Gap

9.7 Reighton Sands (Management Unit 30A)

Figure 9.7 Cliffs at Reighton Sands

9.7.1 *General*

At Reighton Sands, cliff top development comprises the Reighton Sands Holiday Village and a small number of residential properties. There is evidence of large scale land instability and cliff top recession. There are no properties at immediate risk, however it is anticipated that some properties will be damaged or lost within 50 years. Some of the holiday village land and chalets at its seaward limit may also be lost.

There is public access to the beach, although the concrete road has become badly damaged in places, which may present a hazard to pedestrians. The proposed environmental objectives for this unit are:

Proposed Objectives (see Annex D)	
30A.1	Protect cliff top property threatened by erosion and cliff slumping, if feasible, economic and sustainable
30A.2	Maintain vegetated/non-vegetated soft cliffs; allow natural erosion to continue
30A.3	Create or maintain vegetated cliff tops, allowing for landward migration as cliff recedes
30A.4	Avoid interference with intertidal and subtidal sandy and rocky habitat
30A.5	Maintain bathing water quality to comply with EU directive mandatory level
30A.6	Maintain existing cliff top and beach access routes. Seek to create new Public Rights of Way if feasible and appropriate.

9.7.2 *Options*

The favoured option for this unit is **limited intervention**, at variance with the SMP recommendation of **do nothing**. Intervention measures are likely to be limited to removal of structures as the cliff line retreats and they become unsafe. It is recommended that maintenance of the beach access route be undertaken, if feasible.

Given the magnitude and deep-seated nature of the landslide units seaward of properties along this frontage, protection works would not be economically feasible. Nor would such options be technically appropriate due to the importance of this frontage in providing sediment to the Bay. Subsequent strategy reviews should reappraise the situation in this unit, to establish whether a rapid response monitoring system might be appropriate as the risk to property increases.

9.8 *Speeton (Management Unit 30B)*

Figure 9.8 Speeton

9.8.1 *General*

The glacial till cliffs are gradually replaced by harder chalk cliffs and talus slope, as the bedrock outcrops south of Speeton and increases in prominence to the south. The village of Speeton is set some way back from the cliffs and there is little infrastructure along or behind the cliff that is at risk.

The proposed environmental objectives for this unit are:

Proposed Objectives (see Annex D)	
31A.1	Maintain nationally important landscape, including characteristic coastal features (HC)
31A.2	Maintain vegetated and non-vegetated soft cliffs and allow natural erosion to continue (cSAC/SSSI)
31A.3	Create or maintain vegetated cliff tops, allowing for landward migration as cliff recedes (SSSI)
31A.4	Avoid interference with intertidal and subtidal sandy and rocky habitat (cSAC/ SSSI)
31A.5	Maintain existing extent and quality of Jurassic clay exposures and Pleistocene stratigraphy (SSSI)

9.8.2 *Options*

The favoured option for this unit is **no active intervention**, in accordance with SMP recommendation of **do nothing**.

9.9 *Flamborough Headland (Management Units 31A to E)*

Figure 9.9 Bempton Cliffs, Flamborough Headland

9.9.1 *General*

Further south in the Bay, the high cliffs are formed of Cretaceous Chalk with a thin capping of glacial till. The steep cliffs are internationally designated for their geological/ geomorphological asset and seabird life, and form a boundary for the Sensitive Marine Area (SMA) that extends to Flamborough Headland.

At North Landing there are assets such as a public beach and boat launching facilities with associated infrastructure, which are also important to the area.

9.9.2 *Options*

With the exception of North Landing (Unit 31D), the policy for these units is **no active intervention**, in accordance with the SMP recommendation of **do nothing**. Due to the infrastructure at North Landing, a policy of **limited intervention** is recommended to maintain the existing boat launch facilities, compared with an SMP recommendation of **retreat the existing line of defence**.

The limited intervention will comprise inspection and maintenance of the defences at North Landing. Beach levels should also be monitored, with the survey undertaken in November 2000 providing a baseline.

Figure 9.10 *North Landing*

10 Recommendations & Conclusions

10.1 *Policy & Implementation*

The recommended strategy for Filey Bay has been developed through considering individual frontage requirements and constraints, together with consideration of the influences on other management units and on the Bay as a whole and of the interdependencies between frontages. The proposed strategy is summarised in Table 10.1 and illustrated in Figure 10.1. Each management unit has been discussed in detail in Chapter 9.

Where possible, the recommendations made are for the lifetime of the strategy (50 years). In some areas, however, the long-term strategy might be modified to reflect changing circumstances, which cannot be fully identified at this stage, or issues that will not arise for some decades. Where issues are expected to arise at a later date, these have been highlighted and considered in the assessments made at this stage. It will be prudent to revisit these issues at Strategy reviews in the light of any new information.

The detailed assessment made along the frontage have allowed outline planning guidance to be developed for cliff top zones, shown on the maps in Annex C.

The strategy time frame has been set at 50 years, consistent with DEFRA guidance. It is recognised that conclusions drawn today may be modified in the future given new information and changes in local or national government policy. Therefore, the strategy should be reviewed at least as noted in Table 10.1 and updated as necessary.

Actions for implementing this strategy are described in Chapter 11.

