Annex 32.5

Sedimentation, Erosion and Saltmarsh Growth

(Black & Veatch)

Cherry Cobb Sands Compensation Site

Sedimentation, Erosion and Saltmarsh Growth

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1 INTRODUCTION

1.1 SITE DESCRIPTION

1.1.1 Able UK propose a Marine Energy Park (AMEP) on the south bank of the Humber. This is expected to require compensation for the loss of designated estuary habitat and bird feeding areas. A managed realignment on the north bank of the Humber at Cherry Cobb Sands is proposed to meet this compensation requirement.

1.1.2 The size of the required intertidal habitat compensation site has been agreed as 100 ha. The location and general arrangement of the site is shown in Figure 1. The existing ground level within the Compensation Site is fairly uniform and close to 2.5 mAOD. The excavation required to provide fill for the flood defence embankment and to profile the ground levels within the site required to maximise the long term creation of mudflat could change this ground level by up to 1 m locally.

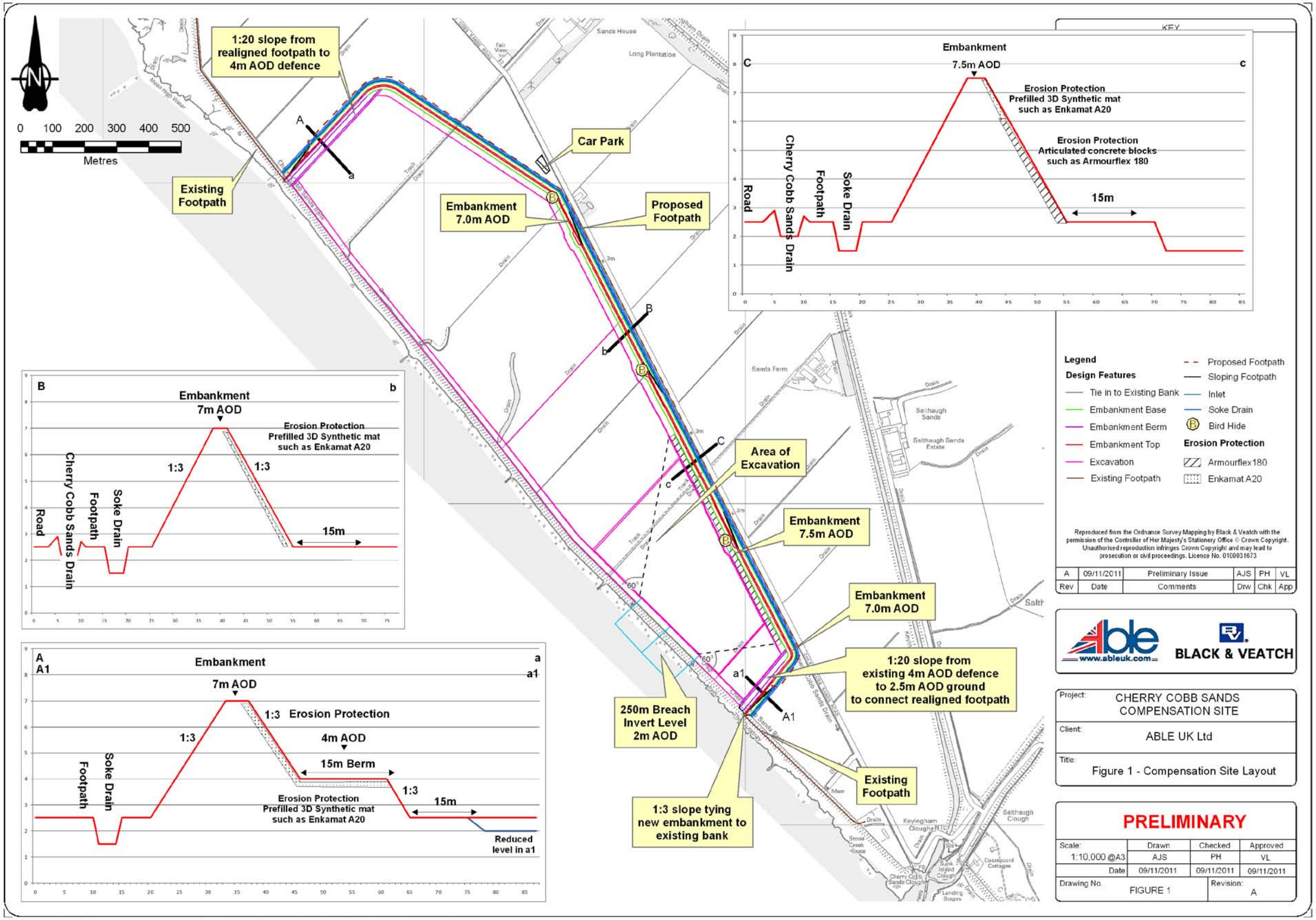

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Figure 1 Proposed 100ha Compensation Site arrangement

