CASE STUDY:

MANAGED REALIGNMENT AND THE RE-ESTABLISHMENT OF SALTMARSH HABITAT, FREISTON SHORE, LINCOLNSHIRE, UNITED KINGDOM

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1. BACKGROUND INFORMATION

This case study is an example of ecosystem restoration for the purpose of coastal flood risk reduction and habitat creation. Managed realignment describes the repositioning of an existing hard sea defence to a more landward location, allowing accommodation space for the creation of intertidal habitat; the resultant increase in the intertidal zone allowing increased flood water storage and wave attenuation (Möller et al., 1999). Managed realignment was implemented at Freiston Shore, Lincolnshire, UK in August 2002.

Coastal communities on the low-lying coastal zone surrounding the shallow North Sea Basin are vulnerable to storm surges (water levels raised by meteorological forcing), particularly those coinciding with high spring tides. Storm surges are often accompanied by high waves which can overtop and breach sea defences. The most devastating storm surge in the 20th Century occurred on 31 January – 1 February 1953 and affected many countries surrounding the Southern North Sea, with a death toll of 1836 people in the Netherlands, 307 in the UK and 22 in Belgium. Over 136 500ha were inundated and more than 100 000 people evacuated in the Netherlands alone (Gerritsen 2005), and over 1200 breaches of defences or flood penetration were recorded along the East coast of the UK (Baxter 2005, see also figure 1).

Figure 1 – A motor torpedo boat lifted by the 1953 surge at Wells-next-the-Sea. Source: Baxter 2005

In 1978 Wells-next-the-Sea on the North Norfolk coast experienced maximum water levels 1.81m above the predicted high tide (Steers et al. 1979). Inundations of comparable height are not rare in the North Sea; Doornkamp (1998) describes 14 damaging surge events in the North Sea basin between 1894 and 1978, and an average of 19 surges per year have a magnitude greater than 0.6m above the average winter tide level.

Predicted accelerated sea level rise poses a particular future threat to communities based along the low-lying coastline of the North Sea, as this will raise the base level for future storm surges. Annual rates of sea level rise of 6mm have been predicted in this area until 2030, increasing to 8.5mm between 2030 and 2100 (Environment Agency 1996a). Two key side effects of an increased tidal flood volume as a result of sea level rise are a change to tidal flow symmetry and increased inshore wave energy due to greater water depths. These factors lead to increased erosion, particularly in the upper intertidal zone, at the margin of existing saltmarshes or at the seaward face of fixed defences. De la Vega-Leinert and Nicholls (2008) estimate that, under a scenario of 'do nothing' (i.e. no maintenance or enhancement of defences), a relative sea-level rise of only 20cm between 1990 and 2050 would lead to flood and erosion damage costs in East Anglia of £1325-1333 million.

Accelerated sea level rise also has consequences for intertidal habitats, frequently referred to as 'coastal squeeze', and illustrated in figure 2 below. While increased wave energy under accelerated sea level rise is a key factor in causing the seaward erosion of saltmarsh, other causes, such as invertebrate activity and sediment starvation may contribute (Wolters et al. 2005).

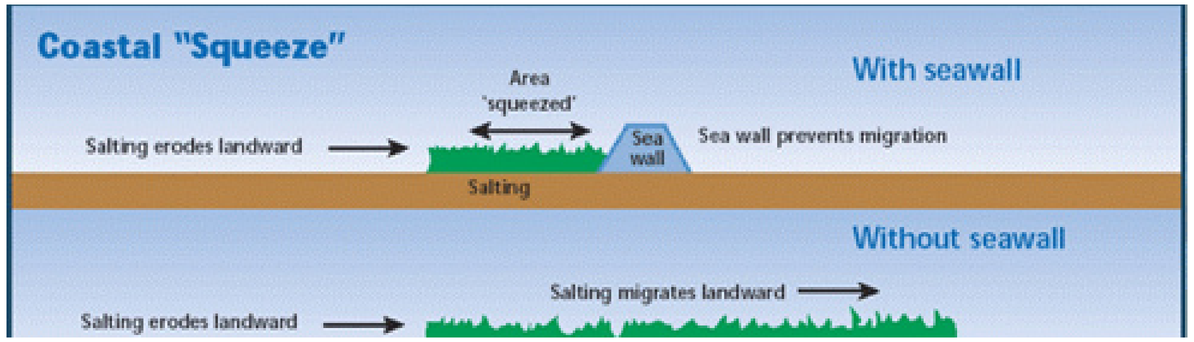

Figure 2: The landward retreat of intertidal habitat with (above) and without (below) restricting fixed defences. The former leads to net loss of habitat ('coastal squeeze'). Source: Environment Agency (1996b)

