TIDE
Tidal River Development

Project part-financed by the European Union (European Regional Development Fund)

The Interreg IVB North Sea Region Programme

‘Alkborough Managed Realignment’

Measure analysis 30
in the framework of the Interreg IVB project TIDE

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Part 1: Measure description

Measure Category: Hydrology/Morphology
Estuary: Humber
Salinity zone: Oligohaline zone
Pressure: Gross change in morphology during the land 100 years.

Country: UK
Specific location: Inner Humber Estuary, North Lincolnshire
Responsible authority: Environment Agency, UK
Links: http://www.abpmer.net/omreg/search_database.aspx?lstSite=Alkborough
Costs: £ 10.2M (Current monitoring costs are approx £75K pa. This is likely to be reduced after 2012).
Map/Picture:

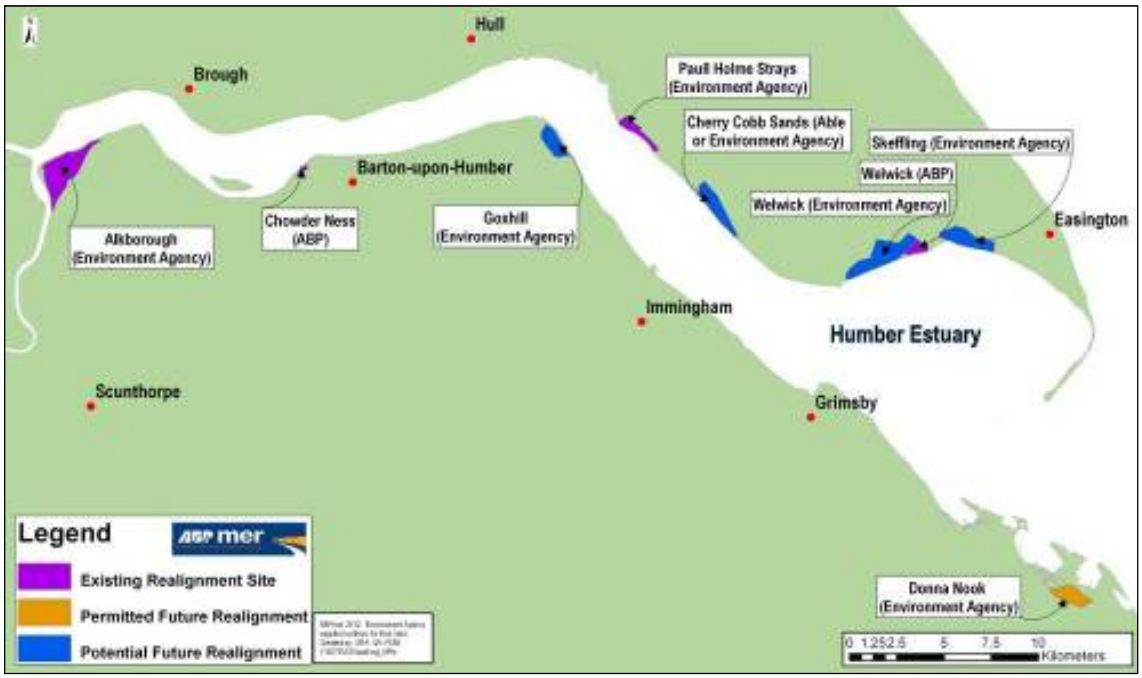

Figure 1: Location of Alkborough within the Humber Estuary

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Figure 2: Aerial photograph of project area (left) prior to scheme and (right) after breaches

Figure 3: Photo of scheme (courtesy of intertidal.co.uk)

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Figure 4: Photo of scheme (courtesy of intertidal.co.uk)

Figure 5: Photo of scheme (courtesy of intertidal.co.uk)

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1.1 Measure description

The measure 'Alkborough managed realignment' was the fourth major MR scheme on the Humber created by the Environment Agency. The Alkborough site, located in Lincolnshire at the confluence of the River Ouse and River Trent, is 440ha and is the largest managed realignment site on the Humber. The primary purpose of the site was to provide flood protection as the size of the site enables large capacity for water storage and reduces tidal levels throughout the upper estuary, thus delaying the need to raise other flood defences. The site's capacity is so great that it could reduce high tide levels in the upper estuary by as much as 150mm.

Whilst the primary aim of the site is flood defence, flooding of the site has led to the development of valuable intertidal habitat including mudflats, saltmarsh, lagoons and reedbeds which will provide compensation for habitat loss (due to port developments and land claim) elsewhere in the estuary. Due to the introduction of new European Directives (Natura 2000) and UK legislation there was a requirement to carry out the scheme in compliance with the requirements of the European Habitats Directives and the UK Habitats regulations 1994. A further objective of the scheme is to create new intertidal habitats to offset those lost through coastal squeeze within the estuary and due to flood defence works. The site was designed to create replacement habitat to compensate for both coastal squeeze (on a 1:1 ratio of habitat loss to creation for coastal squeeze), and for direct construction related losses from defence improvement works in the upper estuary (on a 1:3 ratio for habitat loss to creation for direct construction related losses).

