From: Hewitson, Annette [redacted]
Sent: Friday, July 27, 2012 1:02 PM
To: Able Marine Energy Park
Subject: Able MEP - submission by the Environment Agency in relation to ExA 1st Questions
Importance: High

Please find attached the Environment Agency's comments on other parties' responses to the Examining Authority's first written questions.

Kind regards,
Annette Hewitson
Principal Planning Advisor

Environment Agency
✉ Waterside House, Waterside North, Lincoln, LN2 5HA
☎ [redacted]

Awarded to the Environment, Planning and Engagement Department, Anglian Region, Northern Area.

Able Humber Ports Ltd
Marine Energy Park
Proposal to build a quay and associated development on the south bank of the River Humber

Planning Inspectorate Reference: TR030001

Comments on other parties' responses to The Examining Authority's 1st Written Questions

On behalf of
The Environment Agency
Unique Reference Number: *Ref No. removed*

27 July 2012

The following information is given by the Environment Agency (EA) in respect of answers given by other parties to the Examining Authority's first written questions, and to provide further clarity where possible:

Question 18:
What criteria and weightings have been used for identifying and assessing possible compensation sites? Specifically -

(e) what weight was given to flood risk assessment for the various sites in the high level assessment?

Able Humber Ports Limited (the applicant) in paragraph 18.11 has not addressed the current Standard of Protection or current condition of the defences as published with in the Humber Flood Risk Management Strategy (HFRMS). The map that the applicant refers to, and has reproduced in Figure 18.2, is the area of the Humber Estuary floodplain that would flood if the floodplain were undefended. This map illustrates the area that is at risk of tidal flooding and the importance of flood defences around the estuary.

Flood area 4 (Stone Creek to Paull Holme Strays - please see extract at Appendix A attached) in the attached HFRMS refers to a Standard of Protection of 1.25%[1] (1 in 80) or better and a remaining life of 10 to 20 years. In addition the attached South Holderness Tidal Flood Study (attached as Appendix B – this document was provided to the applicant on 17th February 2012) confirms the Standard of Protection at cross Section CS6 and CS7 in Drawing E4 as 0.5% (1 in 200) in 2010 and 0.5% (1 in 200) in 2058 at CS6 and 1.2% (1 in 83) in 2058. The condition grade of 5 awarded to the defence in the location at Cherry Cobb Sands in 2010 in Drawing C3 was as a result of asset inspection being unable to be undertaken due to vegetation growth. The asset has subsequently been inspected in 2011 and 2012 when the asset condition has varied between grade 2 and grade 3 (explanation provided in section 2.1.10 of the report, attached as Appendix B).

The HFRMS is currently undergoing an implementation review in order to incorporate Defra's partnership funding into the Strategy. It is no longer the case that any frontage around the estuary will not be able to secure any Flood Defence Grant in Aid funding to help improve the defences, it is a question as to how much funding each stretch of flood defence will be able to secure.

Question 19:
What account has been taken of the experience with other compensation sites in the Humber estuary, including Chowder Ness and Paull Holme Strays, and the extent to which they are proven to have provided the precise compensation habitat sought in each case?

In paragraph 19.4 the applicant identifies some of the potential factors that can influence managed realignment development. The applicant does not identify the

[1] Please note, there is a typo in the published Humber Flood Risk Management Strategy for Flood area 4 as the Standard of Protection quoted is 12.5% but should read 1.25%. In evidence of this error we also attach extracts from the Humber Estuary Flood Defence Strategy Development Study Technical Report Version Number 4.0, June 2005 at Appendix C and Appendix D.

location of the site within the tidal frame and the width of the existing foreshore at the site of the proposed realignment. In addition, the applicant does not refer to the understanding of the short, medium and long-term estuary trends, cyclical trends or differences in erosional and depositional sectors (including foreshore) and the potential impact this has on the potential development of a realignment site. Our formal response on this matter will follow in due course.

Question 20:
What factors will determine the choice of the site for the breach in the current sea wall at Cherry Cobb Sands?

The EA has not been able to undertaken a comprehensive review of EX28.1 at this point in time, but we have been advising the applicant on potential alternatives to consider in delivering the compensation site. The EA was not, however, invited to the most recent compensation site design workshop (held on 4th July 2012, attended by the applicant, their consultants and Natural England) and are unable to comment on those discussions. Once we have fully reviewed report EX 28.1 we will submit our formal response, but we anticipate that this report will need to be updated in the light of the potential use of a regulated tidal exchange (RTE) scheme at the Cherry Cobb Sands site and we understand modelling work on this is currently being undertaken.

Question 34:
What are the assessed cumulative and in combination impacts on the river regime in relation specifically to Hull Riverside Bulk Terminal, Green Port Hull, Sunk Dredged Channel Deepening and the Grimsby Ro-Ro Berth?

The EA has not had time to adequately assess the supplementary information and conclusions of EX8.7 and the assessment of the cumulative and in-combination impacts of the above projects on the river regime. The applicant has also undertaken an in-combination and cumulative assessment since the submission of the ES in EX44.1. The EA has not had the time to adequately assess this new information in conjunction with EX8.7 to determine whether the river regime has been adequately considered, but we will comment on this matter in a subsequent formal response to the Examining Authority.

Question 38:
With regard to the channel at Stone Creek-
b) what monitoring regime is proposed?

The applicant has outlined monitoring plans in paragraph 38.4. The EA would like to stress that our preferred option would be that the baseline information covers a 12 month period before any work commences on site at Cherry Cobb Sands, including the relocation of the soke dyke behind the site. If this procedure is not adopted the baseline recorded will not be a true reflection of pre-development conditions, as changes to the drainage will have already commenced.

Question 39:
In disposing of the non-erodible material at HU082 how is this activity to be monitored to ensure that it is discharged in such a way so as to not alter the current regime of the Sunk Channel or to cause mounds on the sea bed.

The EA would like to draw the Examining Authority's attention to EX8.7. The EA has not had time to review this new information and therefore cannot confirm that the new approach is now acceptable. If it should prove to be acceptable, there will still be a requirement for the disposal of the non-erodible material to be conditioned via the Deemed Marine Licence, in particular for the maximum height above chart datum that disposal will be permitted and the maximum volume to be disposed.

Question 41
What is the design life of the quay? What would be the decommissioning implications?

The EA would like to draw the Examining Authority's attention to paragraph 41.4 of the applicant's response to the above question. The new quay will form a new line of flood defence and this is a departure from the "hold the line" policy for this flood cell identified in the HFRMS for the defences surrounding the estuary. This flood cell will now in fact have an "advance the line" approach contained within it. This "advance the line" is not one that has been assessed in the HFRMS Habitat Regulations Assessment. The reasoning behind the Environment Agency's request for the applicant to assess any additional intertidal losses that will take place within the estuary, is as a consequence of the "hold the line" policy that the Environment Agency has assessed and had approved by Defra compared to the "advance the line" approach proposed by the applicant.

Question 51:
Please confirm whether or not the area of sub-tidal habitat being lost to create the berthing pocket is included in the 13.5 ha loss of sub-tidal habitat referred to in the Habitat Regulations Assessment report.

The EA would draw the Examining Authority's attention to the response from the applicant in paragraph 51.7. The EA has not finished its final assessment of EX10.6 at the present time and so has yet to provide a formal response to the applicant on this. However, the EA would alert the Examining Authority to the fact that under the Water Framework Directive this change does need to be adequately assessed as this is a permanent change to the sub-tidal habitat due to the likely frequency of dredging that may be required. We therefore assume that this habitat will not have time to recover to baseline conditions in between dredge operations. Our formal response on this matter will follow in due course.

Question 61:
With specific reference to Section 7, does ABP still maintain that there is serious inconsistency in the description of the proposed berth works in the Environmental Statement? If so, what precisely are these inconsistencies, and what are the issues that have still to be addressed?

The EA has noted the significant representations made by ABP on the above question. We are currently reviewing these points in the light of all the additional supplementary information that the applicant provided with both their written responses to the Examining Authority's Questions and the comments on the Relevant Representations. We intend to respond to the points raised within both the

ABP submission and the applicant's supplementary information. However, we have been unable to do so by this 27th July deadline due to the considerable volume of supplementary information the applicant supplied on 29th June 2012. Our formal response on this matter will follow in due course.

Appendix A

Extract from the Humber Flood Risk Management Strategy – Flood Area 4 (Stone Creek to Paull Holme Strays)

Flood Area 4
Stone Creek to Paull Holme Strays

Key information	
Size of flood area	3300 ha
Number of properties in floodplain	195
Area of agricultural land	3268 ha
Length of defences	11.5 km
Current standard of protection	About 12.5% (1 in 80) or better
Remaining life of defence	Varies, generally 10 to 20 years
Defences managed by	Environment Agency responsible for defences at Paull Holme Strays, other defences managed by Crown Estate

Key

- Flood area boundary
- Flood defence line
- Floodable area
- 200 year floodplain in 2055
- Urban area
- Urban area in floodplain
- Power line
- Railway line
- Road
- Rivers
- Associated British Ports completed habitat creation site
- Completed habitat creation site
- Planned habitat creation site

Most of the properties at risk are at the edge of the floodplain, in the villages of Ryehill or Camerton (Thorngumbald, the village next door, is in Flood Area 5). It contains scattered farms and high-grade agricultural land. The land is drained to the estuary by a system of ditches leading to Keyingham Drain. Although this and the neighbouring area of Sunk Island (Flood Area 3) are separated by Keyingham drain, flooding in one can affect the other. Therefore the two areas should be considered together.

In 2004 we completed a scheme at Paull Holme Strays that created new inter-tidal habitat to replace the losses due to flood defence improvements and sea level rise. We have identified another site near Keyingham as suitable for creating additional habitat but are unlikely to develop it until after 2030.

Existing flood defences

The defences are generally in good condition. Major improvements are likely to be needed in 40 years or so.

Proposed management approach

We have looked at the costs and benefits of continuing to maintain the existing defences in the future and concluded that this will become increasingly expensive as sea levels rise. In the long term those responsible may decide it is not worthwhile carrying on. Uncertainty about the rate at which sea levels will rise and the defences deteriorate means we cannot say when this might happen, although we think it is unlikely to be within the next 20 years. We will re-assess the situation when we review the strategy and keep in touch with those responsible for the defences.

If maintenance is withdrawn from the existing defences, we will look at building secondary banks to protect the villages at the edge of the floodplain. Without further study we cannot confirm this will be possible or say exactly where the banks might be located. The owners of any property not protected may wish to consider other options, which in some cases might include flood-proofing individual houses. We will provide all the advice and information we can to help.

Appendix B

South Holderness Tidal Flood Study
March 2011

Environment Agency

South Holderness Study

Tidal Flood Study

211366-00

Issue | March 2011

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Document Verification

ARUP

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Draft 1	10/01/11	Description	Tidal Flood Study incorporating high level economic analysis and wave overtopping analysis.	
			Prepared by	Checked by	Approved by
		Name	Kate Colledge	Kathryn Kimball	David Wilkes
		Signature			
Draft 2	09/02/11	Filename	Tidal Flood Study_Draft for issue to panel members.docx	
		Description	Amendments made following review by ERYC, EN, ABP Ports, IDB. The previous draft was also sent to NFU and Crown Estates but no comments were received.	
			Prepared by	Checked by	Approved by
		Name	Kate Colledge	Kathryn Kimball	David Wilkes
		Signature			
Issue	24/03/11	Filename	Tidal Flood Study_Final_March 2011.docx	
		Description		
			Prepared by	Checked by	Approved by
		Name	Kate Colledge	David Wilkes	David Wilkes
		Signature	*Signatures removed*		
		Filename		
		Description		
			Prepared by	Checked by	Approved by
		Name			
		Signature			

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Executive Summary

Arup have been appointed by the Environment Agency to undertake a tidal flood study as part of the wider South Holderness Study. This involves identifying and reviewing existing data and reports, analysing stated defence conditions, defence types, assessing the Standards of Protection (SoP) [1] and undertaking a high level economic analysis to assess possible future management options.

The extent of the study area is shown in Drawing A1, Appendix A. The study area has been split into a number of frontages to aid the analysis. The study frontages can be seen in Drawing A2. These frontages have been selected on their defence type, coastal morphology and previous studies coverage. The table below summarises the SoP, residual life and condition grade of Tidal Study Frontages A to L;

Frontage	Region Covered *(Easting, Northing)*	Brief Description	Current SoP Annual Exceedance Probability (AEP) from previous studies	Residual Life	Condition Grade (from NFCDD)
A	Queen Elizabeth Dock to North of Paull Village *(515387,428379 to 516569,426645)*	Flood Defences – Earth embankment and outfall structures	Less than 0.5% (based on still water levels and wave height)	Not Known	1 - Very Good to 3 - Average
B	North of Paull Village to Paull Holme Strays *(516569,426645 to 516967,425210)*	Flood Defences - Walls, revetments, embankments, high land and outfall structures	Less than 0.5% (based on still water levels and wave height)	Not Known	1 - Very Good to 3 – Average
C	Paull Holme Strays to Winestead Drain *(516967,425210 to 533444,418527)*	Flood Defences – Earth embankment and outfall structures	0.65% to less than 0.5% (based on still water levels and wave height)	1 – 5 years to > 20 years	1 - Very Good to 5 – Very Poor
D	Winestead Drain to Marsh Road *(533444,418527 to 538112,417799)*	Flood Defences – Earth embankment and outfall structures	Ranges from 100% to 0.2% (based on still water levels and wave height)	11 – 20 years	2 - Good to 4 - Poor
E	Marsh Road to Beacon (Easington) Lagoons (via Kilnsea) *(538112,417799 to 540922,418472)*	Flood Defences – Earth embankment and outfall structures	Coastal Embankment <0.5% Estuarine Embankment 1.9% to <0.5% (based on still water levels and wave height)	> 20 years	1 – Very Good to 4 - Poor

[1] Standard of Protection (SoP) is the protection provided by a flood defence, generally expressed in terms of average return frequency or return period (e.g 2% Annual Exceedance Probability (AEP) or once in 50 years). This is the definition used in the Humber Strategy. The SoP of previous work by others considers still water levels, wind and wave run up and the absolute level of the defence. The return period of a flood, is a measure of its rarity, defined by the average interval in years between occurrence of floods that exceed it. AEP is the percentage chance of flooding in any given year. For example a return period event of 1 in 100 has an AEP of 1%, there is one percent change of a 1 in 100 year flood occurring in any given year.

F	Easington Cliffs *(540922,418472 to 540584,419426)*	Glacial till cliff line Just <6mAOD+	Likely flood risk during extreme events	No defence present	
G	Easington Gas Terminals *(540584,419426 to 540191,420225)*	Flood Defences – Rock armour	1% (based on still water levels and wave height)	> 20 years	2 - Good
H	Dimlington Cliffs to Hollym *(540191,420225 to 535020,427069)*	Glacial till cliff line +10mAOD	Low flood risk	No defence present	
I	Withernsea (Hollym) to Waxholme *(535020,427069 to 533782,428823)*	Flood defences – Seawall, concrete and rock revetment, groynes and flood gates	2% to 1% (based on still water levels and wave height)	6 to >20 years	1 - Very Good to 3 - Average
J	Waxholme to Tunstall Drain *(533782,428823 to 532105,430986)*	Glacial till cliff line ~10mAOD	Low flood risk	No defence present	
K	Tunstall Drain *(532105,430986 to 531961,431236)*	Mouth of low lying drain with flood embankment	20% (Expectation that defence will be lost due to erosion)	1 to 5 years	3 - Average
L	Tunstall Drain to Aldbrough *(531961,431236 to 526120,439166)*	Glacial till cliff line +10mAOD	Low flood risk	No defence present	

From review of the studies available for each frontage and additional analysis where appropriate, recommendations have been made regarding the way forward for that part of South Holderness Frontage. The table below summarises the recommendation for each frontage;

Frontage	**Region Covered** ***(Easting, Northing)***	**Recommendation(s)**
A	Queen Elizabeth Dock to North of Paull Village (*515387,428379 to 516569,426645)*	Short to Medium Term: General maintenance and inspection of existing assets. Longer Term: As and if defence condition grades deteriorate, then this will trigger further studies to assess possible flood management interactions.
B	North of Paull Village to Paull Holme Strays *(516569,426645 to 516967,425210)*	Short Term: Address scour hole in defence south of Paull Village. Medium to Long Term: As and when defence condition grades deteriorate, then this will trigger further studies to assess possible flood management interactions.
C	Paull Holme Strays to Winestead Drain *(516967,425210 to 533444,418527)*	Short Term: Address the condition of the defences and undertake further assessment and maintenance where necessary. Medium to Long Term: This frontage has been highlighted for potential Managed Realignment for significant lengths. In order to provide tidal flood protection in the future, managed realignment is a possible way forward, and possible associated improvement to non-realigned sections.