PROJECT SCALE

The Freiston Shore realignment trial created 66ha of saltmarsh habitat and 15ha of saline lagoon (figure 3). The Wash Banks coastal defence project, of which this realignment site is a part, protects more than 80 000 ha of low-lying land (Nottage and Robertson 2005), including many villages and the town of Boston (with a population of +35 000).

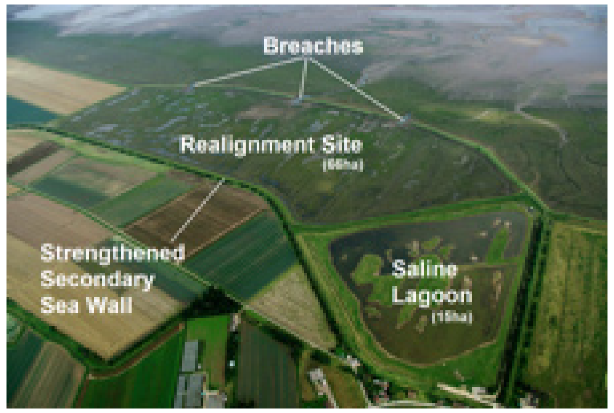

Figure 3 – The Freiston Shore Managed Realignment Site. Photo by Environment Agency.

PLANNING INSTITUTIONS AND SUPPORTING AGENCIES

Freiston Shore was a successful example of cooperation between a number of Government and voluntary organisations. The agricultural land was originally embanked in 1978 and owned by the UK's HM Prison Service. The site was acquired by the Royal Society for the Protection of Birds (RSPB), funded by donations and grant aid not available to Government organisations.

The Department of the Environment, Food and Rural Affairs (DEFRA) has the ultimate responsibility for coastal defence and management policy within the UK. The Environment Agency, however, is responsible for the planning, execution, and maintenance of the scheme. In addition, English Nature (now Natural England) was involved in the planning process due to the potential for damage to protected areas. Consultation of a range of nongovernmental organisations and stakeholders was also part of the implementation process.

As part of the scheme, an in depth monitoring programme was set up at Freiston Shore to monitor processes such as sediment accretion, surface elevation change, vegetation colonisation and invertebrate distribution both inside the site, and on the surrounding intertidal zone. This was funded by the Environment Agency and conducted between 2001 and 2006 by the Natural Environment Research Council's Centre for Ecology and Hydrology (NERC CEH), the Cambridge Coastal Research Unit (CCRU), Department of Geography, University of Cambridge and the School of Geography, Birkbeck College, University of London.

2. PROJECT DESCRIPTION

Managed realignment was originally proposed at Freiston Shore due to increased rates of erosion experienced at the base of the sea wall, and higher repair/maintenance costs as a result. This sea defence was a focus of erosion due to its construction too far seaward, compared to the surrounding artificial shoreline. This made the defence a focus of wave attack, both directly and as a result of refraction around the outlying structure.

In the UK generally, whilst the purpose of managed realignment was originally focused on issues of coastal defence, its importance in helping to meet national and international targets for the maintenance and creation of key coastal habitats is also being increasingly appreciated. Saltmarsh loss rates are estimated at 40-100ha annually (ref), whilst the UK Habitat Action Plan is committed to the creation of 140ha per annum to halt decline and replace losses between 1992 and 1998 (UK Biodiversity Group 1999).

LOCATION AND CONDITIONS

Freiston Shore is located on the East Coast of England, on the Lincolnshire coast of the Wash Embayment, covering 615km2 below high water (figure 4). The Wash is a macrotidal environment, with mean neap and spring ranges of 3.5m and 6.5m, and mean wave heights in the surrounding North Sea reaching up to 2m (Symonds 2006). Similar to the rest of the United Kingdom, Lincolnshire experiences a mid-latitude oceanic climate, with prevailing winds from the South West. This brings a succession of depression systems, which contribute to the creation of storm surges.

