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Supplementary Environmental Information

Assessment of Changes to Morphology (particularly intertidal) between the Humber International Terminal (HIT) & Humber Sea Terminal (HST)

Explanatory Note EX 8.9

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Able Marine Energy Park

Assessment of changes to morphology (particularly intertidal) between the Humber International Terminal (HIT) and Humber Sea Terminal (HST)

Technical Note DDR4808-03

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Contents

1. Introduction

1.1 BACKGROUND

Able UK proposes to construct Able Marine Energy Park (AMEP) near Immingham on the southern bank of the Humber Estuary. AMEP will be a facility for the construction of offshore wind turbines and other activities associated with sources of renewable marine energy. AMEP will consist of a large reclamation approximately 1,300 m in length along the shore and extending 300 – 400 m out into the estuary.

Impacts of AMEP on the hydrodynamic and sediment regime have been assessed and reported in the HR Wallingford (2011). The proposed development is not dissimilar to an existing ABP development located approximately 600m downriver and completed in 2001, i.e. the Humber International Terminal. Figure 1 shows the locations of HIT, Humber Sea Terminal (HST) and the proposed AMEP.

This report uses high resolution Environment Agency (EA) LiDAR data for the period 2001-2010, as well as local ABP collector charts (1991-2008) to assess the longer term changes to morphology (particularly intertidal) subsequent to construction of HIT.

The analysed changes are presented in terms of level, area and volumetric changes on the intertidal. The collector charts are assessed in terms of changes to cross sections before and after construction of HIT. The analysis is then interpreted to inform future longer term morphology changes to the northwest of AMEP.

1.2 OBJECTIVE

To assess present-day trends in intertidal and subtidal morphology since construction of HIT, and use this information to inform on longer term local changes to intertidal and subtidal morphology.

2. Input data for this assessment

The following LiDAR data were purchased by Able UK for this assessment:

Table 1 LiDAR data for assessment of intertidal morphology changes

Year	EA LiDAR Tile
2001	TA1817,TA1818,TA1718, TA1719
2002	TA1817,TA1818,TA1718
2003	TA1817,TA1818,TA1718
2004	TA1817,TA1818,TA1718
2005	TA1817,TA1818,TA1718
2007	TA1817,TA1818,TA1718
2010	TA1817,TA1818,TA1718, TA1719

In addition, ABP collector charts for Stallingborough Haven to Skitter Haven were acquired for 1991, 1996, 2000, 2004, 2008.

3. Changes to intertidal morphology (2001 to 2010)

3.1 ANALYSIS

The intertidal levels derived from each of the LiDAR surveys flown between 2001 and 2010 are shown in Figures 2 - 9.

In terms of direct anthropogenic changes observed in the data, construction of the HIT reclamation appears to be partially complete by 2001 and fully complete by 2002 (earlier LiDAR surveys were not available). The dredging of intertidal for Immingham Outer Harbour (IOH) appears to have been completed during the period between the 2004 and 2005 surveys.

3.2 CHANGES TO INTERTIDAL MORPHOLOGY

Figure 10 shows the changes to intertidal level between 2001 and 2002, and Figure 11 shows the changes to intertidal level between 2001 and 2010. The Figures show that after reclamation of approximately 20ha of intertidal for the HIT, there has followed a period of re-adjustment of the intertidal foreshore to the northwest. The LiDAR, which picks up levels generally above -2m ODN (close to Mean Low Water) shows the foreshore rising and building outwards over time.

Between 2001 and 2010, substantial accretion of between 0.5m to more than 3.0m is observed over a 2km length of intertidal between HIT and HST. The largest amount of accretion is shown as an apparent "ridge" adjacent to the HIT on the lower intertidal area extending north-westwards along the foreshore. This is not actually a ridge of sediment, rather a difference resulting from the fact that the intertidal above -2m ODN has accreted and pushed outwards.

The general appearance of the present-day intertidal foreshore is of a wider, higher intertidal adjacent to HIT, lowering and narrowing as it extends northwards towards HST. The sediments have a muddy appearance (Figures 12, 13) although a detailed assessment of sediment characteristics is provided in Annex 7.2 of the Environmental Statement for AMEP. Approximately 1.3km northwest of HIT, a drainage channel cuts 1-2m through the intertidal (see photograph in Figure 14).

3.3 INTERTIDAL PROFILES

Ten profiles were extracted from the LiDAR data at 200m intervals along the intertidal foreshore. Profile 1 is positioned through the curved northwestern part of the HIT development, which was under construction during the 2001 survey. The further nine profiles extend to the north as shown in Figure 15. Superimposed on the profile plots near to HIT is a reference point showing the approximate location (along a streamline) of the front of the HIT reclamation.

Figures 16 to 25 present the intertidal profiles for each year. The profiles generally extend from a point landwards of the seawall, to a point on the lower intertidal (dependent on the tide at time of LiDAR survey).

A description of the observed changes is provided below:

Profile 1

Profile 1 (Figure 16) extends through the curved northwestern part of the HIT reclamation. The toe of the HIT reclamation is seen at around 390m chainage (approximately 300m from the old seawall). Fronting the reclamation, and between it and the berths, a small strip of intertidal foreshore (approximately 70m wide) is observed to have accreted over time (with a maximum accretion of 4m between 2001 and 2010 immediately fronting the HIT reclamation).

Profile 2

This profile is immediately upriver of the HIT development. Figure 17 shows that overall the picture of change is one of accretion from 2001 to 2010, with the intertidal above -2m ODN building up and pushing out. Maximum accretion of 3-3.5m over this period has occurred approximately 270m from the seawall, where the intertidal has raised from -2.0m ODN to >+1.0m. Landward of this point the intertidal has become flatter. Seaward it appears to have become steeper over time.

Profile 3

Profile 3 is 200m further upriver than Profile 2 and follows a line close to the South Killingholme Oil Jetty and the nearby APT pipe and Outfall. Figure 18 shows the intertidal profile has risen (by more than 3m in places) and pushed outwards between 2001 and 2010. The APT Outfall is located approximately 250m from the seawall (300m chainage in Figure 18) and is shown to be in an area which has accreted by 2-3m over the period 2001 to 2010.

Profiles 4-10

With distance up-estuary (to the north-west) the width of intertidal above -2m ODN reduces as shown in Figures 19 to 25. The upper intertidal level at the toe of the seawall has risen in nearly all cases by approximately 0.5 - 1m, with Profile 7 experiencing a rise of 1-2m. Maximum changes of intertidal level are of 2.5 - 3m (profile 4-6) and 2m (profile 7-10).

Profiles 4-10 have changed from initial concave profiles to more convex profiles with a higher, flatter upper intertidal followed by a lower steeper intertidal.

Profile 8 passes through the meanders of an existing drainage channel (Figure 14 and Figure 23), hence its undulating appearance.

3.4 INTERTIDAL AREAS

Standard tide level contours are shown in Figures 26 - 29, for years 2001, 2004, 2007 and 2010 (approximately equal gaps in time). A table of the standard levels included (where data were available) is provided below.

Table 2 Tide level contours

Standard Tide	Tide Level (m ODN)
MHWS	3.4
MHWN	1.9
MSL	0.2
MLWN	-1.3
Lowest level generally captured by LiDAR	-2.0
MLWS	Not captured by LiDAR

Figures 26-29 show a movement of the contours out into the estuary between 2001 and 2010, reflecting the increase in those parts of intertidal area above these contours. An assessment of the changes to intertidal area is undertaken in Section 5.

4. Changes to subtidal morphology (1991 to 2008)

4.1 ANALYSIS

Using the historical collector charts identified in Section 2, three cross-sections were extracted across the estuary. The cross-sections were taken at 500m spacings and are numbered 0, 5 and 10. Cross-sections 5 & 10 tie in with intertidal profiles 5 & 10, and Cross-section 0 is located approximately 200m downriver of profile 1.

Figures 30 to 32 show the bathymetry relative to Chart Datum. Figures 33 to 35 show the three cross-sections converted to Ordnance Datum (Chart Datum is 3.9m below Ordnance Datum at this location).

4.2 SUBTIDAL MORPHOLOGY

In the region between HIT and HST, the Humber Estuary is approximately 4.5 km wide. Crossing the estuary from south to north the region is characterised by Whitebooth Road and Halton Middle to the west and Foul Holme Channel to the East of Foul Holme Spit. Approximately 1km from HIT are Spoil Grounds.

The main channel can be seen on the western side of the estuary with the deepest section being along side the HIT and nearby developments. Unfortunately, there is data missing from both the 2000 and 2004 surveys, within this deep region, showing a maximum depth of -10 m CD. The 2008 survey shows greater coverage of this area, with depths extending down to –14 m CD close to the HIT development.

4.3 CHANGES TO SUBTIDAL MORPHOLOGY

Figures 33-35 shows that all three of these sections show movement of the estuary bed and the position and extent of the Foul Holme Spit.

Cross Section 0 is positioned to extend through the HIT development and adjacent berth pockets. The cross sectional shape shows a very steep foreshore on the western bank, with a more gradual reduction of depth to Foul Holme Spit two-thirds of the distance across the estuary. It is possible that some deepening of the main channel has occurred from 2000, and the section is close to the deposit grounds (HU060) but there is no clear progression between the years. It also appears that Foul Holme Spit has reduced in height slightly from the 1991 and 1996 levels.

Cross Section 5 is positioned to line up to a similar position as Profile 5. This profile shows the deepest depths found in the 1991 chart down to – 15m ODN at a chainage of about 700m. This deepest part can be seen to gradually fill in over the years from 1991 to 2008. Further across the profile however, the channel is found to deepen between a chainage of about 1500 to 2000m. In a similar way to cross section 0 Foul Holme Spit is found to reduce in height and area over the period considered.

Finally Cross Section 10 the furthest north west of the site, shows again a similar overall estuary profile, however with reduced overall depths compared with the other two cross sections. No clear pattern of change can be detected from the channel depth over the period but again Foul Holme Spite appears to have reduced in height between 2004 and 2008.

5. Interpretation and Assessment

5.1 CHANGES TO INTERTIDAL MORPHOLOGY

It was found from the LiDAR data that a clear trend of accretion was evident in the intertidal foreshore. This accretion caused foreshore levels to increase, particularly higher up on the intertidal, and mean low water levels to be pushed further out into the estuary.

Areas were calculated in hectares for four of the different years of intertidal LiDAR data (with a regular 3-year interval). It can be seen that for all sea levels considered the area of intertidal above these levels increased between 2001 and 2010. This is supported by the graphical representation of the data in Figure 36.

Table 3 Area changes in the intertidal

		Area (hectares)			
		2001	2004	2007	2010
MHWS	+3.4m	0.03	0.04	0.03	0.05
MHWN	+1.9m	3.3	6.0	9.1	19.0
MSL*	0.25m	15.6	19.0	25.9	36.1
MLWN	-1.3m	30.0	32.2	42.4	50.6
other	-2m	40.1		53.0	59.0

* Used 0.25m as approx MSL

Whilst no "control sample" exists to assess changes to intertidal area occurring elsewhere in the Estuary over the same period, the changes to the intertidal are mainly in response to construction of HIT.