Frontage	Region Covered (Easting, Northing)	Recommendation(s)
D	Winestead Drain to Marsh Road *(533444,418527 to 538112,417799)*	Short/Medium Term: Managed realignment to provide inter-tidal habitat and also tidal flood protection to Flood Cell C should be discussed with Natural England and a decision on the way forward made.
E	Marsh Road to Beacon (Easington) Lagoons (via Kilnsea) *(538112,417799 to 540922,418472)*	Short to Medium Term: Work with ERYC and the local community to develop a strategy for the future. Medium to Long Term: This is a constantly evolving environment which could change considerably in years to come therefore continual monitoring and potential options to manage the tidal flood risk is required.
F	Easington Cliffs *(540922,418472 to 540584,419426)*	Short Term: Monitoring of erosion and ground levels. Short to Medium Term: In the future, as erosion and therefore flood risk increases, potential options for managing flood risk should be considered.
G	Easington Gas Terminals *(540584,419426 to 540191,420225)*	Short Term: No further work required Medium to Long Term: Should the gas terminals become disused, the wider flood risk due to deterioration/removal of flood defences and therefore erosion should be assessed.
H	Dimlington Cliffs to Hollym *(540191,420225 to 535020,427069)*	No recommendations for further work.
I	Withernsea (Hollym) to Waxholme *(535020,427069 to 533782,428823)*	Long Term: As the current tidal flood risk in this area is low, no further analysis is required at this time.
J	Waxholme to Tunstall Drain to *(533782,428823 to 532105,430986)*	No recommendations for further work.
K	Tunstall Drain *(532105,430986 to 531961,431236)*	Funding was secured this financial year to construct a new embankment at Tunstall (set back from the existing defences), with contributions from ERYC, the RFDC through Local Levy and benefit in kind contributions from the IDB and Landowners. Unforeseen ground conditions have delayed the project and a workable solution to the geo-technical problems encountered has still to be finalised. If a workable solution cannot be found then alternative options will need to be explored. However this is a constantly evolving environment and may require ongoing monitoring of the condition of the defence in the future.
L	Tunstall Drain to Aldbrough *(531961,431236 to 526120,439166)*	No recommendations for further work.

1 Introduction

Arup have been appointed by the Environment Agency under the National Engineering and Environmental Consultancy Agreement 2 (NEECA2) to undertake a study reviewing and assessing the current level of understanding of tidal flood risk for South Holderness. The study identifies and assesses potential options for future flood risk management. The extent of the study area can be seen in Drawing A1, Appendix A. The study area extends from Aldbrough on the east coast south to Warren Head and along the Humber Estuary to the eastern extent of the City of Hull.

This report aims to summarise the work previously undertaken in the South Holderness Study Area, undertake further analysis and provide a recommendation for future management measures. This document is set out in 5 sections. The first two sections; 2 and 3, describe the data collected for this study and the methodology for the wave overtopping analysis is respectively. Section 4 provides an analysis for each frontage based on the data collected from previous studies and wave overtopping analysis where appropriate. Section 5 summarises the tidal economic analysis undertaken to determine potential options for future tidal flood risk management. The conclusions and recommendations are included in Section 6. Recommendations for further work are included in order to assist with informing the public and/or decision making.

1.1 Tidal Flood Study Frontage

To aid the analysis and reporting, the South Holderness frontage area has been divided into twelve frontages (A to L). These frontages have been selected on their defences type, coastal morphology and previous areas of study. The location of the frontages can be seen on Drawing A2, in Appendix A.

2 Data Collection

This study is partly based on a review of the following existing reports and data:

- Humber Estuary Coastal Authorities Group, 2009 - Flamborough Head to Gibraltar Point Shoreline Management Plan 2 (SMP2)
- Environment Agency, Humber Flood Risk Management Strategy and Flood Cell Outlines
- Environment Agency, 2008, Tunstall Pre-Feasibility Study
- East Riding of Yorkshire Council, 2001, Withernsea Coastal Defence Strategy Study
- Environment Agency, 2008, Easington Lagoons Long Term Plan & Options Development Report
- Environment Agency, 2006, Kilnsea Project Appraisal Report
- Environment Agency, 2005, Skeffling HEFDS Humber Estuary Flood Defence Strategy (HEFDS) Development Study
- Environment Agency, 2009, Sunk Island Flood Management Appraisal Report
- Environment Agency, 2008, Paull Village Flood Alleviation Scheme, Scheme Review
- Environment Agency NFCDD - National Flood and Coastal Defence Database
- The Humber tidal Database and Joint Probability Analysis of Large Waves and High Water Levels (ABP Research & Consultancy Ltd, Nov 1999)
- Joint Probability Analysis of Large Waves and High Water Levels in the Outer Humber Estuary (Black & Veatch, Dec 2006)
- Available LiDAR from the Environment Agency
- OS Mapping (1:10,000 and 1:25,000)
- UKHO, 2009, Admiralty Tide Tables United Kingdom and Ireland

2.1 Summary of Studies Available for this Report

This section provides a brief summary of the reports reviewed for this study, in the order of the references above. Drawings A3 and A4 in Appendix A show the extents of each of these studies.

2.1.1 Shoreline Management Plan 2

The Flamborough Head to Gibraltar Point Shoreline Management Plan 2 first went to public consultation in November 2009. It encompasses the study area from Aldbrough on the North Sea coast to Stone Creek in the Humber Estuary.

The aim of the SMP2 is to identify high-level coastal management options for the management of the coast for three epochs:

- Short term: up to the year 2025
- Medium term: between 2026 and 2055
- Long term: between 2056 and 2105

Management policies for each of these epochs are identified for each policy unit. The coastal management options identified will be one of the following:

- No Active Intervention (Do Nothing)
- Hold the Line
- Advance the Line
- Managed Realignment

The SMP2 policy for each policy unit is described within each of the tidal study frontages in Section 4 of this report.

SMP1 (the predecessor to SMP2 undertaken in 1998) and SMP2 do not provide water level and wind data for extreme events. They both recommend that a Joint Probability Analysis is undertaken of water levels and wave heights to determine a coherent data-set for use in managing the coastline. SMP2 states that the dominant wind direction is from the north-northeast and north east, has a large swell component and is not fetch limited. This is based on information from previous studies dated over 10 years ago. The 1% Annual Exceedance Probability (AEP) wave height has been calculated to be between 4m and 8m, between Flamborough Head and Easington. The annual 10% exceedence significant wave height is 1.0 to 1.5m. Wave heights vary along this coastline due to:

- Exposure of the coastline
- Additional shoaling and refraction effects caused by Spurn Head
- Within the Humber Estuary the coastline is sheltered by Spurn Head.

SMP2 states that the historic rate of sea level rise on this coastline is just over 1.1 mm per annum, based on the sea level measured at Immingham over the period between 1960 and 1995.

Table 1 shows the sea level guidance applicable to the East of England and East Midlands – south of Flamborough Head provided in SMP2.

Table 1 Sea Level Guidance Applicable to the East of England and East Midlands[2]

Time period	Net sea level rise (mm per year)	Total sea level rise in each epoch (mm)	Cumulative sea level rise (mm)
Epoch 1 (2009 to 2025)	4.0	64	64
Epoch 2 (2026 to 2055)	8.5	255	319
Epoch 3a (2056 to 2085)	12.0	360	679
Epoch 3b (2086 to 2105)	15.0	300	979

2.1.2 Humber FRM Strategy

The Humber Flood Risk Management Strategy is a long term plan for the management of flood risk for the Humber Estuary. It was published by the Environment Agency in March 2008. The strategy splits the floodplain of the Humber Estuary into 27 flood cells. It undertook a high level analysis of current flood management practices and proposed a future management approach for each flood cell. The flood cells that lie within the South Holderness study area are:

- Flood cell 1: Easington and Kilnsea
- Flood cell 2: Skeffling
- Flood cell 3: Sunk Island (Winestead Drain to Stone Creek)
- Flood cell 4: Stone Creek to Paull Holme Strays
- Flood cell 5: Hull East (including Paull Village)

The Humber FRM Strategy management approach which was published and approved in March 2008 proposed;

- Flood cell 1: Continue to maintain the defence and look into providing replacement habitat for the lagoons. This will be followed by potential withdrawal in 10 to 20 years time. To be re-assesed each time strategy is reviewed.
- Flood cell 2: At present continue to maintain the defence, followed by potential withdrawal in 10 to 20 years time. To be re-assesed each time strategy is reviewed.
- Flood cell 3: It will become increasingly difficult to maintain defences. With regards to building secondary flood banks, owners of properties may wish to consider other flood protection options, such as flood-proofing individual houses.

[2] Humber Estuary Coastal Authorities Group, 2009 - Flamborough Head to Gibraltar Point Shoreline Management Plan 2 (SMP2), Table 4.1

- Flood cell 4: It will become increasingly difficult to maintain defences. With regards to building secondary flood banks, owners of properties may wish to consider other flood protection options, such as flood-proofing individual houses.
- Flood cell 5: Continue to protect this area. The defences will need to be improved as sea levels rise. This may become expensive therefore contributions from major beneficiaries and developers should be explored.

2.1.3 Tunstall Pre-Feasibility Study (2008)

Studies undertaken as part of this work included:

- Geotechnical desk study
- Hydraulic modelling (ISIS Tuflow)
- Assessment of utility companies information
- Economic assessment of identified options

The Tunstall Pre-Feasibility Study (2008) analysed the condition of the existing coastal embankment and the risk of tidal flooding should the embankment at Tunstall fail. The study determined the embankment had a residual life of 1 - 5 years with the potential for rapid failure in a single event.

The study recommended that further work should be undertaken to develop a robust Project Appraisal Report to secure technical approval of the preferred option and funding subject to availability..

Tunstall Project Appraisal Report (2009)The Tunstall Project Appraisal Report (PAR) is the business case necessary to secure Flood Defence Grant in Aid (FDGiA) funding. It is based on the information from the Tunstall Pre-Feasibility Study. The PAR determined that while no properties were at risk of the embankment failing, other assets were, such as the B1242 coast road, a number of minor roads, a caravan park, archaeological and nature conservation sites and 420 hectares of grade 2/3 agricultural land.

The report concluded the preferred option was to construct a new embankment 250m inland of the existing embankment, creating 6 hectares of inter-tidal habitat. This option had the best cost:benefit ratio and was supported by the local community. This meant that this lessened the amount of appraisal work necessary. The option would provide a minimum present day standard of protection of 2% AEP (>1:50 yr SoP) which equates to 5% AEP (1:20) in 50 years time (including climate change). The estimated residual life of the new embankment will be between 60-100 years considering extreme coastal erosion.

2.1.4 Withernsea Coastal Defence Strategy Study (Posford Duvivier, 2001)

This study provides a review of the coastal defences at Withernsea in 2001 and recommends option for further works following economic analysis. It must be noted that this study is almost 10 years old and it is possible that changes may have occurred to the condition of the assets shown in the report. However, more

recent data such as NFCDD (see section 2.1.10) has been used later in this present report, to update and/or complement information in this area.

2.1.5 Easington Lagoons Long Term Plan & Options Development Report

Beacon (Easington)[3] Lagoons is a Site of Special Scientific Interest (SSSI) as well as a Special Protection Area (SPA), Special Area of Conservation (SAC) and a Ramsar Site[4]. The Lagoons are also protected by the habitat regulations. It has been designated due to the range of coastal habitats present including saltmarsh, shingle, sand dune, swamp and lagoons. This study was commissioned by the Environment Agency and considers the effect of future changes in coastal morphology on the Beacon (Easington) Lagoons. It assesses potential options for relocating these lagoons within the Easington flood cell as the existing lagoons are predicted to be lost due to coastal erosion. This study considers the rate of erosion and the flood risk as a result of breaches on both the coastal and estuarine sides of the flood cell.

2.1.6 Kilnsea Project Appraisal Report

In 2006 a Project Appraisal Report (PAR) was produced for a new flood embankment at Kilnsea. The old flood bank was affected by coastal erosion and the defences were close to being breached. Following the PAR the new bank was constructed and currently provides a 5% AEP SoP (1:20) and is expected to reduce flooding to Kilnsea for the next 20 to 30 years.

2.1.7 Skeffling HEFDS Strategy Development Study

In 2005 the Skeffling Humber Estuary Flood Defence Strategy Development Study was carried out to assess the feasibility of managed realignment at Skeffling. According to this study, managed realignment is not cost beneficial if only the local costs and benefits are taken into account. However it is a cost-effective way of providing some of the habitat needed to compensate for coastal squeeze as part of the wider Humber Strategy, consequently there are still plans to develop the site in this way.

[3] Easington Lagoons have recently be renamed to Beacon Lagoons
[4] Special Sites for Scientific Interest (SSSIs) are the country's very best wildlife and geographical sites (Natural England)
Special Protection Areas SPAs are areas which have been identified as being of international importance for the breeding, feeding, wintering or the migration of rare and vulnerable species of birds found within European Union countries (Natural England)
Special Areas of Conservation SACs are areas which have been given special protection under the European Union's Habitats Directive. They provide increased protection to a variety of wild animals, plants and habitats and are a vital part of global efforts to conserve the world's biodiversity (Natural England).
Ramsar sites are wetlands of international importance, designated under the Ramsar Convention (Natural England)

2.1.8 Sunk Island Flood Management Appraisal Report

This study was commissioned by the Environment Agency in 2009. The Sunk Island Flood Management Appraisal Report considers flood risk in flood cells 3 and 4 of the Humber Strategy (Drawing A3). It identifies future high level management options to reduce flood risk for the communities and agricultural land currently protected by flood defences in this area. The following work was undertaken as part of this study:

- A condition survey of the current defences
- Wave overtopping analysis and flood mapping from potential breach sites
- An economic assessment of the high level options identified

The recommended option from this study is to realign at Outstray's and Welwick and raise the defences in line with climate change in-between the two realignment sites. This recommendation is based on the assumption that the realignment site costs will be offset by the benefits of providing habitat needed to compensate for coastal squeeze as part of the wider Humber Strategy. The Environment Agency is currently in discussion with Crown Estates regarding responsibilities for future management of the flood defences in this area.

2.1.9 Paull Village Flood Alleviation Scheme, Scheme Review

In 2005 the Environment Agency undertook Paull Village Flood Alleviation Scheme Detailed Appraisal Report (DAR). In April 2008 a further study was commissioned to provide a review of the DAR. The work required to develop a potential flood alleviation scheme to appraisal stage for approval was reassessed. The report concluded that the proposed scheme at Paull no longer appears to be cost effective. The report recommends a more cost effective option therefore needs to be investigated.

The Paull Village DAR review provides information about the SoP and condition grades for Paull Village Flood Defence.

2.1.10 NFCDD - National Flood and Coastal Defence Database

The National Flood and Coastal Defence Database (NFCDD) provides information regarding the condition grade of coastal defences and fluvial defences for those rivers designated as main rivers. The national condition grades are as follows:

- Grade 1 – Very Good; Cosmetic defects that will have no effect on performance
- Grade 2 – Good; Minor defects that will not reduce the overall performance of the asset
- Grade 3 – Fair; Defects that could reduce performance of the asset
- Grade 4 – Poor; Defects that would significantly reduce performance of the asset. Further investigation needed

- Grade 5 – Very Poor; Severe defects resulting in complete performance failure

NFCDD is a live database and asset conditions can and do change following Environment Agency's asset inspections. It should be noted that; in cases where the NFCDD asset inspector cannot access/adequately see the structure/defence in question, the asset will automatically reduce by one condition grade, between successive inspections. This has happened within the South Holderness study area and is highlighted in later sections of this report.

Drawing A3 in Appendix A shows the extent of NFCDD information used within this study. Additional information was provided throughout this study to update the NFCDD information as a result of recent works carried out along the frontage.

2.1.11 Joint Probability Analysis

Joint Probability Analysis (JPA) has been undertaken of extreme waves and water levels. The first analysis was undertaken in 1999 and this was extended to included additional locations in 2006;

- The Humber Tidal Database and Joint Probability Analysis of Large Waves and High Water Levels (ABP Research & Consultancy Ltd, Nov 1999)
- Joint Probability Analysis of Large Waves and High Water Levels in the Outer Humber Estuary (Black & Veatch, Dec 2006)

The still water levels from these JPAs have been used in this report to gain an assessment of SoP for those areas where previous studies had not calculated SoP.

2.1.12 LiDAR

LiDAR (**Li**ght **D**etection **A**nd **R**anging) is an optical remote sensing technology that measures properties using scattered light to find range and/or other information of a distant target. In this case the feature of interest is the ground levels. The extent of the LiDAR available for the study area can be seen on Drawing A5 in Appendix A.

2.1.13 UKHO, 2009, Admiralty Tide Tables United Kingdom and Ireland

The primary port applicable to this frontage is Immingham on the south bank of the Humber. The closest secondary port is at Spurn Head and the next secondary ports are at Bridlington and Hull docks. In general Immingham represents the study area from east of Hull to Skeffling and Spurn Head represents from Skeffling and along the North Sea coast. Table 2 below shows the predicted tide levels given in the Admiralty tide levels.