Figure 4 – Location of Freiston Shore, UK. Adapted from: Thomson et al. 2004.

The Wash is a sediment sink, so the intertidal zone has the potential to accrete and increase in surface elevation with predicted accelerated sea level rise. Marine sediment movement is the biggest contribution to the sediment budget, while the four principal rivers flowing into the Wash play only a minor role in sediment input. Collins et al. (1981) report suspended silt concentrations of 200 mg l-1 in flows over upper tidal flats, although over-marsh concentrations have been assumed to be lower at 150 mg l-1 (French 1993). Modelling suggests that with such suspended sediment concentrations saltmarshes in The Wash reach 95% of their final elevation (typically 0.7m below Highest Astronomical Tide (Kestner 1975)) after 150 years.

The Wash is part of The Wash and North Norfolk Coast Special Area of Conservation, due to the occurrence of the following habitats: sublittoral sandbanks slightly covered by sea water permanently; mud/sandflats not covered by seawater at low tide; large shallow inlets and bays; reefs; Salicornia and other pioneer annual species; Atlantic salt meadows (Glauco-Puccinellietalia maritimae); and Mediterranean and thermo-Atlantic halophilous scrubs (Sarcocornetea fruticosi), with coastal lagoons as a qualifying feature. The Wash is also important for the significant presence of the Annex II species, the Common seal Phoca vitulina, which breeds on the extensive flats. The Wash's SPA designation is not only based on the presence of 21 species of Annex I birds and regular migrants but also on the occurrence of an internationally important assemblage of birds, regularly comprising over 400,000 waterfowl.

Freiston Shore and the surrounding area show a diverse ecology. The intertidal zone fronting the site is a gradient of broad sand flats near low water, changing to intertidal mudflat and saltmarsh as elevation increases landward. The halophytic vegetation present at Freiston Shore is characteristic of an Atlantic saltmarsh type found across the east and south-east coast of the UK, with field observations and remote sensing imagery analysed by CCRU showing seasonal bands of algae and sparse Salicornia europea on the seaward edge. The seasonal pioneer vegetation zone comprises dense stands of S. europea and S. europea-Suaeda maritime. Transitional and mid-marsh zones are characterized by Aster tripolium and patches of Spartina anglica, and a mosaic of Puccinellia maritima-based communities to the south of the site, and dense Atriplex portulacoides to the north. This habitat mosaic supports a wide diversity of invertebrate taxa. Brown et al. (2007) recorded several ragworm, oligochaete worm, springtail, mite, beetle, gastropod, and crab species. This trophic level in turn supports a large population of migratory birds; indeed, the Wash embayment supports the largest number migrating waterfowl in the UK (West et al. 2007), especially from breeding grounds in the arctic. Typical species found in the Wash area include wader species such as Dunlin, Redshank and Oystercatchers, and other species including Black-tailed Godwits, Brent Geese (Musgrove et al. 2001, West et al. 2007) and 31 pairs of rare Avocets.

The area surrounding Freiston Shore experiences socio-economic issues distinct from many other parts of the UK, such as a dispersed population base and over-reliance on agriculture and land-based economic activity. Much of the Lincolnshire coast has been previously embanked and reclaimed, so land use within this region is predominantly agricultural, with 85% of the tidal flood plain area classed as rural (Environment Agency 1996a). Shell fisheries (cockles, mussels and oysters) also contribute to the local economy (Myatt et al. 2003a). Indeed, the Freiston Shore realignment site has been shown to provide an important nursery area for 12 species of fish, including economically important species such as European sea bass (Dicentrarchus labrax) and Atlantic herring (Clupea harenpus) (Brown et al. 2007). Tourism is also a vital component of the coastal area for activities such as walking and bird watching. The realignment site at Freiston Shore has contributed to this greatly, attracting over 57 000 visitors in 2003/04 (compared to 11 000 before realignment), and adding over £150 000 into the local economy in the first year (Nottage and Robertson 2005).