Overall, 660,000m^3 of sediment was deposited in the study area between 2001 and 2010. This led to raised intertidal levels over an area of approximately 60 hectares, with an increase in intertidal area above -2m ODN (1m above MLWS) of 20 hectares. Examination of ABP bathymetric collector charts shows little evidence of any changes to the total area of intertidal above Chart Datum.

5.2 CHANGES TO SUBTIDAL MORPHOLOGY

Cross-sectional areas were calculated for the three cross sections below a reference plane chosen as MHWS (and cropped where necessary to represent the same cross-sectional width for each Section). The absolute values of the areas are not important, but the changes in cross-sectional areas may be useful to appraise any signals that may present between 1991 and 2008. Figures 33 to 35 show that this is a dynamic part of the Estuary, particularly in the vicinity of Foul Holme Spit.

Tables 4 and 5 show a reasonable consistency in cross-sectional area over the period assessed. However it is seen that Cross-Sections 5 & 10 upriver of HIT were increasing in area between 1991 and 1996, then decreasing in 2000 and 2004. The effect corresponds to an increase in the mean depth (across the entire cross-sections) of 0.3m between 1991 and 1996, followed by a decreasing in mean depth of 0.5-0.7m between 1996 and 2004 (as is visible in Figures 34 and 35). The mean bed level for sections 5 & 10 was highest in 2004. Areas for 2008 were not calculated as the data did not extend over the same width. However, Figures 34 and 35 show the bed levels to have returned to 2000 values where shown.

Table 4 Cross sectional areas for sections 0, 5 and 10

	1991	1996	2000	2004
Cross Section 0	33,000	33,400	38,400	34,100
Cross Section 5	37,400	38,400	37,400	36,300
Cross Section 10	36,300	37,300	36,600	35,700

Table 5 Percentage changes to cross-sectional areas since 1991

	1996	2000	2004
Cross Section 0	1.2%	6.7%	3.3%
Cross Section 5	2.7%	0.0%	-2.9%
Cross Section 10	2.8%	0.8%	-1.7%

The Environment Agency has postulated a nine year cycle for the subtidal morphology in this Reach of the Humber Estuary (S. Manson, w.o.m.). It is possible that some evidence for this is contained within these Figures but the period over which the data have been considered is too short to confirm with any confidence.

6. Conclusions

Morphological changes have been assessed for the Humber Estuary in relation to the construction of HIT. The following conclusions may be made:

6.1 INTERTIDAL

- Overall, 660,000m^3 of sediment was deposited onto the intertidal upriver of HIT between 2001 and 2010. This led to raised levels over an area of approximately 60 hectares, with an increase in intertidal area above -2m ODN (1m above MLWS) of 20 hectares. Examination of ABP bathymetric collector charts shows little evidence of any changes to the total area of intertidal above Chart Datum.
- The rate of intertidal accretion shows no sign of slowing down, nine years after construction.

6.2 SUBTIDAL

- The subtidal morphology of this Reach of the Humber Estuary is dynamic, showing up to 6m vertical changes in the vicinity of Foul Holme Spit.
- West of Foul Holme Spit, the variability in seabed levels for Cross-Sections 5 and 10 is generally within 1m between 1991 and 2008.
- East of Foul Holme Spit the variability in seabed levels for Cross-Sections 5 and 10 is generally up to 2-3m, connected with the large changes that may be observed to Foul Holme Spit.
- Cross-Section 0 through the HIT development appears to show considerable variability between 1991 and 2000, particularly focused in the region around Foul Holme Spit. Between From 2000 to 2004 the Spit decreases in level. The variability in seabed levels appears to be reduced, through this Cross-Section, from 2000 onwards. It should be noted that the Cross-Section immediately west of Foul Holme Spit passes close to the deposit grounds.
- The appearance of the seabed for Cross-Section 0 (extending from the HIT) shows more small scale variability in level, perhaps indicative of the formation or movement of larger bedforms at this location than across the other two sections.

6.3 IMPLICATIONS FOR PREDICTING LONGER TERM CHANGE IN RESPONSE TO AMEP

The changes on the intertidal in response to HIT appear to be continuing 9-10 years after construction. The rate of increase in area above the -2m ODN contour has begun to slow down but the vertical accretion rates within this zone have not. The changes provide a useful picture of likely longer-term change to intertidal northwest of AMEP. The changes indicate a stable form northwest of AMEP would not be reached for many years, and would ultimately take the form of a new low water line coming off the end of the quay/dredged sideslopes and extending approximately parallel and seawards of the existing low water line up to HST. Beyond HST, the future evolution is less predictable, because the presence of HST may influence the longer term morphology so long as it is operational.