Table 2 Admiralty tide table MHWS & MHWN at Immingham and Spurn Head

	Immingham (mAOD)	Spurn Head (mAOD)
Mean High Water Springs (MHWS)	3.4	3
Mean High Water Neaps (MHWN)	1.9	1.6
Mean Low Water Neaps (MLWN)	-1.3	-1.2
Mean Low Water Springs (MLWS)	-3	-2.8

3 Wave Overtopping Analysis

In addition to using the information obtained from previous studies (outlined in Section 2.1), Wave Overtopping Analysis was undertaken to provide more information about the current and future SoP[5] of the tidal defences along the South Holderness Frontage.

Wave Overtopping Analysis has been carried out in accordance with Eur0top guidance methodology (2007)[6] for Frontages A, B, D, E, F and I. For Frontage C wave overtopping analysis was undertaken as part of the Sunk Island Study. Frontage G, H, J, K and L comprise high land and are not deemed at risk of wave overtopping in the next 100 years. The aim of the wave overtopping calculation is to find the annual probability of event that is likely to cause a breach of the asset due to wave overtopping.

The Eur0top guidance methodology (2007)[6] indicates the acceptable limits for wave overtopping range between 1 and 10 litres per second per metre (l/s/m) for critical discharge for soft defences. The 100 year Humber Strategy of the Environment Agency outlines acceptable limits for overtopping of soft defences, such as embankments, as 5 l/s/m. Therefore the minimum SoP for the defences is assumed to be the annual probability of an event during which the rate of wave overtopping exceeds the critical value of 5 l/s/m.

Cross-sections were selected within the identified study frontages to undertake wave overtopping analysis. Cross-section locations were selected to provide a fair representation for the defences for each frontage based on the most up to date LiDAR. Each cross-section was derived from the most accurate LiDAR information available at the cross-section location (slopes and top crest levels). See Appendix E for drawings showing cross section locations.

The input water levels and wave heights were obtained from the two JPAs described in Section 2.1.11.

This water level data was updated to 2010, 2060 and 2110 levels using Policy Planning Statement 25 (revised March 2010)[7] climate change guidance for input into the overtopping calculations. The 1999 JPA gave a range of Still Water Levels (SWL) and the corresponding wave height and period for various extreme events. The 2006 JPA gave a range of SWL and wave height. The wave periods for the 2006 JPA data were calculated by assuming a Pierson-Moskowitz spectrum (see Andrew Chadwick, John Morfett and Martin Borthwick (2004). Hydraulics in Civil and Environmental Engineering. 4th ed. New York: Spon Press. p275).

[5] SoP is the protection provided by a flood defence, generally expressed in terms of average return frequency or return period (e.g once in 50 years). The return period of a flood, is a measure of its rarity, defined as the average interval in years between occurrence of floods that exceed it. AEP is the percentage chance of flooding in any given year. AEP is 1/return period. For example a return period event of 1 in 100 has an AEP of 1%, there is one percent change of a 1 in 100 year flood occurring in any given year.

[6] Environment Agency, August 2007. EurOtop Manual, Wave Overtopping of Sea Defences and Related Structures: Assessment Manual.

[7] Planning Policy Statement 25: Development and Flood Risk, Revised March 2010

Wave overtopping calculations were undertaken for the following return periods, taking into account sea level rise applied to water levels and increased storminess applied to wave heights;

- 100% Annual Exceedence Probability (AEP) (1 in 1 year return period)
- 10% AEP (1 in 10 year return period)
- 2% AEP (1 in 50 year return period)
- 1% AEP (1 in 100 year return period)
- 0.5% AEP (1 in 200 year return period)

The foreshore was taken into account as part of the analysis by considering its geometry extracted from the LiDAR and compared with the Mean Low Water Spring and the Mean High Water Spring to determine the slope to be used for run-up. The analysis was checked by Arup maritime engineers.

A limit was added to the wave height which meant it could not be higher than 2/3 of the water depth. This was to take the foreshore into account which would dissipate the wave energy.

The findings of the wave overtopping analysis are included within the section for each Frontage later in this report.

4 Analysis of Frontages

The following section describes for each frontage the relevant studies and the available information with regard to the following:

- Defence type and condition
- SoP given in the existing studies as well as additional analysis where appropriate
- The current and future tidal flood risk

A series of long sections have been produced for all frontages and show the 0.5% AEP still water level for current day (2010), 2060 and 2110 which was gained from the JPAs listed in Section 2.1.11. Joint Probability Analysis. The defence and high ground levels have been gained from the most detailed available LiDAR along the full frontage. The drawings are included within Appendix D.

4.1 Frontage A – Queen Elizabeth Dock to North of Paull Village

Frontage A runs from just east of Queen Elizabeth Dock, past the Saltend Chemical Works and ends to the north of Paull Village (Drawing A6, Appendix A). This frontage is protected by earth embankments and high ground. The following structures are present along Frontage A:

- Three outfall structures at Lord's Clough, one of which has pointing doors with a penstock and the others are flapped outfalls
- Three pumped outlets, an outfall and stop logs at Saltend
- A flapped and pumped outfall at Hedon Haven
- An outfall at Pollard Clough
- An outfall at Burstwick New Clough which consists of two sets of pointing doors, a penstock and recently installed infrastructure for the installation of a 24 inch (600mm) mobile pump
- An outfall at Hedon Haven (far barn)

The location of the structures within Frontage A can be seen on Drawing C1, Appendix C.

The Environment Agency manage the defences along Frontage A.

4.1.1 Studies applicable to Frontage A

The study undertaken relevant to this frontage is:

- Humber FRM Strategy

The Humber FRM Strategy states '*We will continue to protect this area. The defences will need to be improved as sea levels rise.*'

4.1.2 Standard of Protection

Wave overtopping analysis was used to determine the SoP for Frontage A.Due to the consistency of defence height along Frontage A, two cross-sections were used to assess the SoP using Wave Overtopping Analysis. The location of these cross-sections represents the changing defences and foreshore characteristics; large foreshore entering into tributary (cross-section 1) and smaller foreshore perpendicular to the estuary (cross-section 2). For cross-section locations see Drawing 002 in Appendix E.

The overtopping analysis results for Frontage A show that no overtopping occurs for either cross-section for any return period up to 0.5% AEP (1 in 200 year) in 2010, 2060 and 2110. The defences along Frontage A are sufficiently high and have sufficient foreshore to provide a greater than 1 in 200 year SoP in 100 years time (2110). Overtopping for Frontage A is therefore not an issue due to the height and slope of the flood defences at the time of calculation for the next 100 years.

4.1.3 Condition of Defences

The condition grades for Frontage A, according to NFCDD, range from Grade 1 (very good) to Grade 3 (average). The condition of the individual assets for Frontage A can be seen on Drawing C1.

It must be noted that the defences which are Grade 3 are backed by high land which protects against flood risk.

The responsibility for the assets along Frontage A can also been seen on Drawing C1, Appendix C.

4.1.4 Summary of Current and Future Tidal Flood Risk

The land behind the flood defences is low lying in some areas with the lowest ground levels at around 2mAOD. Any overtopping/breach is likely to result in flooding of the chemical works located within this area and various depots, as well as agricultural land. However, due to the condition and the SoP of the tidal defences there is a low risk of tidal flood from these defences in the current day and into the future. Although there is a residual risk from flood events in excess of the 0.5% AEP (1 in 200 year)

4.1.5 Recommendations

It is recommended that the following work is undertaken for Frontage A:

- Short to Medium term: The defence along Frontage A is in good to very good condition with the exception of the section of defence in Grade 3 (fair) condition. The Grade 3 section is backed by high land which protects against flood risk. The SoP of this section of defence is high over the next 100 years therefore little work is required along this frontage in the short to medium term other than general maintenance of assets.

- Long term: Although the SoP in 100 years is still high, the existing defences may come to the end of their design life. The condition assessment may show the defences becoming classified as poor or very poor condition. This will act a trigger for undertaking further works to assess possible flood management options.

4.2 Frontage B – North of Paull Village to Paull Holme Strays

Frontage B commences from a point just North of Paull Village through the village to a point directly to the West of Paull Holme Strays. The extent of the study area is shown in Drawing A7, Appendix A.

This frontage is protected by:

- Earth embankments
- High land
- Reinforced concrete walls
- Concrete revetment

The following structures are present along Frontage B:

- A flood gate at Paull Village
- Three flapped outfalls

The location of the structures can be seen on Drawing C2, Appendix C.

The Environment Agency manage the defences along Frontage B.

4.2.1 Studies applicable to Frontage B

The studies undertaken relevant to this frontage are:

- Humber FRM Strategy
- Paull Village Flood Alleviation Scheme Review (2008)

In 2005, the Environment Agency undertook Paull Village Flood Alleviation Scheme Detailed Appraisal Report (DAR). In April 2008 a study provided a review of the report undertaken in 2005 in order to re-assess the necessary work required to develop a potential flood alleviation scheme to the appraisal stage for approval. The review concluded the proposed work in the DAR was no longer cost effective and stated a more cost effective solution needs to be considered.

In undertaking this scheme review, information about the SoP and condition grades was provided and is stated within section 4.2.2 and 4.2.3.

The 2008 review identified components of the current flood defences at Paull Village:

- Section 1 - Embankment

- Section 2 & 3 – Reinforced Concrete Wall with Sloped Revetment
- Section 4 – Steeply Sloped Reinforced Concrete Wall with No Revetment
- Section 5 – Concrete Revetment
- Section 6 – Coastal Erosion Protection Wall

The location of these sections can be seen in Drawing A7, Appendix A.

4.2.2 Standard of Protection – Previous Studies

Paull Village

The SoP for Paull Village was assessed as part of the Paull Village Flood Alleviation Scheme using wave overtopping analysis (wave and still water level). The frontage was divided by flood defence type as shown in Drawing A7, Appendix A.

Table 3 below shows the SoP for Paull Village defences described in Section 4.2.1

Table 3 Current SoP for Paull Village

	AEP current day (2007)	AEP 2057	AEP 2107
Section 1 and 2	1% (1 in 100 yr)	5% (1 in 20 yr)	>10% (1 in 10yr)
Section 3	0.2% (1 in 500 yr)	2% (1 in 50 yr)	>10% (1 in 10yr)
Section 4	1% (1 in 100 yr)	10% (1 in 10yr)	>10% (1 in 10yr)
Section 5 and 6	Generally 0.2% AEP, except low areas north of Anson Villas (up to 1% AEP, 1 in 100 yr)	Generally better than 1% AEP, except low areas north of Anson Villas (up to 10% AEP, 1 in 10 year).	No results provided

In Section 5 of the frontage there are currently two scour holes in the existing concrete sea wall. Although this has an impact upon the integrity of the coastal erosion defence the flood defence here is high ground behind the sea wall, hence the SoP is not affected. However these scour holes will need to be addressed in the short term to avoid any further damage.

4.2.3 Standard of Protection – Wave Overtopping Analysis

Due to the recent overtopping analysis carried out for Frontage B by the Environment Agency in 2008 for Paull Village Flood Alleviation Scheme, Scheme Review, overtopping analysis was carried out for only two cross-sections as a check. For cross-section locations see Drawing 003, Appendix E.

The overtopping analysis results for Frontage B shows the SoP as follows;

- 2010; <0.5% AEP (>1:200yr)
- 2060; between 1% AEP and 0.5% AEP (1:100yr and 1:200yr)
- 2110; between 100% AEP and 10% AEP (1:1yr and 1:10yr)

The results obtained from this wave overtopping analysis differ slightly from Paull Village Flood Alleviation Scheme, Scheme Review. At this point, the methodology used for overtopping analysis within the Paull Village Flood Alleviation Scheme, Scheme Review is not known therefore it is difficult to understand the reason for the difference.

The overtopping analysis for Frontage B suggests that in the short term the defences have a very good (0.5% AEP, >1:200yr) SoP. The SoP decreases in the medium and long term but only really becomes a concern from 2060 onwards when the SoP falls below 1.3%AEP (1:75yr).

4.2.4 Condition of Defences

The condition grades for Frontage B, according to NFCDD, range from Grade 1 (very good) to Grade 3 (average). The condition of the individual assets for Frontage B can be seen on Drawing C2, Appendix C. The responsibility for the assets along Frontage B can be seen on Drawing C2, Appendix C.

4.2.5 Summary of Current and Future Tidal Flood Risk

The current day (2010) SoP for Frontage B is high, with an AEP of lower than 0.5% (1 in 200 year) and hence the flood risk to properties and agricultural land behind Frontage B is low. It must however be considered that land behind tidal defences in this location is low and therefore any overtopping/breach is likely to result in flooding. For this reason it is important to also consider the condition of the defence and increased risk of flooding as a result of the two areas of scour described in section 3.2.3.

Considering 100 years of climate change the SoP reduces considerably, with an AEP of between 10% and 100% (1 in 10 year and 1 in 100 year) and hence increased risk of flooding.

4.2.6 Recommendations

With the exception of the two scour holes in the frontage, the defences along Frontage B are generally in a good condition and will protect against flooding in the short and medium term. It is recommended that the scour holes are addressed in the short term.

In the medium to long term as the defences reach the end of their design life their integrity is likely to diminish. The condition assessment may show the defences becoming classified as poor or very poor condition. This will act a trigger for undertaking further works to assess possible flood management options.

4.3 Frontage C – Paull Holme Strays to Winestead Drain

This area is known as Sunk Island and has been considered in great detail as part of the Sunk Island Flood Risk Management Study. The extent of Frontage C can be seen in Drawing A8, Appendix A. The defences in this area consist of an earth flood embankment and various outfalls. The following structures are present along Frontage C:

- An outfall, fishpass, pumping station and pumped outfall at Paull Holme Strays
- Two pumped outfalls between Paull Home Strays and Stone Creek
- Four pointing door outfalls at Stone Creek
- Two pointing doors at Spragger Clough
- Winestead Pumping Station

The structures within Frontage C can be seen on Drawing C3, Appendix C.

Crown Estate, ABP and the Environment Agency manage the defences along Frontage C.

4.3.1 Studies applicable to Frontage C

The studies undertaken relevant to this frontage are;

- Flamborough Head to Gibraltar Point Shoreline Management Plan 2
- Humber FRM Strategy
- Sunk Island Flood Risk Management Study

Frontage C falls within Policy Unit K of the SMP. The current coastal management option for this policy unit is 'Hold the Line and maintain the standard of flood protection for the next 100 years'. However, to ensure sustainable flood defences and help meet the requirements of environmental legislation the Humber FRM Strategy identified limited managed realignment of defences as a possible option for this frontage. The SMP states that final policy recommendation is to be informed by the Humber FRM Strategy.

The Sunk Island Study considered the frontage from Paull Holme Strays to Winestead Drain in greater detail than the wider Humber FRM Strategy and assessed a number of flood management options for Sunk Island. The preferred option is managed realignment in two areas; Outstrays and Stone Creek to provide inter-tidal habitat as compensation for coastal squeeze in other parts of the Humber Strategy area. For the remaining frontage the preferred option was to raise the existing defences to 0.5% AEP (1 in 200 yr) SoP into the future allowing for climate change. In order to gain government funding for this scheme, third party contributions would almost certainly be needed to support the economic feasibility.

Managed realignment is likely to result in the loss of some agricultural land but will not affect residential and commercial property, historic environment assets or

key infrastructure. The approximate defence alignments identified in the Humber Flood Risk Management Strategy have been adopted for SMP appraisal purposes.

4.3.2 Standard of Protection

As part of the Sunk Island Study (undertaken in 2008 to 2010) wave overtopping analysis was undertaken for Frontage C to determine the SoP (Table 4). As the analysis was undertaken recently it was deemed acceptable to be used for this study rather than repeat the analysis. For cross-section locations please see Drawing 004, Appendix E.

Table 4 Current SoP and Future SoP for Frontage C

2008	2058	2108
CS1: 0.5% AEP (1: 185yr)	CS1: 4% AEP (1:24 yr)	CS1: 100% AEP (1:1 yr)
CS2: <0.5% AEP (>1:200 yr)	CS2: 3% AEP (1:31 yr)	CS2: 100% AEP (1:1 yr)
CS3: 0.65% AEP (1: 153yr)	CS3: 8% AEP (1:12 yr)	CS3: 100% AEP (>1:1 yr)
CS4: <0.5% AEP (>1:200 yr)	CS4: <0.5% AEP (>1:200 yr)	CS4: 8% AEP (1:12 yr)
CS5: <0.5% AEP (>1:200 yr)	CS5: 1.9% AEP (1:52 yr)	CS5: 4% AEP (1:25 yr)
CS6: <0.5% AEP (>1:200 yr)	CS6: <0.5% AEP (>1:200 yr)	CS6: 9% AEP (1:11 yr)
CS7: <0.5% AEP (>1:200 yr)	CS7: 1.2% AEP (1:83 yr)	CS7: 5.5% AEP (1:18 yr)
CS8: <0.5% AEP (>1:200 yr)	CS8: 0.64% AEP (1:156 yr)	CS8: 14% AEP (1:7 yr)

In terms of SoP, the defences along Frontage C should be of little concern within the next 20 to 30 years, as the SoP is estimated to be >1.3% AEP (1:75year). After this time options for increasing the SoP should be investigated for lower sections for defence in order to raise the SoP to > 1 in 75 years in 2110. Should overtopping occur along this frontage, there is flood risk to the wider South Holderness area due to the connectivity between catchments in this area. This is evident from LiDAR shown in Drawing A5, Appendix A.