DESCRIPTION OF ECOSYSTEM MEASURES APPLIED

As part of the realignment scheme, the existing sea defence was breached in three places (see figure 3), and a new landward lying secondary defence was strengthened. Linear drainage channels were also excavated within the site to facilitate sediment and nutrient delivery into the interior of the realignment area. In addition to the full coastal realignment, a smaller (15 ha) saline lagoon was created, allowing regulated sluice-controlled exchange of tidal water on the highest spring tides of the year only (see Figure 3). Within the saline lagoon, some topography was created to enable birds to roost on higher ground, and a varied grazing regime produced a number of sub-habitats suitable for different bird species. No further ecosystem measures were applied.

PROJECT STARTING POINT; MILESTONES

Managed realignment at Freiston Shore took 6 years to implement from the time of recommendation:

1978-1983	Latest reclamation of saltmarsh at Freiston Shore by HMP North Camp
1996	Publication of the Lincolnshire Shoreline Management Plan (SMP), recommending managed realignment at Freiston Shore
1997	Publication of the Wash Banks Strategy, in response to the SMP
2000	Strengthening of secondary sea wall and creation of cross wall
Sept 2001	Set up of accretion and vegetation monitoring locations
Aug 2002	Breaching of sea defences in three locations
Apr 2003	Colonisation by pioneer saltmarsh vegetation
Sept 2006	CEH Monitoring programme ends
Present	Monitoring of surface elevation change by CCRU

3. RESULTS

Managed realignment at Freiston Shore can be considered a success, with vegetation establishing more quickly here than at many other realignment trials in the UK. Brown et al. (2007), and analysis of multispectral imagery by CCRU has shown that 86% of the site was vegetated by 2006, mostly by pioneer annual S. europea, though perennial mid-marsh species such as A. tripolium, P. maritima and A. portulacoides were beginning to establish, particularly at higher elevations in the North-West corner of the site. However, some time will be required for sediment accretion within the rest of the site to increase surface elevation to a height able to support more mature saltmarsh species. These species are characterised by an increased biomass and surface area, and produce a more complex vegetation mosaic, so may be better able to act as a buffer to incoming wave energy.

Whilst data is not available specifically for Freiston Shore, Möller et al. (1999) showed through field trials that UK saltmarshes could reduce wave height by almost 61% by increasing bed surface friction, and could reduce total wave energy by an average of 82%. Other studies have shown that swards of saltmarsh grass vegetation can reduce wave heights by 70% and wave energy by over 90% (Bird 2000), though this is a highly non-linear process.

A reduction of near shore wave attenuation (due to increased water depths) is likely to result from sea level rise. This could lead to an increased cross-shore profile slope and thus higher wave energy levels in the upper intertidal zone. A permanent benefit of increased wave attenuation, and thus coastal protection will require the entire coastal profile to continue to adjust in the future (by migrating inland).

Due to the relatively high initial surface elevation, and a rich seed source on surrounding marshes, pioneer vegetation quickly established at Freiston Shore, but time is required for succession to higher marsh mosaics with increased wave attenuation function. This relies on the deposition of sediment (potentially increased as vegetation density increases) and accretion to a higher surface elevation, in order to support mature marsh types. UK saltmarshes are thought to accrete at a rapid initial rate, before slowing at higher elevations, as inundation frequency decreases (figure 5).

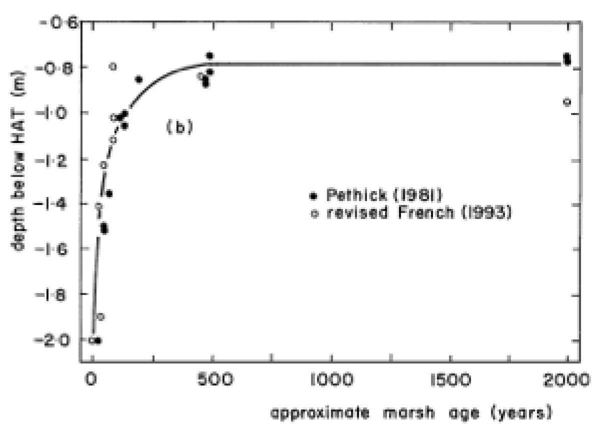

Figure 5 – Age-Altitude Curve for North Norfolk Marshes. Source: Allen 2000

It has been predicted that, based on data from the North Norfolk coast (to the east of the Wash embayment), a pioneer Salicornia zone may develop from an unvegetated mudflat within 25 years, and may reach a Juncus maritimus high marsh successional stage within 90-200 years (Chapman 1959, Chapman 1960). However, potential managed realignment sites may start at a higher surface elevation than an unvegetated mudflat (as land was originally reclaimed from higher marsh), so will not require as much time to accrete further sediment to increase surface elevation. It is also not just vegetation establishment that is important, but also the restoration of ecosystem function.