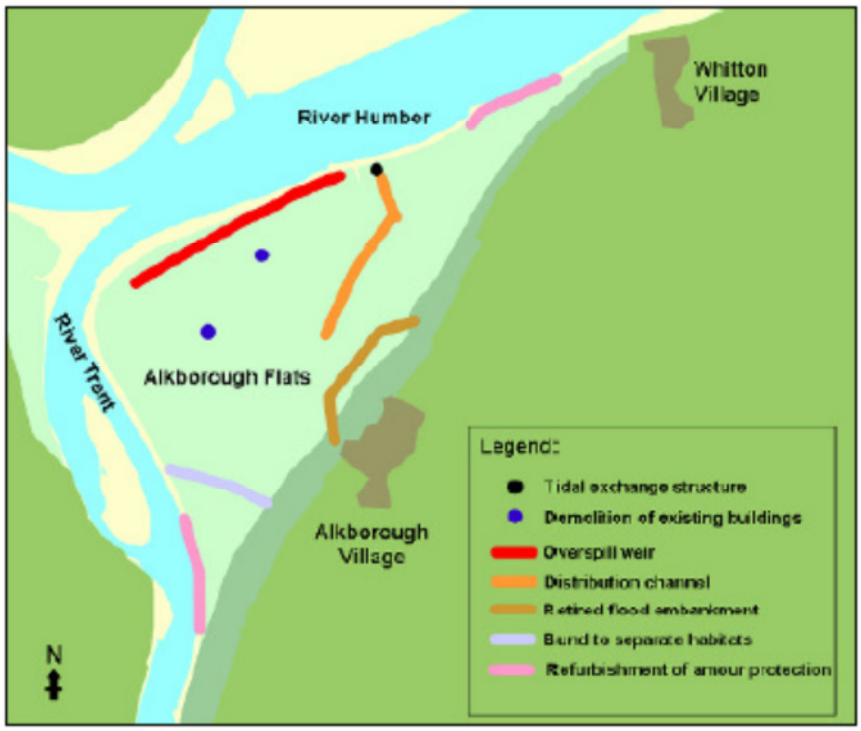

Figure 6: General arrangement of the works

Alkborough has a has a total area of 440 hectares, of which 370 hectares lie between the tidal defence and the 5mOD contour at the base of the escarpment. The remaining 80 hectares lie between the tidal defence and the low water mark. Prior to the opening of the scheme land levels within the site varied between 2mOD and 4mOD. The land at Alkborough has been reclaimed from

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the estuary over many years with the most recent phase of reclamation in the 1950s. The project was designed to reverse this trend and allow the land to be re-connected to the estuary.

One of the major restrictions to the managed retreat at Alkborough was the need to maintain navigability in the Humber Estuary, for which the engineering solution was to lower the outer defence with the Humber but to breach only an armoured 20-metre gap through which the tidal cycle moves water on and off the inundated part of the Alkborough site. The remaining 1,500 metres of embankment with the Humber was lowered to act as a weir and permit overtopping in extreme events; half was set at a level of 5.1m OD with the remainder set at 5.45m OD. Figure 6 shows the general layout of the site.

On the shoreline with the River Trent, which joins the Ouse on the outer corner of the Alkborough Flats site, the old flood bank was retained to prevent remeandering of the river, and also thereby to protect navigation in the Humber. A new setback bank has been constructed on the landwards side of the Alkborough site to protect a pre-existing sewage treatment works.

Now 170 hectares of the site is permanently exposed to flooding, reverting to mudflat, saltmarsh and, at least in part, reedbed. The remaining 230 hectares of land beyond the regularly inundated areas will serve as storage capacity during extreme surge events.

Status of the measure
The measure was breached in September 2006.

1.2 Monitoring

A 10 year monitoring programme is planned at Alkborough. The first 5-year phase of monitoring began in 2007 and will be reviewed in 2011/12 and altered accordingly. For the first 5 years a detailed monitoring programme has been established to assess the general development of the site and ensure it has provided functioning intertidal habitat. Mudflat development and accretion, invertebrates (including estuarine and those inhabiting freshwater/brackish features), saltmarsh communities, aquatic plants (inhabiting freshwater/brackish features), fish and epibenthos, and birds are being monitored at the site. Additional information is collected adjacent to the site including fresh water invertebrates, odonata and water vole surveys. The monitoring results are reported back to the Environment Agency and the Environmental Steering Committee. Table 1 below shows the parameters monitored at Alkborough.

Table 1: Summary of monitoring programme at Alkborough

Construction	Start Date	Initial frequency	Initial duration	Adaptations to original monitoring	End date
Topographic survey	September following inundation	annually	5 years post inundation		2011
Changes to intertidal invertebrates	September following inundation	annually	5 years post inundation	31 stations were initially selected - A number of these stations will remain permanent throughout the five year monitoring period	2011 (additional surveys being discussed)

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Construction	Start Date	Initial frequency	Initial duration	Adaptations to original monitoring	End date
				but as the site develops in terms of mudflat morphology and flooding characteristics, a number of these stations may have to be abandoned and new stations selected.	
Saltmarsh composition	September following inundation	annually	5 years post inundation		2011
Sediments	September following inundation	annually	5 years post inundation	Additional surveys in 2010 and 2013	2013
Monitoring of fish	September following inundation	3 times a year (Jun, Oct and Mar)	5 years post inundation		2011-2012
Waterfowl	overwinter season following inundation	Bi-monthly (Oct - Mar)	5 years post inundation		2011-2012

1.3 Monitoring results

The following sections are based upon the results from the most recent monitoring report, the third year of monitoring, 2009 (Solyanko *et al*. 2011). Figure 7 shows the sampling locations used for the various areas of the site.
To summarise by 2008/09 a total of 150 different species of birds have been recorded on the site and 30 red- and amber-listed bird species have bred on site including avocet. In the winter of 2007/08, 10,000 lapwing (*Vanellus vanellus*), 6,500 golden plover (*Charadrius apricarius*) and 600 shelduck were recorded feeding and roosting on the site. In addition, 14 species of mammals, 20 types of butterflies and 14 species of dragonfly and damselfly have also been recorded.

1.3.1 Accretion

The sediments inside the realignment site can be characterised as coarse silts to fine silts, outside the site, the sediments were less uniform and were composed of medium silts. Inside the site, an increase in particle size in 2009 was recorded at all stations associated with drier and more vegetated areas and this pattern is consistent across the site. Variation in particle size inside the site was comparable to those outside. Silt content increased in 2009 at most of the stations inside the site. Sand content showed a direct opposite trend to silt.

Both organic and water content are significantly higher inside the site, there was no clear spatial pattern to this but they showed a slight decrease compared to previous years. The higher organic and water content inside the realignment site is likely to be due to the vegetation (either colonising or remnant terrestrial vegetation) and input of faeces from feeding and roosting birds. Additionally,

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the sediments inside the site are not yet consolidated to the same degree as they are outside and much of the realignment site remains flooded throughout the spring tide.

Accretion has continued across the realignment site, with the exception of area 5a (see Figure 6) where elevation appears to be decreasing over time. Possible explanations for this include initial flooding and sedimentation, followed by compaction and dewatering of the sediment and variation in the area surveyed. Also the extent of the survey area is limited by the presence of standing water and/or the presence and height of the vegetation.

