D. Case Study Examples

D.1 Introduction

The case studies examined below are intended to provide relevant examples of the various techniques for saltmarsh management discussed in Chapter 5 of the Manual. They represent the most recent case study examples that were available to us at the time of drafting. However, that is not to say that all of the examples are 'recent' or illustrate recent practices. That is, some of the examples included here are relatively old, but are included (as the most recent examples available to us) in order to make the Manual as comprehensive as possible. The age of the case studies described is, however, an interesting illustration in itself of the likely current use of particular techniques. Moreover, examples are not only provided or successful saltmarsh management schemes, but are also provided of failed approaches.

D.2 Technique: grazing

D.2.1 Bridgewater Bay, Somerset

Description

Bridgewater Bay National Nature Reserve is located on the north Somerset coast within Bridgewater Bay, which lies on the south side of the Severn Estuary and the eastern edge of the Bristol Channel. Sheep grazing as a management technique on the marshes has been practised since the 1960's. The main objective of using grazing for management at Bridgewater is to attract large numbers of wintering wildfowl, in particular Wigeon.

Grazing on the saltmarshes is carried out between April to October, with the aim of maintaining a sward height of two inches during the grazing months. The intensity of grazing is not strictly managed but, rather, is dependant on local conditions. For example, during particularly dry years the number of sheep grazing on the marsh is reduced and, similarly, during particularly wet years the numbers are increased. In general, however, numbers are not strictly regulated.

Monitoring

The numbers of waterbirds are monitored regularly as part of the national Wetland Birds Survey (WeBS) organised by the British Trust for Ornithology, the Wildfowl and Wetlands Trust, the Royal Society for the Protection of Birds and the Joint Nature Conservation Committee.

Effectiveness of the scheme

Although sheep grazing has proved effective in maintaining a suitable sward height for wintering wildfowl, English Nature would prefer a mixed grazing regime to be

implemented. However, due to the relatively high cost of cattle and the associated risks of grazing in a tidal situation, the practice of cattle grazing has been restricted.

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D.2.2 Aberlady Local Nature Reserve, East Lothian

Description

Aberlady Bay was designated Britain's first nature reserve in 1952. In recent years numbers of breeding Lapwings and Redshanks at the reserve have shown a steady decline. A report by East Lothian council presented to the Reserve Advisory Group on the status of breeding birds, attributed these declines to a reduction in suitable nesting habitat, predation of nests, particularly by crows, and human disturbance. A follow up paper on management of the saltmarsh to the Advisory Group suggested various management recommendations including the establishment of a small trial plot to assess the impact of grazing on breeding redshanks and lapwings.

Following advice from Scottish Natural Heritage it was decided that the trial area should consist of two 1 hectare plots in the northern part of the saltmarsh/freshwater marsh transition area. Both plots were enclosed using 700m of 90cm high, 10 cm mesh electric fencing, powered by a 12V battery unit, charged with a solar panel.

The experiment was due to commence in 2001 but following the outbreak of foot and mouth disease the trial was delayed until the following year. Following discussions with a local farmer nine Suffolk-cross sheep were introduced to one of the plots on 16th October 2002. The sheep were then moved into the second plot on December 17th where they remained until 5th February 2003. It was originally hoped that Cattle could be used on one of the plots, but it was felt that the exposure of the site would be detrimental to their health and the fencing used would not be robust enough to contain them.

Monitoring

Due to the delayed start to the trial, two seasons of pre-scheme monitoring were gathered before the sheep were introduced to the plots. At each plot vegetation height and species coverage was measured at 100 random sampling points whilst breeding bird numbers were recorded as part of the ongoing census on the reserve.

Effectiveness of the scheme

The results of the 2003 bird census on the reserve show that the grazing experiment appears to have been successful. Prior to the trials, annual bird counts recorded 1-2 breeding pairs of Lapwing and Redshank with numbers increasing to 6-7, post grazing. The increase in breeding adults on both sites also led to an increase in fledged young.