Managed realignment can provide a long-term solution to disaster risk reduction. Research by the University of Newcastle (1998) showed that, with rates of sea level rise of 3/6mm per year, a 100m saltmarsh margin could be maintained for 12-25 years with the previous defence line at Freiston Shore. However, realigning to the secondary defence line was predicted to maintain this saltmarsh strip for more than 200 years.

A flexible approach and continued monitoring is key to the success of any such coastal risk reduction scheme. It is likely, that 'step-changes' in vegetation cover occur over time, as surface elevation increases and vegetation communities adapt. The attenuation capacities of different vegetation canopy types have not yet been quantified, although preliminary studies indicate that there are differences that warrant further investigation (Möller, 2006).

4. SUSTAINABILITY

The Wash embayment (including Freiston Shore) is covered by a number of national, European and international habitat legislations such as the EU Birds and Habitats Directives and the Ramsar Convention (Environment Agency 2006). Therefore, sections of the Wash are variously designated as National Nature Reserves, Sites of Special Scientific Interest, Special Protection Areas, a Special Area of Conservation and a European Marine Site (see section Location and Conditions above).

The Freiston Shore site is currently owned and maintained by the RSPB, and promoted nationally as an important nature reserve. 'Ecotourism' aimed primarily at the bird watching community will promote future protection. Local farming groups are also encouraged to utilise this site in a sustainable manner through low density pastoral activity on the outer saltmarsh.

5. LIMITATIONS ON THE USE OF ECOSYSTEMS IN THIS PARTICULAR HAZARD

Many of the obstacles to the success of managed realignment are not due to the nature of coastal hazards, but rather are linked to social and economic issues that may limit its uptake. One such issue is the negative perception of stakeholders (landowners, local groups) and the public towards realignment. In particular, stakeholders have a perception of a defeatist attitude that is 'giving in to the sea'. There may also be an element of 'feeling safer' behind a large engineered defence structure. Sea walls, for example may be perceived as a more effective coastal defence compared to a natural marsh, though this may not actually be the case. Indeed, Leggett et al. (2004) noted that reasons for community opposition may include the idea that only hard defences provide absolute protection. It is often the case though that the construction of defences induces further development in zones previously at risk, leading to larger losses when that defence is eventually overtopped (Kates et al. 2006). Public attitudes to managed realignment schemes are also shaped by factors such as confidence in statutory bodies, awareness of the scheme, length of time the scheme is in the public domain, contact between stakeholders (including public consultation) and personal experience of flood events (Myatt et al. 2003a, Myatt et al. 2003b). A particular issue experienced at Freiston Shore was distrust of the authorities and organisations involved in the consultation, planning and funding processes (Myatt et al. 2003a). Education could be increased, and perceptions changed by providing a regular consultation process and access to information tailored to individual realignment projects.

Another cause of adverse public opinion is the perceived low level of compensation for releasing land to tidal exchange. Without adequate rates of compensation available (whether for land purchase or payment for loss of use) it will be difficult to persuade landowners to sell their land or change land use to flood defence and habitat creation. Since managed realignment brings recreational, societal and environmental benefits as well as flood defence, one solution may be to apply for funding/compensation for these benefits alongside flood defence funding (Ledoux et al. 2005). Payments for conversion of grassland/arable land to saltmarsh under DEFRA's Higher Level Environmental Stewardship scheme in 2005 ranged from £500-700 per hectare (DEFRA 2005). As a consequence of this level of financial incentive landowners may only be prepared to abandon lower value agricultural land, of which there is only a small proportion along The Wash and North Sea coastline. Landowners will also be dissuaded by the fact that most countryside stewardship payments have a current limit of 10 years, while managed realignment schemes will (ideally) last over a much longer timescale (Leggett et al. 2004).