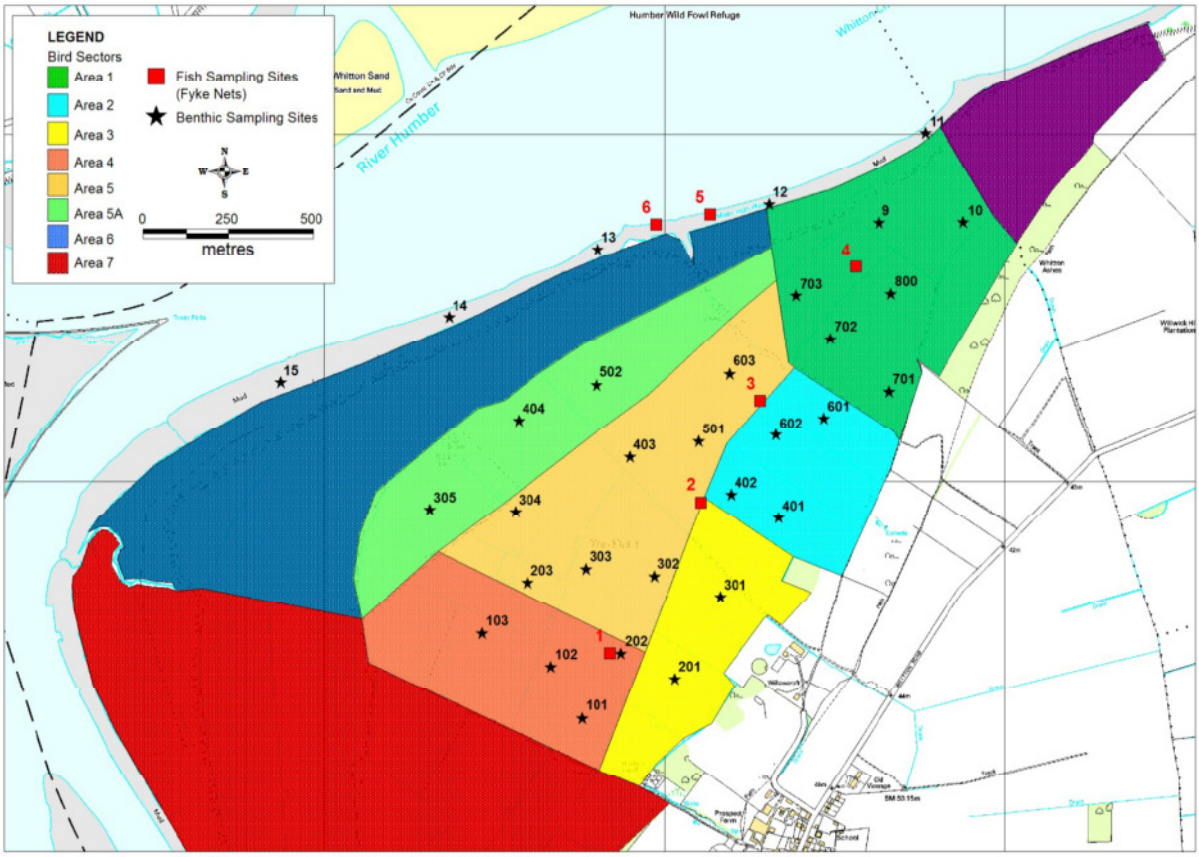

Figure 7: Sampling locations

Figure 8 shows that between September 2006 and December 2007 stations with greater numbers of inundations experienced greater rates of accretion (up to 0.6m).

The areas of highest elevation and accretion are generally situated around the distribution channel where elevation is predominantly greater than 3.2 m, reaching a maximum of 3.4 m in some part of sectors 1, 4 and 5 (Figure 7). In 2008, elevation in most of this area was 3- 3.2 m with small areas being 3.3 m. A significant increase in elevation has occurred in most sectors (except 3 and 5a) since 2007 although the rate of accretion appears to be decreasing over time. Differences between 2008 and 2009 were not significant. Elevation outside the realignment site is variable over time with the highest elevation being recorded in September 2008. Elevation for March 2008 and September 2009 was equal. It is of note that this area undergoes frequent cycles of erosion and deposition, as indicated by the steep and terraced nature of the mudflat.

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Like other realignment sites on the Humber, the initial rate of accretion at Alkborough has been rapid but is now stabilising to some extent. Average accretion ranged from 0.02 m to 0.09 m, compared to values of up to 0.06 m during the first year. Maximum accretion is predominantly around the distribution channel and it is suspected that a high level of accretion has also occurred within the channel. Accretion levels outside the site are stable (statistically) and most of the area has remained at an elevation of 0 – 2.6 mOCD. It is apparent that the mudflats in this area undergo frequent cycles of erosion and deposition.

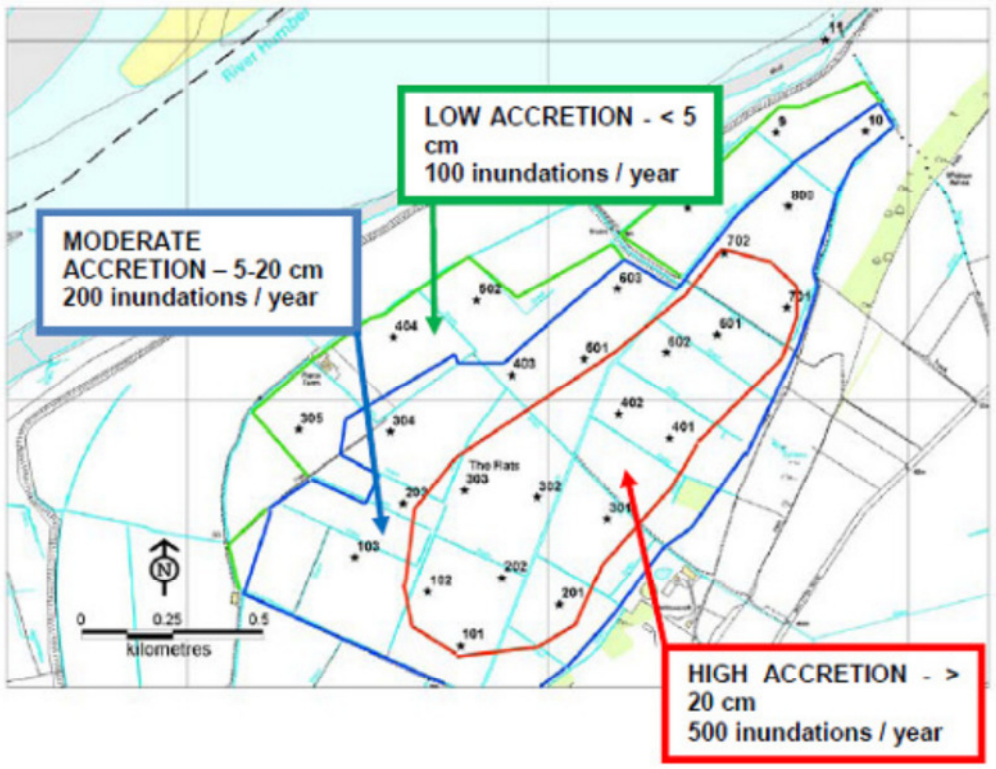

Figure 8: Spatial patterns in sediment accretion in relation to predicted inundation (from IECS (2009))

New analysis undertaken by Halcrow (in prep 2012), of the yearly elevation data that is collected for the site, confirms the previously reported tendency for the majority of the site to act as a sediment sink and accrete. The initial rapid siltation from 2006 to 2008 (0.6m) has not continued and the average rates of accretion between 2008 and 2012 range between 0.03m and 0.09m per year. For most sectors siltation rates appear to have been relatively constant since the March 2008 survey.