1.2 FORESHORE TOPOGRAPHY AND MODEL LIMITS

1.2.1 The outflow from the Cherry Cobb Sands compensation site is expected to flow into a large creek named for this study as "Cherry Cobb Sands Creek" that runs parallel to and about 80m seaward of the existing flood defences. The topography of the creek and foreshore is shown on Figure 2 with the local model boundaries. Cherry Cobb Sands Creek drains to the south and picks up drainage flowing through the four sluices at Stone Creek and continues parallel to the coast for a further 2 to 2.5km before turning seaward and entering the low water channel of the Humber. The southernmost part of the creek is believed to be fairly dynamic. Foul Holme Sands separates Cherry Cobb Sands Creek from the main Humber low water channel.

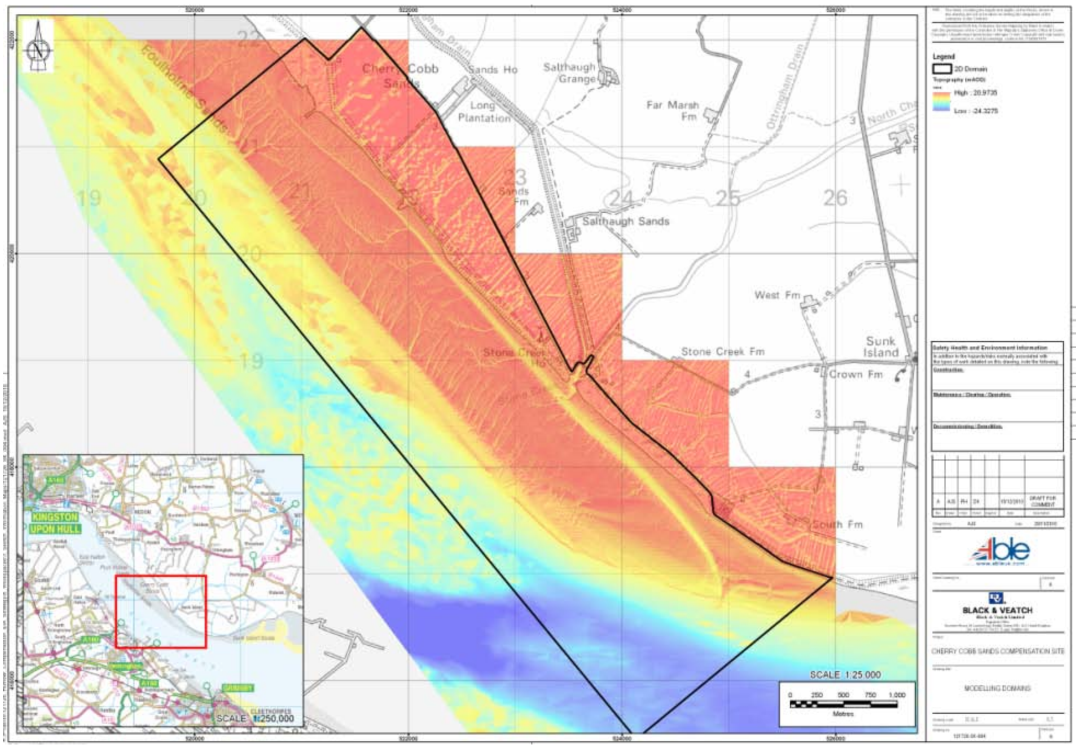

Figure 2 Foreshore topography near Cherry Cobb Sands

1.3 HUMBER TIDAL CONDITIONS

1.3.1 The frequency of occurrence of specified high tide levels at Immingham on the south bank of the Humber estuary almost opposite the proposed Compensation Site is shown on Table 1. Almost 60% of tides are high enough to inundate the existing ground levels at the site, though this does vary by ±5 % from year to year because of differences in tidal conditions. Only around 12 ± 3% of tides have a high water level of at least 3.4 mAOD the level of MHWS (Mean High Water Springs) which is enough to inundate the site by at least 0.9m.