If suitable land is available, the legislative framework surrounding land use change may further limit the implementation of managed realignment. Environment Agency (1999) describe up to 17 separate legislative mechanisms that may need to be passed before permission to realign an area can be granted (figure 6). Many of these acts are related to changes in land use (e.g. the Town and Country Planning Act 1990, Land Drainage Act 1991) or environmental impact (EC Environmental Impact Assessment Directive 85/337/EEC, Environmental Protection Act 1990). Managed realignment can often conflict with legislation designed to protect particular land uses or land designations. For example, while managed realignment and saltmarsh creation often fulfils habitat regulations, these regulations could provide an obstacle if the land to be realigned is already a protected habitat (Pethick 2002, Leggett et al. 2004) or if external impacts were to potentially affect protected habitats further along the coast. In some situations, saltmarsh on the seaward side of an embankment is protected under the Habitats Directive, as is freshwater grazing marsh inside the embankment. In this instance it would be illegal to allow any development to affect either habitat, but if no development takes place then saltmarsh is lost (Pethick 2002) due to coastal squeeze. Conflicts such as this would have to be resolved if managed realignment is to become a more popular coastal defence option.

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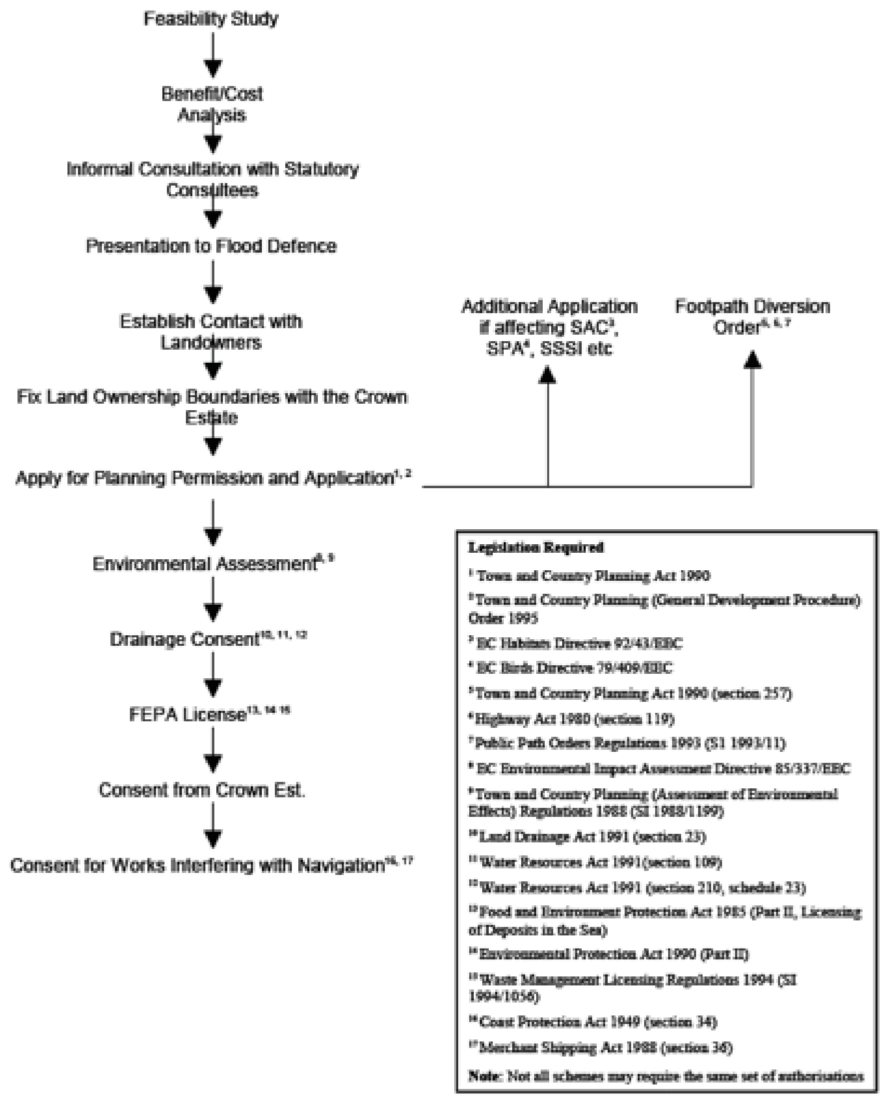