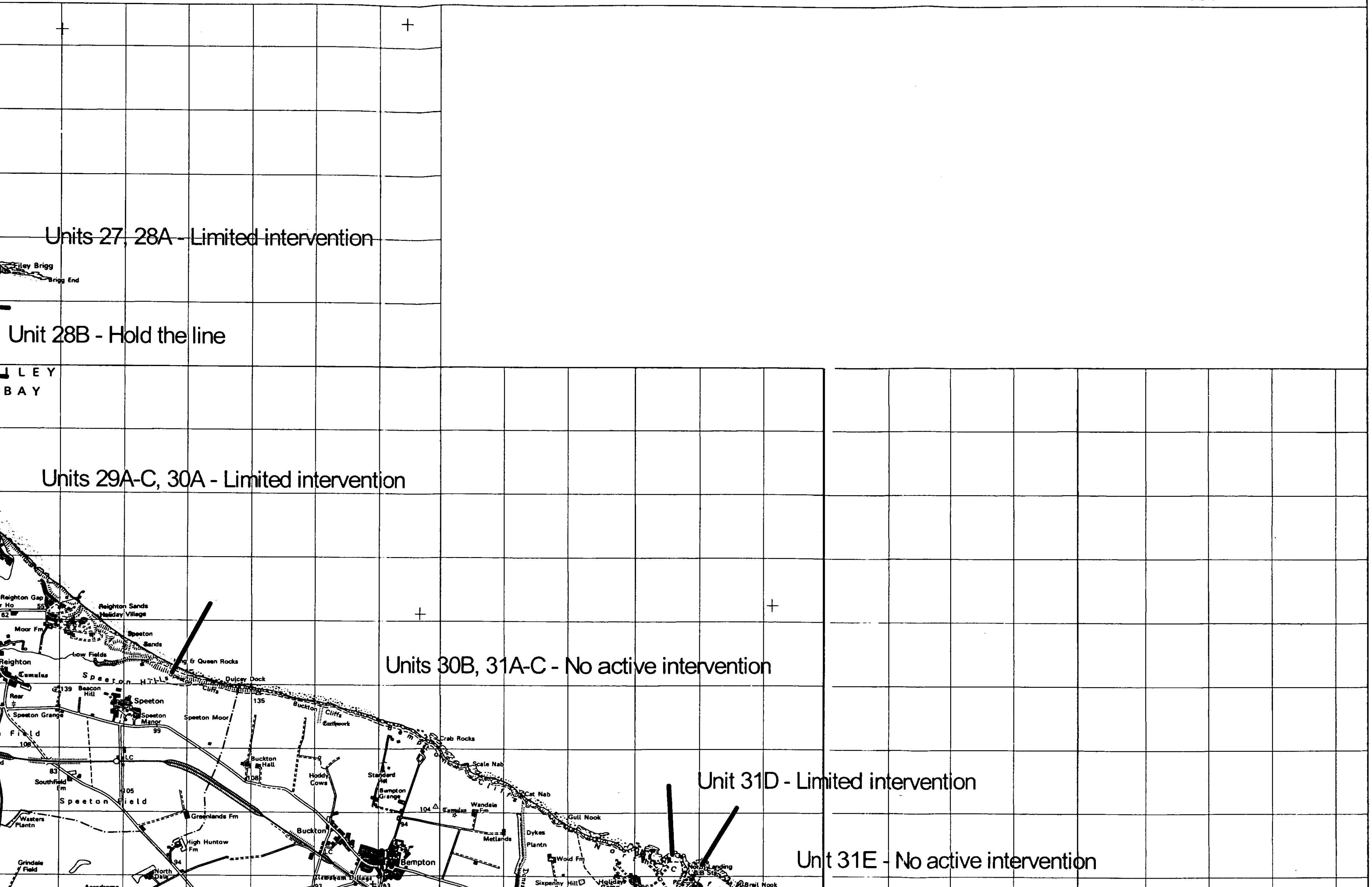
Management unit		SMP preferred management policy	Revised Strategy management policy	Preferred option	Review frequency
27	Filey Brigg	Retreat	Limited intervention	Manage public footpath, relocating landward as necessary due to cliff recession	5 years
28A	Filey Sands	Do nothing	Limited intervention	Manage public access along cliff top, relocation of Sailing Club	5 years
28B	Filey Town	Hold the line	Hold existing defence line	Rock armour protection to ends of seawall Coastal stability study	5 years (unless findings from coastal stability study indicate a need for more urgent action)
29A	Muston Sands	Do nothing /(Retreat)	Limited intervention	Manage public access along cliff top	5 years
29B	Primrose Valley - Amtree Park	Retreat	Limited intervention	Rapid response monitoring system for Flat Cliffs and monitoring	5 years
29C	Hunmanby Gap	Retreat	Limited intervention	Monitoring to identify any future need for intervention	5 years
30A	Reighton Sands	Retreat	Limited intervention	Monitoring to identify any future need for intervention, repairs to public beach access	5 years
30B	Speeton	Do nothing	No active intervention	No intervention required	10 years
31A	Flamborough Head	Do nothing	No active intervention	No intervention required	10 years
31B	Flamborough Head	Do nothing	No active intervention	No intervention required	10 years
31C	Flamborough Head	Do nothing	No active intervention	No intervention required	10 years
31D	North Landing	(Do nothing)/ Retreat	Limited intervention	Monitoring of beach and structures	10 years
31E	Flamborough Head	Do nothing	No active intervention	No intervention required	10 years

Table 10.1 Summary of proposed strategy options

Options in brackets are those which the SMP identified as requiring further detailed consideration, particularly in relation to transition zones

FILEY BAY
COASTAL STRATEGY STUDY

Halcrow
2001



10.2 Compliance with Shoreline Management Plan

Generic coastal defence policies for the whole of this shoreline were established in the Shoreline Management Plan. This strategy has sought to confirm the appropriateness of these policies and to identify measures necessary to implement them. Recommendations have been made for changes to the proposed policies where this is deemed to be necessary. These changes are generally based on revised policy definitions given in DEFRA guidance, following production of the SMPs.

The key policy change is the recommendation of 'limited intervention' in place of 'managed retreat' for several units within the Bay. In addition, at Reighton the policy has been revised from 'do nothing' to 'limited intervention' to reflect the need for management of beach access as the coastline retreats.

10.3 Strategy Impacts

10.3.1 *Built Environment*

The strategy fulfils the objective of protecting property where environmentally sustainable, feasible and economic. In pursuing the recommended strategy an estimate of the number of properties predicted to be at risk from erosion and coastal retreat during the fifty years of the strategy is given in Table 10.2.