Table 1 Frequency of occurrence of high tides at Immingham 1996, 2008-2011

Level mAOD	1996	2008	2009	2010	2011	Average (5 years)	Average (3 years) 1996, 2008, 2010
Percent >2.5	64.0	55.5	56.7	58.6	59.6	58.9	59.4
Percent ≥ 3.0	41.2	32.3		34.8			36.1
Percent ≥ 3.4	15.4	9.6	10.8	11.2	11.9	11.8	12.1
Percent ≥ 3.8	2.5	0.4	1.3	2.6	2.8	1.9	1.8
Percent ≥ 4.0	0.3	0.0		0.7			0.3

2 EXPERIENCE FROM HUMBER MANAGED REALIGNMENT SITES

2.1 KEY FEATURES OF HUMBER MANAGED REALIGNMENT SITES

2.1.1 Four managed realignment sites have been developed in the Humber. Key details of these sites are set out in Table 2. The sites at Paull Holme Strays and Welwick are both on the north bank of the Humber and within 15km of the proposed Compensation Site at Cherry Cobb Sands. The sites at Alkborough and Chowder Ness are both upstream of the Humber Bridge on the south bank of the Humber. This information has been abstracted from Refs 1, 2 and 3.

Table 2 Humber managed realignment sites

Site Name	Location in Humber	Area (ha)	Year	Type of breach
Paull Holme Strays	Middle estuary	80	2003	150 m and 50 m breaches Approx 2100 m of flood bank remains
Chowder Ness	Inner estuary	15	2006	570m breach 200m of flood bank remains
Welwick	Outer estuary	54	2006	1400m of flood bank removed; Two approx 130 m breaches made through fronting saltmarsh
Alkborough	Inner estuary	370	2006	20 m breach and 1500 m lowered bank Approx 3000 m of flood bank remains

2.1.2 The four sites each adopted different arrangements for allowing the tide to enter the site. At Paull Holme Strays two breaches in the flood embankment were made to below the lowest natural ground level within the site to ensure drainage in the first year. The remainder of the flood embankment remains in place. Extrapolation from post breach monitoring suggests minimum ground levels within the site were probably around 1.5m AOD prior to breaching. Waves entering the site through the 150 m long breach are likely to have been generated over 3.5 km fetch to the south west.

2.1.3 At Welwick, the flood embankment fronting the estuary was removed from the whole site. However, as the site was fronted by saltmarsh which had an average level of 3.2 mAOD (Hemmingway *et al.*, 2008) two sections of saltmarsh were removed to allow tidal inundation and drainage of the site which had a minimum ground level immediately prior to breaching of 1.75 mAOD (ABPmer, 2010). One of the objectives of the site was to increase energy levels within the site to improve the probability that mudflat habitat will be maintained. The site is open to greater than 10km fetch to the south and southeast which would encourage moderate wave activity at high tide. Unfortunately, while the remainder of the fronting saltmarsh remains in place its high level will prevent the wave energy present outside the site from entering on all but the highest tides when the saltmarsh may be submerged by up to 0.5m.

2.1.4 The design for the small realignment at Chowder Ness followed similar principles to Welwick (Hemmingway *et al.*, 2008). Since there was no fronting saltmarsh at Chowder Ness, tidal waters are now able to enter the site over about 75% of the frontage. The long breach and absence of obstructions to seaward allows wave energy to enter this site and increases the probability that mudflat habitat will be maintained. The Chowder Ness site is also exposed to moderate wave energy as there is a 6 – 10 km fetch to the west and northwest.

2.1.5 The 20 m main breach at Alkborough is very short to limit the reduction in high water level on normal spring tides. This small breach suppresses the tidal range inside the site. The 1500m length of lowered defence is set above the level of Highest Astronomic Tide to allow water during extreme tidal events to flood this site and so reduce extreme tide levels upstream. This lowered section is not overtopped during normal tides. Very little wave energy can enter the site through the narrow breach so the majority of the wave energy within this site will be internally generated.

2.2 *ACCRETION AT PAULL HOLME STRAYS*

2.2.1 The managed realignment site at Paull Holme Strays was breached in September 2003 at two locations; a 150 m breach of the northern part of the site and a 50 m breach of the southern part of the site. After breaching monitoring was carried out over a 5 year period that terminated in September 2008 with a final monitoring report (Environment Agency, 2009) that discussed the results from the many topics covered. Within this monitoring a major programme of sedimentation and vegetation monitoring was carried out, initially by CEH and latterly by Coastlife (Brown, 2009). The monitoring showed that the site was still developing after five years, and a reduced frequency monitoring programme continues.

2.2.2 The monitoring of sedimentation and vegetation started in May 2004, around 8 months after the site was breached. As a result the monitoring did not directly measure initial sedimentation, but estimated initial ground levels by extrapolating back to September 2003 on the basis of the siltation measured after May 2004. This leads to a small uncertainty in initial ground levels at individual sites, though as the best fit trend lines used to back-extrapolate September 2003 levels were statistically robust with R^2 values>0.99 the confidence in the average estimates of accretion at the site and original ground levels are high.