1.3.2 Infauna

Infaunal species diversity was low in 2009. A total of 21 species was recorded across both sites, with a total of 19 species found inside the realignment site and 6 species of benthic invertebrates recorded outside the realignment site. Typically for upper estuarine areas, species diversity was low at all stations. Stations with the lowest numbers of estuarine species present were in the dry parts of the site. There were no clear spatial patterns in organism abundance when considering all species and mean abundance was variable across the site.

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In 2009, biomass across the site was low with (<10 g m-2 at most of the stations). Biomass was low outside the realignment (<1 g m-2 at three stations). The low biomass ratio at all stations indicates dominance by small-bodied organisms. No significant differences were found between the abundance inside the realignment site as a whole and the established mudflats outside the site.

Inside the realignment site, species from the order Collembola were the most abundant and were recorded at 89% of stations. This order was also dominant in terms of biomass. The highest numbers of Collembola were recorded at station 401 with over 444,795 individuals m-2. The estuarine oligochaete *Paranais litoralis* was the next most abundant species recorded at 89% of stations. This species was the dominant species at 13 out of the 26 stations. Other taxa present at most stations within the realignment site included Enchytraeidae and other Oligochaetae worms, Nematodes, Ostracods, and insects from the taxa Ceratopgonidae, Chrionomidae, Diptera and other larvae unidentifiable to the species level. Outside the realignment site, the estuarine oligochaete *Heterochaeta costata* was the most abundant species and was recorded at all stations. It is of note that this species was not recorded inside the site.

Multi-dimensional scaling (MDS) showed a separation between the benthic communities inside and outside the realignment site. The separation between the two areas is still strong when only estuarine species are taken into account although some stations from outside the site (11 and 13) appeared to be connected with stations inside, but this was mainly due to presence of oligochaete *Paranais litoralis*. Generally, the differences between the two communities can be attributed to the presence of the freshwater/terrestrial species in the samples together with the comparatively low abundance and diversity of estuarine species inside the realignment site.

Species richness, abundance and biomass have increased notably at some of the stations inside the realignment site (201, 302, 303, 305 and 401) since 2007. Stations 201, 302 and 303 are situated close to the distribution channel, whereas station 305 is situated further from the channel. Only abundance and biomass increased at stations 601 and 603, which are situated close to the channel. Species richness, diversity, abundance and biomass at other stations inside and outside the site have fluctuated with no clear spatial or temporal patterns. Species richness inside the site as a whole increased (for all species and for just estuarine species) significantly between 2007 and 2009. Species richness outside the site has not changed significantly between these years.

Abundance inside the site increased significantly between 2007 and 2009 (for all species and for just estuarine species). Abundance inside the site (considering estuarine species only) did not change between 2008 and 2009, although increased significantly between 2007 and 2009. Abundance increased significantly outside the site between 2007 and 2009. Diversity of all species has not changed inside or outside the realignment site between these years. Considering only the estuarine species, diversity increased significantly between 2007 and 2009 and between 2008 and 2009. Biomass of all species significantly increased inside the site between 2007 and 2009, but no significant changes were detected between 2008 and 2009. Biomass of estuarine species significantly increased between these years.

1.3.3 Vegetation

A series of 2 m x 2 m quadrat surveys was carried out in areas where significant amounts of vegetation had colonised in order to determine species composition and to identify areas of initial

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colonisation (Figure 9). Altogether, quadrats were described at 15 transects. Two transects were run from the High Water Strand Line (T1 and T2) to the pioneer zone, others were linked to the benthic sampling points and situated inside the realignment site.

Whilst there were significant areas of terrestrial vegetation remaining (principally *Lolium perenne*), areas of salt tolerant vegetation are clearly developing. As sediment accretion proceeds, the spatial distribution and density of *L. perenne* is expected to decrease. The distribution and density of *Puccinellia maritima* (common saltmarsh grass), *Aster tripolium, Juncus inflexus, Carex otrubae* and *Phragmites australis* increased compared to previous years indicating that saltmarsh species are continuing to colonise the site. There were 12 saltmarsh species noted in 2009, an increase of 6 on the 2008 survey, and further indication of the transition from a terrestrial to a wetland site.