Figures

Figure 1 Location plan showing location of HIT, HST, and proposed AMEP

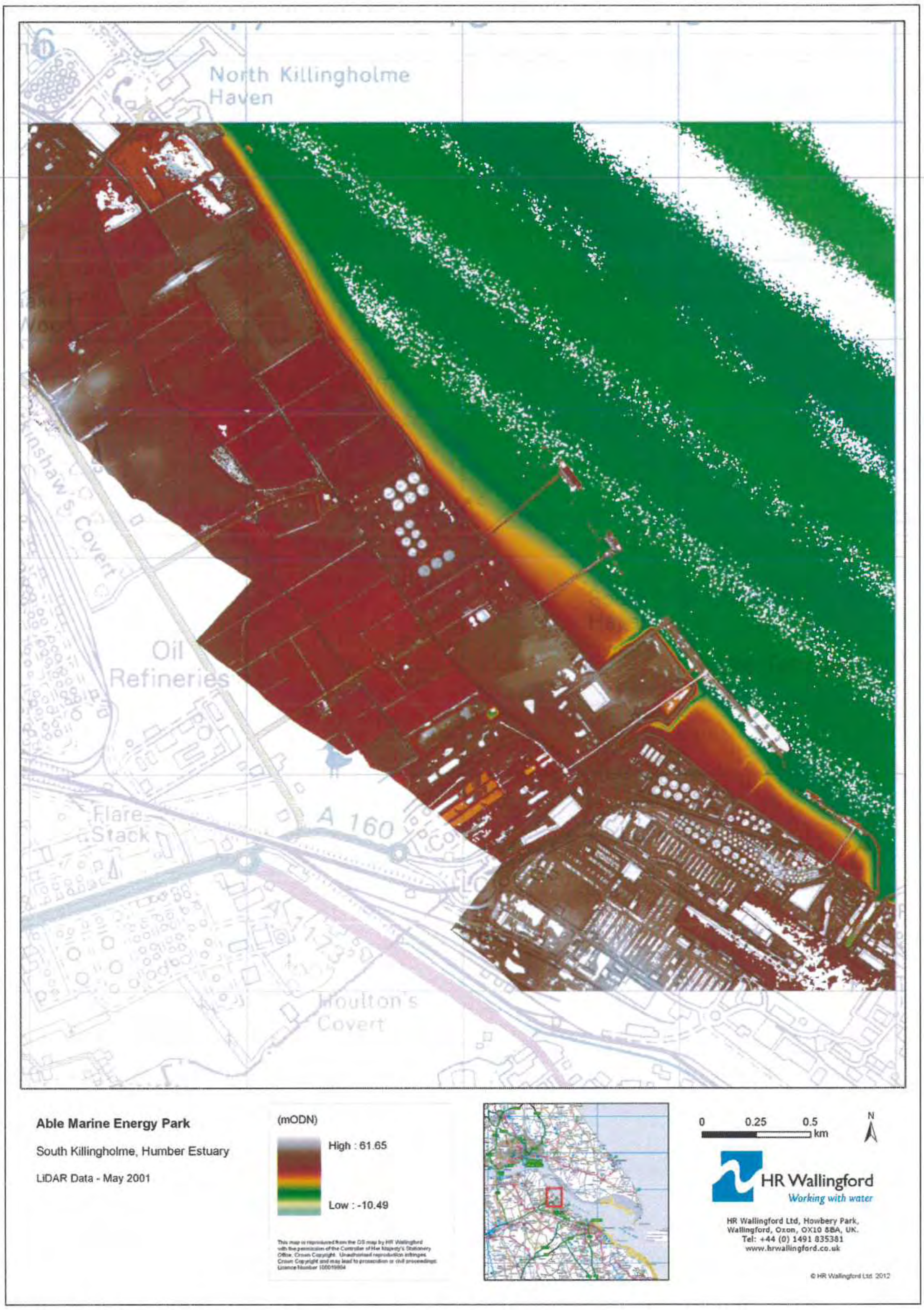

Figure 2 Intertidal foreshore LiDAR data for 2001

Figure 3 Intertidal foreshore LiDAR data for 2002

Figure 4 Intertidal foreshore LiDAR data for 2003

Figure 5 Intertidal foreshore LiDAR data for 2004

Figure 6 Intertidal foreshore LiDAR data for 2005

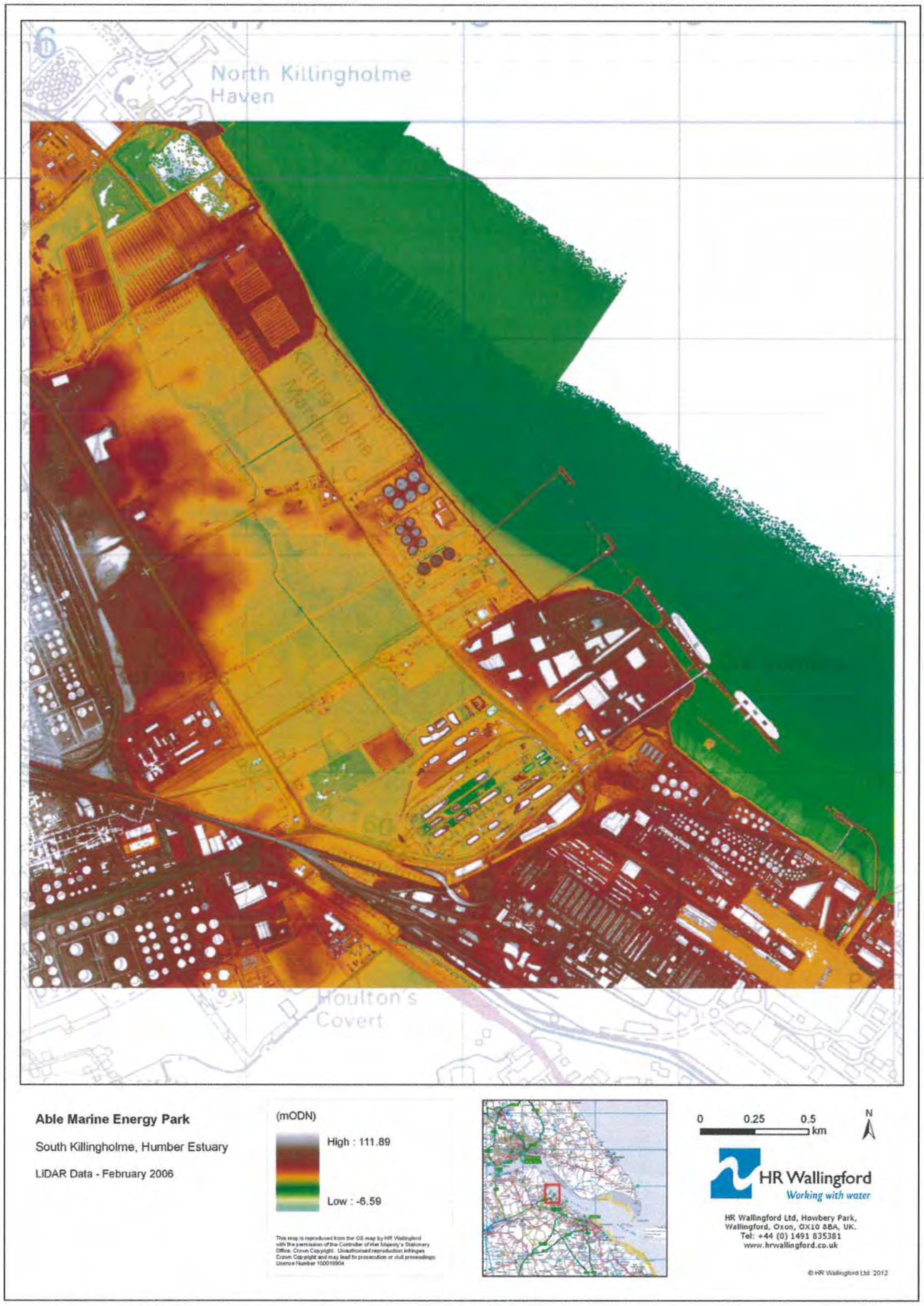

Figure 7 Intertidal foreshore LiDAR data for 2006

Figure 8 Intertidal foreshore LiDAR data for 2007

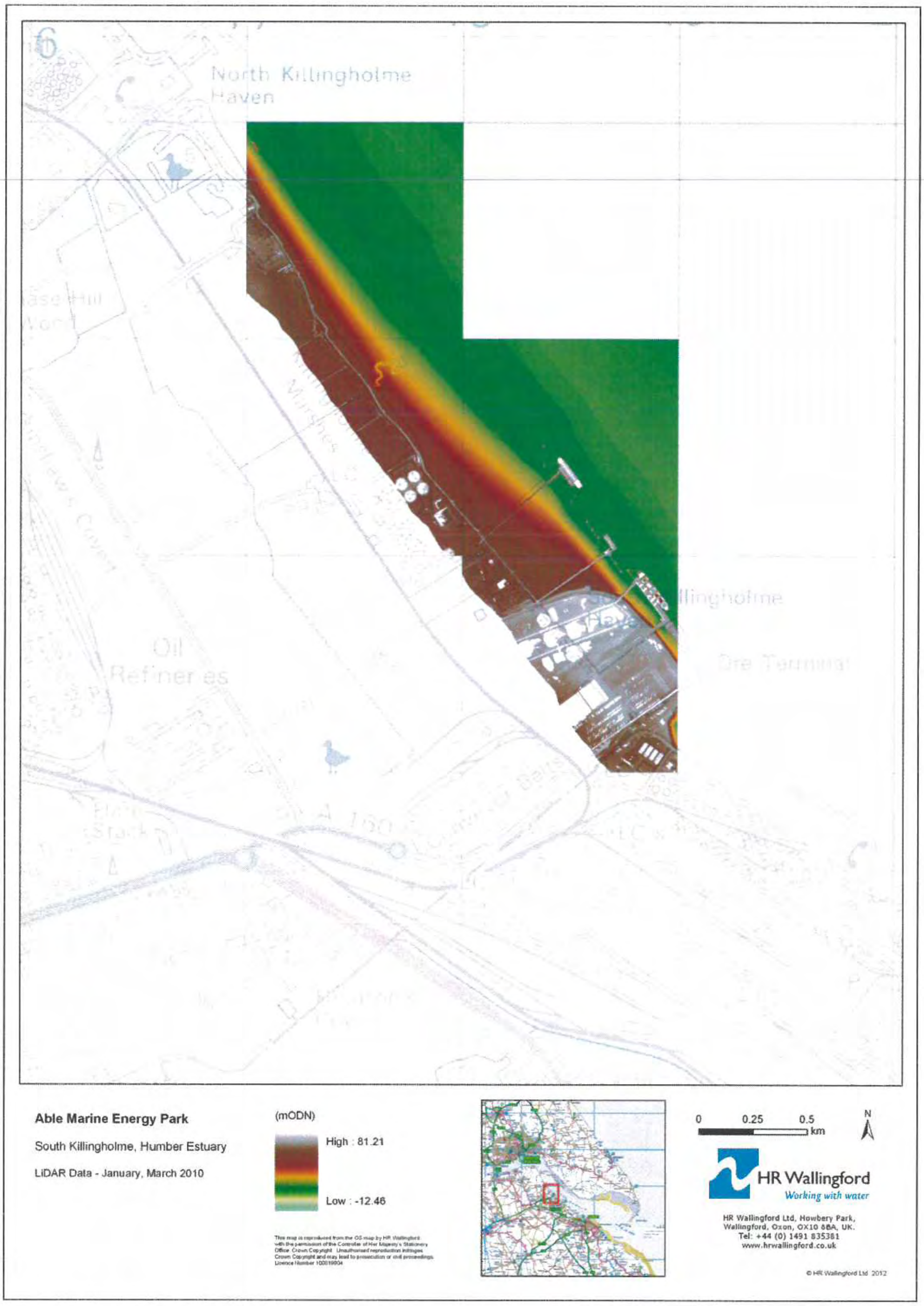

Figure 9 Intertidal foreshore LiDAR data for 2010

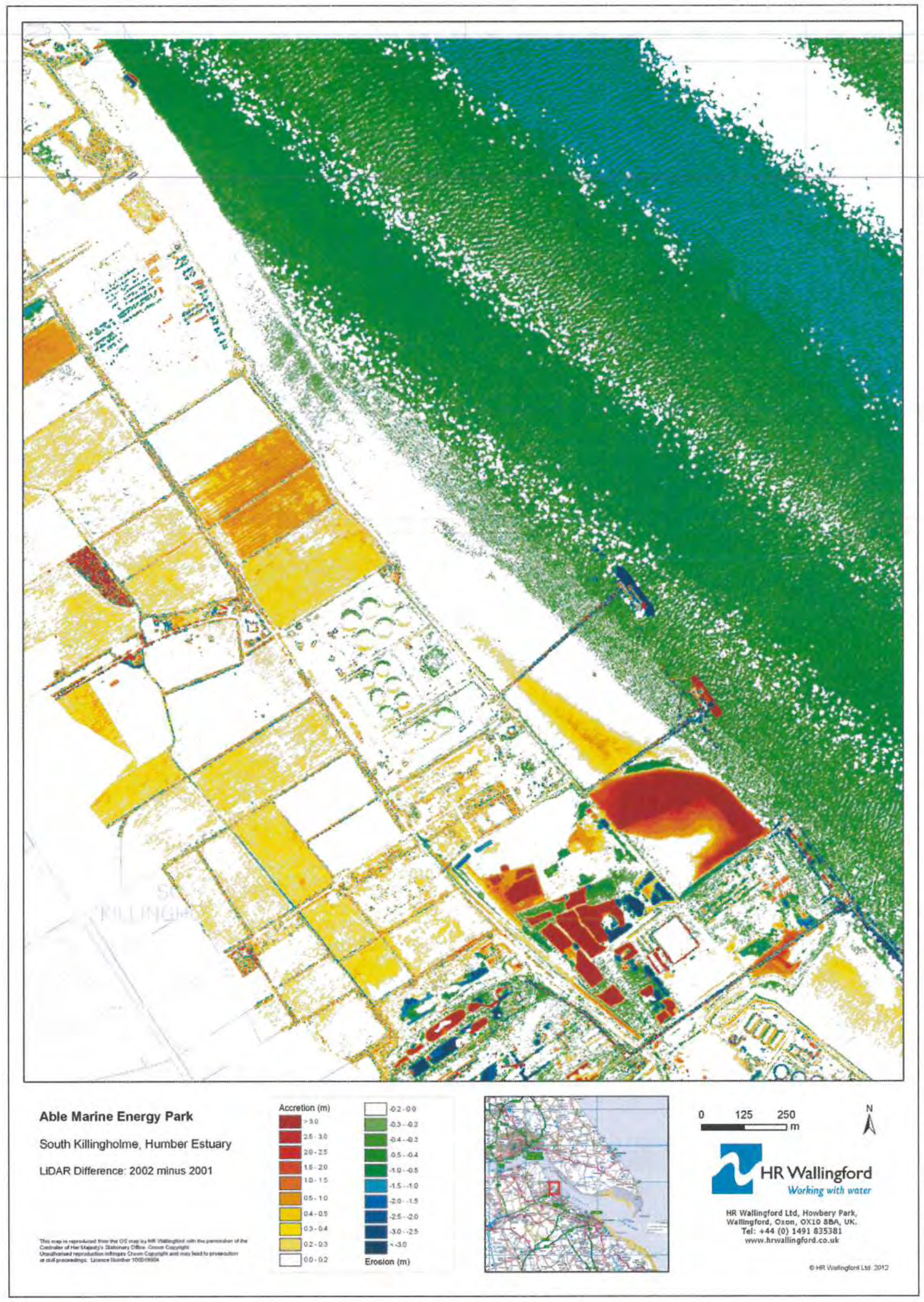

Figure 10 LiDAR differences between 2002 and 2001

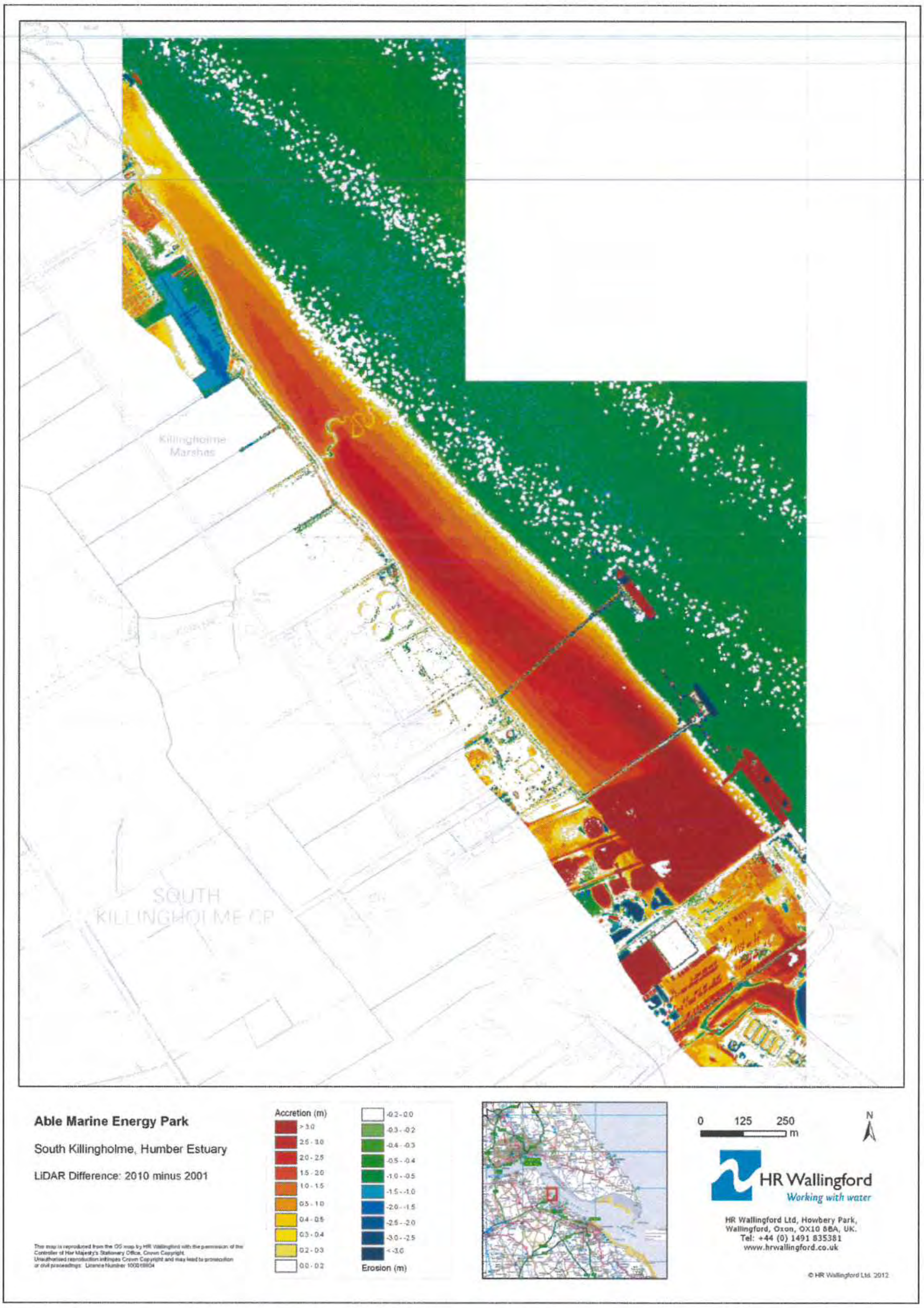

Figure 11 LiDAR differences between 2010 and 2001

Figure 12 Intertidal foreshore from HST (left) to HIT (right), May 2012

Figure 13 Intertidal foreshore looking towards E.On and Centrica Intakes (May 2012)

Figure 14 Drainage channel located at Profile 8 (May 2012)