2.2.3 Analysis shows that the accretion within the Paul Holme Strays site over the first five years is primarily determined by ground level. 36 sites within the realignment were monitored, of which 35 were maintained throughout the 5 years. The levels of these sites were measured in September 2005 and 2008, and grouped into four level classes based on their level in 2005 as shown in Table 3. The average change in ground level within each level group is shown on Table 4. Greater siltation has been experienced at those sites which were initially at a lower level.

2.2.4 At sites that were initially at lower ground levels, the siltation after five years was just less than three times the siltation in the first year. For sites at higher ground levels, with lower initial siltation rates, the siltation over five years was four or five times that experienced in the first year.

Table 3 Level monitoring groups at Paull Holme Strays

Level group (in 2005)	Number of sites	Level range in 2005 mAOD	Level range in 2008 mAOD
<2.0	1	1.95	2.53
2.0-2.3	5	2.17-2.30	2.58-2.78
>2.3-2.6	10	2.32-2.57	2.70-2.86
>2.6-3.0	11	2.65-2.99	2.93-3.18
>3.0-3.5	8	3.05-3.49	3.20 -3.65

Note: From Tables 3.1 and 3.7 from Brown (2009).

Table 4 Average siltation at Paull Holme Strays 2003-2008

Level group (in 2005)	Average ground level of group (mAOD)						Ratio of 5 year to 1 year accretion
	Estimated Sept 2003	Sept 2004	Sept 2005	Sept 2006	Sept 2007	Sept 2008	
<2.0	-	-	1.95	-	-	2.53	
2.0-2.3	1.82	2.05	2.22	2.33	2.40	2.46	2.8
>2.3-2.6	2.18	2.33	2.44	2.51	2.57	2.60	2.9
>2.6-3.0	2.77	2.80	2.83	2.85	2.87	2.89	4.0
>3.0-3.5	3.21	3.22	3.23	3.23	3.24	3.25	5.0

Note: From Tables 3.1 and 3.8 from Brown (2009)..

2.3 *ACCRETION AT OTHER HUMBER MANAGED REALIGNMENT SITES*

2.3.1 All Humber realignment sites have experienced significant siltation within the first year as indicated in Table 5. The results are fairly consistent suggesting that in the Humber, in areas with lower ground levels, which were typically between 1.5 and 2.5 mAOD accretion in the first year was of the order of 0.1 – 0.3 m. In areas of higher ground the rate of accretion was typically much less. This difference in accretion rate is not unexpected, because the depth of inundation and the frequency of inundation are both much greater on the lower parts of the site.

2.3.2 The evidence in Table 5 suggests that the removal of the flood bank at Welwick, but the retention of the majority of the fronting saltmarsh has not changed the rate of accretion compared with that experienced at Paull Holme Strays. At Chowder Ness, by contrast, the reported siltation rate is around two thirds the rate reported for Paull Holme Strays.

Table 5 Initial siltation rates in Humber managed realignment sites

Site	Average siltation (m)		
	Low initial ground level		High initial ground level
	First year	First two years	First year
Paull Holme Strays	0.23 (Table 4 row 2)	0.4 (Table 4 row 2)	0.01 (Table 4 row 5)
Welwick	0.15 (Hemmingway *et al.*, 2008), 0.25 (Armstrong, 2010)	Not known	Not known
Chowder Ness	0.09 ((ABPmer, (2010) & Hemmingway *et al.* (2008))	0.27 (Armstrong, 2010)	Not known
Alkborough	> 0.2 (Hemmingway *et al.*, 2008)	Not known	< 0.05 (Hemmingway *et al.*, 2008)

2.4 COMPARISON OF HUMBER MANAGED REALIGNMENT SITE DEVELOPMENT

2.4.1 The experience at Chowder Ness is interesting as it does provide evidence of how accretion might potentially be slowed by removal of flood defences. This suggests that if the flood embankment and any fronting saltmarsh can be removed from in front of a managed realignment, the rate of accretion might be slowed and accretion within the realignment site delayed. However, the experience at Welwick indicates that merely removing the flood bank, but leaving any existing saltmarsh in place is unlikely to be effective at reducing accretion in a new managed realignment site.

2.4.2 If the conditions at Chowder Ness could be fully replicated at another site in the Humber, there is the possibility that it may take 50% longer for a given amount of accretion to take place. This would imply that the duration of mudflat in a managed realignment might be increased by 50% before levels became high enough to allow saltmarsh growth. The physical differences between Chowder Ness and other sites in the Humber estuary could relate either to their exposure to wave energy or to differences in the sediment concentrations in the water column.

2.4.3 The wave energy available at the Chowder Ness site is relatively high for the inner Humber as it is exposed to a 6 – 10 km fetch to the west and northwest. At many sites in the middle Humber the fetch available will be less as the middle estuary width is only about 2 km at the Humber Bridge rising gradually to 4 km at Immingham. If the additional wave energy within the Chowder Ness site is the main cause of the lower accretion rates, this benefit will be less marked at sites within the middle Humber estuary where fetch lengths are limited. At Cherry Cobb Sands the fetch is approximately 4 km across the estuary.