Location	Residential Properties*	Other Properties and land
Filey Country Park	0	Sailing Club
Muston Sands	0	Part of golf course
Primrose Valley - Amtree Park:		
- Flat Cliffs - Lower Flat Cliffs - Back Sea View - Primrose Valley Road	41 12 6 4	Pumping Station, Some Haven Holidays land and infrastructure
Hunmanby Gap:		
- Sands Road	3	Pumping Station
Reighton:		
- Sands Close - Sands Road - Boat Cliff Road - The Larches	6 2 2 17	Some caravan park land including chalets

Table 10.2 - Estimates of properties at risk under proposed strategy implementation

** Some of these properties are likely be holiday homes that are not occupied for parts of the year*

10.3.2 *Water and Aquatic Environment*

The strategy will have no long-term adverse effects on the aquatic environment. Achieving the objectives of maintaining or improving bathing water quality is beyond the control of the coastal defence strategy, however it remains one of the key issues to maintain the quality of the aquatic environment.

Proposed rock / shingle placement may cause short-term increases in sedimentation of the water column, which could affect fish and other marine organisms. It is recommended that the seasonal timing of such works be considered in relation to fisheries and fish spawning periods. In general, works during the autumn and winter periods are likely to have lower impact as the water is naturally more turbid than in the spring and summer.

10.3.3 *Ecology and Nature Conservation*

The interventions proposed by the strategy have no significant adverse effects on nature conservation. Furthermore, no significant adverse effects on qualifying or designated biological or geological interest features of statutory protected areas (SSSIs, SPA and cSAC) are predicted from the proposed policies of non-intervention or limited intervention. Outside statutory protected areas, but within the SNCI, there will be some loss of existing nature conservation interests on the retreating soft cliffs and cliff tops as a result of natural processes of cliff erosion and retreat. This is accepted by the strategy as there are no technically feasible and sustainable interventions that would avoid the losses. Even if it were technically possible to arrest the process of cliff erosion, the nature conservation interest of the soft cliffs would be radically altered as the slumping process is integral to their ecology.

The mitigation recommended by the strategy to re-create vegetated cliff-top and cliff-face habitats, including freshwater pools, lost to erosion will provide some benefits to nature conservation. In general, maintaining natural processes and managing the process of retreat will contribute to the sustainable conservation of wildlife habitats and species characteristic of this Natural Area. However, there will be a need for proactive policies to enable habitat setback to occur, since otherwise cliff-top and cliff-face habitats will become squeezed between the retreating cliff line and existing land uses on the cliff top such as caravan parks and agriculture. It is recommended that setback be implemented through:

(a) land acquisition in the set-back zone by nature conservation bodies, including local authorities and the Yorkshire Wildlife Trust;

(b) bringing agricultural land under more sympathetic conservation management through stewardship funding or similar initiatives; and

(c) adoption and implementation of appropriate planning policies by local planning authorities, including the prohibition of any new building or extensions to existing buildings, for land in the set-back zone.

10.3.4 *Landscape*

The proposed interventions will have no significant adverse effects on landscape. Proposed works to defend developed sections of coast are generally in keeping with the existing character of the coastline.

Where no coastal defence interventions are proposed, the mitigation recommended by the strategy will provide some benefits to visual amenity on the retreating soft cliffs and cliff tops, compared to doing nothing. The character of significant landscape elements of the Heritage Coast will be maintained by the recommended policies of doing nothing and limited intervention. However, in the soft cliff areas between Muston Sands and Speeton, the process of erosion will bring existing development such as houses and caravan parks closer to the cliff edge before they are eventually lost. This will result in increased prominence of intrusive landscape features along the cliff top and shoreline. Mitigating this impact will be difficult as there are no established powers that can require structures to be removed because of their landscape impacts, in advance of erosion making them unsafe. However, should opportunities arise to negotiate large-scale removal and relocation of existing facilities such as caravan parks to more sustainable and less visually intrusive locations, rather than waiting for piecemeal loss at the cliff top, it is recommended that the local authorities should pursue them. Opportunities to screen existing or new sites with tree planting should also be followed up where possible.

10.3.5 *Agriculture*

The impacts of the strategy on agriculture will be minor. There will be some small direct losses of agricultural land, and the strategy also recommends that areas of agricultural land might be acquired on the open market and/or brought into conservation management to offset losses to cliff recession.

10.3.6 *Tourism and Recreation*

Adverse effects on tourism and recreation will arise from the partial loss to the sea of the following cliff top assets:

- Some margins of the course at Filey Golf Club
- Part of caravan parks at Primrose Valley and Reighton, and part of the Amtree Park site
- Coastal footpath at Filey Brigg
- Filey Sailing Club

There will be a recreational benefit from the strategy recommendations to re-route footpaths lost to erosion in the northern half of the study area. This responsibility should be shared between North Yorkshire County Council (as footpaths authority) and Scarborough Borough Council (as coastal protection authority). Intervention to re-route existing footpaths is not expected to be needed within the East Riding of Yorkshire administrative area. However, all authorities should seek opportunities to establish new footpaths in conjunction with coastal retreat, with the objective of linking the whole study area with a coastal footpath.

The proposed strategy interventions to defend built areas have been designed to avoid deterioration in the quality of beaches in the study area, which are of great importance.

Implementation of the strategy recommendations to sustain Filey Town sea wall would, if carried out in the summer months, have an adverse effect on tourism and recreation since it will require the use of heavy machinery on the beach. It is therefore recommended that this work be carried out in the autumn or winter, and that the peak holiday months should be avoided.

10.3.7 *Fisheries*

The strategy will not have any long-term adverse impact on boat launching facilities. However, there may be short-term restrictions on boat launching at Coble Landing when the works to secure the northern end of Filey Sea Wall against outflanking are implemented. There may also be short-term impacts on inshore fisheries (including long-lining, trawling, nets and pots) as a result of barge deliveries of rock for coastal defences, but these will be controlled to minimise their impact.