Figure 6 – Potential Legislative Procedures Required for the Authorisation of a Proposed Managed Realignment Scheme. Compiled from: Environment Agency (1999)

A particular technical barrier according to Ledoux et al. (2005) is a lack of scientific understanding of saltmarsh restoration. Difficulties in predicting the habitat type emerging from a realigned site could be a particular problem if the aim is to produce like-for-like habitat to compensate for losses elsewhere. A lack of system understanding also influences the time-scale over which managed realignment is deemed a feasible defence option; management decisions and confident predictions of future geomorphological and ecological behaviour can only be made with a better knowledge of long-term coastal functioning.

There is a lack of research undertaken to study the external impacts of realigning coastlines on the surrounding intertidal system. While the potential for unforeseen externalities has been theorised (Ledoux et al. 2005, French 2006) there is very little scientific literature that provides quantitative data on what these impacts may be. Research by CCRU at Freiston Shore has shown that the creeks attached to the breaches outside the site increased in width and volume dramatically immediately after breaching in order to exchange a larger volume of water over the same tidal cycle (figure 7). As well as having implications for saltmarsh loss due to erosion, eroded material was deposited inside and outside the site close to the sea wall, increasing surface elevation and potentially changing the vegetation stage that could be supported.

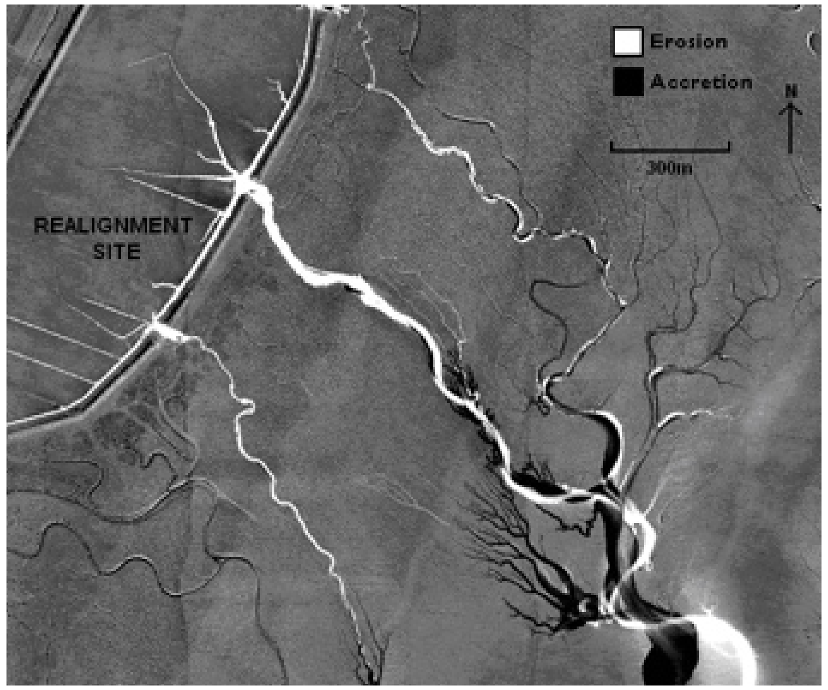

Figure 7 – Airborne LiDAR image highlighting creek widening (erosion) and infilling (accretion) between November 2002 and November 2006

6. IMPLEMENTATION COSTS

Initial Investment

The capital costs to implement managed realignment at Freiston Shore were estimated at £1.98 million (Nottage and Robertson 2005). These costs were met through the Environment Agency's flood defence budget, DEFRA and the Lincolnshire Flood Defence Committee. Works involved the strengthening of a secondary sea wall to the back of the site, and the construction of a cross wall to the south-west to provide an area behind for a saline lagoon. Capital works costs would also include the excavation and landscaping of the saline lagoon, as well as the excavation of primary drainage channels within the site, and breaches.

Maintenance Costs

A monitoring scheme was implemented between 2001 and 2006 at Freiston Shore, requiring ongoing funding during this period. Ongoing maintenance costs would also have to budget for smaller repairs to the secondary sea wall, which could be damaged by extreme storm and surge events. These costs are part-funded through a 20 year DEFRA Habitats Scheme, and renting of the external marsh for cattle grazing provides some small extra income.