2.4.4 Sediment concentrations are highest in the inner estuary which is close to the turbidity maximum in the estuary and so the site at Chowder Ness is likely to experience higher sediment concentrations than sites downstream of Hull. If the sediment concentration were 50% higher at Chowder Ness than at middle estuary sites, then the difference in accretion rates between Chowder Ness and Welwick or

Paull Holme Strays is in reality more marked than the results of Table 5 would initially suggest. When the results are corrected for this difference the corrected siltation rate at Chowder Ness might be around 50% of the rate observed Paull Holme Strays. This suggests that the time for a given level of accretion to occur might double for a site with no fronting saltmarsh compared to one with a fronting saltmarsh or remaining flood wall.

2.4.5 In the middle Humber estuary it is noteworthy that there is a long established saltmarsh area known as The Outstray between Paull Holme Strays and Cherry Cobb Sands where there is a significant area of permanent saltmarsh where the flood defence alignment forms a shallow embayment. This area of saltmarsh was well established 70 years ago when it was used as part of the decoy defences for Hull; the reason for its current listing as a Scheduled Monument.

2.4.6 Although removal of saltmarsh might be expected to lengthen the time before saltmarsh grows by between 50 and 100% depending on assumptions about ambient suspended sediment concentrations, the experience from The Outsray indicates there remains a high probability that a stable saltmarsh will develop on any managed realignment site on the north bank of the Humber opposite Immingham.

3 *SALTMARSH GROWTH IN HUMBER MANAGED REALIGNMENTS*

3.1 SALTMARSH GROWTH AT PAULL HOLME STRAYS

3.1.1 The coverage of the Paull Holme Strays managed realignment site with saltmarsh was also monitored. The results shown in Table 6 indicate that the sites with higher ground level were covered with saltmarsh more rapidly. After about 3 years the ground initially above 3 mAOD had around 70% ground coverage by saltmarsh while land initially at about 2.8 mAOD took around 5 years to achieve the same coverage, by which time it had accreted to an average of 2.9 mAOD.

3.1.2 The land that was initially at lower levels, accreted rapidly, but saltmarsh took longer before starting to appear. The parts of the site initially at around 2.2 mAOD achieved in excess of 30% coverage with saltmarsh after 5 years, and in this time had accreted to around 2.6 mAOD. Areas of the site below 2 mAOD when the site was breached, accreted to around 2.5 mAOD after 5 years, but were only just starting to experience saltmarsh growth.

3.1.3 The initial species to become established over the realignment site was *Spartina anglica*, which remains the only species in the lower elevated areas (2-2.3m ODN), with more species becoming apparent as the height increases.

3.1.4 At the medium height range (>2.3-2.6m ODN) the dominant species was still *Spartina anglica*, but with other species such as *Salicornia europaea, Aster tripolium, Puccinellia maritima, Suaeda maritime* and *Atriplex prostrate* becoming apparent.

3.1.5 At the higher elevation range (>2.6 – 3.0m ODN) *Puccinellia maritima* has been the dominant plant since 2007, also with high densities of *Aster tripolium* and *Spartina anglica*, with a marked decline of *Atriplex prostrate*.

3.1.6 Between 3.0 and 3.5m ODN, the pre-breach populations of *Elytrigia repens* has persisted at the higher sites and remains an important component of the species composition here, along with *Aster tripolium* and *Puccinellia maritima* which have both spread rapidly.

3.1.7 A variety of other, less abundant species have also colonised the area, and are typical of common salt marsh species found on natural salt marshes.

Table 6 Saltmarsh ground cover at Paull Holme Strays

Level group (in 2005)	Average ground coverage with saltmarsh (percent)					
	Sept 03	Sept 04	Sept 05	Sept 06	Sept 07	Sept 08
2.0-2.3	0.0	0.0	0.0	0.0	0.8	1.5
>2.3-2.6	0.0	0.0	0.1	1.3	9.1	34.2
>2.6-3.0	0.0	3.8	14.7	44.1	57.3	76.8
>3.0-3.5	0.0	40.9	55.0	74.4	67.5	74.8

Note: From Tables 4.2 from Brown (2009).