4.3.3 Condition of Defences

The condition grades for Frontage C, according to NFCDD, range from Grade 1 (very good) to Grade 5 (very poor). The NFCDD condition of the individual assets and the party responsible for the assets along Frontage C can be seen on Drawing C3, Appendix C.

Drawing C3, Appendix C highlights a length of defence as '*Some Elements Not Inspected*'. As part of the most recent NFCDD inspections, it was not possible to undertake a full inspection of all the elements within this length as they were overgrown with vegetation at the time of inspection. As a result, the asset condition was downgraded as per the requirements of NFCDD (as outlined in section 2.1.9 of this report). It is intended that further clearance works will be undertaken on this section of the flood bank during 2010 and it is envisaged that once the works are completed the assets will be re-assessed and the condition of the asset will improve.

From the Sunk Island Study, the residual life of the defences ranges from 1 to 5 years to greater than 20 years.

4.3.4 Summary of Current and Future Tidal Flood Risk

As part of the Sunk Island Study a flood risk assessment was undertaken to identify the number of properties at risk assuming no flood defences exist. The current tidal defences around Sunk Island are some 20km long and protect:

- In the region of 10,000ha of grade 1 and grade 2 agricultural land,
- Up to 1056 residential homes and farmsteads
- Three high pressure gas pipelines which transmit in the region of 50% of the gas consumed in Britain and are therefore deemed to be part of the UK's critical national infrastructure.

Again, as part of the Sunk Island Study, the extent of flood risk of the 1 in 200 year event assuming **no tidal flood defences** is shown on Drawing B1, Appendix B. The depth of flooding associated with the 1 in 200 year event assuming **no tidal flood defences** is shown on Drawing B2, Appendix B. It must be noted that these outlines are produced without the inclusion of tidal flood defences which are currently present, therefore these tidal flood extents are more significant than would occur in reality with the presence of the current tidal defences.

4.3.5 Recommendations

The Frontage C coastal defences protect a large area of the South Holderness Study Area. A large amount of work has already been carried out as part of the Sunk Island Flood Risk Management Study in relation with assessing the tidal flood risk and this should be included within the South Holderness Study to assess connectivity between the South Holderness Area.

The SoP is relatively high, however in the short term it is important to address the condition of the defences (and hence residual life) and undertake further inspections and maintenance where necessary. A breach in the defence in this location would have great effect on the wider South Holderness area.

Frontage C has been highlighted as a potential location of Managed Realignment schemes to provide important inter-tidal habitats in accordance with the Humber FRM Strategy. Section 5 of this report assesses the economic feasibility of options for managing tidal flood risk from Frontage C into the future.

4.4 Frontage D – Winestead Drain to Marsh Road

Frontage D represents the estuarine area from Winestead Drain to Marsh Road, which is south of Easington Village. This area is also known as Skeffling (Flood Cell 2 of the Humber Strategy). The extent of this frontage can be seen in Drawing A9, Appendix A.

The whole of Frontage D is protected from tidal flood risk by earth embankments. At Skeffling Clough there is a pumping station, a piped section from the pumping station and a piped outfall. Winestead Pumping Station also exists on the boundary between Frontage C and Frontage D. The structures within Frontage D can be seen on Drawing C4, Appendix C.

The Environment Agency manage the defences along Frontage D.

4.4.1 Studies applicable to Frontage D

The studies undertaken relevant to this frontage are:

- Flamborough Head to Gibraltar Point Shoreline Management Plan 2
- Humber FRM Strategy
- Skeffling HEFDS Strategy Development Study

Frontage D falls within Policy Unit K of the SMP. The current coastal management option for this policy unit is 'Hold the Line and maintain the standard of flood protection for the next 100 years'. To ensure sustainable flood defences and help meet the requirements of environmental legislation limited Managed Realignment of defences has been identified as a possible management option for this frontage. The SMP states that this process is to be informed by the Humber FRM Strategy.

According to this study, managed realignment is not cost beneficial if only the local costs and benefits are taken into account. It is a cost-effective way of providing some of the habitat needed to compensate for coastal squeeze as part of the wider Humber Strategy, consequently there are still plans to develop the site in this way.

Managed Realignment is likely to result in the loss of some agricultural land but will not affect residential and commercial property, historic environment assets or key infrastructure.

4.4.2 Standard of Protection – Previous Studies

The SMP states that the SoP for this area is 5% AEP (1 in 20 year) generally and in some places 20% AEP (1 in 5 year). The Skeffling HEFDS Strategy Development Study states that the SoP varies from 10% AEP (1 in 10 year) to 0.2% AEP (1 in 500 year). Wave and still water level was used to gain this information as part of the SMP.

4.4.3 Standard of Protection – Wave Overtopping Analysis

Wave overtopping analysis was undertaken to assess the SoP. Six cross-sections were assessed (Drawing 005, Appendix E attached). The locations were selected

to provide a fair understanding of the SoP provided by Frontage D as the six cross-sections are located to represent the change in height, slope and foreshore of the defence. Table 5 summarises the wave overtopping analysis results for Frontage D.

Table 5 Current SoP and Future SoP for Frontage D

2010	2060	2110
CS1: between 100% AEP and 10% AEP (1:1yr and 1:10yr) (Dam Breach[8]) CS2: between 10% AEP and 2% AEP (1:10yr and 1:50yr) (Dam Breach) CS3:7.1% AEP (1:14yr) CS4: 1.4% AEP (1:73yr) CS5: 1.1% AEP (1:88yr) CS6: <0.5% AEP (>1:200yr)	CS1: >100% AEP (<1:1) CS2: between 100% AEP and 10% AEP (1:1yr and 1:10yr) (Dam Breach) CS3: 50% AEP (1:2yr) CS4: 7.1% AEP (1:14yr) CS5: 7.7% AEP (1:13yr) CS6: 7.1% AEP (1:14yr)	CS1: >100% AEP (<1:1yr) CS2: >100% AEP (<1:1yr) CS3: >100% AEP (<1:1yr) CS4: >100% AEP (<1:1yr) CS5: >100% AEP (<1:1yr) CS6: >100% AEP (<1:1yr)

There is a low SoP in general along Frontage D. The lowest SoP is from cross-section 1, near Winestead Pumping Station, along Welwick Bank and Weeton Bank to cross-section 4. Any proposed works should make consideration for climate change which means the full length of Frontage D should be considered for a project to provide a greater SoP to properties and farmland behind Frontage D. It also must be noted that the connectivity between land in South Holderness needs to be considered. Due to the low land levels in this area, and the hydraulic connectivity to adjacent flood cells the low SoP of Frontage D causes a flood risk to areas not directly behind Frontage D, such as Sunk Island. Drawing A5, Appendix A shows the low lying areas of South Holderness in brown and it is evident from the extent of the brown area how overtopping or a breach to Frontage D could affect wider areas of South Holderness.

The findings of the wave overtopping analysis matches the SoP stated in the SMP.

4.4.4 Condition of Defences

According to the SMP, the residual life of defences in this area is between 11 and 20 years.

The condition grades for Frontage D, according to NFCDD, range from Grade 2 (good) to Grade 4 (poor). The NFCDD condition of the individual assets and the party responsible for the assets along Frontage D can be seen on Drawing C4, Appendix C.

4.4.5 Summary of Current and Future Flood Risk

The majority of Frontage D is at high risk from flooding in the current day from events of 100% AEP (1 in 1 year) in some areas. As time progresses, climate change increases the risk of flooding to the land behind Frontage D.

If a breach in the defences occurs along this frontage there is a great likelihood of a flood path toward the west (the area behind Frontage C). However, the area of

[8] Dam Breach occurs when the still water level is greater than the defence height

flooding is likely to be limited to the north and east due to the higher ground to the north of Skeffling, Weeton and Welwick.

4.4.6 Recommendations

It is recommended that the following work is undertaken for Frontage D due to the low standard of protection and the low residual life of the present defence:

Short term: Managed Realignment to provide inter-tidal habitat should be reviewed in consideration of the wider Humber Strategy and aligned in the emerging SMP2 Policy and a decision on the way forward made. Habitat creation would have the advantageous by-product of requiring new flood defences to be built around the managed realignment site. This would lead to loss of agricultural land however it would ensure that properties are protected for the medium to long term. Section 5 of this report assesses the economic feasibility of options for Frontage D into the future.

4.5 Frontage E – Marsh Road to Beacon (Easington) Lagoons (via Kilnsea)

Frontage E is bordered by both the Humber Estuary and the North Sea. On the Humber Estuary coastline it stretches from Winsetts Bank (Marsh Road) to Warren Head, and on the North Sea coast it stretches from Warren Head to the north of Long Bank, near Easington. Drawing A10, in Appendix A shows the extent of Frontage E. This study does not include Spurn Point.

This frontage is affected by the coastal processes of both the North Sea and the Humber Estuary. However due to the existing studies undertaken for Beacon (Easington)[9] Lagoons (see below) it has been decided to keep this as one study frontage rather than split it into two to reflect the different processes.

The coastal (North Sea) flood defences consist of earth embankments which are aligned behind a fronting barrier beach system which separates the inner lagoon from the active seashore.

The estuarine (Humber Estuary) defences consist of a primary earth embankment with 1m x 1m gabions along the frontage and a secondary earth embankment which ties into existing defences (Drawing A10, Appendix A).

The following structures are present along Frontage E:

- Flapped outfall at Easington clough and penstock
- Outfall south of Kilnsea
- Penstock outfall near Spurn Road
- Two penstocks on Easington New Bank

This area is also known as Flood Cell 1 for the Humber Strategy. The structures within Frontage E can be seen on Drawing C5, Appendix C.

[9] Since commencing this study Easington Lagoons have been re-named Beacon Lagoons by the Environment Agency

The defences along Frontage E are mostly managed by the Environment Agency.

4.5.1 Studies applicable to Frontage E

The studies undertaken relevant to this sub-area are:

- Flamborough Head to Gibraltar Point Shoreline Management Plan 2
- Humber FRM Strategy
- Easington Lagoons Long Term Plan and Options Development Report

The SMP covers the North Sea coast and also includes the Humber Estuary up to Stone Creek. Frontage E falls within Policy Unit I of the SMP on both the North Sea and Humber Estuary coasts. The current coastal management option for this policy unit is to 'Hold the Line' in this area.

The Easington Lagoons Study investigates the loss of both the coastal defences, in the Easington flood cell, as well as the loss of the lagoons due to coastal erosion. The study is principally concerned with the loss of lagoon habitat and the potential for habitat to be replaced elsewhere in the flood cell. The Humber Strategy 2008 found that the coastal defences are likely to be affected by coastal erosion in 40 years and it is likely to be difficult to obtain government funding to replace them. As a result the Easington Lagoons Study assumes that:

- There will be no future capital works undertaken to maintain the existing line of coastal defence
- The Environment Agency will be unable to justify maintenance of the present line of coastal defence after the next 20 years and will be obliged to withdraw maintenance
- No third party will take on the continuing maintenance of the present line of defence

The Easington Lagoons Study does provide information regarding the SoP of the defences as well as the condition and likely failure due to coastal erosion, but does not state a future management plan for the defences.

4.5.2 Standard of Protection – Previous Studies

The SMP states an SoP of 5% AEP (1 in 20 year) current day (2009) for the estuarine defences and 1% AEP current day (2009) for the coastal defences. Wave and still water level was used to gain this information as part of the SMP. No information is provided regarding the predicted SoP in the future.

Easington Flood Cell

The Easington Lagoons report provides information regarding the different defence lengths, associated levels and SoP of the assets lengths within this area. These are shown in Table 6 below. Analysis of the defence levels shows that the secondary defence has a much lower crest level than the primary banks, indicating that the northern and southern areas are only likely to remain hydraulically separate during flooding events with low return periods.

Table 6 Flood Defence Asset Information for Easington Flood Cell

Defence (Figure B4, Appendix B)	Length (m)	Crest Level (m)	Foreground Level (m)	AEP
Coastal: Earth embankment	1800	5.8	3.10	<1%
Estuarine: Primary earth embankment (north of secondary bank tie in)	1270	4.98	3.13	20%
Estuarine: Primary earth embankment (south of secondary bank tie in)	1700	5.09	2.81	5%
Estuarine: Secondary earth embankment	2380	4.16	2.80	20%

The Easington Lagoons study used extreme sea level data from Black and Veatch Ltd (2006) *Joint Probability Analysis of Large Waves and High Water Levels in the Outer Humber Estuary, Environment Agency*.

4.5.3 Standard of Protection – Wave Overtopping Analysis

Wave Overtopping Analysis has recently been undertaken for the tidal flood defence at Easington Lagoons as part of the Easington Lagoons Study[10]. The main requirement for wave overtopping analysis along Frontage E was for the estuarine defence South East of Kilnsea (cross-sections 3 and 4) and the coastal defence at Kilnsea (cross-section 5). To make a comparison with the overtopping analysis carried out recently two cross-sections were placed North West of Kilnsea and at Easington Lagoons. The location of all cross-section can be seen on Drawing 006, Appendix E. Table 7 summarises the wave overtopping analysis results for Frontage E.

Table 7 Current SoP and Future SoP for Frontage E

2010	2060	2110
CS1: <0.5% AEP (>1:200yr) CS2: <0.5% AEP (>1:200yr) CS3: 2% AEP (1:50yr) CS4: <0.5% AEP (>1:200yr) CS5: <0.5% AEP (>1:200yr) CS6: <0.5% AEP (>1:200yr)	CS1: <0.5% AEP (>1:200yr) CS2: 3.2% AEP (1:31yr) CS3: 14.3% AEP (1:7yr) CS4: <0.5% AEP (>1:200yr) CS5: <0.5% AEP (>1:200yr) CS6: 0.6% AEP (1:160yr)	CS1: between 10% AEP and 2% AEP (1:10yr and 1:50yr) (dam breach) CS2: >100% AEP (<1:1yr) CS3: >100% AEP (<1:1yr) (dam breach) CS4: between 1% AEP and 10% AEP (1:1yr and 1:10yr) (dam breach) CS5: 50% AEP (1:2yr) CS6: 33.3% AEP (1:3yr)

Comparing the results from the Easington Lagoons study (overtopping located at the lagoons site) with the results from cross-section 6 from this analysis it shows that the results are very similar. The lower SoP from this analysis results is likely to be caused by 10 years of difference with water levels. This therefore verifies this analysis.

At present the overtopping results suggest that all defences have a good SoP with the exception of cross-section 3 which is the estuarine defence south of Kilnsea which has a SoP of 1.9% AEP (1:54yr). The SMP suggested that this defence has a SoP of between 20% AEP and 10% AEP (1:5 years and 1:20 years).

10 Environment Agency, 2008, Easington Lagoons Long Term Plan & Options Development Report

4.5.4 Condition of Defences

The condition grades for Frontage E, according to NFCDD, range from Grade 1 (very good) to Grade 4 (poor). The condition of the individual assets for Frontage E can be seen on Drawing C5, Appendix C. The responsibility for the assets along Frontage E can also be seen on Drawing C5.

The Easington Lagoons Study describes a condition survey that was undertaken by Lewis and Duvivier (now Royal Haskoning) in 1983, however the information held in NFCDD now supersedes this survey.

The Easington Lagoon Study carried out an analysis on the residual life of the defences by taking the life expectancy of the Maccaferri gabions and adding this to the year at which the defence was put in place. The study states that the flood bank appears to be in reasonable condition in terms of general integrity.

Weathering and general ageing of the embankment armour is thought to be the determining factor in its longevity, limiting the armour life to about Year 30. There is also a risk of a more incipient failure in the Long Bank armouring from about Year 40.

The Easington Lagoons Study provided a detailed study of the residual life of the coastal flood defences at the Lagoons Site. Several points along the coastal flood defence were assessed for loss due to coastal erosion. The expected year of loss for individual lengths ranges from 2038 to 2093. Figure 1 below shows the predicted erosion rates and the location of the existing defences while Table 8 provides details of the expected life of these defences.