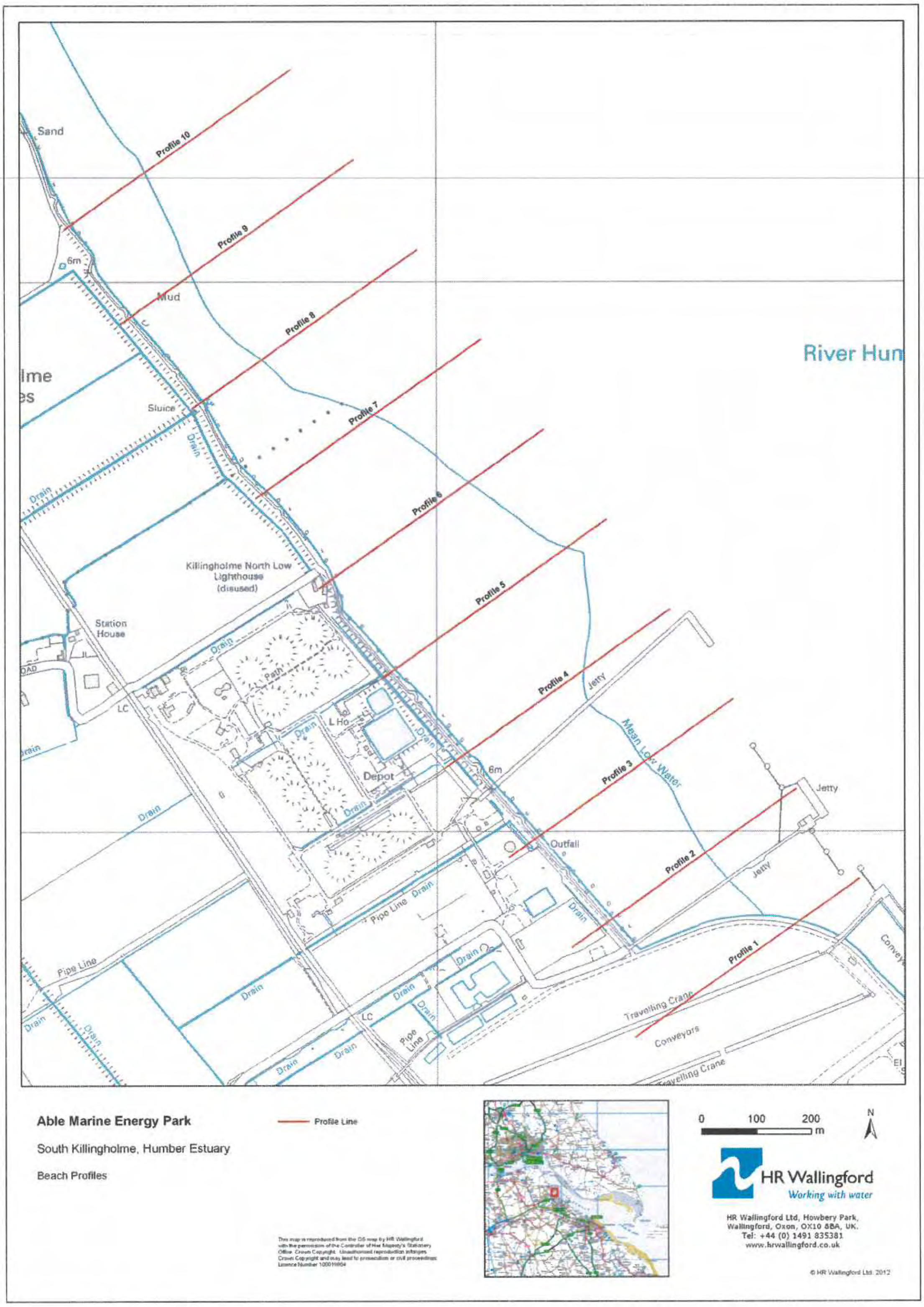

Figure 15 Location of intertidal foreshore LiDAR and Bathymetric profiles

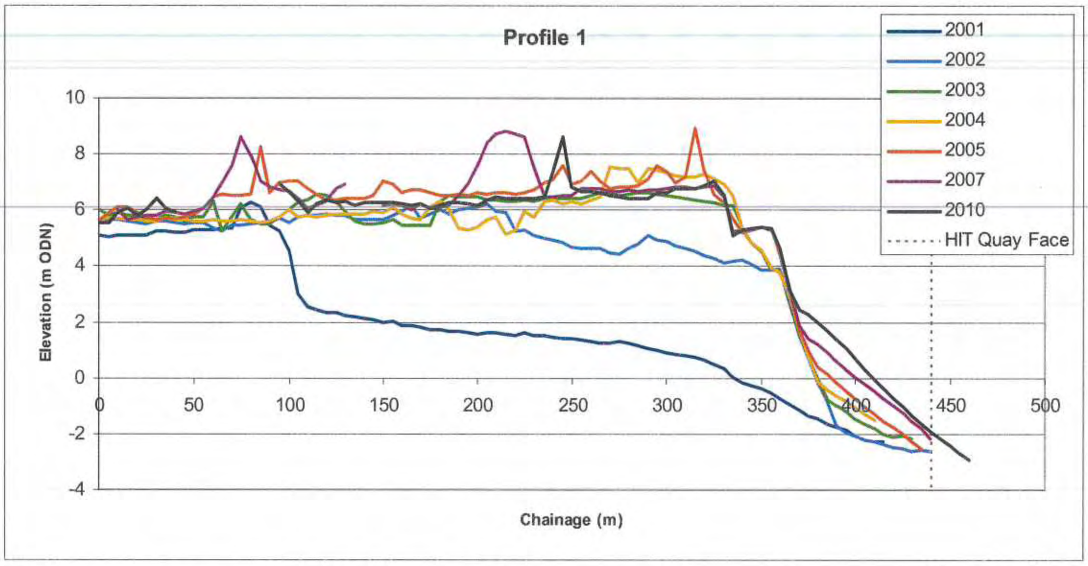

Figure 16 Intertidal foreshore LiDAR data for Profile 1

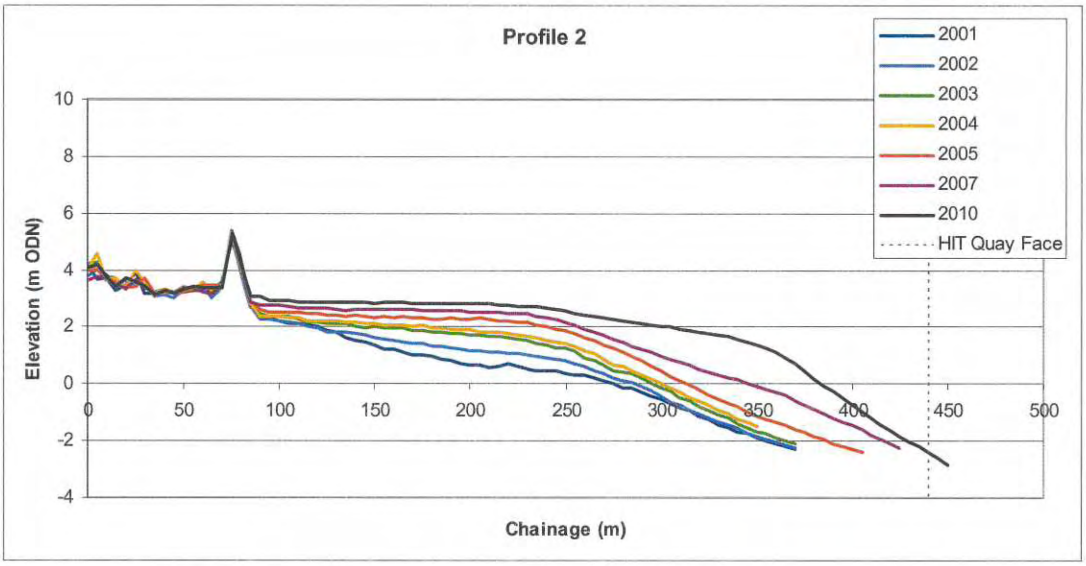

Figure 17 Intertidal foreshore LiDAR data for Profile 2

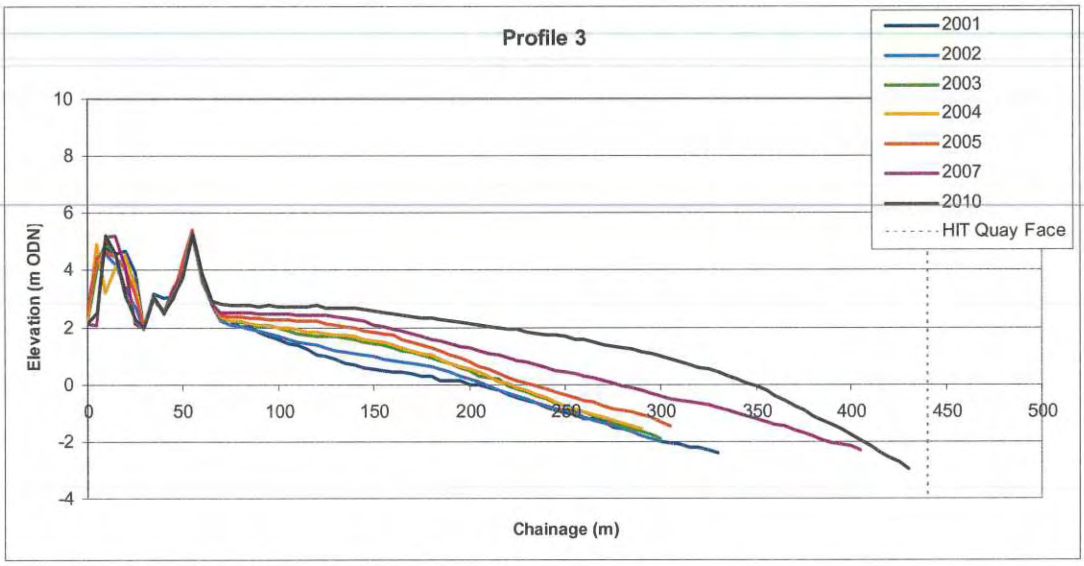

Figure 18 Intertidal foreshore LiDAR data for Profile 3