3.2 *SALTMARSH GROWTH AT WELWICK AND CHOWDER NESS*

3.2.1 Results from the monitoring at Welwick and Chowder Ness have been briefly reported (Armstrong, 2010) and illustrated by site photographs (ABPmer, 2010) for 2009. Three years after breaching there has been substantial growth of pioneer plants (e.g. glasswort, *Salicornia*) at Welwick while other plants (eg common saltmarsh grass, *Pucinellia maritima* and cord grass, *Spartina anglica*) are increasing slowly in number. At Chowder Ness after three years, a small area of saltmarsh has developed with sea aster (*Aster tripolium*) common while other low marsh plants are slowly increasing in number. Unfortunately the information and photos are not sufficient to quantify the proportion of each site covered by saltmarsh at that time.

3.2.2 These results indicate that at both sites which started at similar initial levels, saltmarsh plants are becoming established around 3 years after breaching at both Welwick and Chowder Ness, though probably more slowly at the latter site.

4 DEVELOPMENT OF FAUNA ON MANAGED REALIGNMENT SITES

4.1 BENTHIC INVERTEBRATES AND AVIFAUNA IN MANAGED REALIGNMENT SITES

4.1.1 Intertidal mud flats are important feeding areas for shorebirds, and some wildfowl, during low water periods when they are exposed, and for diving ducks and fish when they are submerged.

4.1.2 Initial invertebrate colonisation of managed realignment sites tends to be fairly rapid following the breach of the site. For example fourteen species were recorded in the Tollesbury site in Essex just two months after breaching in 1995, and 18 to 19 species a year there after until 2007 when 21 species were recorded (CEH, 2008). In total, 31 species were recorded over the 12 year monitoring period, with species such as *Cerastoderma edula* (cockle), *Macoma balthica* (baltic telin), *Neris diversicolor* (rag worm) and the common shore crab (*Carinus maenas*) commonly recorded. It was found that birds were quick to colonise the site, either for roosting or to feed. In the first few years at Tollesbury after realignment, waterbird assemblages were generally variable and large changes were observed adjusting to the biological and physical evolution of the site. Numbers of wading birds were low in the first year after creation but increased thereafter, reflecting the development of the invertebrate community within the mudflats of the site.

4.1.3 At Paull Holme Strays benthic invertebrates were initially quick to develop following the breach, although rates of change slowed over subsequent years. By 2008 the realignment site had achieved a species richness comparable to the communities of the established mudflats outside the site, which remained relatively stable over time (Environment Agency, 2009). However, there were still some significant differences to the middle estuary community in terms of species richness, abundance and diversity. This was expected as benthic invertebrate communities have been observed to take longer than five years to develop elsewhere since rapidly accreting sediments are too fluidised for burrowing organisms to survive in. Inside the site the early colonising small bodied species present in high numbers (*Paranais litoralis*) were being replaced by larger bodied organisms (*Hediste diversicolor*). However, it was noted that the increase in saltmarsh and high elevations with low frequency of inundation are likely to reduce the supply of larvae required for colonisation. The terrestrial / freshwater organisms that previously dominated the site were no longer a significant component of the community.

4.1.4 Following the colonisation of the site at Paull by invertebrates was the use of the site by birds since the invertebrate community provide a valuable food source for waterbirds. Monitoring at Paull found that within five years of breaching the bird assemblages at the site were broadly typical of a mid-estuary community. The mudflats on the northern part of the site supported the highest densities of foraging birds and the higher water islets of the southern part of the site were important for roosting/loafing birds. Overall the inside of the site supported more foraging wildfowl and fewer waders than the areas outside of the site and was functioning as an extension of the upper shore.

4.1.5 Three years after breaching the site at Welwick (Armstrong, 2010), the invertebrate assemblage in the mudflat has increased in abundance, diversity and biomass, but still typically remains lower compared to fronting pre-existing mudflat sites. At Chowder Ness (Armstrong, 2010) a similar pattern has been followed, though the assemblage within the managed realignment site is now reported as being similar to that found in the fronting mudflat. The density of invertebrates at both sites is very variable, but the maximum density found at Chowder Ness in 2009 was twice that reported at Welwick.

4.1.6 It is therefore expected that the compensation site at Cherry Cobb Sands will relatively rapidly become colonised by invertebrates, with the communities adjusting in diversity and abundance over time as the physical and biological conditions change and become more stable, and will eventually support communities typical of outside of the site. Closely following the colonisation of the site by invertebrates will be the use of the area by waterfowl.

4.2 REQUIREMENTS FOR AVIFAUNA AT CHERRY COBB SANDS

4.2.1 The bird assemblages using the site will depend on the type of substrate in the different parts of the site and the invertebrate assemblages found there. The following paragraphs provide information on some of the bird species for which the compensation site will be important for, and their feeding and/or loafing preferences (Dennison, 2011).