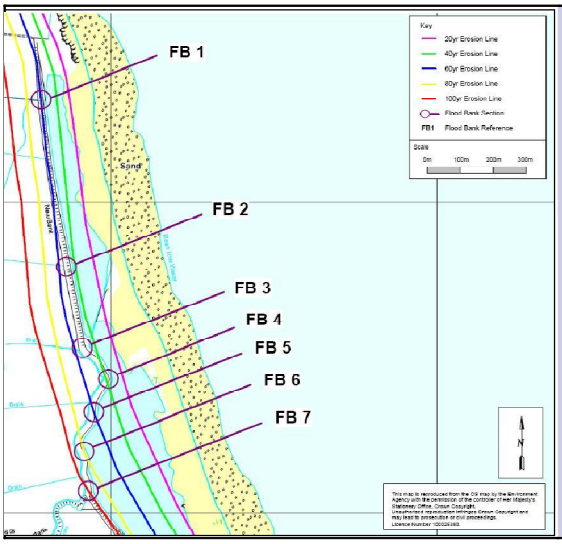


Figure 1 Location of defences and predicted coastal erosion rates for Beacon (Easington) Lagoons

Table 8 Expected life of the existing coastal defences due to coastal erosion

Flood Bank Point	Expected loss to coastal erosion	Expected year of loss
FB1	Year 55	2063
FB2	Year 45	2053
FB3	Year 50	2058
FB4	Year 30	2038
FB5	Year 50	2058
FB6	Year 70	2078
FB7	Year 85	2093

4.5.5 Summary of Current and Future Flood Risk

As part of the Easington Lagoons Study, an estimate of flood depth and extent was calculated by comparing the conveyance capacity of the breach and the flood cell flood storage volume. The estimate considers the length of the defence, the current SoP (20% AEP) and the range of extreme water levels now and in the future.

The Easington Lagoons Study states that with sea level rise the probability of breaching due to the overtopping of defences will increase with time. As a result it is likely that the defences will breach within the next 30 years. In order to determine the flooding event at which the secondary defences are overtopped, a comparison of the predicted flood depths with the crest levels of the secondary estuary defence was conducted. This showed that:

- Two separate areas (with the secondary defence as the boundary) is most appropriate for flood events of 2% AEP or lower in 2008 (or 4% AEP or lower in 2038)
- One larger area is appropriate for flood events greater than these.

Figure B3, Appendix B indicates the extent of the flood outlines using flood depths from a combined breach scenario (breach in the coastal and estuarine defence) for flood event up to a 1% AEP event in 2008 and 2038.

4.5.6 Recommendations

The standard of protection of Frontage E defences is fair to high at present (2011). Economic Analysis has been undertaken for Frontage E. Section 5 of this report assesses the economic feasibility of options for Frontage E into the future and provides recommendations.

4.6 Frontage F – Easington Cliffs

Frontage F represents the coastal cliffs from the north of Easington Lagoons to the south of Easington Gas Terminal. The coastal cliffs for Frontage F range from around 6mAOD to 10mAOD. At present there are no flood or coastal defences along this frontage and due to low lying land behind the southern section of the cliffs, there is a potential flood risk from coastal erosion in the future which could result in a flood path to Easington Village. Frontage F is shown in Drawing A11, Appendix A.

4.6.1 Studies applicable to Frontage F

The study undertaken relevant to this sub-area is:

- Flamborough Head to Gibraltar Point Shoreline Management Plan 2

Frontage F falls within Policy Unit H of the SMP. The current management option for this area according to the SMP is 'No Active Intervention'. However the SMP states, *"management of outflanking of the existing defences would be permitted subject to necessary approvals"*.

4.6.2 Standard of Protection – Wave Overtopping Analysis

Frontage F is not protected by man made defences, it is a natural coastline suffering from erosion at an average rate of 1.75m/yr. Landward of the current coastal cliff the ground level becomes lower. Therefore as a result of coastal erosion of the cliff the natural defence in this area is lowering on a yearly basis. At present the natural coastal defence height in the form of a cliff is over 8mAOD hence there is no requirement for overtopping calculations to be undertaken for the present day. However with the projected average erosion rate of 1.75m/yr, in 50 years time the defence is estimated to be 5.8mAOD. Combined with sea level rise tidal flooding in this area could be significant.

Wave Overtopping Analysis was carried out at one cross-section with a predicted cross-section assuming coastal erosion (Drawing 007 attached) and the results allowing for coastal erosion and sea level rise indicate that in 2060 overtopping of the coastal cliffs will occur in events between 10% AEP and 2% AEP (1:10 year and 1:50 year) and over. In 2110 overtopping would occur in events greater than 100% AEP event (1:1 year).

As the coastal cliffs in this area erode the higher ground providing the current SoP will be lost resulting in regular tidal flooding in the next 50 years and beyond. Erosion in this location needs to be closely monitored in the future and appropriate measure taken for a way forward when the defence height provided by the ground level/coastal cliff decreases.

4.6.3 Condition of Defences

There are no man made coastal defences within this frontage.

4.6.4 Summary of Current and Future Tidal Flood Risk

The current tidal flood risk from Frontage F is low, however as erosion increases in the future and higher land is eroded, lower land behind will effectively become the new tidal defence and hence increase flood risk.

4.6.5 Recommendations

Due to ongoing coastal erosion of the low lying cliffs and subsequent tidal flood pathway it is recommended that in the short term this frontage is observed for erosion and associated ground level reduction and hence increased flood risk.

4.7 Frontage G – Easington Gas Terminals

Frontage G represents the coastal area from Easington Village, covering the Easington Gas Terminal to the south of Dimlington. This is shown in Drawing A11, Appendix A. This section of coast is currently protected by rock armour.

4.7.1 Studies applicable to Frontage G

The study undertaken relevant to this sub-area is:

- Flamborough Head to Gibraltar Point Shoreline Management Plan 2

Frontage G falls within Policy Unit H of the SMP. The current coastal management policy for this area is to 'Hold the Line' to protect the gas terminals where defences exist and 'No Active Intervention' elsewhere. The future policy is:

- Present to 2025 – 'Hold the line' for current defences
- 2025-2105 – Management policy will be to continue to protect the Gas Terminals as long as the planning status allows defences. Management of outflanking of the existing defences may be permitted, subject to necessary approvals to protect the nationally important gas supplies and while there is a strategic need for the site.

4.7.2 Standard of Protection

The rock armour protection is designed to protect against coastal erosion.

Previous studies show that the SoP to protect against flood risk is provided by the high ground which is >10mAOD (Drawing LS_006, Appendix D). The SMP states that the SoP at Easington is 1% AEP year current day (2009). Wave and still water level was used to gain this information as part of the SMP.

4.7.3 Condition of Defences

The condition grades for Frontage G, according to NFCDD, is Grade 2 (good). The condition of the individual assets for Frontage G can be seen on Drawing C6,

Appendix C. The responsibility for the assets along Frontage G can also be seen on Drawing C6.

According to the SMP, the residual life of the defences is greater than 20 years.

4.7.4 Summary of Current and Future Tidal Flood Risk

There is a very low risk of tidal flooding at present due to the high land along this frontage. Due to the preferred coastal management option for this frontage this is unlikely to be a risk in the near future. However should the coastal management option change in the future this may impact upon the future flood risk.

4.7.5 Recommendations

In the short term it is recommended that no further work is required along this frontage providing the current SoP and condition of the defences is maintained. In the future, should the Gas Terminals become disused, there may be deterioration of coastal defences and therefore erosion in this location. At this time the wider flood risk should be assessed, however from an initial investigation it appears that a floodpath to Easington is not likely to be a risk in the medium to long term.

The defences in front of the gas terminals may have to be removed should the strategic need for the site no longer be required. The planning conditions on the development stipulate the removal of these defences and should this become a possibility then an action plan and consultation process would be needed.

4.8 Frontage H – Dimlington Cliffs to Hollym

Frontage H represents the coastal area from Dimlington Cliffs to the south of Withernsea (Hollym).This coastline comprises high cliffs ranging in level from 10mAOD to 25mAOD.

From the information available it is apparent that there is a risk of coastal erosion but there is no[11] risk from tidal flooding in the next 100 years.

There are no recommendations for further work in relation to tidal flood risk.

4.9 Frontage I – Withernsea (Hollym to Waxholme)

Frontage I represents the coastal area of Withernsea (Hollym to Waxholme). This section of coastline is defended by concrete and rock revetments, a concrete seawall, groynes and flood gates. Frontage I is managed by East Riding of Yorkshire Council.

4.9.1 Summary of Current and Future Tidal Flood Risk

There is currently a low risk of tidal flooding at Withernsea.

[11] This area is outside the floodplain shown on the Environment Agency Flood Maps

When assessing the LiDAR for South Holderness (Drawing A5) it is evident that there is a valley landward of Withernsea which would be at risk of tidal flooding in the future should the coastline erode to this point. At this location flood gates are shown to be in place according to NFCDD. However as long as the SMP recommendation for 'Hold the Line' along this frontage is implemented, it is unlikely that tidal flood risk would be an issue for this frontage over the next 100 years.

4.9.2 Conclusions and recommendations

The current tidal flood risk at Withersea is low therefore no further analysis is required at this time.

4.10 Frontage J – Waxholme to Tunstall

Frontage J represents the coastal area from Waxholme (north of Withersnea) to Tunstall Drain. This section of coastline is fronted by glacial till cliffs with a height of ~10mAOD.

From the information available it is apparent that there is a risk of coastal erosion but there is no risk[12] from tidal flooding in the next 100 years.

There are no recommendations for further work in relation to tidal flood risk.

4.11 Frontage K –Tunstall Drain

Frontage K represents the coastal area of Tunstall Drain. The coastal defence at Tunstall comprises an earth embankment with a foreshore of clay cliffs, which is currently (2010) about 10m wide. This foreshore is eroding at a rate of ~1 to 2 metres a year. The extent of the Frontage K can be seen on Drawing A12 in Appendix A.

The defences along Frontage K are managed by the Environment Agency.

4.11.1 Studies applicable to Frontage K

The studies undertaken relevant to this frontage are:

- Flamborough Head to Gibraltar Point Shoreline Management Plan 2
- Tunstall Pre-Feasibility Study
- Tunstall project Appraisal Report

Frontage K falls within Policy Unit E of the SMP. The current coastal management option for this policy unit is 'No Active Intervention' with the exception of Tunstall Drain. According to the SMP, the intent of management for this area is to allow natural processes to continue along the currently undefended

[12] This area is outside the floodplain shown on the Environment Agency Flood Maps

areas. However the SMP states that works may be necessary to maintain the functionality of Tunstall Drain.

The Tunstall Pre-Feasibility Study analysed the condition of the existing coastal embankment and the risk of sea flooding should the embankment at Tunstall fail. The study determined the embankment had a residual life of 1 - 5 years with the potential for rapid failure in a single event.

The study recommended that further work should be undertaken to develop a robust Project Appraisal Report (PAR) to secure technical approval of the preferred option and funding subject to availability.

The PAR determined that while no properties were at risk of the embankment failing, other assets were, such as the B1242 coast road, a number of minor roads, a caravan park, archaeological and nature conservation sites and 420 hectares of grade 2/3 agricultural land.

The PAR report concluded the preferred option was to construct a new embankment 250m inland of the existing embankment, creating 6 hectares of inter-tidal habitat. This option had the best cost:benefit ratio and was supported by the local community. This meant that this lessened the amount of appraisal work necessary. The option would provide a minimum present day standard of protection of 2% AEP (>1:50 yr SoP) which equates to 5% AEP (1:20) in 50 years time (including climate change). The estimated residual life of the new embankment will be between 60-100 years considering extreme coastal erosion.

4.11.2 Standard of Protection

According to the SMP the existing defences have a low residual life which is of greater concern than the standard of protection (SoP). The LiDAR[4] shows that the embankment height is ~7mAOD (Drawing LS_008, Appendix B). According to water levels stated in the Tunstall Report, the water levels for a 0.5% AEP (1 in 200 year) tidal event is 5.034mAOD, therefore the defence height of approximately 7mAOD should be sufficient to provide a significant SoP in the region of the 0.5% AEP (1 in 200 year) event. However, it must be noted that this assumption has only been made with regard to the water levels only and not the impacts of waves and wave overtopping.

The concern regarding the SoP of Tunstall Drain is echoed by the Tunstall Pre-Feasibility Study and the Tunstall Project Appraisal Report and is also evident when reviewing the LiDAR for the whole study area (Drawing A5, Appendix A).

The Tunstall Pre-Feasibility Study estimated the extreme tide level using Dixon & Tawn (1997) *Estimates of Extreme Sea Conditions*. Table 9 below shows the extreme tide levels.

Table 9 Extreme tide level estimated at Tunstall[13]

Annual Exceedance Probability (Return Period)	Estimated Peak water levels (m AOD)
MHWS	3.237
2% (1 in 50yr)	4.628
1% (1 in 100yr)	4.788
0.5% (1 in 200yr)	4.906
0.2% (1 in 500yr)	5.034

As part of the Tunstall Studies, a geotechnical desk study was carried out. This reports that there is a width of 10m of boulder clay between the cliff face and the current earth embankment which forms part of the flood defence line. See Figure 2 below. Observations from the walkover undertaken as part of the geotechnical study state that the coast is being eroded as a series of small bays typically 10m in width. This suggests that a breach in the existing embankment could be 10m width. The undermining of the ground beneath the embankment and erosion of the embankment itself could result in a rotational failure or failure due to piping. It would not necessarily fail due to progressive collapse. The report states that this process could cause the embankment to breach within 1 - 5 years, with the potential for rapid failure in a single event.

Once breached, wave action will cause further erosion and widen the breach.

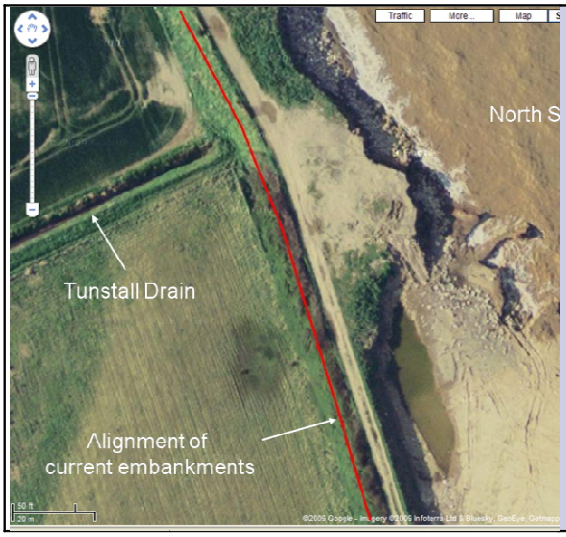


Figure 2 The alignment of the current defences at Tunstall and the ongoing coastal erosion.

4.11.3 Condition of Defences

According to both the SMP and the Tunstall Report the residual life of the clay embankment defence at Tunstall is predicted to be 1 to 5 years due to coastal erosion.

The condition of the defences according the NFCDD is Grade 3 (fair). There are low spots in the embankment, which increase the coastal flood risk as these are also potential locations of a future breach. The condition grades and

[13] Table 9 is obtained from Tunstall Pre-Feasibility Study, November 2008. Figure 3, page 8.

responsibility for the assets along Frontage K can be seen on Drawing C7, Appendix C.

4.11.4 Summary of Current and Future Tidal Flood Risk

The flood extent for a 0.2% AEP (1 in 500 year) flood event should a breach occur at Tunstall is shown on Drawing B4, Appendix B. It is likely that the embankments at Tunstall will be breached in the near future unless additional coastal management measures are implemented.

A breach here would cause no flooding to properties, but other assets such as the B1242 coast road, a number of minor roads, a caravan park, archaeological and nature conservation sites and 420 hectares of grade 2/3 agricultural land would be affected. From modelling undertaken as part of the Tunstall Study, there is a low risk of flooding to the Humber Frontage as a result of a breach in the Tunstall Tidal Flood Defence.

In the future, providing the preferred option from the Tunstall Project Appraisal Report is implemented the tidal flood risk would be reduced to a minimum present day SoP of 2% AEP (1:50 year).

4.11.5 Conclusion and Recommendations

In order to reduce the risk of flooding to assets behind the coastal embankment at Tunstall and to create 6 hectares of inter-tidal habitat, funding was secured to deliver the preferred scheme as recommended by the PAR. Unfortunately unforeseen ground conditions have delayed the project and a workable solution to the geo-technical problems encountered has still to be finalised. If a workable solution cannot be found then alternative options will need to be explored.

4.12 Frontage L –Tunstall to Aldbrough

Frontage L represents the section of coast from north of Tunstall Drain to near Aldbrough. The extent of the Frontage L can be seen on Drawing A16, Appendix A. Frontage L is lined with high cliffs comprising glacial till. According to the contours on the 1:25,000 OS mapping, the cliff height ranges from ~10mAOD to ~25mAOD along the coastal length of Frontage L.

From the information available it is apparent that there is a risk of coastal erosion but there is no risk[14] from tidal flooding in the next 100 years.

There are no recommendations for further work in relation to tidal flood risk.