Because fishing effort is all year round (though the target species vary), seasonal control of the working period would not necessarily enable any impacts to be avoided altogether. The details of controls, such as barge access routes and delivery points, will need to be agreed with the fishermen when the requirements for rock and other materials are determined.

10.3.8 *Transport Network and Traffic*

The interventions proposed by the strategy will have no significant adverse effects on transport network and traffic, except that there will be a benefit from the proposal to maintain the access road to Flat Cliffs for as long as technically possible.

10.3.9 *Cultural Heritage*

The strategy provides for the protection of the cultural assets of Filey Town and seafront, which is a Conservation Area. Reighton Conservation Area, which is located further inland, is not affected by the strategy. Based on estimated cliff recession potential, the known archaeological sites at risk within the strategy lifetime are tabulated in Annex A, Table 7.2. The most significant site at risk is the site of Filey Roman Signal Station, which is a Scheduled Monument. The strategy accepts this as there is no technically feasible and sustainable solution to defend it. Excavation and recording is proposed to mitigate the loss of the site. This may also be appropriate in relation to some of the other sites expected to be lost. Mitigation in respect of sites expected to be lost to erosion should be commissioned and co-ordinated by English Heritage (in relation to the Scheduled Monument) and by the archaeological units of the two local authorities (North Yorkshire County Council and Humber Archaeology Partnership).

It is not anticipated that any known archaeological sites will be adversely affected by coastal defence interventions. If, however, a need for archaeological mitigation were identified during the development of specific schemes, this would be the responsibility of the coastal defence operating authority commissioning the works.

10.3.10 *Air Quality*

The strategy will have no significant effects on the atmospheric environment. The potential for construction works to release dust will be limited by the damp nature of materials in the intertidal zone, and it is not expected that any specific mitigation measures would be needed over and above normal good working practice.

10.4 *Strategy Economics*

10.4.1 *Summary of Economic Assessments*

The recommended strategy as presented in Table 10.1 and Figure 10.1 has been considered in economic terms as part of the assessment process (presented in Annex E and summarised for each management unit in Chapter 9). This assessment is summarised in Table 10.3 for those units where intervention is required. The economic assessment follows guidance produced by the

Department for Environment, Food and Rural Affairs (DEFRA), and considers all expenditure over the strategy timeframe, discounted to present value (PV) to take account of the timing of expenditure. The benefit cost ratio (BCR) is a simple measure of the economic worth of the scheme.

Management unit	Option	PV Costs (£k)	PV Benefits (£k)	Benefit Cost Ratio
Filey Town	Rock protection at ends of seawall	62.5	226.8	3.6
Amtree Park	Rock revetment	703.0	764.3	1.1
	Rapid response monitoring system	45.6	186.1	4.1
Hunmanby Gap	Rapid response monitoring system	45.6	1.9	0.04

Table 10.3 Summary of economic assessment

10.5 *Risk and Sensitivity Assessment*

Sensitivity and risk play an important part in determining the preferred strategy. When undertaking works or operating schemes in the future it is important that the risks are identified and appropriate actions are taken. A key requirement to ensure control of risks will be ongoing monitoring for the study area in order to assist in future strategy reviews. Where works are proposed, early consultation with relevant parties will be important to reduce the likelihood of objections to schemes at a later date.

To ensure that the strategy recommendations made are "robust", the sensitivity to change of certain factors has been considered in the strategy development. The following sections highlight particular concerns under headings of relevance to strategic planning adopted from the MAFF FCDPAG4 document 'Approaches to Risk'.

Potential risks have been identified and addressed as far as possible in the development of the strategy, as summarised in the risk register, Table 10.4. These risks will, however, remain primary considerations as the strategy and individual schemes are progressed in the future. Actions to assist in reducing risks include continual improvement in knowledge, such as ongoing monitoring for the study area. Where other actions are deemed necessary to assist in controlling risks, these are identified below.

10.5.1 *Poor definition of the extent of the problem*

Clearly one of the key factors in determining the timing of intervention works within Filey Bay is the rate of coastal recession. Field observations and interpretation of historic maps have allowed assessments of recession rates to be made throughout the Bay. Understanding of this recession will be improved by continued monitoring which will allow predictions to be updated as necessary.

10.5.2 *Lack of knowledge or appreciation of processes*

An understanding of processes within Filey Bay has been developed based on previous studies and on modelling. In order to improve this understanding a number of recommendations are made as part of the strategy. Firstly, it is recommended that a comprehensive monitoring programme be undertaken, which will allow continual improvement in understanding of processes. In addition, a more detailed hydrodynamic study of Filey Bay is recommended to further improve this knowledge, and in particular develop further understanding of offshore movements of sediment.

10.5.3 *Uncertainties about the performance of existing and proposed defences*

The key defences that are considered in the strategy are at Filey Town. An assessment of defence performance has been based on beach profile information, cross-section drawings and photographs and trial pit investigations, however this information is limited. In order to improve this understanding, a detailed inspection of the seawall is recommended, to establish wall foundation levels, as part of a coastal stability study. Installation of tell-tale monitors on the wall face to establish minimum beach levels and any drops in the clay profile is also recommended.

10.5.4 *Interaction between different schemes & multiple failures*

Factors considered here include the timing and phasing of works and availability of funding. These can affect works going ahead, which in some cases may have a major effect on adjacent frontages. Given the limited nature of the proposed intervention works it is not anticipated that there will be any adverse interaction between different areas of the frontage.

10.5.5 *The economic evaluation of damages*

The degree of detail in which damages have been assessed is more than adequate for a strategic level of analysis. At a more detailed stage, for example a Feasibility Study or Engineers Report it is likely (and usual) that additional benefits would be recognised, increasing benefit values.

However, it is also possible that at detailed design stage of any schemes, unforeseen problems may be identified which may increase costs. Equally, changes in market forces may mean certain materials or operations become more expensive. The possibility of increases in costs has been assessed during the economic assessment, by testing the preferred options to ascertain what magnitude of increase in cost would make the scheme economically unjustified.