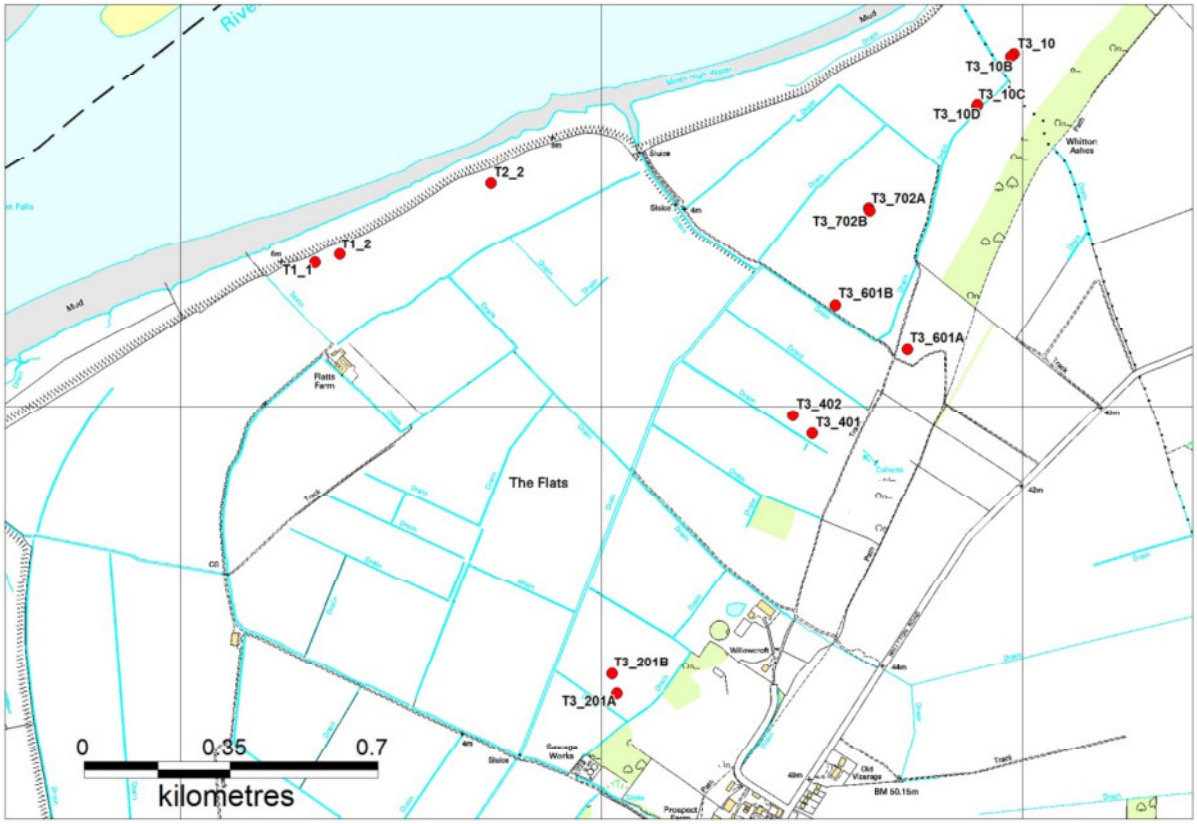

Figure 9: Locations of saltmarsh survey quadrats

The most abundant and widespread plant species was *Phragmites australis* which was present all over the site. *P, australis* was already growing along the drainage ditches and this presence has probably aided the quick colonisation of other site areas through seeds blowing onto the mudflat.

1.3.4 Birds

A total of 13 species of wader was recorded between October 2009 and March 2010, which is three species less than the previous year. In comparison to 2008/2009, oystercatcher was found in 2009/2010, but knot, little stint and ringed plover were not recorded. The most frequently occurring species was redshank which was recorded feeding on the site on 42 of the 84 sampling occasions,

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although this species was only recorded using the site for roosting once. Lapwing were observed feeding on the site on 24 (out of 84) occasions and roosting on 17 occasions. Curlew were recorded feeding on the site on 24 occasions and roosting on 16 occasions. Dunlin were also recorded frequently at the site. Other species were recorded on less than 10 occasions, either feeding or roosting.

A total of 18 species of wildfowl was recorded, which is one species less than last year. Spoonbill and whooper swan were not recorded in 2009/2010, but one new species, the brent goose, appeared on the site. Shelduck was the most frequently occurring species, recorded feeding on 51 occasions and roosting on 28 occasions. Teal was seen feeding on 25 occasions and roosting on 35 occasions. Other frequently occurring species were wigeon which were recorded feeding on 23 and roosting on 22 occasions, and mallard which was recorded feeding on 19 occasions and roosting on 25. Other commonly recorded species were grey heron, teal and graylag goose.
The maximum total number roosting waders was 13164 birds recorded in December 2009 (including 6350 count for lapwing and 6800 count for golden plover). The results indicate that greater numbers of wildfowl used the realignment site for feeding, but greater numbers of waders used it for roosting.

Principal Coordinates Analysis (PCoA) was carried out to detect any spatial and temporal patterns in the distribution of birds across the site. It is of note that the some of the sectors contain contrasting habitat types and therefore attract birds with a wide variety of habitat requirements. However, when maximum and cumulative data are plotted, there is a strong association between bird species and habitat preference. The figures indicate that sector 6 (a grassy area) is used as a feeding area by curlew only, and another grassy area in sector 7 is used by curlew and lapwing. Other species of waders are primarily using areas 1, 2, 4 and 5 (frequently flooded areas of developing mudflat). The most important sectors for roosting waders appear to be sectors 1, 4 and 5, which are also the key wader feeding areas.

1.3.5 Fish

Water quality parameters reflected the normal temperature and salinity range expected in upper estuary zones and showed a degree of seasonal variability. Salinity can be extremely low inside the site, reaching as low as 0.3 and it is probably driven by river flow rates and rainfall. Small differences in temperature were noted between realignment (RL) and river bank sites (CTRL) probably reflecting the more variable conditions inside the realignment site resulting from the shallow and enclosed environment.

Fyke net sampling found that the species composition was reflective of the oligohaline nature of the area and was dominated by estuarine species adapted to low salinity (i.e. flounder and gobies), diadromous species (i.e. eel and smelt) and freshwater species. The remaining species included fresh water species or estuarine fish, most of which were only captured very occasionally. Among the more abundant freshwater species, 3-spined stickleback, chub and roach were relatively more prevalent inside the site. Breams (common and white) were also found in moderate numbers. Of interest is the presence of perch, a predatory fish, which indicates use of the site by prey species since the initial breach of the site.

Consistent seasonal variability and site preferences was only apparent for eels which were considerably more abundant in the summer and inside the site. These differences are probably linked

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to the migratory behaviour of the species. The increase in the number of eels in the realignment may indicate an improvement in habitat quality with increasing time since the site was breached. This observation is a positive note given the current decline of eel populations across Europe. The dominant size spectra in the fykes however, suggests that the main role of the realignment site is as a nursery.

Common prawn (*Palaemon longirostris*) was found in large numbers but was practically restricted to the river bank where it was the dominant invertebrate species. This species is able to maintain stable populations across brackish estuarine waters. The most common crustacean inside the site was the grass shrimp, a similar brackish estuarine prawn which is known to favour still waters and those with low current velocities. The crustacean community showed a less abundant but more even community inside the site. Of note was the recording of Chinese mitten crabs, an invasive species originated from the coast of Japan.

The epibenthic trawls assessment targeted fish and shellfish of much smaller size than the fyke nets. The intention was to describe the small fish community and epibenthic food resource associated with the site. The trawl data confirmed 3-spined stickleback as a resident species inside the site and along with common goby, and juveniles of dace, roach and breams, comprise the majority of the small fish assemblage using the site.

The majority of invertebrates found inside the realignment (using a trawl) were mysids (*Neomysis integer*), species well adapted to the low salinity regime of the site. There was some variation between years but more importantly, the density of these animals was found to be highly seasonal with a marked increase in the summer. The summer coincides with the growing season of all fishes and mysids are likely an important prey for the entire small fish assemblage, shrimps (Order Decapoda, Caridea) and larger fish.