[14] This area is outside the floodplain shown on the Environment Agency Flood Maps

5 Tidal Economic Analysis Summary

This section provides a summary of the Tidal Economic Analysis undertaken as part of this study. For more details of the analysis please see Appendix F. The aim of the economic analysis is to provide an initial appraisal of when tidal flood defence improvement works are likely to be required along the South Holderness Frontage, identify any future works required and the economic feasibility of undertaking these works.

5.1 Outline Methodology

The economic analysis has been undertaken in line with existing government guidance. This standard guidance has informed a number of key assumptions for both calculating the benefits and the costs of the potential options. The two main assumptions are:

- When calculating potential costs incurred by maintaining or improving these defences the capital and maintenance costs required have been assessed over a 100 year appraisal period to ensure that defences provide protection against an event with a 1.3% AEP (1 in 75 year) . Other key assumptions regarding how the costs and benefits were calculated are listed in the full report.
- When calculating the benefits, as this is a high level analysis, the properties and agricultural land below HAT (the Highest Astronomical Tide) have been assumed to be written off. This gives an upper bound estimate of the damages that would result if the defences are breached and so of the benefits of improving them. The exception to this is for Flood Cell C where the results of the detailed Sunk Island Study (Arup, 2009) where used to calculate flood extents.

Identifying and using flood cells

For each of the Frontages A to F, a “flood cell” is used to represent flood risk. These flood cells are based on physical characteristics, i.e. the topography of the land. This enabled us to calculate the economic benefit of continuing to provide that defence based on the number of properties and area of land that is protected as a result of its existence, i.e. the benefit: cost ratios for each flood cell.

The flood cells are shown on Figure 2, Appendix F.

5.2 Summary of Economic Findings

Section 5.2 provides a summary of the economic analysis for Flood Cells A to E. For more details of the analysis please see Appendix F

Section 6.2.1 to 6.2.4 below describes the findings of looking at each flood cell individually. Section 6.2.5 looks at combining the flood cells where there is interconnectivity and flooding in one cell will likely lead to flooding in the adjacent cell(s).

5.2.1 Flood Cells A and B

The fact that these two frontages are currently in good condition and provide a good SoP means that the costs of maintaining them over the next 100 years are relatively low. Combining low costs with high benefits (due to the high numbers of properties protected by these frontages) means there is likely to be a strong case for continuing management in the long term. Therefore it is probable that government funds (in the form of Flood Defence Grant in Aid – FDGiA) can be obtained to support their maintenance and there would be a good prospect for making necessary improvements in the future. It will still be necessary to seek external contributions from major beneficiaries in line with current recommendations.

5.2.2 Flood Cell C

The high level economic analysis shows that it could be difficult to protect Flood Cell C as a stand alone cell in the future without taking steps to reduce the cost of the works needed. This outcome is described in the Humber Strategy (2008) and confirmed by the Sunk Island Study (2009). This analysis has also highlighted that there is a flood risk to Flood Cell C from Flood Cell D should Frontage D breach/overtop. Proposed managed realignment schemes in Flood Cells C and D provide an opportunity to protect Flood Cell C in the future if supported by external contributions.

5.2.3 Flood Cell D

The analysis has shown that government funding (FDGiA) is unlikely to be available to maintain and raise Frontage D into the future. This is mainly due to the low numbers of properties at risk in this area resulting in a poor benefit: cost ratio. This means that significant external funding would be required in order to manage these defences.

In Flood Cell D it may be possible to undertake a management realignment scheme to provide habitat. This would have the advantageous by-product of requiring new flood defences to be built around the managed realignment site. This would lead to loss of agricultural land however it would ensure that properties are protected for the medium to long term. This would have an impact on the local community and extensive stakeholder consultation would be needed to ensure that any negative impacts are minimised. If this work was not undertaken Flood Cell D would be subject to natural inundation in the future, for which homeowners and landowners would receive no compensation.

Furthermore the potential for managed realignment in Flood Cell D would improve the case for protecting Flood Cell C. This is because there is currently a flood route from the existing Frontage D into Flood Cell C. An optimised managed realignment site in Flood Cell D would protect Flood Cell C from flood risk from this source in the future.

5.2.4 Flood Cell E

Unfortunately the economic analysis has identified that any future works to raise the existing defences in Flood Cell E would not be able to attract FDGiA funding due to the limited number of properties at flood risk in the area.

There are therefore two issues for this flood cell:

- The existing defences will need to be raised in due course. The cost of this work would mean that very substantial external contributions would be needed for this to happen.
- The North Sea defences will ultimately be washed away, probably within 20 to 30 years, by the retreating shoreline, and so the defences will need to be rebuilt further back which will be prohibitively expensive.

We recognise that this is a major issue, but there is no simple alternative for this area. The flood risk here is complex since it arises from the North Sea *and* the Humber Estuary. Stakeholder consultation will be key to flood management in the future.

5.2.5 Interconnectivity between flood cells

Due to the low lying nature of South Holderness there is interconnectivity between the flood cells. Flooding in one call may lead to flooding in the adjacent cell once the defences have been breached/ overtopped.

The following options were assessed:

1. Protecting Flood Cells A and B and a cross bank between Flood Cells B and C
2. Protecting Flood Cells A, B and C and a cross bank between C and D

The first of these options would allow the SoP to be maintained to Flood Cells A and B where there is a clear economic case. The building of a cross bank here would give a benefit cost ratio of around 40. Therefore this ratio is high enough for further investigations to be undertaken should the flood defences in Flood Cell C fall below the existing SoP.

The high level economic analysis shows that there is a case for looking in further detail of combining the costs and benefits of Flood Cells A, B and C to justify a cross bank between C and D. As the SoP of the defences in D is currently low it is recommended that this is investigated further as a possible flood risk management method. There is a clear flood path between Flood Cells C and D which the second of these options addresses. This option is described in more detail in Section 3.2.2 Appendix F.

6 Environmental Assessment

6.1 Introduction

This chapter summarises the results of a gap analysis that compares the various flood risk management options for identified the north bank of the Humber Estuary in the Humber Estuary Flood Risk Management Strategy (FRMS) with this Tidal Flood Study. The purpose of this gap analysis is to establish whether the strategic environmental impacts identified in the Strategic Environmental Assessment of the Humber FRMS cover all of the possible impacts that could occur as a result implementing the options identified in the High Level Economic Assessment. From this it can be determined whether any actions, other than those already identified in the Humber FRMS and Strategic Environmental Assessment (SEA) need to be implemented to explore potentially adverse impacts and identify mitigation measures.

6.2 Gap Analysis

6.2.1 Individual Frontages

The two reports that are being compared use different terminology to describe similar sections of the frontages on to the Humber Estuary. Where this is relevant it is described below in Table 10 under the Environmental Gap Analysis column.

Table 10. Gap analysis between the Humber Strategy and the options identified in the High-level.

Frontage	Region Covered *(Easting, Northing)*	Recommendation(s)	Environmental Gap Analysis
A	Queen Elizabeth Dock to North of Paull Village *(515387,428379 to 516569,426645)*	Short to Medium Term: General maintenance and inspection of existing assets. Longer Term: As and if defence condition grades deteriorate, then this will trigger further studies to assess possible flood management interactions.	*Humber Flood area 5 (continue to protect the area).* The Strategy and High Level Economic Assessments both agree with maintaining the existing defences and undertaking maintenance. No additional environmental assessment required because the significant high-level issues have been identified in the FRMS SEA.
B	North of Paull Village to Paull Holme Strays *(516569,426645 to 516967,425210)*	Short Term: Address scour hole in defence south of Paull Village. Medium to Long Term: As and when defence condition grades deteriorate, then this will trigger further studies to assess possible flood management interactions.	

Frontage	Region Covered *(Easting, Northing)*	Recommendation(s)	Environmental Gap Analysis
C	Paull Holme Strays to Winestead Drain *(516967,425210 to 533444,418527)*	Short Term: Address the condition of the defences and undertake further assessment and maintenance where necessary. Medium to Long Term: This frontage has been highlighted for potential Managed Realignment for significant lengths. In order to provide tidal flood protection in the future, managed realignment is a possible way forward, and possible associated improvement to non-realigned sections.	*Humber FRMS Flood areas 3 and 4 (Further assessment required to identify future management options).* In the short term the options for this area are to maintain the line with a medium to long term option of some managed realignment. No additional environmental assessment required because the significant high-level issues have been identified in the FRMS SEA.
D	Winestead Drain to Marsh Road *(533444,418527 to 538112,417799)*	Short/Medium Term: Managed realignment to provide inter-tidal habitat and also tidal flood protection to Flood Cell C should be discussed with Natural England and a decision on the way forward made.	*Humber FRMS Flood area 2 (Maintenance to continue but this will be reviewed when the strategy is updated).* The recommendations for this frontage appear to be different to the short to medium term proposals in the FRMS. As a result only the 'generic' impacts associated with realignment have been considered. It is suggested that this would benefit from further environmental assessment to review whether there are any strategic scale impacts that haven't yet been identified.
E	Marsh Road to Beacon (Easington) Lagoons (via Kilnsea) *(538112,417799 to 540922,418472)*	Short to Medium Term: Work with ERYC and the local community to develop a strategy for the future. Medium to Long Term: This is a constantly evolving environment which could change considerably in years to come therefore continual monitoring and potential options to manage the tidal flood risk is required.	*Humber FRMS Flood area 1 (No further maintenance to Kilnsea embankment. The future management options will be reviewed when the strategy is updated).* The Strategy and High Level Economic Assessments both agree with the proposed approach. No additional environmental assessment required because the significant high-level issues have been identified in the FRMS SEA.

6.2.2 Combinations of frontages and flood cells

The SEA of the FRMS does consider in combination, cumulative and synergistic impacts. However, it only considers these effects at a spatial scale in terms of the

5 year programme. As a consequence it does not consider site specific cumulative effects that could occur as a result of maintenance works to frontages A, B, C and the 'cross bank element' between cells C and D.

As a result it is recommended that these impacts are considered in more detail so that the site specific issues can be identified and highlighted for future reference. This assessment is documented in the following section.

6.3 Assessment of potential environmental effects

As described previously this section reviews the impacts from the interventions identified in this Tidal Flood Study that have not already been considered as part of the Strategic Environmental Assessment that supported the Humber Flood Risk Management Strategy. In order to do this the potential environmental implications of maintenance works to frontages A, B and C and a barrier bank between Frontage C and D have been assessed against a generic suite of environmental topics (see Table 11 overleaf).

Table 11. Assessment of options not already assessed by the Humber FRMS Strategic Environmental Assessment.

Topic	Potential Constraints and Opportunities			
	Frontage A Maintenance	**Frontage B Maintenance**	**Frontage C Maintenance**	**Frontage D Barrier bank option**
Population	Public footpaths (used for recreation and access) that that run along the top of existing flood embankments). Possible disruption during maintenance works. Temporary closures or diversions may be necessary.	Public footpaths (used for recreation and access) that that run along the top of existing flood embankments). Possible disruption during maintenance works. Temporary closures or diversions may be necessary. A site at Hedon Haven has been identified in the East Riding Allocations DPD for future dock related employment land. If this site is developed in the future it might provide an opportunity for further enhancements.	Public footpaths (used for recreation and access) that that run along the top of existing flood embankments). Possible disruption during maintenance works. Temporary closures or diversions may be necessary.	Public footpaths (used for recreation and access) that that run along the top of existing flood embankments). Possible disruption during maintenance works. No direct effects on sensitive receptors e.g. noise or dust adversely affecting nearby residents.
Biodiversity	Proximity to the Humber Estuary Natura 2000 site (SPA, SAC, Ramsar site and SSSI). Any maintenance works should be screened against the conservation objectives as set out in the situation documents for each designation. If significant effects are identified an Appropriate Assessment will be required.			Proximity to the Humber Estuary Natura 2000 site (SPA, SAC, Ramsar site and SSSI). Any maintenance works should be screened against the conservation objectives as set out in the situation documents for each designation. If significant effects are identified an Appropriate Assessment will be required.
	Possible protected species present (e.g. ground	Possible protected species present (e.g. ground	Possible protected species present (e.g. ground	Possible protected species present (e.g. ground nesting birds, water voles, great crested newts and

Topic	Potential Constraints and Opportunities			
	Frontage A Maintenance	**Frontage B Maintenance**	**Frontage C Maintenance**	**Frontage D Barrier bank option**
	nesting birds, water voles and otters) on or adjacent to works area.	nesting birds, water voles and otters) on or adjacent to works area.	nesting birds, water voles and otters) on or adjacent to works area.	otters) on or adjacent to works area. Opportunity to create new habitat and enhance existing habitat value of adjacent waterbodies e.g. Winestead Drain, and / or new flood defence structures, e.g. planting on the earth flood embankment.
Water	Any impacts on the water environment will be managed through standard good site environmental management.			
Landscape character and designations	The East Riding of Yorkshire Council has carried out a Landscape Character Assessment for the entire area. The main sensitivities in the South Holderness area are: • Flat to gently undulating landscape below 15m AOD. • Extensive views over the Humber Estuary south and west. • Historic significance as a landing point and defence. • Lack of tree cover resulting in openness and long distance views with big skies. • Sparse scattered farmsteads. • Fields are regular and display a pattern that reflects phases of reclamation.			
	No effects			The size and location of a new barrier bank will be critical as well as the form or type of construction. In terms of alignment the flood defence structure should try to follow and complement existing field boundaries so that the evidence of historic land reclamation can be retained. The height of the structure should try to match the character of existing structures that contribute to the character of the area. Likewise options that involve earth embankments should be considered so that they tie into character of area provided by the existing embankments that run along the Humber Estuary.

Topic	Potential Constraints and Opportunities			
	Frontage A Maintenance	**Frontage B Maintenance**	**Frontage C Maintenance**	**Frontage D Barrier bank option**
Visual Amenity	No effects			Although the topography of the South Holderness area is flat resulting in long distance views this option is unlikely to have a significant impact on visual amenity. This is because there are limited visual receptors (e.g. isolated farms and possibly residential properties in Welwick and Patrington Haven).
Cultural Heritage	There are no designated heritage sites adjacent to this frontage. If the maintenance works are limited to existing flood defence structures then there should not be any impacts on heritage assets.	The main heritage feature in this area is the Fort Paull Battery (Scheduled Monument and associated listed structures / buildings). Works in this area needs to be sensitive to these constraints, particularly if they could impact directly or indirectly on the setting of these features.	There are a few listed structures and scheduled monuments close to the frontage and as a consequence works in this area needs to be sensitive to these constraints, particularly if they could impact directly or indirectly on the setting of these features (these include Stone Creek anti aircraft battery, World War 2 decoys for Hull Docks).	There are no designated sites close to the alignment of the embankment. However, during its construction the barrier bank might encounter as yet undiscovered archaeological remains related to the area's historic land reclamation or other historic activities.
Infrastructure and Transport	Impacts on transport infrastructure are likely to be limited unless major maintenance works require significant volumes of material to be transported to and / or from site thereby generating significant volumes of traffic.			There could be significant transport impacts if material to construct the barrier bank cannot be won locally. This is particularly relevant because the material would have to travel along the main route into the area (B1445).
	This frontage is close to industrial infrastructure on the eastern fringe of Hull which might present a constraint to maintenance works.	This frontage is close to industrial infrastructure at Salt End which might present a constraint to maintenance works. Services may also be a	Services may be a constraint (e.g. gas, water, electricity and telecommunications).	Depending upon the specific alignment of the barrier bank there may be potential impacts on services (e.g. gas, water, electricity and telecommunications). Proximity to Winestead Drain and other drainage ditches may also present a constraint to the construction of a barrier bank.

Topic	Potential Constraints and Opportunities			
	Frontage A Maintenance	**Frontage B Maintenance**	**Frontage C Maintenance**	**Frontage D Barrier bank option**
	Services may also be a constraint (e.g. gas, water, electricity and telecommunications).	constraint (e.g. gas, water, electricity and telecommunications).		
Planning and environmental assessment	Further guidance should be sought from NEAS for maintenance to determine whether or not specific maintenance works will require Environmental Impact Assessment under SI 1999/1783 as amended.			The construction of a barrier bank would require planning consent and might also fall within the remit of the Environmental Impact Assessment regulations SI 1999/293.

7 Conclusions and Recommendations

This tidal study has summarised and reviewed the current information available to provide information regarding defence type and condition, SoP and the current tidal flood risk in the frontage. For some frontages additional information was gained from wave overtopping analysis and economic appraisal.