10.5.6 *Large-scale impacts on natural processes*

It is not considered that intervention works proposed will have any adverse large-scale impacts on processes. This may be further assessed by means of the hydrodynamic studies recommended as part of the strategy.

10.5.7 *Variations in future storm frequency & direction*

The preferred strategy has been informed by modelling undertaken to establish longshore transport processes. This modelling was driven by wave data derived from the Met Office wave model, with some sensitivity testing of the influence of wave direction.

Modelling studies included the response of the beach to storm conditions, which indicated that at some locations the cliff toe becomes exposed to wave attack under extreme conditions as beach levels drop. At Filey Town beach levels in front of the seawall drop under extreme conditions, and it has been reported that the clay layer is exposed on occasion. Clearly the prospect of increased storminess resulting from climate changes suggests that these scenarios will occur with increasing frequency. This may result in erosion of the exposed clay layer, leading to a trend of lowering beach levels. Monitoring should assist in identifying any such trend, and consideration should be given to the impact of such changes during strategy reviews.

10.5.8 *Timing of Expenditure*

Many influencing factors exist which could lead to delays in implementation and these are discussed above. Recommended intervention times are seen as the approximately correct time for action. Where uncertainty exists regarding the necessity of schemes, monitoring is proposed to inform strategy reviews. Should the monitoring reveal less dramatic changes in processes/foreshore levels than predicted from the current study, then there may be capacity to delay expenditure. Alternatively monitoring may recommend a more urgent requirement for intervention works. An action plan for the works is given in Table 11.1.

10.5.9 *Variation in Costs*

The costs of works have been derived based on current prices taken from a range of projects and from typical cost rates provided by SBC. These costs may increase, the extent of works may be underestimated (or unforeseen problems could arise), equally, availability of materials could become more scarce in the future. Instead of attempting to pre-empt any market changes or design details to estimate any increase in applied costs, a reverse process has been undertaken to evaluate by what percentage costs would have to increase to drastically alter the economic justification of the preferred strategy. The threshold of justification was assumed to be a benefit cost ratio of 3 (the median value of funded schemes in 1998).

Strategy risk identification	Probability (H/M/L)	Consequence (H/M/L)	Mitigation measures (to be) undertaken	Action by
Poor definition of extent of problem	L	M	Review of strategy at 5-year intervals	SBC
Lack of knowledge of processes	M	M	More detailed hydrodynamic studies are recommended	SBC
Uncertainties of defence performance	M	H	Partially informed by site inspection and investigation at Filey Town seawall. Recommendations for more detailed coastal stability study at Filey	SBC
Interaction between different schemes	L	L	Limited intervention options proposed at discrete locations; interactions not anticipated	Addressed in strategy
Economic evaluation of damages	L	M	Assessment made a high level appropriate to strategy; more detailed studies likely to yield higher benefits, improving economic justification	Addressed in strategy
Large scale impact on natural processes	L	L	Limited intervention so significant impact not likely	Addressed in strategy
Variations in storm frequency / direction	M	M	Monitoring of beach response and wave / water level data collection	SBC
Timing of expenditure	M	M	Sensitivity testing of economic assessment to establish scope for variation	Addressed in strategy
Variation in costs	M	M	Sensitivity testing of economic assessment to establish scope for variation	Addressed in strategy

Table 10.4 *Risk Register*

10.6 *Opportunities arising from the Strategy*

10.6.1 *Joint funding initiatives*

Given the presence of Yorkshire Water infrastructure in the risk zone, there may be scope for pursuing joint funding of works where appropriate. This is particularly recommended at Flat Cliffs where provision of alternative access is recommended to ensure continued access for residents and to the pumping station, given the anticipated short lifespan of the existing access route.

10.6.2 *Natural Environment*

It has been identified that there are opportunities for recreation of vegetated cliff-top and cliff-face habitats, including freshwater pools, to replace those lost to erosion. There will be a need for proactive policies to ensure this habitat recreation and avoid squeezing of habitats between the receding cliff line and the boundaries of holiday parks and other developed areas. This may be achieved by land acquisition in the set-back zone by nature conservation bodies, more sympathetic management of agricultural land and adoption and implementation of appropriate planning policies.

10.6.3 *Liaison*

Management of the inherent instability of the coastal slopes will be most effectively carried out in close liaison with the local residents. The recommendation for a rapid response monitoring system will require participation of the residents to ensure effective implementation and management.

10.6.4 *Control of monitoring instrumentation*

Throughout the development of the strategy, consideration has been given to rapid response systems to warning of potential ground movements. Such a system has been recommended for Flat Cliffs, and subject to the findings of the proposed coastal stability study for Filey Town, it may also be beneficial to install such a system there. Opportunities for automated logging of such systems should be considered and it is recommended that a study of the use of telemetry be undertaken to establish whether this might be beneficial. This may also benefit the Council's approach to monitoring outside the strategy area.

10.7 *Further Investigation*

10.7.1 *Studies and Research*

Through the development of the Strategy, a need for further investigation on certain issues has become apparent. These generally arise in areas where some uncertainty remains surrounding future trends in processes, the justification of potential schemes, or conflicts of environmental objectives.

Initiatives recommended to address these issues and increase the resolution of the Strategy are presented in Table 10.4.

SCHEMES	**Priority**
Study of telemetry (see Section 10.6.4)	1
Design & implementation of rapid response monitoring system for Flat Cliffs (see Section 9.5)	To follow telemetry study
Coastal stability study for Filey Town (see Section 9.3)	1
PROCESSES	
Complete hydrodynamic modelling study of Filey Bay to improve understanding of coastal processes (see Section 5.4)	2
Future review and updating of process understanding from monitoring data, to be undertaken at 5 year intervals (see Section 10.7.2)	3

Table 10.4 Further Studies

10.7.2 *Monitoring*

Recommendations for future monitoring form a key part of the strategy, and are given in more detail in Chapter 11. The main findings relating to quality of monitoring data are presented here with suggestions for considerations when reviewing current practices.