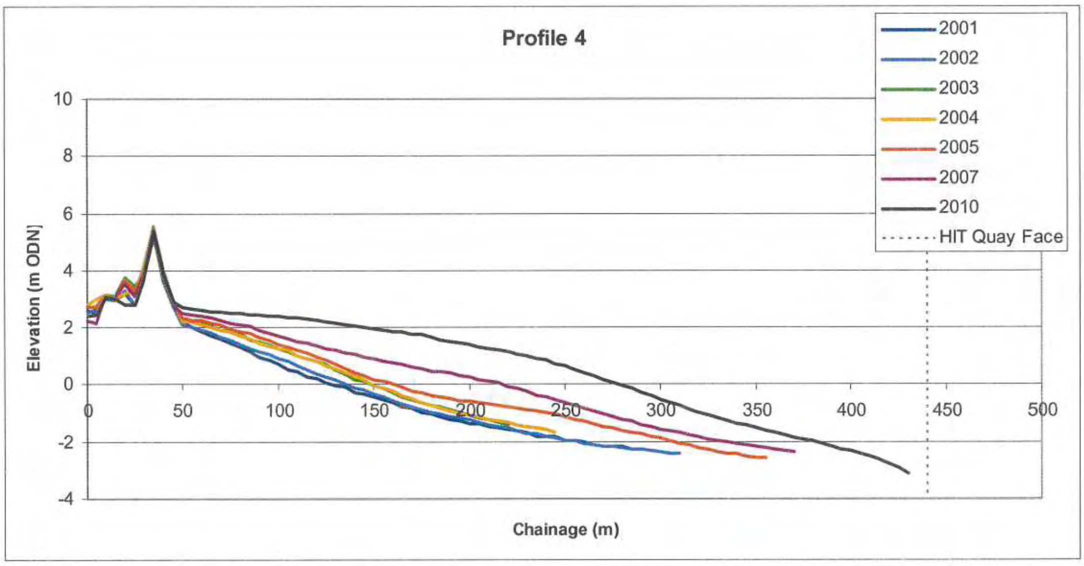

Figure 19 Intertidal foreshore LiDAR data for Profile 4

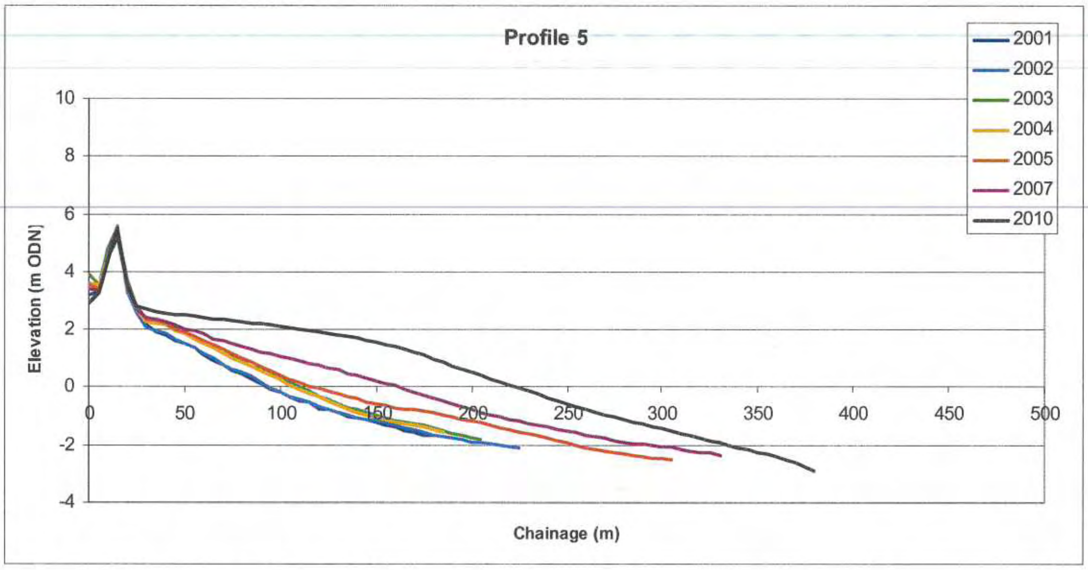

Figure 20 Intertidal foreshore LiDAR data for Profile 5

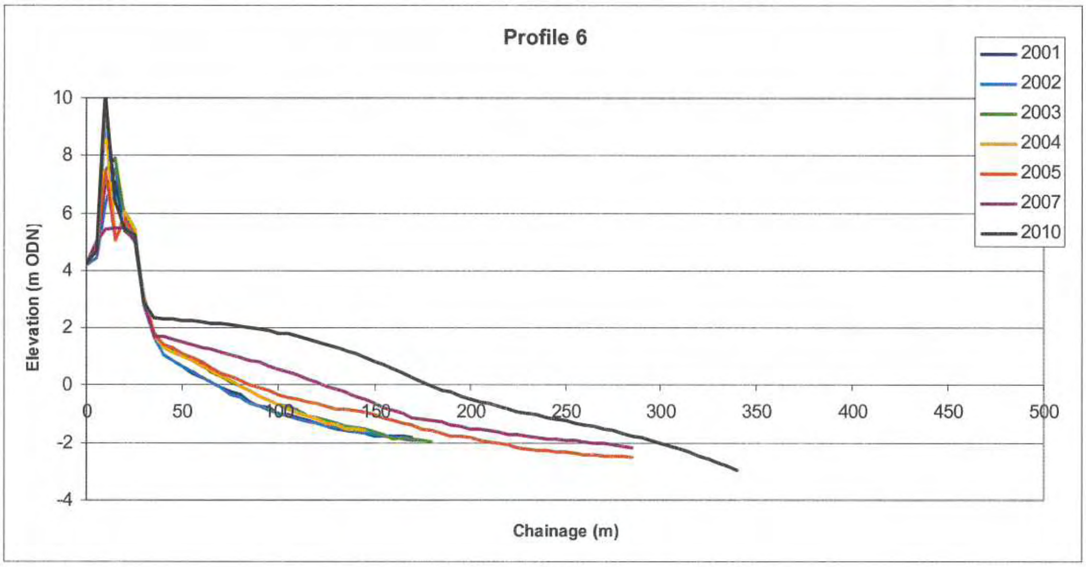

Figure 21 Intertidal foreshore LiDAR data for Profile 6

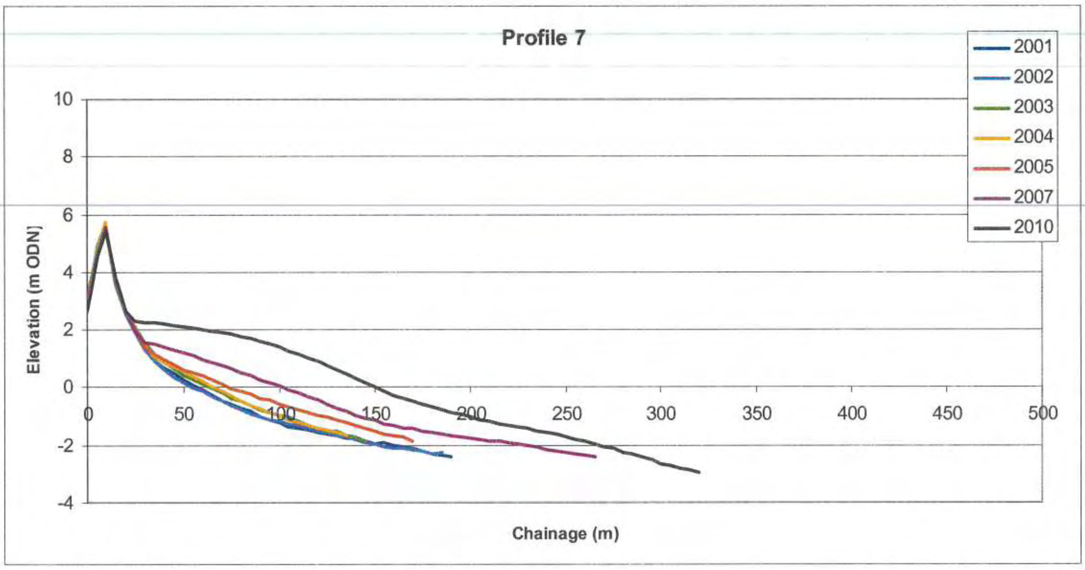

Figure 22 Intertidal foreshore LiDAR data for Profile 7