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Part 2: Execution of main effectiveness criteria

2.1 Effectiveness according to development targets of measure

2.1.1 Flood protection

The main purpose of the measure was to provide flood protection by storing water. The high water event of November 2011 was the first event to cause overtopping of the overspill weir since the opening of the scheme. Data from this event has been used to illustrate the flood storage function of the scheme (Halcrow, in prep 2012). On the flood tide the rate of water level rise within the site matches that in the wider estuary when flows are constrained with the distribution channel. Once this is overtopped the rate of water level in the site slows and begins the lag behind the main estuary. If water levels in the estuary rise above the level of the overspill weir then the amount of water passing into the site increases rapidly. This raises water levels across the whole site at a rate comparable to that seen in the main estuary. The large inflow of water from the estuary reduces peak water levels in the estuary. The actual elevations within the scheme lag behind the main estuary. As a consequence of this lag, the scheme continues to infill during the initial part of the ebb tide, until water levels drop below the level of the overspill weir.

It has not been possible to demonstrate the impacts of the scheme on water levels by comparing high tides events pre- and post-scheme. This is because there is a poor correlation between pre-scheme water levels at Spurn Point and Goole indicating that tidal heights at Goole are also affected by other parameters (e.g. wind, freshwater flow, atmospheric pressure).

A linear extrapolation of the accretion rates show that siltation will reach the present day MHWS level in all sectors, except Sector 5A, in 13 to 35 years after site opening. However, the linear regression used for this calculation will tend to under predict the amount of time since accretion rates are likely to decline as surface elevations approach MHWS. Allowing for sea level rise does significantly alter these predictions as the level of MHWS can be expected to increase in the future due to sea level rise. It is possible that future accretion rates would increase in line with sea level rise which would reduce the time for the site to accrete to this level. Over time the site will continue to accrete and thus reduces the space available for water storage and reduce the effectiveness of the site to provide flood protection.

2.1.2 Habitat quality

There are no specific targets for the creation of compensatory habitat; general descriptions of the quality of various aspects of the habitats are described in the sections below.

2.1.3 Benthic community

The 2009 third year of monitoring report (Solyanko *et al* 2011) records that the benthic community composition inside the realignment site has not changed greatly over time and was composed of both freshwater species and estuarine species.
Flooding inside the site is spatially variable which has led to variation in accretion rates and also a higher degree of variability in the sediment characteristics. Additionally, vegetation is either

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colonising the site or still remains from the pre-construction period and this, together with the spatial variation in flooding and the low salinity of the water, has led to the development of a mosaic of different habitats. Vegetation is colonising areas of infrequent flooding and/or of higher elevation. Many of these habitats are favourable to species of a freshwater or terrestrial origin, which accounts for the exceptionally high number of species from the class Insecta which have a fresh water larval stage to the life cycle.
Furthermore, the site is sheltered and does not experience the same cycles of erosion and deposition as the steep, narrow mudflat outside. Therefore, the benthic community as a whole appears to be more diverse with higher biomass inside the realignment that outside on the established mudflats. However, when considering the estuarine species only, it is clear that the community inside the site is not as developed as that outside with species richness and biomass being considerably lower. Additionally, the species composition is different with communities outside being dominated by the oligochaete *Heterochaeta costata* with smaller number of *Paranais litoralis* and *P. litoralis* being the dominant estuarine species inside the site, generally in higher numbers. Given that most of the infaunal species found in this part of the estuary inhabit the top 1-2 cm of the sediment, it is reasonable to assume that fluctuations in community structure would follow periodic erosion and events. Overall, the benthic community in the area consists of both freshwater and estuarine species. Previous assessment of sites on the Humber estuary (Allen, 2000; Mazik, 2004; Mazik et al., 2007; Mitchell, 2008) that the communities inside and outside the realignment site are impoverished, with low species diversity and abundance compared to more saline parts of the estuary. However, community structure outside the realignment site is typical of that area of the estuary (Allen et al, 2006).

It is unlikely that a diverse and abundant estuarine benthic community will develop at the realignment site for several reasons. Firstly, the elevation of the Alkborough site exceeds 2.8 m in all areas which is unfavourable for colonisation by infauna. The site is situated in a highly turbid part of the estuary with low salinity, a combination that is stressful for most species. In addition, the irregular flooding, and sections of the site that remain under water for a long time do not reflect the mudflats outside. Unlike the external mudflats which experience regular flooding by the incoming tide, the elevation of the site and its narrow, single breach mean that flooding occurs only on spring tides. Whilst this is a useful and key feature in terms of flood defence (which is the main function of the site), it does mean that the opportunities for larvae and adult benthic species to enter the site are limited. It is also important to point out that there are few species inhabiting the natural mudflats and it would be unrealistic to expect a diverse community to develop in the realignment site. In addition, the sheltered nature of the Alkborough site favours sediment accretion and for these reasons it is likely that a vegetated saltmarsh will develop rather than a mudflat.

2.1.4 Bird Usage

The Alkborough realignment site is well used by a large number of birds, which include a variety of species apparently attracted by the diverse nature of the habitat (mudflat, areas of standing water, reeds and areas of terrestrial vegetation). These habitats have attracted benthivorous (mainly waders), herbivorous/omnivorous (wildfowl) and piscivorous species (cormorants, herons and grebes). Thirteen species of wader and 18 species of wildfowl were observed feeding and/or roosting on the site during the 2009-10 survey (31 species in total). Five species were lost and two new ones were gained in comparison to the 2008-09 survey. The most important sectors for both roosting and

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feeding waders appear to be sectors 1, 4 and 5. Sectors 1, 2, 4 and 5 are frequently flooded areas of developing mudflat, and therefore probably have the most invertebrate food items.

Greater numbers of wildfowl used the realignment site for feeding, but greater numbers of waders used it for roosting. If the Nov/Dec 2009 high wader numbers are discounted, the wildfowl are the main users of the site for both feeding and roosting. However the presence of high numbers of wading birds during these months may be indicative of the realignment site being an important stopping point on migratory routes, or as an overwintering ground where food is available readily when it may not be elsewhere due to the cold weather. The abundance of estuarine benthic invertebrates is not thought to be sufficient to support the numbers of foraging birds seen regularly on the site and it is suggested that epifaunal species (e.g. *Neomysis* spp.) and, for some birds, fish may be the dominant food source.

The most frequently occurring species included typical mudflat species such as redshank and dunlin, curlew, lapwing and the wildfowl shelduck, teal, wigeon, and mallard (the wildfowl are typical of freshwater areas around the estuary). Occasional large numbers of golden plover were also recorded on the site. The site still appears to be supporting several avian species of international conservation importance including avocet (*Recurvirostra avosetta*) which breeds within the Humber European Marine Site, golden plover (*Pluvialis apricaria*) and bar-tailed godwit (*Limosa lapponica*) which qualify as Annex 1 wintering species occurring on the Humber (English Nature, 2003).