(a) Topography and bathymetry

As part of the strategy study, a bathymetric and topographic survey was undertaken. This will serve as a baseline for future surveys to be implemented during the strategy lifetime. This survey included beach profiles throughout the Bay. It is recommended that additional beach profiles be recorded throughout the Bay at higher resolution as identified in the SMP. As part of the survey, permanent markers were located on the cliff top to allow measurement of cliff position and further quantification of recession rates. Full recommendations for monitoring including frequencies and spatial resolution are given in Section 11.2.

(b) Waves and water levels

Wave data used in the modelling study was taken from the UK Met Office Northern European Wave model. Offshore wave conditions were obtained at a selected point and transformed to inshore points using mathematical modelling. This data is generally well controlled by the Met Office's own quality assurance procedures.

Recommendations were made in the SMP for deployment of a wave rider buoy and a tide gauge at either Whitby or Scarborough. These recommendations should be implemented to benefit both this strategy and those strategies for adjacent frontages.

(c) Review of monitoring data

The proposed monitoring programme will result in a significant quantity of data on beach and cliff changes being collated. As well as standard processing and quality checks, it is recommended that this data be reviewed and reported at 5 yearly intervals to identify any trends and inform strategy reviews.

11 Implementation plan

11.1 *Recommended Programme of Work*

A schedule of recommended activities is given in Table 11.1. Key activities to be undertaken early in the strategy are: the proposed stability study for Filey town; a study into the use of telemetry for monitoring. The latter will provide benefits to SBC both for this strategy area and other adjacent areas, should future needs for ground movement monitoring be identified. This will benefit the planning and implementation of a rapid response monitoring system for the Flat Cliffs community. Provision of outflanking protection at Filey town should be undertaken within the first 5 years of the strategy.

Development of contingency plans to address potential property losses should be undertaken at an early stage in the strategy, and this should be reviewed at 5 year strategy intervals as estimates of properties at risk are updated.

A strategic monitoring programme should be put in place to operate throughout the strategy. It is expected that this will form part of an overall programme operated by SBC for all of the coastline within their administrative boundaries.

It is expected that many of these activities will attract DEFRA Grant Aid as highlighted in Table 11.1.

11.2 *Monitoring Requirements*

Monitoring of coastal processes and defence condition will provide a key source of information for use in future refinements of the strategy for the Bay. In order to make the most effective use of this information, it is recommended that it is stored in a database that allows easy interrogation and access to the data. SBC operate their own P.C. based "Keyshore" database and it is anticipated that this system will be used for data management, to ensure ease of retrieval for future studies / analysis, ensuring the most effective use of data collected during the strategy time frame.

The Shoreline Management Plan gives monitoring recommendations for the full extent of sub-cell 1d (Huntcliffe to Flamborough Head), under the following headings:

- Aerial photography
- Bathymetric survey
- Offshore wave climate
- Wind records
- Water levels
- Beach profile surveys
- Defence condition survey
- Cliff top erosion monitoring
- Visual observation

The recommendations given in the SMP are considered in more detail below, with additional recommendations made where identified as necessary. The scope of monitoring identified in the SMP forms the basis of a regime that will allow the collection of substantial baseline data on hydrodynamic conditions, shoreline evolution and cliff recession, allowing assessment of rates of change and identification of trends in processes. While recommendations are made here for monitoring of Filey Bay, it is noted that these feed into Scarborough Borough Council's strategic monitoring programme for the full length of frontage in their administrative area.

Monitoring of ground movement is recommended at Flat Cliffs as part of a rapid response monitoring system. Piezometers and tiltmeters have already been installed during the Ground Investigation that was undertaken as part of the strategy and it is recommended that these are monitored while a full monitoring system is being design and implemented. Baseline readings are included in Norwest Holst's site investigation report. Ideally this monitoring should commence as soon as possible until a more structured warning system is designed and in place. Several hours input would be required to visit the site, take readings and compare with the baseline.

With regard to monitoring of natural features, such as the foreshore and cliffs, the bay divides into two sections of differing priorities, based on geology. The northern part of the bay from Filey Brigg to Speeton is prone to more rapid changes, due to the softer geology comprising glacial till. This section is likely to experience changes due to seasonal and climatic influences, over a shorter timescale reflected in the proposed monitoring regime. The southern part, comprising the harder cretaceous rocks, is less prone to these short term changes and longer intervals between inspections or survey are therefore proposed.

Recommendations are made for a review of monitoring data at 5 yearly intervals to inform strategy reviews (Section 10.7.2 and Table 11.1). This will help to identify any changing trends in processes that may influence the strategy.