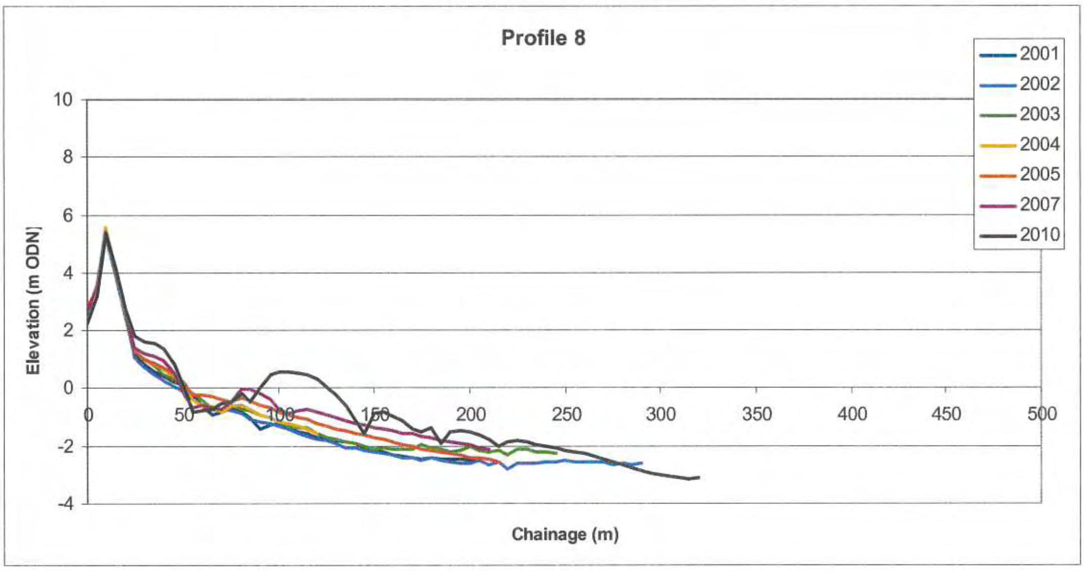

Figure 23 Intertidal foreshore LiDAR data for Profile 8

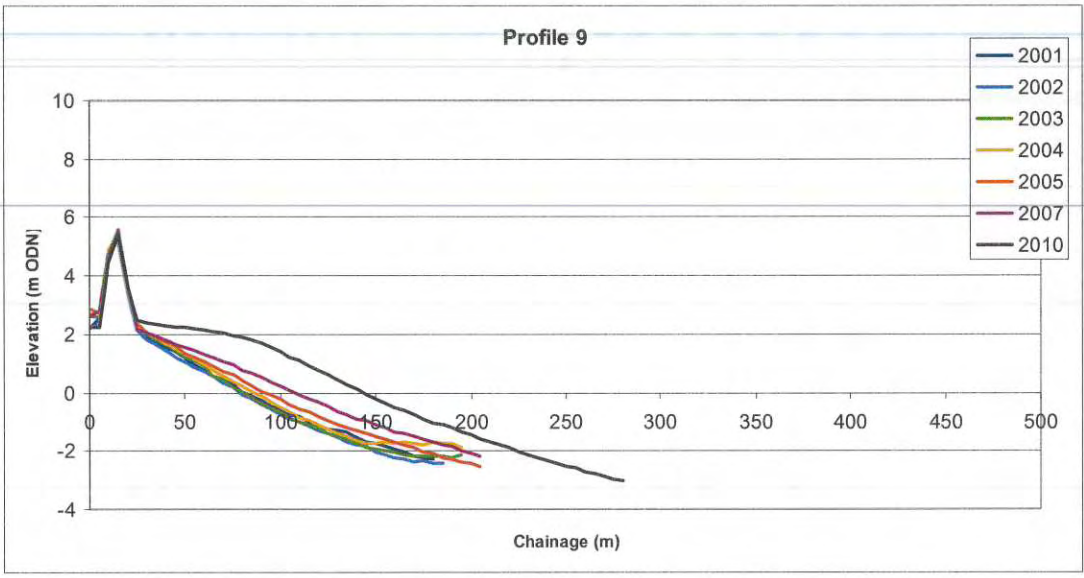

Figure 24 Intertidal foreshore LiDAR data for Profile 9

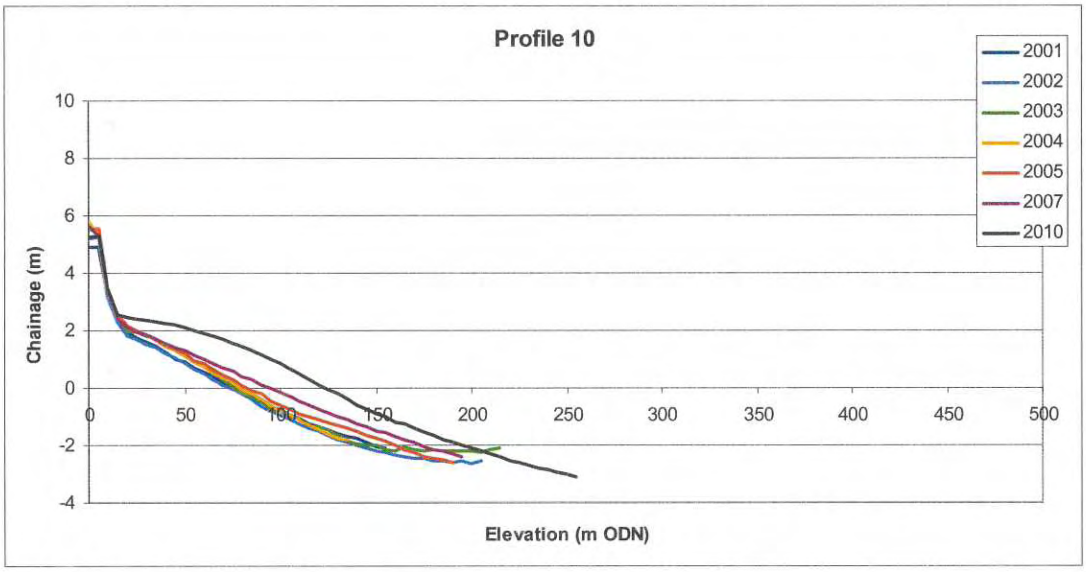

Figure 25 Intertidal foreshore LiDAR data for Profile 10

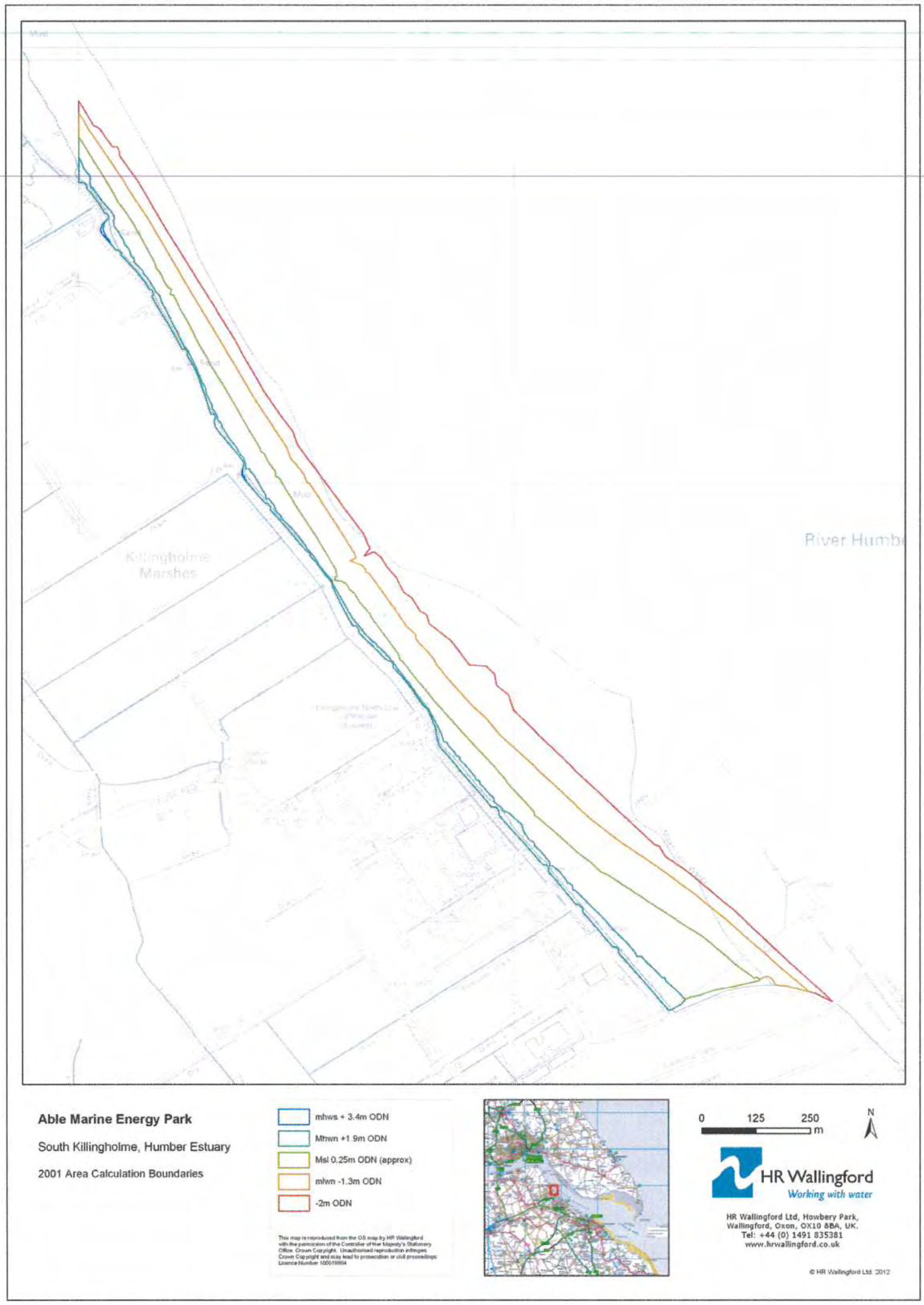

Figure 26 Tide contour lines derived from LiDAR 2001

Figure 27 Tide contour lines derived from LiDAR 2004