2.1.5 Fish

A varied fish assemblage has been identified, together with an equally diverse epibenthic invertebrate assemblage. Data shows that the fish assemblage changes seasonally and is dominated by small fish, which is consistent with the known role of estuarine areas as nurseries for juvenile fish and hunting grounds for subadult and adult fish. This is consistent with the current understanding of fish usage of shallow estuarine areas and intertidal habitats and correlates to the abundance and variety of small prey items. All these features are likely to be linked by functional interactions operating in a similar way and showing a broad equivalence to neighbouring estuarine habitats. This emphasises the value of managed realignment schemes in restoring historical estuarine habitat losses.

2.1.6 General effectiveness

The primary aim of the Alkborough site is flood defence (not compensation for land claim) and therefore, any estuarine habitat created could be regarded as valuable, particularly in the upper Humber where embankments limit the extent of the intertidal area. However, the site does have a role in compensation for habitat loss due to coastal squeeze.
The flooding and sedimentation regime within the realignment site have resulted in the formation of a mosaic of habitats which is considerably more diverse than that on the natural mudflats outside the site. Habitats present include mudflat, standing water, wet grassland and reed beds and fulfil the habitat requirements of a wide range of species or fish and birds. In contrast, the benthic communities are impoverished (throughout this region of the estuary) and do not yet represent those on the mudflats outside the site and are largely composed of freshwater and terrestrial species. The high elevation of the site and the small breach reduce the frequency of tidal flooding

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compared to that of the natural mudflats and this is thought to limit the potential for colonisation by benthic invertebrates and favour colonisation by vegetation.

High densities of epibenthic invertebrates and small fish have been recorded inside the realignment site and are thought to be the primary food source for the birds using the area. A high proportion of the fish using the site are typically freshwater species and are thought to be utilising the range of habitats within the site which are otherwise not available within the main channel of the estuary.

Overall the Alkborough site does not necessarily compensate for habitat loss and coastal squeeze in terms of mudflat creation and infaunal community development. It does however appear to be acting as a nursery area for fish and a significant feeding and roosting area for birds. In this respect, the development of the site appears to have been beneficial to this region of the estuary which is otherwise largely characterised by narrow mudflats with species poor communities and, in most areas, little vegetation.

Over time it is anticipated that the site will become well vegetated and cease to be fully inundated by high tides. This will mean that the site will not provide the 'like for like' direct habitat compensation and its ability to provide water storage during extreme events will also be reduced. The Environment Agency is currently investigating options for changing the breach configuration and altering the scheme to a regulated tidal exchange scheme.

2.2 Impact on ecosystem services

Step 1: Targeted ecosystem services

The key objective of this measure was to provide flood protection and in addition to compensate for losses associated with coastal squeeze. This is linked with ecosystem services 'flood water storage' and 'dissipation of tidal and river energy' as well as 'biodiversity'. It also provides 'opportunities for recreation and tourism' through becoming a tourist and bird watching attraction.

Table 2: Targeted ecosystem services

Measure	
Food: animals	
Water for industrial use	
Water for navigation	
Climate regulation: carbon sequestration	X
Regulation extreme events or disturbance: flood water storage	X
Regulation extreme events or disturbance: water current reduction	
Regulation extreme events or disturbance: Wave reduction	
Water quantity regulation: drainage of river water	
Water quantity regulation: dissipation of tidal and river energy	X
Water quantity regulation: landscape maintenance	

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Measure	
Water quantity regulation: transportation	
Water quality regulation: transport of pollutants and excess nutrients	
Water quality regulation: reduction of excess loads coming from the catchment	
Erosion and sedimentation regulation by water bodies	
Erosion and sedimentation regulation by biological mediation	
"Biodiversity"	X
Aesthetic information	
Opportunities for recreation & tourism	X
Inspiration for culture, art and design	
Information for cognitive development	

Step 2: Involved habitats

Intertidal mudflat, saltmarsh, standing water, wet grassland and reed beds were created as a result of this measure.

Table 3: Ecosystem services analysis for Alkborough: Indication of habitat surface and quality change, i.e. situation before versus after measure implementation.

MEASURE		before		After	
		surface (%)	Quality (1-5)	surface (%)	quality (1-5)
Marsh habitat	above mean high water, floods at spring tide	**0**	**0**	**45**	**4**
Intertidal steep habitat	floods every tide, mainly steep zones at marsh edges	**0**	**0**	**5**	**5**
Intertidal flat habitat	floods every tide, flat zones	**0**	**0**	**30**	**4**
Subtidal shallow habitat	never surfaces, less deep than 2m	**0**	**0**	**5**	**4**
Subtidal moderately deep habitat	never surfaces, 2m-5m	**0**	**0**	**0**	**0**
Subtidal deep habitat	never surfaces, deeper than 5m	**0**	**0**	**0**	**0**
ADJACENT LAND	NON FLOODED LAND	**100**	**4**	**15**	**3**
		100		100	

Quality
1 = very high quality
2 = high quality
3 = medium quality
4 = low quality
5 = very low quality

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The measure Alkborough Managed Realignment and flood storage in the mesohaline zone of the Humber estuary was about the creation of intertidal habitat by transforming adjacent land into mainly marshland and intertidal flat habitat with a moderately to very high change in the habitat quality.

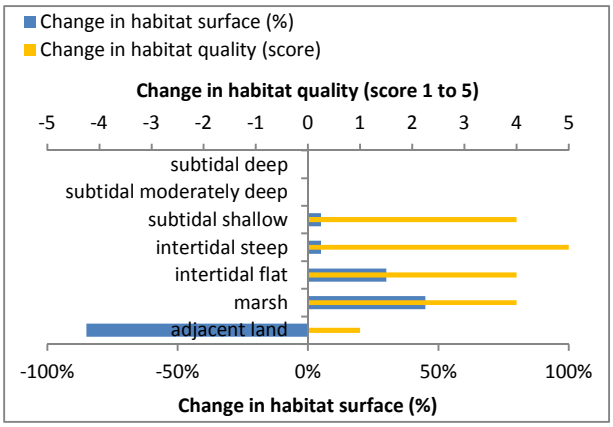

Figure 10: Ecosystem services analysis for Alkborough Managed Realignment and flood storage: Indication of habitat surface and quality change, i.e. situation before versus after measure implementation.