Figure D.1 Sheep grazing on trial plot on Aberlady Nature Reserve, 2003

Unfortunately the experiment was not continued the following season due to problems sourcing suitable grazing stock so long term effects cannot be assessed. However East Lothian council are planning to repeat grazing later in 2005 providing suitable stock can be sourced.

Recommendations following the first trial experiment included:

- Introduction of cattle to a more-sheltered trial plot, with more robust fencing
- Areas important for nesting Lapwings/Redshanks should be protected by electric fencing

Further Information

Thomas, I. (2003). An Assessment of the Saltmarsh Grazing Trial at Aberlady Bay Local Nature Reserve. Unpublished report. East Lothian Council.

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D.3 Technique: small-scale vegetation planting

D.3.1 Bosham, Chichester Harbour, West Sussex

Description

Bosham is located in a relatively sheltered area within Chichester Harbour. The saltmarsh at this location is generally dominated by common cordgrass (*Spartina anglica*). The area is very low in elevation and experiences very low wave energy. Sediment is accreting throughout the upper bay. *Spartina* has colonised the area naturally and is mixed at the lowest elevations on the west side of the bay with glasswort (*Salicornia* spp.). On the east side of the bay elevations are higher, with one metre deep tidal rivulets. The saltmarsh community here is mixed, consisting of sea purslane (*Atriplex portulacoides*), common sea lavender (*Limonium vulgare*), common saltmarsh grass (*Puccinellia maritima*), sea aster (*Aster tripolium*), cordgrass (*Spartina* spp.) and some *Salicornia* spp. At the highest elevations sea couch (*Elytrigia atherica*) and some common reed (*Phragmites australis*) dominate.

In May 1998, the Chichester Harbour Conservancy planted *Spartina* in a small area (approx. 450m^2) at the site of a former car park. The surrounding area of existing saltmarsh is almost entirely restricted to dense stands of *Spartina*. Sprigs were taken from wild stands of *Spartina* growing in ditches around Bosham and transplanted at approximately 0.3-0.6m intervals. To prevent continued car parking, large stones were placed along the road edge and the area was planted between the stones and the water.

Monitoring

Due to the site's small size, there is no monitoring program in place other than visual assessment of the growth of the transplanted sprigs.

Effectiveness of the scheme

Following transplantation, the sprigs have grown and spread, and have developed seed heads. This is a very low wave energy site, but is inundated at high tides in excess of one metre depth. Two months after planting one hundred percent survival of the plants was evident.

This site provides a good example of how common cordgrass (*Spartina anglica*) can be planted and utilised for multiple purposes. That is, the planting has stabilised the substrate and prevented erosion, in conjunction with making the area more aesthetically pleasing to visitors to the area.

Figure D.2 Spartina planting at Bosham, Chichester (copyright Chichester Harbour Conservancy)

Further information

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Brooke, J., Landin, M., Meakins N. and Adnitt C. (2000). *The Restoration of Vegetation on Saltmarshes*. Environment Agency R&D Technical Report W208.

D.3.2 Cleavel Point, Poole Harbour, Dorset

Description

The saltmarsh at Cleavel Point underwent restoration following the excavation of a 0.15m diameter backwash pipeline in 1997/1998. *Spartina* was transplanted using turfs of approximately 0.15m square taken from the adjacent marsh. Care was taken to ensure that *Spartina* squares were removed from random locations so that the production of large bare patches was avoided. The turfs were replanted 'firmly' to prevent them from being washed away at the next tide and pegged in a 1m intersecting grid. It was important to plant the turfs at the same soil depth and tidal location as that at which they were originally growing.

A nearby area that had also suffered damage from the pipeline installation also underwent restoration work. Seeds were obtained for this project using a large

vacuum cleaner (Devax); it was considered important to obtain seeds from a nearby marsh in order to ensure that they were genetically adapted to local conditions. The seeds were then dried and stored in a shed prior to being hand sown on the affected area of saltmarsh.

Figure D.3 Spartina development following transplantation, Bosham, Chichester (copyright Chichester Harbour Conservancy)

Monitoring

As with the Bosham scheme, due to the small area involved, there is no monitoring program other than visual assessment.