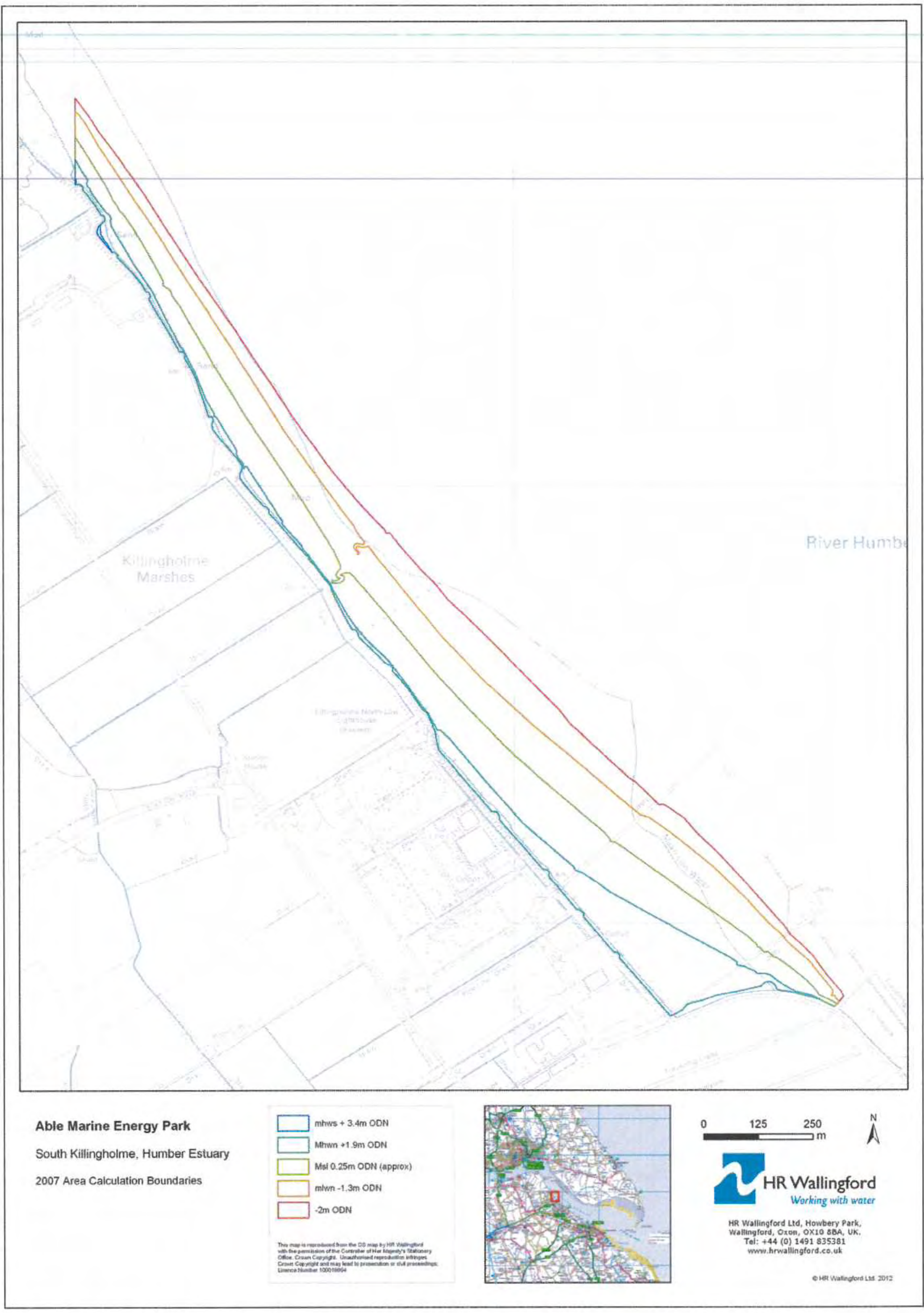

Figure 28 Tide contour lines derived from LiDAR 2007

Figure 29 Tide contour lines derived from LiDAR 2010

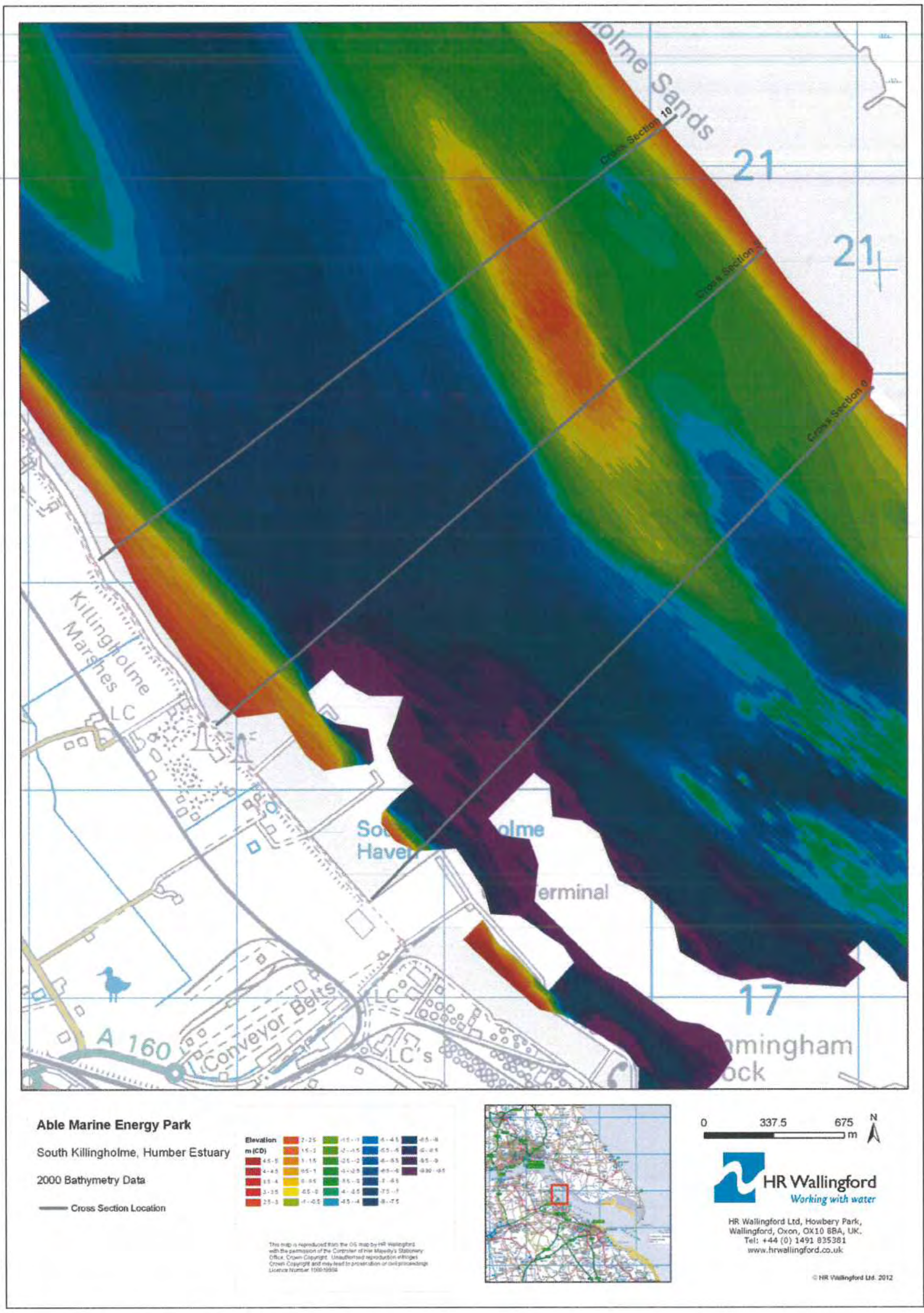

Figure 30 Bathymetric Data for 2000

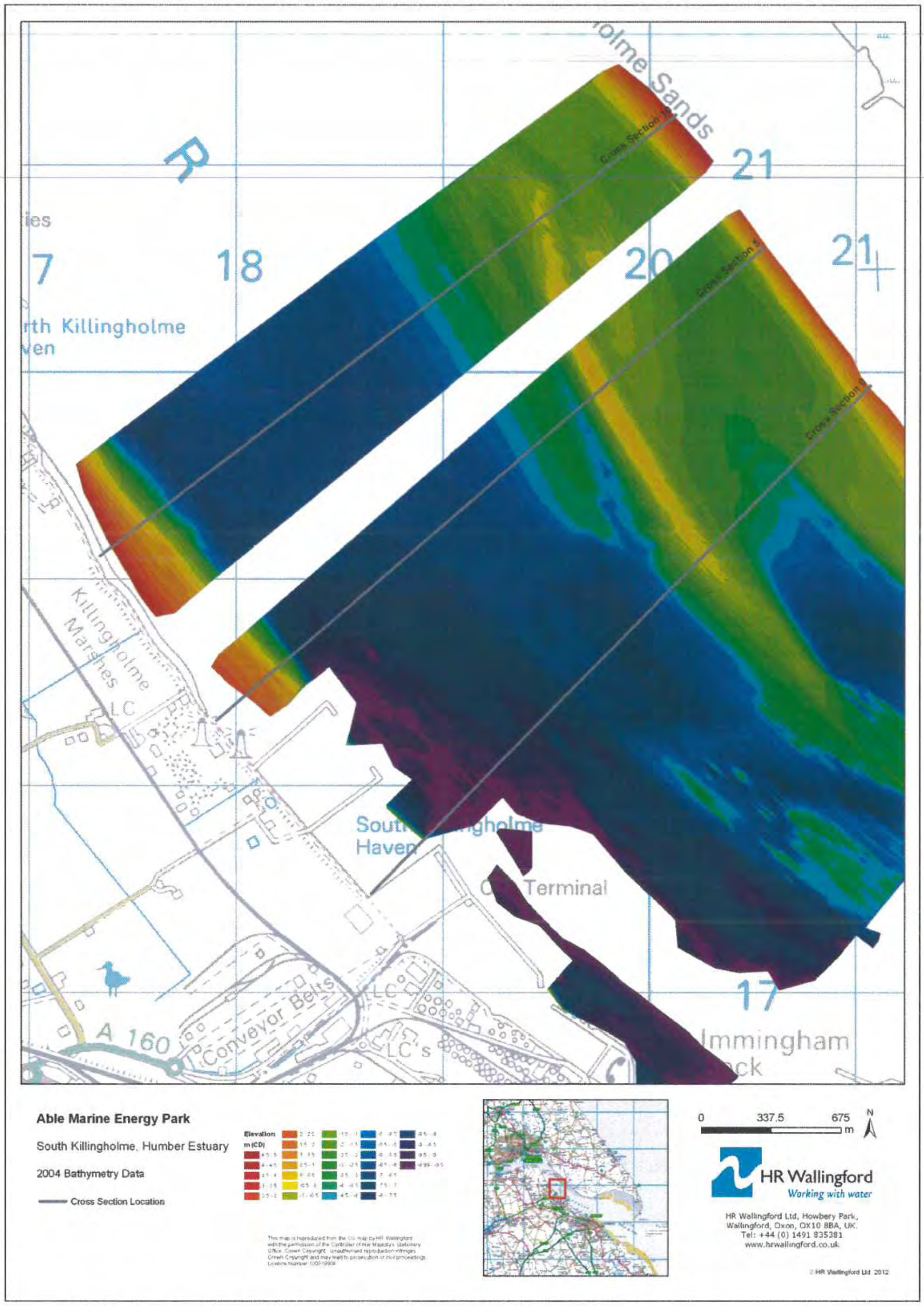

Figure 31 Bathymetric Data for 2004

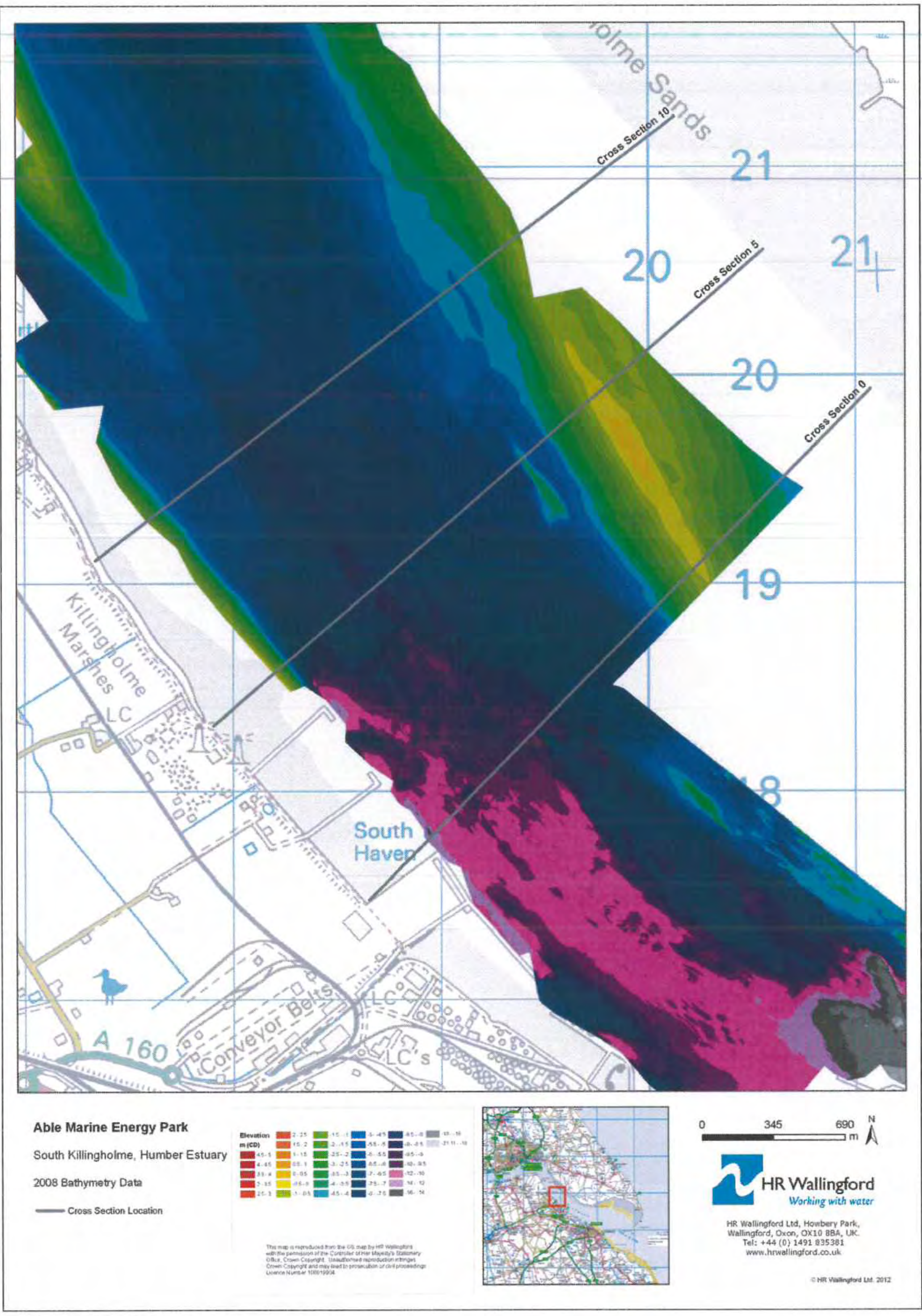

Figure 32 Bathymetric Data for 2008