From the analysis of the information available the following table summarises the SoP, residual life and condition of each frontage;

Frontage	Region Covered *(Easting, Northing)*	Brief Description	Current SoP Annual Exceedance Probability (AEP) from previous studies	Residual Life	Condition Grade (from NFCDD)
A	Queen Elizabeth Dock to North of Paull Village *(515387,428379 to 516569,426645)*	Flood Defences – Earth embankment and outfall structures	Less than 0.5% (based on still water levels and wave height)	Not Known	1 - Very Good to 3 - Average
B	North of Paull Village to Paull Holme Strays *(516569,426645 to 516967,425210)*	Flood Defences - Walls, revetments, embankments, high land and outfall structures	Less than 0.5% (based on still water levels and wave height)	Not Known	1 - Very Good to 3 – Average
C	Paull Holme Strays to Winestead Drain *(516967,425210 to 533444,418527)*	Flood Defences – Earth embankment and outfall structures	0.65% to less than 0.5% (based on still water levels and wave height)	1 – 5 years to > 20 years	1 - Very Good to 5 – Very Poor
D	Winestead Drain to Marsh Road *(533444,418527 to 538112,417799)*	Flood Defences – Earth embankment and outfall structures	Ranges from 100% to 0.2% (based on still water levels and wave height)	11 – 20 years	2 - Good to 4 - Poor
E	Marsh Road to Beacon (Easington) Lagoons (via Kilnsea) *(538112,417799 to 540922,418472)*	Flood Defences – Earth embankment and outfall structures	Coastal Embankment <0.5% Estuarine Embankment 1.9% to <0.5% (based on still water levels and wave height)	> 20 years	1 – Very Good to 4 - Poor
F	Easington Cliffs *(540922,418472 to 540584,419426)*	Glacial till cliff line Just <6mAOD+	Likely flood risk during extreme events	No defence present	
G	Easington Gas Terminals *(540584,419426 to 540191,420225)*	Flood Defences – Rock armour	1% (based on still water levels and wave height)	> 20 years	2 - Good
H	Dimlington Cliffs to Hollym *(540191,420225 to 535020,427069)*	Glacial till cliff line +10mAOD	Low flood risk	No defence present	

I	Withernsea (Hollym) to Waxholme *(535020,427069 to 533782,428823)*	Flood defences – Seawall, concrete and rock revetment, groynes and flood gates	2% to 1% (based on still water levels and wave height)	6 to >20 years	1 - Very Good to 3 - Average
J	Waxholme to Tunstall Drain *(533782,428823 to 532105,430986)*	Glacial till cliff line ~10mAOD	Low flood risk	No defence present	
K	Tunstall Drain *(532105,430986 to 531961,431236)*	Mouth of low lying drain with flood embankment	20% (Expectation that defence will be lost due to erosion)	1 to 5 years	3 - Average
L	Tunstall Drain to Aldbrough *(531961,431236 to 526120,439166)*	Glacial till cliff line +10mAOD	Low flood risk	No defence present	

From review of the studies available for each frontage and additional analysis where appropriate, recommendations have been made regarding the way forward for that part of South Holderness Frontage. The table below summarises the recommendation for each frontage;

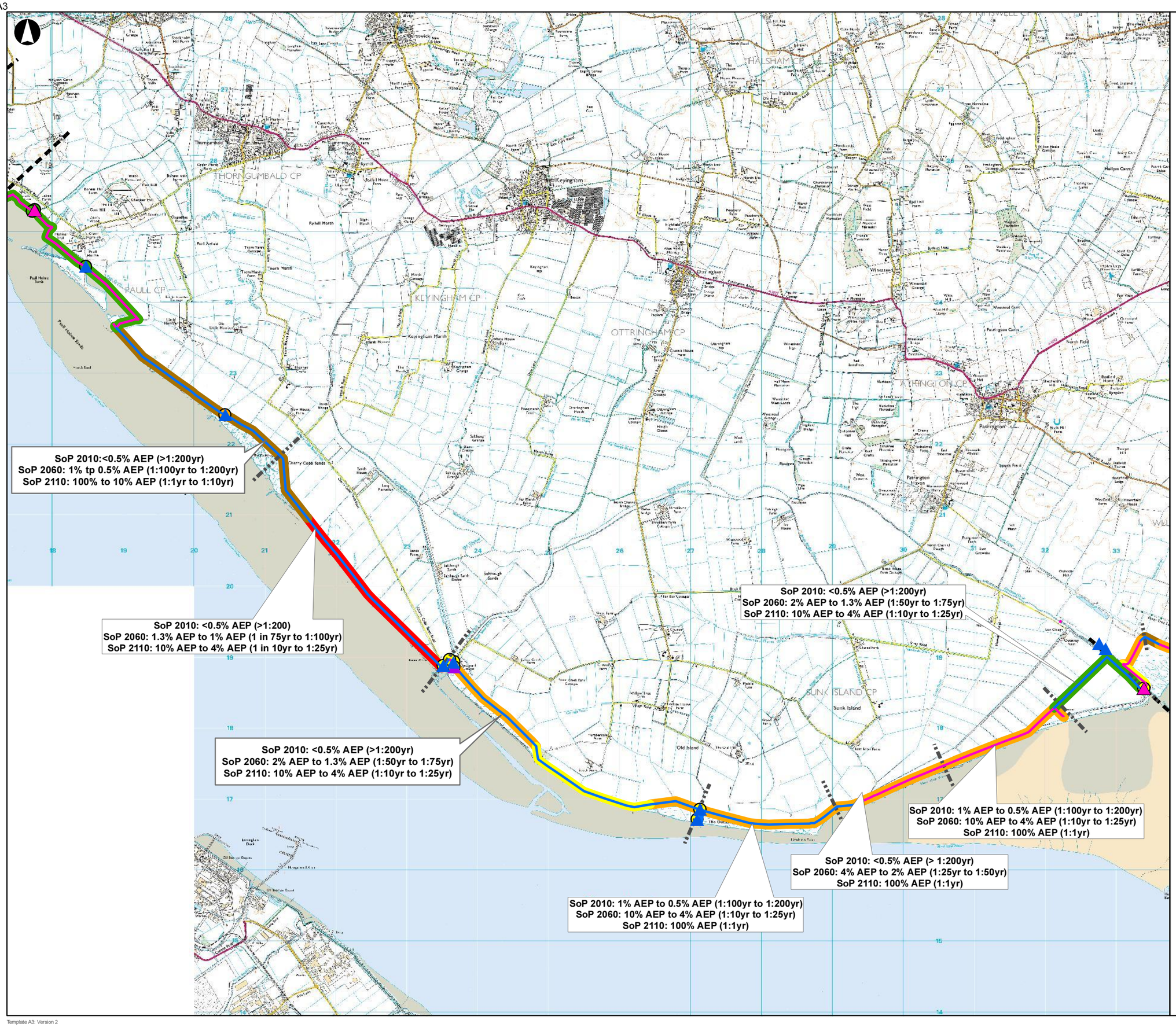
Frontage	**Region Covered** ***(Easting, Northing)***	**Recommendation(s)**
A	Queen Elizabeth Dock to North of Paull Village (*515387,428379 to 516569,426645)*	Short to Medium Term: General maintenance and inspection of existing assets. Longer Term: As/if defence condition grades deteriorate, then this will trigger further studies to assess possible flood management interactions.
B	North of Paull Village to Paull Holme Strays *(516569,426645 to 516967,425210)*	Short Term: Address scour hole in defence south of Paull Village. Medium to Long Term: As and when defence condition grades deteriorate, then this will trigger further studies to assess possible flood management interactions.
C	Paull Holme Strays to Winestead Drain *(516967,425210 to 533444,418527)*	Short Term: Address the condition of the defences and undertake further assessment and maintenance where necessary. Medium to Long Term: This frontage has been highlighted for potential Managed Realignment for significant lengths. In order to provide tidal flood protection in the future, managed realignment is a possible way forward, and possible associated improvement to non-realigned sections.

Frontage	Region Covered (Easting, Northing)	Recommendation(s)
D	Winestead Drain to Marsh Road *(533444,418527 to 538112,417799)*	Short/Medium Term: Managed realignment to provide inter-tidal habitat and also tidal flood protection to Flood Cell C should be discussed with Natural England and a decision on the way forward made.
E	Marsh Road to Beacon (Easington) Lagoons (via Kilnsea) *(538112,417799 to 540922,418472)*	Short to Medium Term: Work with ERYC and the local community to develop a strategy for the future. Medium to Long Term: This is a constantly evolving environment which could change considerably in years to come therefore continual monitoring and potential options to manage the tidal flood risk is required.
F	Easington Cliffs *(540922,418472 to 540584,419426)*	Short Term: Monitoring of erosion and ground levels. Short to Medium Term: In the future, as erosion and therefore flood risk increases, potential options for managing flood risk should be considered.
G	Easington Gas Terminals *(540584,419426 to 540191,420225)*	Short Term: No further work required Medium to Long Term: Should the gas terminals become disused, the wider flood risk due to deterioration/removal of flood defences and therefore erosion should be assessed.
H	Dimlington Cliffs to Hollym *(540191,420225 to 535020,427069)*	No recommendations for further work.
I	Withernsea (Hollym) to Waxholme *(535020,427069 to 533782,428823)*	Long Term: As the current tidal flood risk in this area is low, no further analysis is required at this time.
J	Waxholme to Tunstall Drain to *(533782,428823 to 532105,430986)*	No recommendations for further work.
K	Tunstall Drain *(532105,430986 to 531961,431236)*	Funding was secured this financial year to construct a new embankment at Tunstall (set back from the existing defences), with contributions from ERYC, the RFDC through Local Levy and benefit in kind contributions from the IDB and Landowners. Unforeseen ground conditions have delayed the project and a workable solution to the geo-technical problems encountered has still to be finalised. If a workable solution cannot be found then alternative options will need to be explored. However this is a constantly evolving environment and may require ongoing monitoring of the condition of the defence in the future.
L	Tunstall Drain to Aldbrough *(531961,431236 to 526120,439166)*	No recommendations for further work.

Appendix A

Drawings

A3



Legend

- Environment Agency
- Internal Drainage Board
- Third Party
- Environment Agency
- Internal Drainage Board
- Third Party
- Structure - Grade 1
- Structure - Grade 2
- Structure - Grade 3
- Structure - Grade 4
- Structure - Grade 5
- Defence - Grade 1
- Defence - Grade 2
- Defence - Grade 3
- Defence - Grade 4
- Defence - Grade 5
- Tidal Study Boundaries

Standard of Protection (SoP)
Annual Exceedance Probability (AEP)
Based on Wave Overtopping Analysis

Issue	Date	By	Chkd	Appd
F2	2011-01-17	KP	KK	DW

Metres
0 700 1,400 2,800

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Client
ENVIRONMENT AGENCY

Job Title
NEECA2 South Holderness Study

Drawing Title
NFCDD Asset Conditions and Standard of Protection Frontage C

Scale at A3
1:50,000

Drawing Status
For Issue

Job No	Drawing No	Issue
211366	C3	F2

17/01/2011 12:16:27

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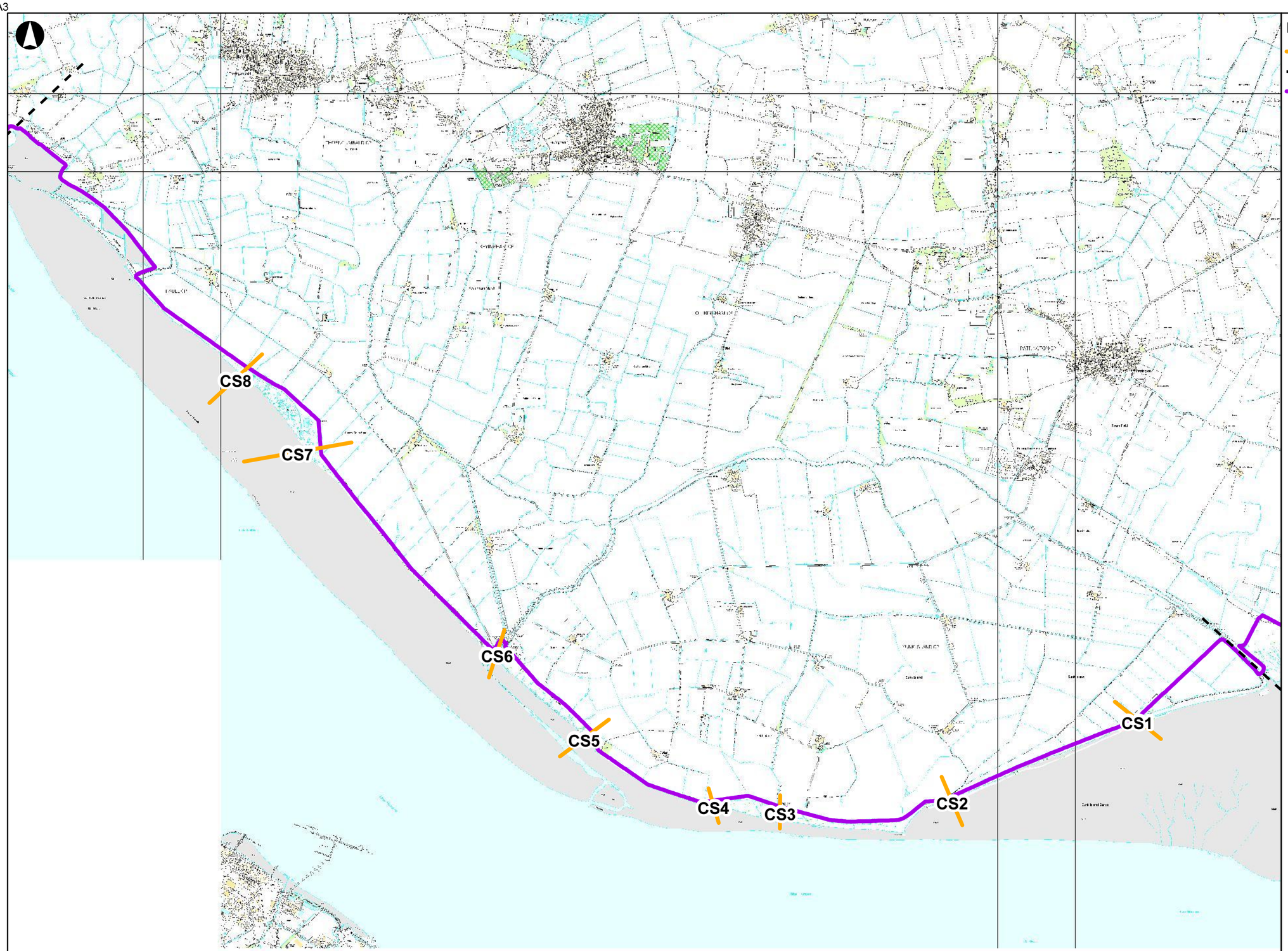
A3



Legend

- Sunk Island Overtopping Cross-sections
- Tidal Study Boundaries
- Coastal Defence Line

14/01/2011 16:26:48

Issue	Date	By	Chkd	Appd
F2	2011-01-11	KC	KK	DW

Metres
0 625 1,250 2,500

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Client

ENVIRONMENT AGENCY

Job Title

NEECA2 South Holderness Study

Drawing Title

Frontage C
Cross-sections for
Wave Overtopping Analysis
used in Sunk Island Study

Scale at A3

1:50,000

Drawing Status

For Issue

Job No	Drawing No	Issue
211366	E4	F2

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Appendix C

Extract from the Humber Estuary Flood Defence Strategy Development Study Technical Report Version Number 4.0, June 2005: Final Report

2. EXISTING DEFENCES

2.1 Description of defences

There are 235 km of flood defences on the Humber Estuary, River Ouse and River Trent within the strategy area. The majority of these, some 187 km, are earth embankments armoured generally with rock or stone pitching. Along some lengths the crest has been raised by a concrete wall or gabions. In other areas sheet-pile walls have been used to strengthen or to raise the crest level of embankments. The remainder of the defences are a combination of sheet-pile walls, reinforced concrete walls, masonry walls and dock walls. More detailed descriptions of the defences are given in the Key Issue Assessments[3] and the Detailed Appraisals[4].

Many of the existing defences were constructed in the 25 years following the 1953 east coast flooding. Whilst improvements have been undertaken on a regular basis since then, recent works have been mainly in response to particular problems rather than as part of a strategic plan for flood management and defence improvement. The works planned for the first five years of the strategy period will seek to improve the condition and standard of protection of those lengths of defence that are most at risk of failure. Beyond that time-frame there will be increasing scope for a proactive programme of strategic improvements.

The defences are at risk of failure due to overtopping causing a breach and due to poor condition. Failure due to poor condition can result from general deterioration, poor stability or erosion undercutting the toe of the embankment. Erosion is a particular and serious problem at a few discrete locations – Swinefleet Village, Winteringham Ings, Halton Marshes and Stallingborough. The condition of the main defence structures around the estuary is generally good. The areas of concern are localised but the flat nature of the land protected means that a single point of failure can lead to widespread and damaging flooding.

For each land use band Defra[13] have established a range of indicative standards of protection to act as an aid in establishing the range of options to be considered. Most of the defences provide a standard that is above the lowest level in the range and about a third provide a standard better than the top end of the range. There are however several lengths of defence where improvement in the standard of protection is necessary and would be economically justifiable.