4.2.2 **Redshank** respond well to behind the seawall tidal conditions and may achieve a similar density inside to that outside the site all else being equal (but it is not clear that this is borne out from all the Humber re-alignment sites). As far as Redshank are concerned, it would be helpful to provide lots of wide open creek edges, they would need to be at least 10m wide and hold a little water when the tide is out. As for roost sites, they like promontories of marsh or islands for safety.

4.2.3 **Dunlin** prefer open mudflats to give them a good vista, rather than enclosed sites and they follow the tide along open expanses of mudflats so a larger, more open managed realignment site is preferable. They prefer open, low vegetated/shingle islands with an open 360-degree vista for roosting. They do not respond well to enclosed sites so any realignment would need to be big and any topographical features provided for them away from edge features such as the existing or remnant flood-defence bank.

4.2.4 **Black-tailed Godwits** like muddy substrate. They will use fresh/brackish pools with shallow water and mud (water depth in which they feed tends to be 0.1-0.15m, sometimes a little deeper). They do seem to require good populations of bivalves (not cockles but Arenaria, Macoma, Tellina types); so it may take a few years for good numbers of slightly larger individuals to develop. They are happy to roost on sites that Dunlin and Redshank use and around the Humber make use of the muddy edge of saline lagoons and rocky foreshore areas when tides allow, they are also quite happy to roost in shallow water by islands.

5 SEDIMENTATION AND EROSION PREDICTICTIONS

5.1 ANTICIPATED ACCRETION AT CHERRY COBB SANDS

5.1.1 The existing ground level at Cherry Cobb Sands of 2.5 mAOD falls between two of the level classes adopted for Paull Holme Strays, but will be reduced to provide fill for the embankment by up to 1 m. Estimated future accretion at Cherry Cobb Sands in areas of low velocity has been interpolated between the results of Table 4 for initial levels of 1.82, 2.18 and 2.44 mAOD. The estimated future levels are plotted on Figure 3. Average ground levels are predicted to increase from 1.82 mAOD to 2.46 mAOD after about five years and to have risen from to 2.44 mAOD to 2.73 mAOD after about five years. Siltation thereafter is expected to continue but at a progressively slower rate.

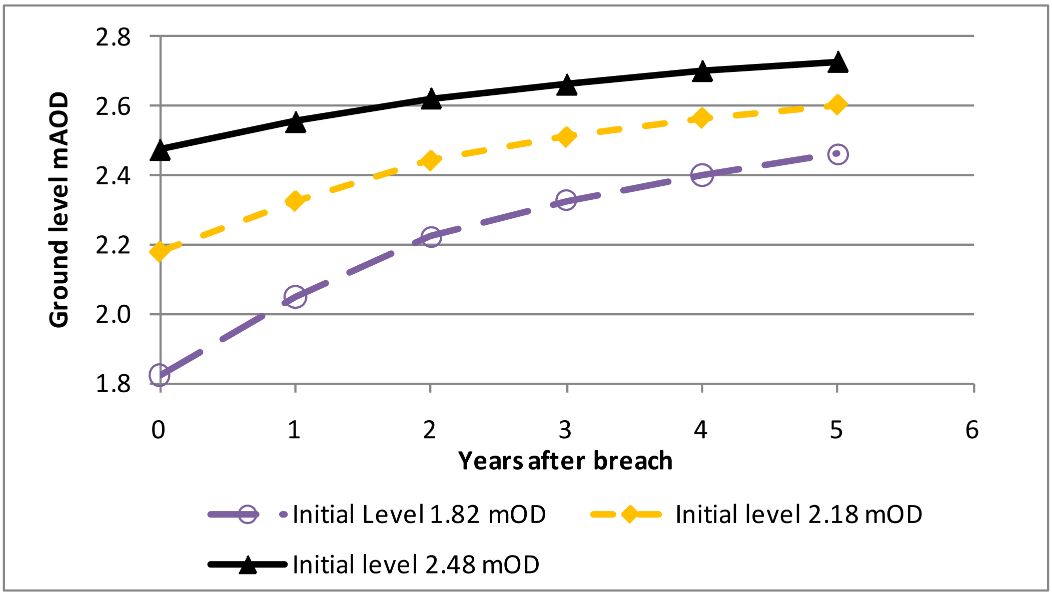

Figure 3 Anticipated accretion in low velocity areas at Cherry Cobb Sands

5.2 ANTICIPATED SALTMARSH GROWTH AT CHERRY COBB SANDS

5.2.1 The anticipated saltmarsh coverage at Cherry Cobb sands has been interpolated between the results shown in Table 6 based on the coverage achieved at Paull Holme Strays from initial levels of 2.18 and 2.77 mAOD. The estimated future coverage of saltmarsh at Cherry Cobb Sands is shown on Figure4. There is anticipated to be very limited saltmarsh coverage for the first two years after breaching, but thereafter, saltmarsh colonisation is expected to be fairly rapid, achieving around 60 percent coverage after 5 years.