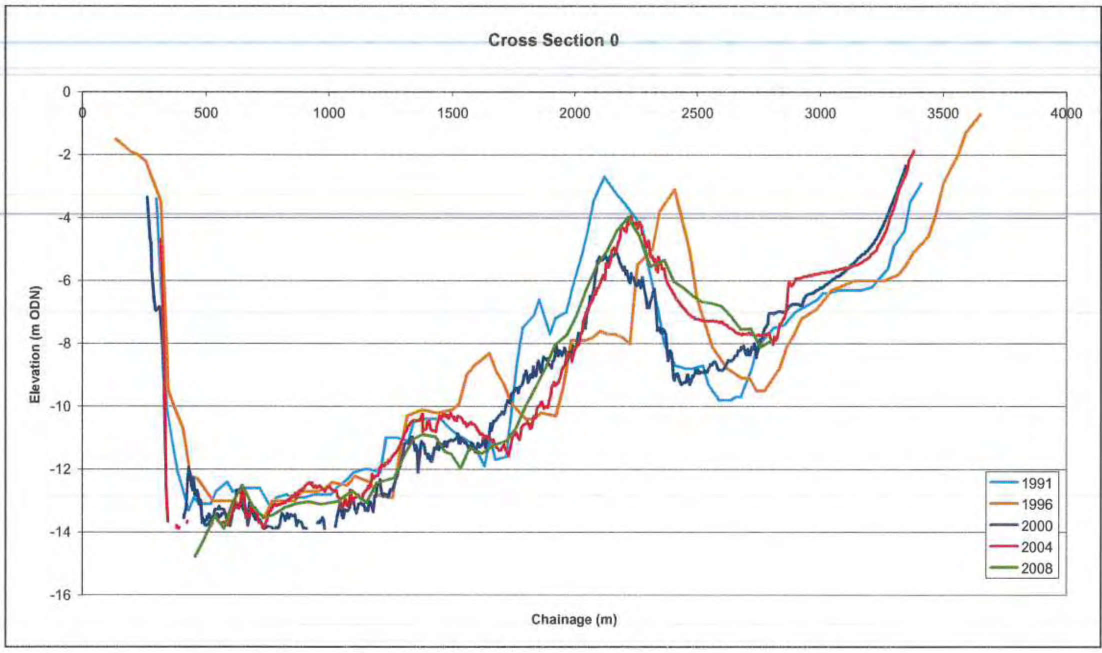

Figure 33 Estuary bathymetry for 1991 to 2008 at Cross Section 0

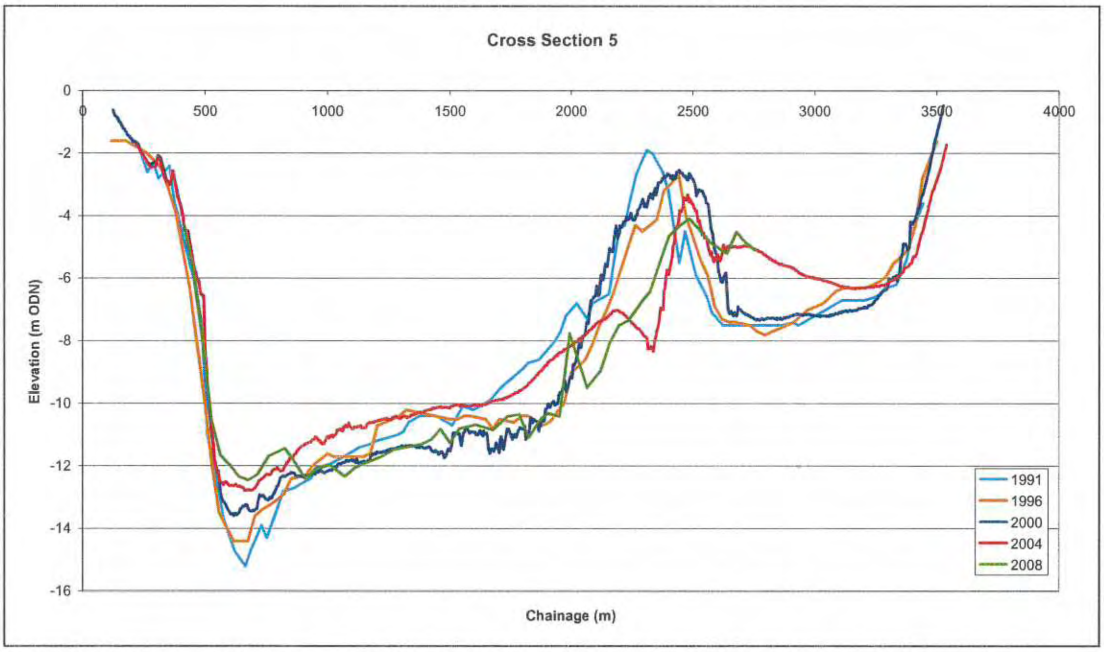

Figure 34 Estuary bathymetry for 1991 to 2008 at Cross Section 5

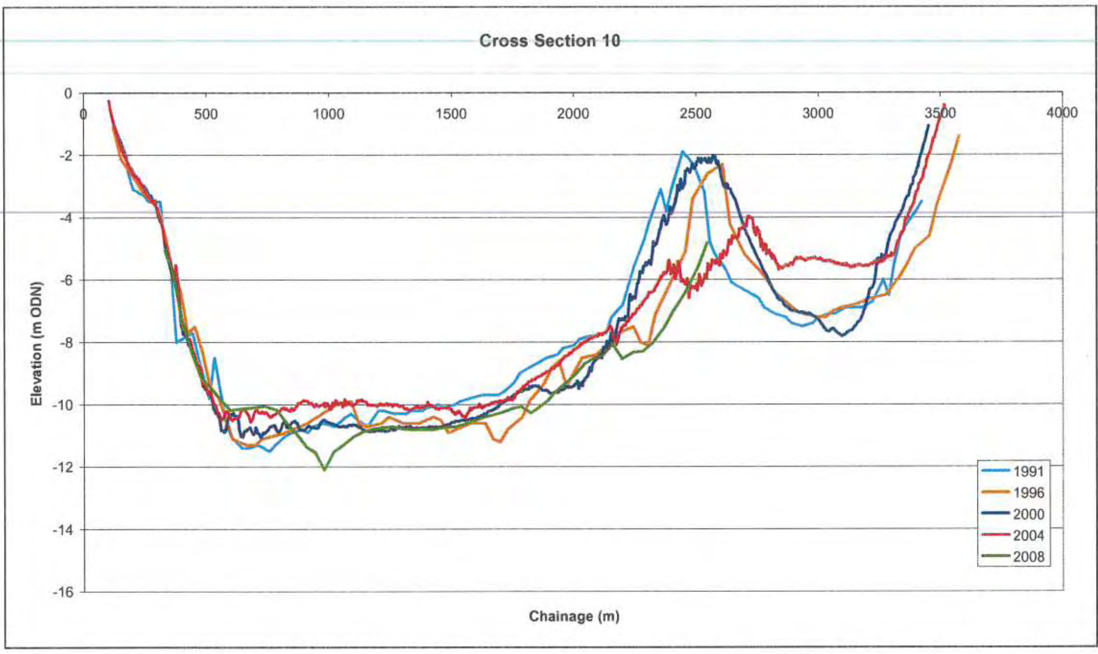

Figure 35 Estuary bathymetry for 1991 to 2008 at Cross Section 10

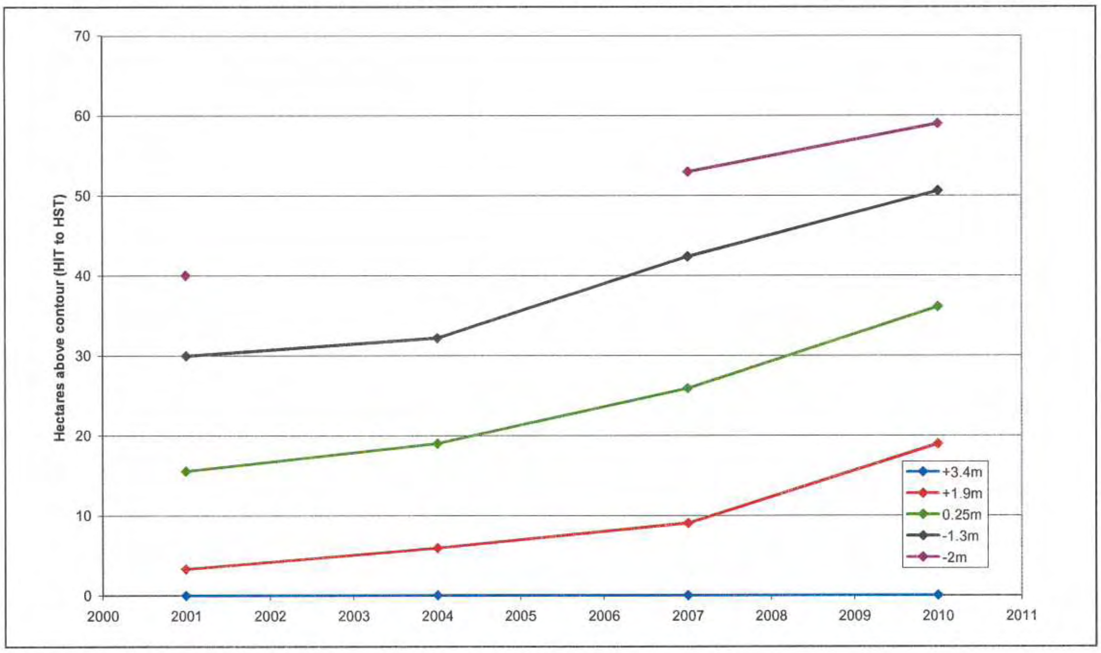

Figure 36 Area above height contours from HIT to HST