From the ES assessment it is concluded that this measure generates overall a positive expected impact for many ES, with a very positive expected impact for "biodiversity" and a positive expected impact for:

- Cultural services
- Some regulating services: Erosion and sedimentation regulation (by water bodies); Water quality regulation: reduction of excess loads coming from the catchment; Erosion and sedimentation regulation (by biological mediation); Water quantity regulation: landscape maintenance; Climate regulation: Carbon sequestration and burial.

The expected impact for the different beneficiary groups is overall positive, with a positive to very positive expected impact for indirect and future use and for local use.

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Table 4: Ecosystem services analysis for Alkborough Managed Realignment and flood storage: (1) expected impact on ES supply in the measure site and (2) expected impact on different beneficiaries as a consequence of the measure

Alkborough Managed Realignment and flood storage – Creation of ~440 a of intertidal habitat

Cat.	Ecosystem Service	Score
S	"Biodiversity"	3
R1	Erosion and sedimentation regulation by water bodies	2
R2	Water quality regulation: reduction of excess loads coming from the catchment	2
R3	Water quality regulation: transport of polutants and excess nutriënts	0
R4	Water quantity regulation: drainage of river water	0
R5	Erosion and sedimentation regulation by biological mediation	2
R6	Water quantity regulation: transportation	0
R7	Water quantity regulation: landscape maintenance	2
R8	Climate regulation: Carbon sequestration and burial	2
R9	Water quantity regulation: dissipation of tidal and river energy	1
R10	Regulation extreme events or disturbance: Wave reduction	1
R11	Regulation extreme events or disturbance: Water current reduction	1
R12	Regulation extreme events or disturbance: Flood water storage	1
P1	Water for industrial use	0
P2	Water for navigation	0
P3	Food: Animals	0
C1	Aesthetic information	2
C2	Inspiration for culture, art and design	2
C3	Information for cognitive development	2
C4	Opportunities for recreation & tourism	2

Beneficiaries:	
Direct users	0
Indirect users	2
Future users	3
Local users	2
Regional users	1
Global users	1

X Targeted ES

Legend: expected impact*	
3	very positive
2	positive
1	slightly positive
0	neutral
-1	slightly negative
-2	negative
-3	very negative

*: Indicative screening based on ES-supply surveys and estimated impact of measures on habitat quality and quantity. Quantitative socio-economic conclusions require local supply and demand data to complement this assessment.

2.3 Degree of synergistic effects and conflicts according to uses

So far the site appears to be developing inter-tidal habitats as expected, although the rate of accretion and initial elevation of the site is leading to the development of saltmarsh habitats rather than mudflats. The quality of the habitat is as expected for an evolving site in it is location within the estuary. The purpose of the site was to provide flood protection and the site is achieving this, although in the long term it will be less effective due to continued accretion. The Environment Agency are investigating options for changing the site, however it is likely that any changes will impact upon the developing habitats within the site and these impacts will need to be investigated further.

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Part 3: Additional evaluation criteria in view of EU environmental law

3.1 Degree of synergistic effects and conflicts according to WFD aims

This measure was about the creation of a natural flood storage area for the purposes of flood protection which in turn can also improve water and sediment quality and reduce sedimentation in the main channel, which in turn reduces dredging requirements. In addition the site also provides habitat in the Humber Estuary. The compensation measure was not designed to meet the requirements of the Water Framework Directive (WFD). However, it covers both of the main pressures the oligohaline zone of the Humber estuary is affected by.

Table 5: Main pressures of the oligohaline zone of the Humber

Indicator	code	Main pressures **oligohaline** zone Humber	Effect?					Description
			- -	-	0	+	++	
S.I.	1.4	Gross change in morphology during the land 100 years.					X	The land was originally reclaimed from the estuary; the creation of the site effectively restores the balance.
S.I.	3.1/3.2	Decrease of water and sediment chemical quality				X		
S.I. = state indicator; D.I. = driver indicator								

3.2 Degree of synergistic effects according to Natura 2000 aims

This measure was about the use of land as a natural flood storage area for the purposes of flood protection. In addition the site led to the creation of new intertidal habitat to compensate for losses elsewhere in the Humber Estuary. Therefore, it is considered that this measure contributes to the protection and conservation of intertidal wetlands within the Internationally Designated Humber Estuary.

Table 6: Conservation objectives concerning the BHD

Conservation objectives (Humber)	**Specification**	**Effect?**					**Short explanation**
		- -	**-**	**0**	**+**	**++**	
Protected Habitats: Estuary	Intertidal wetland (brackish)					X	Newly created intertidal habitat in Internationally Designated Nature Conservation Site.

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Part 4: Crux of the matter

The “crux of the matter“ refers to the basic, central or critical point of an issue. For example, in this context, the main issues relating to the development and progression of the specific measure detailed within this FAS Repost represent the crux of the matter.

The main purpose of the measure is to provide flood storage during extreme events with an additional objective of providing compensatory habitat for coastal squeeze.

The majority of the site act as a sediment sink and accretes. The initial rapid siltation from 2006 to 2008 (0.6m) has not continued and the average rates of accretion between 2008 and 2012 ranges between 0.03m and 0.09m per year. A linear extrapolation of the accretion rates show that siltation will reach the present day MHWS level within the majority of the site in 13 to 35 years after site opening.

The flooding and sedimentation regime within the realignment site have resulted in the formation of a mosaic of habitats which is considerably more diverse than that on the natural mudflats outside the site. Habitats present include mudflat, standing water, wet grassland and reed beds and fulfil the habitat requirements of a wide range of species or fish and birds. In contrast, the benthic communities are impoverished (throughout this region of the estuary) and do not yet represent those on the mudflats outside the site and are largely composed of freshwater and terrestrial species. Overall the Alkborough site does not necessarily compensate for habitat loss and coastal squeeze in terms of mudflat creation and infaunal community development. It does however appear to be acting as a nursery area for fish and a significant feeding and roosting area for birds. In this respect, the development of the site appears to have been beneficial to this region of the estuary which is otherwise largely characterised by narrow mudflats with species poor communities and, in most areas, little vegetation.

Over time it is anticipated that the site will become well vegetated and cease to be fully inundated by high tides. This will mean that the site will not provide the 'like for like' direct habitat compensation. Over time the site will continue to accrete and thus reduces the space available for water storage and reduce the effectiveness of the site to provide flood protection. The Environment Agency is currently investigating options for changing the breach configuration and altering the scheme to a regulated tidal exchange scheme.

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