Effectiveness of the scheme

The planted area is growing well, but the area where natural colonisation was allowed is still bare in a number of places. This site is expected to become completely covered by vegetation and, considering the availability of propagules of various marsh plants, this should occur with little difficulty. The pipeline crossing location comprises only a very small part of the overall natural marsh which occurs at this site.

The adjacent site that similarly underwent remedial work has also proved to be successful, with species such as common saltmarsh grass (*Puccinellia maritima*), glasswort (*Salicornia* spp.) and sea aster (*Aster tripolium*) germinating well.

Further information

Brooke, J., Landin, M., Meakins N. and Adnitt C. (2000). *The Restoration of Vegetation on Saltmarshes*. Environment Agency R&D Technical Report W208.

Figure D.4 Spartina anglica was planted using turfs at Cleaval Point, Dorset (from Brooke et al., 2000)

D.4 Technique: sedimentation fences

D.4.1 Wellhouse, Strood Channel, West Mersea, Essex

Description

Lateral erosion of the saltmarsh edge at Wellhouse of up to 0.6m a year was putting at risk the integrity of a concrete block armoured earth bank. The width of the remaining saltmarsh was between 0-20m. In places the toe of the bank showed signs of failure and some of the concrete blocks had been ripped out, allowing waves to gouge hollows in the earth bank. As the sea defence protected 37ha of farmland it was determined that maintenance works needed to be carried out. However, to reduce the medium term maintenance costs, it was decided to combat further saltmarsh erosion and attempt to reverse saltmarsh loss by encouraging sedimentation using sedimentation fences.

Rows of double wooden stakes filled with brushwood were constructed running perpendicular to the shore. The fences were not of uniform length, varying between 20-80 metres. Some of the perpendicular fences were connected with fences running parallel to the shore to enclose areas of mudflat, forming fields or 'polders'.

Monitoring

Although the sedimentation fences were installed in 1986, post-project monitoring did not begin until six years later. Subsequent monitoring, between 1992 and 1995, involved twice yearly surveys carried out in April and October and involved measuring the following:

- Vertical accretion/erosion using a grid of bamboo canes.
- Sediment density using a graduated brass bar.
- Position of seaward extent of saltmarsh (gives an indication to the degree of success in controlling the lateral erosion of the saltmarsh).