Alternative Costs

Coastal defence planning in the UK is currently based on non-statutory guidance documents, the Shoreline Management Plans (SMPs), that divide the coast according to geomorphological, sedimentological, and land-use zone criteria and suggest appropriate coastal management approaches. Recent revisions of the first round of SMPs (commissioned during the 1990s) suggests four alternative management approaches: (a) Hold the line (maintain or upgrade the level of protection provided by current defences), (b) Advance the line (build new defences seaward of existing defences), (c) Managed Realignment (allow retreat of the shoreline with monitoring and, if appropriate, management to limit or control movement), and (d) No active intervention (a decision not to invest in providing or maintaining defences).

Alternative cost estimates for two of these approaches at Freiston were £19 million under the 'do nothing' scenario ('d' above) and £2.06 million over 50 years for maintenance of the existing line of defence (Nottage and Robertson 2005) ('a' above). These costs are set against a scenario of rising flood defence costs for the UK, with predictions of up to £75 billion required by 2080 (Evans et al. 2004). The wave attenuation function of saltmarsh vegetation has predicted to decrease the overall costs of sea defence structures, so could contribute to lowering the cost of coastal defence. The Environment Agency (1996b) estimated that, under typical wave conditions, an 80m wide saltmarsh margin could reduce a sea defence height from 12m to 3m, with a financial saving greater than an order of magnitude. In addition to these savings, it is difficult to quantify the financial benefits of nature conservation and ecosystem services associated with realignment at Freiston Shore.

7. CARBON BENEFITS

Wetland systems exhibit high net primary productivity and organic matter production, and can act as an important carbon store; Neue (1997) estimated that approximately 250Gt of carbon are conserved in tropical wetlands alone. Globally, saltmarshes sequester 210±20 gC m-2 a-1 (Chumura et al. 2003), with a great deal of local variability. Soil carbon densities are greatest in interior marshes which are higher and flooded less frequently, but accumulation rates are higher near sediment sources (such as creeks) and at lower elevations A knowledge of global wetland area is needed to calculate sequestration rates but there is considerable uncertainty in global wetland area estimates. Using 180,000 km2 for mangroves and 23,000 km2 for saltmarshes the rate is calculated at 0.043 Pg C a -1. However, this is only for surface soils; the total in the top 0.5 m of the soil profile is probably x10 this figure.

There is less quantitative data on the carbon sequestration capacity of North West European saltmarshes, though Cannell et al. (1999) estimated that British saltmarshes in 1990 sequestered 0.1 MtC per annum. This compares to rates of 0.1MtC for forest soils, 0.3 MtC for non-forest biomass and 0.4 MtC for set-aside soils in the UK in 1990. Smith et al. (1983) describes a methodology for calculating carbon storage in coastal wetland soils by the monitoring of carbon content, accretion rate and soil bulk density.

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8. CONCLUSIONS AND LESSONS LEARNED

The case study of Freiston Shore illustrates that managed realignment can be a viable and successful strategy to adapt to the impact of sea level rise and/or increased wave action on low-lying coasts. By providing additional flood storage capacity and intertidal surfaces that attenuate incident wave energy, flood risk is reduced, at least in the short to medium term, after the new intertidal surface has become stabilised and vegetated. Over longer (+50 year) time periods, the increased defence efficiency cannot be guaranteed, as continued landward retreat may be necessary to maintain an intertidal profile that supports saltmarsh vegetation.

To achieve maximum benefit from realignment schemes, the continued monitoring of site conditions before, during, and after implementation is critical. Monitoring results from Freiston and indeed other managed realignment schemes in the UK (Brown et al., 2007) suggest that thresholds exist within the evolution of these ecosystems that alter their resilience and vulnerability to future hydrodynamic, sedimentological, and climatic changes. Such thresholds still need to be adequately quantified. To achieve this, continued monitoring is necessary and adds to the cost of scheme implementation. Furthermore, the implementation of managed realignment as a strategic 'soft engineering' option to coastal flood risk reduction is not just a geomorphological or ecological challenge, but is also influenced by social, political, and land ownership constraints.

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