5.2.2 Anticipated pioneer halophytic plant species include samphire (*salicornia* spp.) and other pioneer plants such as common sea blite (*Suaeda maritime*) to start growing around the edges of the realignment site along the bases of the embankments which are slightly higher.

5.2.3 Assuming the site is breached during summer months it is expected that the seeds or rhizomes from nearby saltmarsh areas would be carried in the water in to the

Compensation Site in late summer. The seeds or rhizomes would be caught up in the existing vegetation as it dies back when the area becomes saline. Seeds would also collect on any elevated rough surfaces such as the base of the new embankments and would start to grow in the spring time.

5.2.4 The colonisation of halophytic plants would continue to increase as the site accretes over the next few years. Each year it is anticipated that more species of plants will become established, and a greater extent of colonisation, with species such as sea purslane (*Halimione portulacoides*), and the saltmarsh grass (*Puccinellia maritima*) to become apparent, starting at the higher edges of the realignment site, and taking several more years to become established in the middle where it is lower.

5.2.5 If there are pool areas lower than the current lowest points on the site, it is unlikely that these will become established with vegetation and may just remain as bare mud or if the area is rich in nutrients they may be covered in algae.

5.2.6 After several years, mid-marsh plants such as sea lavender (*Limonium vulgare*) and sea aster (*Aster tripolium*) for example, will begin to grow.

5.2.7 It would be advantageous to the ecology of the site to encourage drainage by creating a creek network if one is not likely to form naturally (more work is needed to confirm this), and the creation of small islands around the site would be good for the bird population and general diversity of the site.

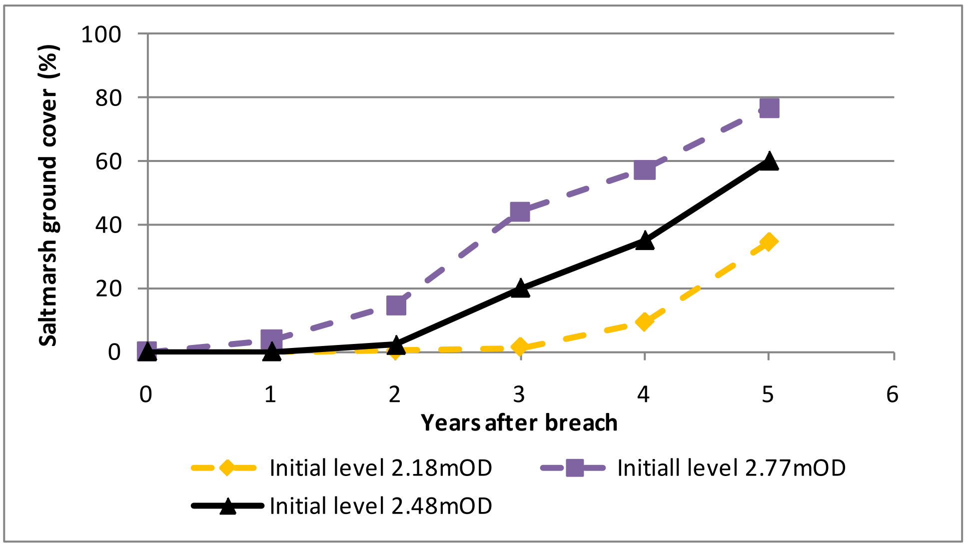

Figure4 Anticipated saltmarsh coverage at Cherry Cobb Sands

6 *CONCLUSIONS*

6.1.1 The four managed realignment sites that have been developed in the Humber estuary since 2000 have each experienced rapid sediment accretion. The rate of accretion is higher in areas where ground levels are initially lower.

6.1.2 The experience at Chowder Ness suggests that the removal of the existing flood defence embankment fronting a managed realignment site will probably reduce accretion rates and so prolong the time before saltmarsh develops. This assumes that any obstruction to wave energy reaching the site such as provided by existing saltmarsh is also removed.

6.1.3 The experience at Welwick suggests that accretion rates in a new managed realignment site are unlikely to reduce if it is fronted by saltmarsh which is left in place.

6.1.4 The saltmarsh in the shallow embayment known as The Outstray in the middle estuary indicates that whatever measures are taken to reduce accretion rates, saltmarsh is likely to develop in any embayment over the long term.

6.1.5 The five years of monitoring at Paull Holme Strays indicates that siltation rates are dependent on the initial ground level and reduce as levels rise and the frequency of inundation reduces.

6.1.6 Monitoring at Paull Holme Strays and anecdotal evidence from Welwick and Chowder Ness indicates that saltmarsh development is fairly rapid once sediment levels rise to those where saltmarsh is able to survive.