	Description (section references are those in Strategy report)	Respons-ibility (funding)	Year	Cost details	NPV Total (£)	Expenditure / year (£)							
						1	2	3	4	5	5-10	10-20	20-50
					PV factor	1.00	0.94	0.89	0.84	0.79	0.68	0.44	0.14
SCHEMES	**Filey Town coast protection works** Rock protection at wall ends to prevent outflanking	SBC (DEFRA)	1-5	£54k capital; £6k design	56,943	6,000	54,000						
SCHEMES	**Flat Cliffs rapid response monitoring system** Design/installation of ground movement sensors/response system	SBC (DEFRA)	2	£30k set-up, £1k/yr maint.	40,411		30,000	1,000	1,000	1,000	4,000	8,000	24,000
STUDIES	**Telemetry feasibility and planning study** To investigate use of telemetry for logging/control of monitoring systems; possible scope for involvement of YW	SBC/YW? (SBC/YW?/ DEFRA)	1	£10k	10,000	10,000							
STUDIES	**Review feasibility of new access route to Flat Cliffs** Residents/landowners to consider provision of alternative access to ensure evacuation	Private (Landowners /residents)	1-2	TBC	-								
STUDIES	**Filey Town coastal stability study (Sect 11.3)** To comprise more detailed ground investigation and detailed mapping to inform a quantitative risk assessment of the threat to the seawalls from land instability and the consequence of failure	SBC (DEFRA)	1-2	£35k reporting: £65k SI	97,170	50,000	50,000						
STUDIES	**Filey Bay hydrodynamic modelling (Sect 11.3)** Development of detailed hydrodynamic model for Filey Bay to improve understanding of sediment movements	SBC (DEFRA)	1-5	£35k	33,019		35,000						
STUDIES	**Development of action plan for risk areas** To develop contingency plans	SBC	5-10	£10k	9,717	5,000	5,000						
MONITORING	**Strategic monitoring** To be undertaken as part of SBC's strategic monitoring programme - See Table 11.2	SBC (DEFRA)		See Table 11.2	-								
MONITORING	**Installation of tell-tale monitors on Filey Town seawall (see Section 9.3.2)** Monitors will be triggered when exposed due to drops in beach levels under storm conditions	SBC	1-2	£8k	7,774	4,000	4,000						
MONITORING	**Monitoring review** Review of cliff and beach monitoring data to identify changes, to be at 5 year intervals to inform strategy reviews	SBC	5 yr intervals		13,733					5,000	5,000	5,000	30,000
MAINT.	**Maintenance of beach access at Reighton** Scope to undertake in conjunction with Reighton Holiday Park	SBC	as required	12k	8,282		4,000				4,000	4,000	
MAINT.	**Filey Town seawall maintenance** Repairs to wall face and coping as required	SBC	annual		41,123	2,500	2,500	2,500	2,500	2,500	12,500	25,000	75,000
				Total (£)	**301,634**	**27,500**	**144,500**	**83,500**	**3,500**	**8,500**	**25,500**	**42,000**	**129,000**

Abbreviations: SBC - Scarborough Borough Council; DEFRA - Department for the Environment, Food and Rural Affairs; YW - Yorkshire Water

Table 11.1 Recommended programme of works

11.2.1 *Aerial Photography*

Comprehensive vertical and oblique aerial photograph records exist for the Bay. The vertical photography was taken in October 1999. Oblique photographs are available from 1984 and from the Futurecoast project.

SBC have recently commissioned a programme for analysis of the aerial photographs, to establish how these might be best used to inform future management. The dynamic frontage of Filey Bay would clearly benefit from annual surveys being flown, to allow assessment of changes to the cliffs, however it is recognised that there is a significant cost associated with this and 5 yearly surveys are therefore recommended.

11.2.2 *Bathymetric Survey*

On the recommendation of the SMP, a bathymetric survey was undertaken in November 2000, covering the extent of Filey Bay. It is recommended that this be repeated on a 5 yearly basis.

11.2.3 *Offshore Wave Climate*

Information on the offshore wave climate was derived from the Met Office Wave model, for use in the modelling studies undertaken as part of the strategy. There is limited measured information on waves for the area. The SMP recommends the deployment of 1 or 2 directional wave rider buoys for the whole SMP area, in suitable offshore locations. It is clear that such a deployment will greatly benefit future studies for Filey Bay and it is recommended that one of these be located such that it will provide data offshore of Filey Bay. This should be undertaken as soon as possible, and it is recommended that the deployment be for a minimum of 5 years.

11.2.4 *Wind Records*

The SMP recommends that a digital wind recording station be established, at an exposed coastal location. Wind records are generally considered to be the most reliable source of long term meteorological information and can be used for the derivation of a wave climate for the area. It is recommended that this installation be undertaken to inform not only the Filey strategy, but also strategies for adjacent frontages.

11.2.5 *Water levels*

Water levels used in the development of the strategy study were derived from the Admiralty Tide Tables. There is limited information on extreme water levels as no long term water level records are available for the area

A 'Class A' tide gauge is located at Whitby with records from 1980. This data can be obtained from POL. It would appear that this information was not available at the time of the SMP as the recommendation was made that a tide gauge be located at either Whitby or Scarborough. There would of course be benefits in installing an additional tide gauge at Scarborough, as this is closer to the strategy area, and this should be considered subject to availability of resources.

11.2.6 *Beach Profile Surveys*

As part of the study, beach profiles were taken for the full length of the Bay at approximately 500m intervals. Permanent ground markers were set up that will facilitate repeat surveys. It is recommended that repeat surveys are undertaken twice a year, preferably post-summer to identify scope for build-up of the beach and post-winter to establish the effect of winter storms in lowering beach levels.

In addition to these survey profiles, there will be value in increasing the resolution at built-up areas, such as the frontages of Filey Town (unit 28B), Primrose Valley - Amtree Park (29B) and Reighton Sands (30A). At these locations, profiles should typically be at 100 to 200m spacings.

11.2.7 *Defence Condition Survey*

Periodic visual inspection and topographic survey of the defence structures in the Bay should be undertaken. It is recommended that this is undertaken on an annual basis. Reference should be made to the data contained in the CPSE records for the frontage (as summarised in Chapter 6), which refers to each of the structure elements, and updating this as appropriate.

It is also recommended that tell-tale monitors be installed on the seawall to establish the risk of undermining of the seawall due to lowering beach levels during storms. These monitors are discussed in more detail in Section 9.3.2.

11.2.8 *Cliff Top Recession Monitoring*

Cliff top recession monitoring will allow estimates of cliff recession rates to be refined at a later date, based on actual measurements. As part of the survey work undertaken for the strategy study, permanent markers on the cliff top can be used to evaluate cliff recession. Cliff position relative to these markers should be recorded on an annual basis.

11.2.9 *Visual Observation*

Visual inspection of the Bay will help to identify any risk areas such as zones of increased ground movement or accelerated cliff recession. Ideally the full length of the bay should be walked on an annual basis, to identify areas of significant change, particularly where this may result in an increased risk to property or infrastructure.