With both condition and standard of protection there is a probability of failure of the defences, this probability increasing with time due to sea level rise and deterioration of the defence structure. The methods used to determine the probability of failure and the year in which intervention is deemed to be necessary to maintain an adequate standard of protection are outlined below. A fuller description of the methodology is given in the Engineering Studies Report[2].

2.2 Condition assessment methodology

In determining the vulnerability of a flood defence to failure through a deficiency in its condition, it is necessary to consider when the probability of failure becomes unacceptable rather than when the structure reaches the end of its working life. The acceptable probability of failure is related to the required standard of protection and will vary depending on the land use of the area defended. Thus the condition of the defences protecting urban areas such as Hull would be expected to be better than defences protecting only farmland in the same way as the crest level of the defences would be higher.

The probability of failure of a defence structure due to its condition has been assessed using a relationship between the age of the structure and its existing condition rating, the relationship varying for different types of defence. This gives an indication of when the probability of failure will become unacceptable for the standard of protection that is appropriate for the particular land use band. The time when that occurs is when it is necessary to intervene to improve the defences if it is economic to do so.

2.3 Walkover condition survey

The computation of intervention year for the LTP was based on information on the condition of the defences as held in the Flood Defence Management System (FDMS), now superseded by the National Flood & Coastal Defence Database (NFCDD). This was supplemented by some specific information from Environment Agency flood defence staff. In order to assess more reliably the intervention year for developing the defence improvement programmes in the key issue assessment reports and the detailed appraisals, a walkover survey of the defences in the relevant flood cells was undertaken in May and June 2004. Although this survey used the same recording format as the Agency's asset inspections, it was not intended to be used as a full asset survey as the information being recorded was for a more specific purpose.

The aims of the walkover survey were to:

- provide information for options development in the key issue assessments and detailed appraisals;
- estimate the residual life of the defences;
- provide an outline photographic record of the defence types in each flood cell;
- gain a more precise understanding of the condition rating obtained from Environment Agency databases.

The minimum residual life of the defences in each flood cell is shown in Table 2.1 (on next page). The residual life considers only the visible condition of the main defence structure. It does not take account of possible stability problems or of the future effects of erosion. Figure 3 indicates the lengths where the residual life is estimated to be less than 5 years, less than 15 years and less than 25 years. The figure is based primarily on the walkover survey but also uses records in the FDMS database for those defences which were not inspected.

2.4 Standard of protection

The standard of service for overtopping has been assessed using a wave run-up model to compute the volumes of water overtopping the defences with the various combinations of water level and waves determined by the Joint Probability Analysis (JPA)[8]. It is assumed that above a maximum average rate of overtopping, usually 5 litres per second per metre run of the defences, the defence will breach, resulting in extensive flooding, or the volume of water itself will itself cause flood damage or risk to life. For hard defences, or embankments with protected crest and back slope, the allowable rate of overtopping can be increased provided there are no vulnerable assets immediately behind the defences.

Sea level rise means that the standard of service will decline and the year in which the probability of failure becomes unacceptable can be estimated. The rate of sea level rise has been taken as 2 mm a year up to 2004 and 6 mm year after that.

Table 2.1 Residual life of defences

Flood cell		Minimum residual life (years)
1/1	Kilnsea	< 5
1/2	Skeffling	< 25
1/3	Sunk Island	< 25 (< 5 locally)
1/4	Stone Creek to Paul Holme	< 15
2/1a	Paull	< 5
2/1b	Hull East	<25
2/2	Hull West	< 15 (< 5 locally)
2/3	Hessle	< 5
2/4	North Ferriby	< 25
3/1	Brough	>25 (< 25 locally)
3/2	Brough Haven to Weighton Lock	>25 (< 5 locally)
4a/1	Saltmarshe	>25(< 15 locally)
4b/1	Goole	> 25 (< 5 locally)
4c/1	Goole Fields	< 25 (< 5 locally)
4d/1	Crowle	> 25 (< 5 locally)
4e/1	Gunness to Flixborough	>25 (<25 locally)
4e/2	Flixborough Grange	>25
4e/3	Alkborough	>25 (< 15 locally)
5/1	Whitton to Winteringham	>25
5/2	Winteringham Ings	< 10
5/3	Ferriby Sluice to South Ferriby Cliff	>25 (<5 locally)
6/1	Barton Cliff to Barton Haven	> 25
6/2	Barton Haven to Barrow Haven	> 25
6/3	Barrow Haven to East Halton Skitter	> 25 (< 25 locally)
7/1	Halton and Killingholme Marshes	< 5
7/2	Immingham to River Freshney	< 15 (< 5 locally)
7/3	Grimsby Docks	< 15 (< 5 locally)
8/1	Cleethorpes and Humberston	> 25
8/2	Tetney to Saltfleet Haven	> 25

Shaded cells are those that were included in the walkover survey.

2.5 Topographic survey

Some of the information on defence levels used in the assessment of existing standards of protection for the LTP was old and sparse. To ensure that the data used for the appraisals was complete and up-to-date, a topographic survey was carried out along the full length of the shoreline for which key issue assessments were planned, except where recent level data was already available. The survey covers about 80 km of the defences around the estuary (about one third of the total length) and provides crest levels, generally at about 100 m centres, and complete cross sections at 1 km centres, or less if the defence type changes.

The topographical survey was done using GPS benchmarks and provided valuable information in determining the existing standard of service and the extent of improvement works. It was recommended that the survey should be extended to include all the defences around the Humber, the survey being related to the Agency's new GPS benchmark network. A survey of datum levels of the principal tide gauges in the estuary was also recommended to ensure that the tide levels used in hydraulic modelling and those used for flood warning are to the same datum as the defence levels.

In place of the ground-based topographic survey, a low level LIDAR survey of all the defences in the estuary has recently been flown and data processing is in progress. When this is complete the results will be compared with the earlier ground-based survey work. The crest levels of the embankments obtained by the LIDAR survey will be checked for any significant differences to the information used to assess standards of protection. Work to compare the new tide gauge data with the original data is planned for later this year.

2.6 Review of standards

The standards of protection were reviewed using the new values for the defence levels obtained from the ground-based topographical survey to check that the basis for selection of schemes for the first fifteen years was valid. The minimum standard of protection for each flood cell is summarised in Table 2.2 (on next page). The standards for highlighted flood cells are based on the new topographic data.

With one exception the standards of protection were of the same order as those calculated previously and the differences did not invalidate the prioritisation process on which the LTP was based. The standard of protection on the south bank of the River Ouse between Boothferry Bridge and Hook was found to be much better than previously calculated, suggesting that the crest level data used to produce the LTP were not correct. The findings were confirmed by Atkins who are undertaking a strategy for Goole, considering the Ouse, the Aire and the Don / Dutch River. This means that, apart from the recently completed urgent stability works at Hook Road in Goole, no flood defence improvements are needed along this frontage of the Ouse in the first fifteen years of the strategy.

The lengths of flood defence where the existing standard of service falls below the lower end and below the upper end of the range of indicative standards of protection are shown on Figure 4.

Longitudinal profiles showing the crest levels of the defences and the source of that information are shown on Figures 5 and 6. The current 50 year and 500 year return period water levels are also shown on the profiles. It should be noted that these lines do not represent the required defence level for that return period as they include no allowance for waves, which are a major determinant of standard of protection within most of the Humber Estuary downstream of Trent Falls.

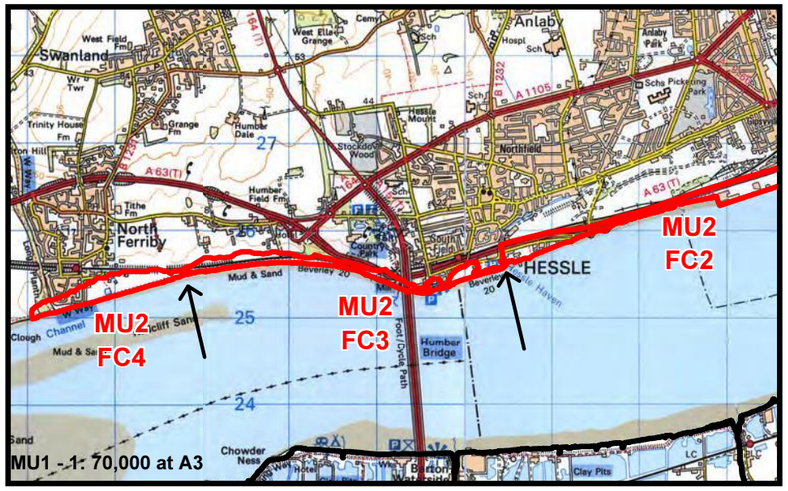
Table 2.2 Minimum standards of protection

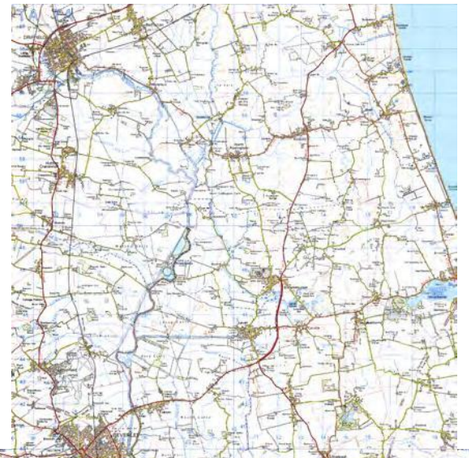
Flood cell		Indicative range (years)	Minimum standard (years)
1/1	Kilnsea	2.5 to 20	5
1/2	Skeffling	2.5 to 20	20 (2 locally)
1/3	Sunk Island	10 to 100	10 (2 locally)
1/4	Stone Creek to Paull Holme	10 to 100	80
2/1a	Paull	10 to 100	20
2/1b	Hull East	100 to 300	100
2/2	Hull West	100 to 300	200 (20 locally)
2/3	Hessle	10 to 100	1
2/4	North Ferriby	10 to 100	100 (5 locally)
3/1	Brough	50 to 200	40
3/2	Brough Haven to Weighton Lock	10 to 100	15
4a/1	Saltmarshe	10 to 100	5
4b/1	Goole	100 to 300	> 200
4c/1	Goole Fields	10 to 100	30
4d/1	Crowle	10 to 100	> 200
4e/1	Gunness to Flixborough	10 to 100	> 100
4e/2	Flixborough Grange	10 to 100	> 200
4e/3	Alkborough	1 to 5	80
5/1	Whitton to Winteringham	2.5 to 20	100
5/2	Winteringham Ings	10 to 100	4
5/3	Ferriby Sluice to South Ferriby Cliff	10 to 100	10
6/1	Barton Cliff to Barton Haven	10 to 100	20 (15 locally)
6/2	Barton Haven to Barrow Haven	10 to 100	20
6/3	Barrow Haven to East Halton Skitter	10 to 100	10
7/1	Halton and Killingholme Marshes	50 to 200	50
7/2	Immingham to River Freshney	100 to 300	200 (100 locally)
7/3	Grimsby Docks	100 to 300	5 (1 locally)*
8/1	Cleethorpes and Humberston	50 to 200	500 (5 locally)
8/2	Tetney to Saltfleet Haven	10 to 100	40

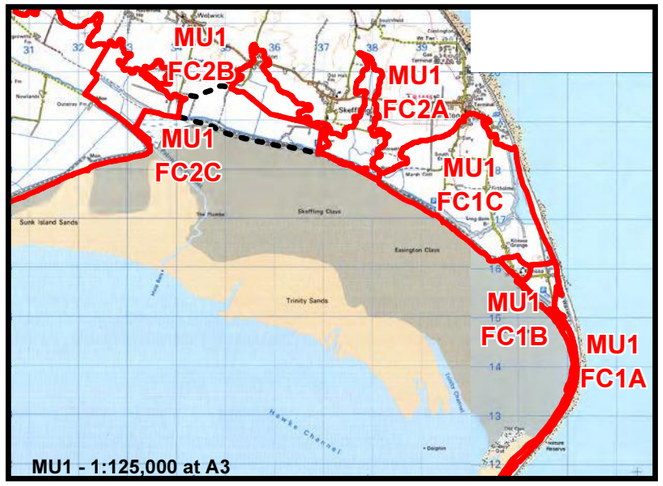
* Greater protection is provided to the town of Grimsby by the storage volume within the dock basins.

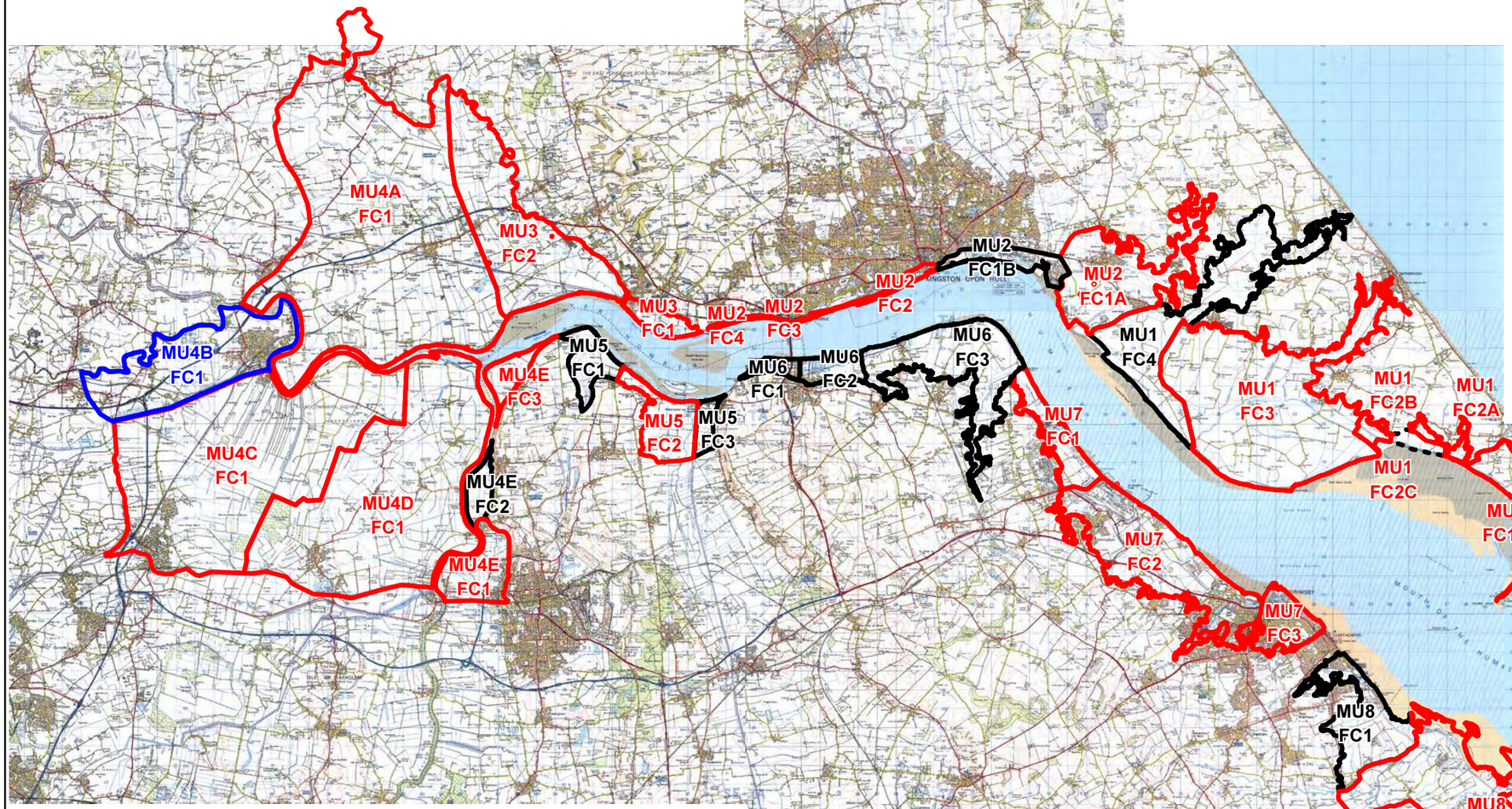
Appendix D

Extract (Figure 1) from the Humber Estuary Flood Defence Strategy Development Study Technical Report Version Number 4.0, June 2005: Final Report









		Date
Designed	PJN	Nov 04
checked	LT	Nov 04
Drawn	PJN	Nov 04
Checked	AR	Nov 04
reviewed	DCK	May 05

Rev.	Nature of Revision	Drawn	Chkd.	Rvwd.	Appd.	Date

Key

MU6 FC1 — Flood Cell reference

Flood Cells for which key issue appraisals have been prepared.

Flood Cell for which a separate strategy is being undertaken.

0 5 10
kilometres

Humber Estuary Flood Defence Strategy

Location of Flood Cells and Key Issue Assessments

ENVIRONMENT AGENCY

Contract no.	Approved:	Date:
108677	AR	June 2005

BLACK & VEATCH Halcrow

Scale: 1:275,000

Drawing no. Figure 1

R:/Projects/108516/Workspaces/FC_and_MU_270505_fig1.WOR SJC 290605