Feature	Location	Interval	Method	Cost / inputs	Spatial resolution
Beach	Filey Brigg to Speeton	6 months	Topographic	£20,000 /yr + 4 man days data management	As in November 2000 baseline survey, with increased resolution at Filey Town, Amtree Park, Reighton Sands
	Speeton to Flamborough Headland	1 year	Visual	As part of walkover survey	
Cliffs	Filey Brigg to Speeton	6 months	Visual / topographic	6 man days / yr	At cliff marker locations
	Speeton to Flamborough Headland	1 year	Visual	As part of walkover survey	
Defences	Filey, Hunmanby, North Landing	1 year	Visual / topographic	8 man days/yr	
Bathymetric survey	Filey Bay	5 years		£2,500 every 5 years + 4 man days data management	Repeat of November 2000 survey
Walkover survey	Filey Bay	1 year	Visual	8 man days /yr	
Aerial photography	Filey Bay	1 year		£25,000 (Subject to conclusions of study by Posford Duvivier)	Scale 1:4,000
Wave recorder	These items are lower priority and are subject to being identified as providing benefit to adjacent strategies.			£40,000 /year*	
Wind records				£5,000 set-up + £1,000 /year*	
Water level gauge				£40,000 set-up + £1,000 /year*	

Table 11.2 *Monitoring recommendations*

* *From SMP*

11.3 Further Studies

11.3.1 *Study of Hydrodynamics of Filey Bay*

Studies of sediment processes have highlighted that limited information is available to develop a full understanding of inputs and losses to Filey Bay from offshore. While it is believed that there is no shortage of sediment within the Bay, there are clear benefits in developing an understanding of these processes more fully, particularly with regard to the impact of any potential dredging activities. The Bay is dependent on the wide sandy beaches to provide natural wave energy dissipation and coast protection. These beaches are of significant amenity value to the local area, and a key attraction for many of the holidaymakers to the area, generating associated income for the local economy.

It is proposed that a full hydrodynamic model be produced for the Bay. This model would be developed using available information on seabed sediments, the data collected during the bathymetric survey and wave data derived from the Met Office wave model to develop a more detailed understanding of sediment movements within the Bay and in particular to identify any offshore pathways. This would help to further develop the sediment budget for the Bay by quantifying offshore losses and establishing the dependency of the Bay on the sediment inputs from the eroding cliffs. It is noted that it would be beneficial for this study to be undertaken in time to inform the SMP review as well as the first strategy review.

11.3.2 *Coastal Stability Study for Filey Town*

The coastal slopes of Filey Town between Coble Landing and Martin's Gill are protected by a sea wall and cover an area of about 30ha. The studies undertaken as part of this strategy indicate that the seawall is not at risk of failure within the strategy lifetime as a result of coastal erosion, although the situation should be continually monitored to inform strategy reviews. There is however widespread evidence of damage to roads, walls and buildings due to ground movement that is consistent with the degradation of deep-seated landslides. It is likely the landslides were present prior to construction of the sea wall which has undoubtedly assisted in stabilising the coastal slopes (whether intended or not). The sea wall has vertical crack damage that possibly coincides with discrete landslide units. In respect of the sea wall at Filey, the following issues need to be considered:

- To what extent is the sea wall at risk of failure due to ground movement over the next 50 years;
- Can the protection of the coastal slopes by the sea wall be maintained or improved over the next 50 years;

- What would be the consequences to development on the coastal slopes if the current level of protection is not maintained;
- What are the options for future management of coastal slope instability, comprising planning and development control, monitoring, emergency planning, and engineering stabilisation measures (including coast protection).

The key uncertainties to be quantified are:

- The depth and mechanisms of failure
- The sub-surface geology and material characteristics (i.e. shear strength)
- The frequency of landslip/ground movement
- The magnitude or rates of sub-surface ground movement
- The impacts of ground movement on development
- The potential for sudden cliff failure (i.e. Holbeck Hall)
- Wall foundation levels, geometry and backfill material
- The degree of protection/stabilisation provided by existing sea wall
- The potential hazard and risk to development (including the sea wall)

The following provisional list outlines a number of elements at risk.

Elements at Risk	Components
Infrastructure	Roads, Pavements, Buildings, Retaining Walls, Sea Wall
People	Residents, Employees, Visitors
Business	Leisure/amusement, Catering, Retail, Fishing
Other	Public utilities (PCs, shelters etc), Services, Lifeboat Station, Beach huts, Private utilities (pumping station), Access

Additional detailed investigations are recommended to fulfil the following objectives.

- To establish the extent of coastal slope instability and any discrete landslide systems/units;
- To establish the extent of damage that can be attributed to ground movement;
- To document past records of ground movement and damage to infrastructure;
- To document the available geotechnical data;
- To assess the ground behaviour conditions;

- To provide guidance for planning and development control in areas of unstable land;
- To identify the uncertainties with the available information and ground behaviour assessment;
- To recommend appropriate ground investigation and monitoring based on objective criteria arising from the ground behaviour assessment;
- Revise the ground behaviour assessment as ground investigation data becomes available;
- Evaluate hazard and risk with regard to current coast protection and slope stabilisation measures. Consider the protection and stabilisation measures required to maintain coastal stability over the next 50 years, accounting for climate change (increased wave loading and rainfall/groundwater conditions);

The main task activities would comprise:

(a) Desk study review, including building and planning control records, geotechnical data etc.,
(b) Field mapping, comprising geomorphological and geological mapping of coastal slopes,
(c) Damage survey, comprising mapping and classification of damage due to ground movement,
(d) Ground behaviour assessment and stability analysis, comprising an interpretation of all information within a geomorphological framework
(e) Provide guidance for planning and development control in areas of unstable land (PPG 14), and the future management strategy for the area;
(f) Identify scope of ground investigation and monitoring requirements,
(g) Procure ground investigation,
(h) Feasibility and preliminary design of engineering measures,
(i) Optional hazard and risk evaluation to prioritise works.

The main deliverables would comprise geomorphological, ground behaviour and planning guidance maps, and a full technical report including recommendations for ground investigation where appropriate.

12 References

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