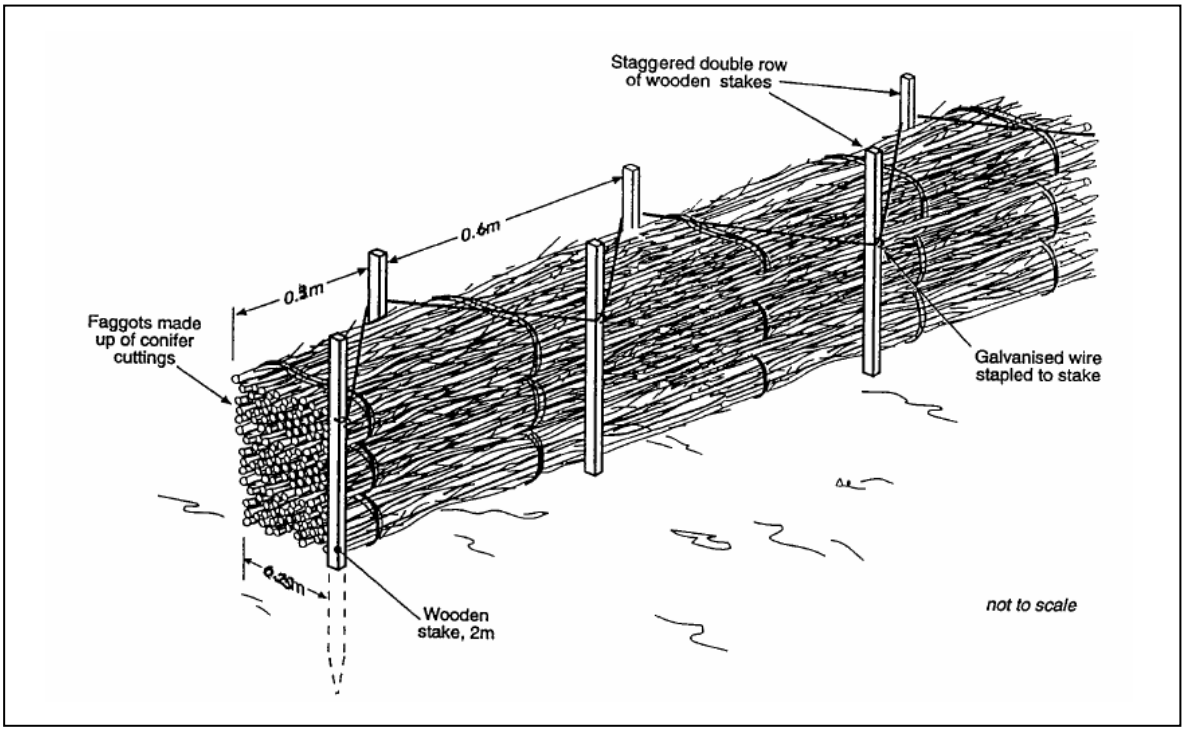

Figure D.5 Detail of the sedimentation fence (from Carpenter and Brampton, 1996)

Effectiveness of the scheme

Unfortunately as monitoring did not begin until six years after the fences were installed it is difficult to assess what the initial rate of accretion was following the inception of the scheme. Subsequent monitoring has shown that there is a significant difference in levels between the polders and the groynes, with the former showing higher accretion rates. However, the regression of the saltmarsh has not been prevented and the scheme is regarded to have been unsuccessful. Furthermore, even If the scheme had been successful in promoting the stability of the saltmarsh cliff, the economic justification for it would be questionable, as the cost and

maintenance of installing the fences was similar to the value of the land they were trying to protect.

To adequately gauge the success/failure of the scheme, a baseline survey should have been carried out to establish existing conditions with monitoring following at regular intervals directly after installation.

Further information

Carpenter, K.E. and Brampton, A.H. (1996). *Maintenance and Enhancement of Saltmarshes*. Environment Agency R&D Note 473.

D.5 Technique: coir rolls

D.5.1 Lymington River

Description

In conjunction with the Lymington Harbour Authority, in 1994 New Forest District Council (NFDC) decided to implement a small-scale trial to defend the leading edge of an eroding length of saltmarsh from wave attack. Instead of using traditional rock revetments to protect the leading edge of the marsh, a new approach using rolls of coconut fibre (coirs) was employed. If it proved to be successful, the main justification for using this technique would be the significant cost savings made compared to the cost of installing rock revetments.

The trial scheme was carried out on a 160m eroding length of saltmarsh and consisted of a double row of wooden stakes pushed vertically into the mud. Within these stakes, rolls of coir were placed and secured into position with twine. To investigate how distance from the cliff edge affected the performance of the coir fence, the fence was installed at three different distances: tight against the cliff edge, a few metres from the cliff and further away to form an embayment.

Monitoring

Subsequent monitoring of the trial site demonstrated that the scheme was ineffective, as the saltmarsh edge behind the constructed fence line continued to retreat at 1m/year.

Effectiveness of the scheme

According the NFDC, the ineffectiveness of the scheme according to NFDC related to the following problems:

- Wave action worked apart the coir rolls allowing water to flow through the gaps, causing scour.
- During periods of submergence, wave reflection between the cliff edge and the rolls exacerbated erosion.
- Scour and subsidence caused the coir rolls to sink.

Following the project, NFDC suggested possible improvements to the scheme which included (see Figure D.5):

- Tying the ends of the rolls together to form one long unbroken roll. This would prevent gaps from forming and may help to reduce scour.
- Scour around the base of the fence could be reduced by changing the orientation of the fence from the vertical to an angled face.
- Wave reflection between the cliff edge and the coirs could be reduced by securing the rolls tightly against the eroding cliff edge.

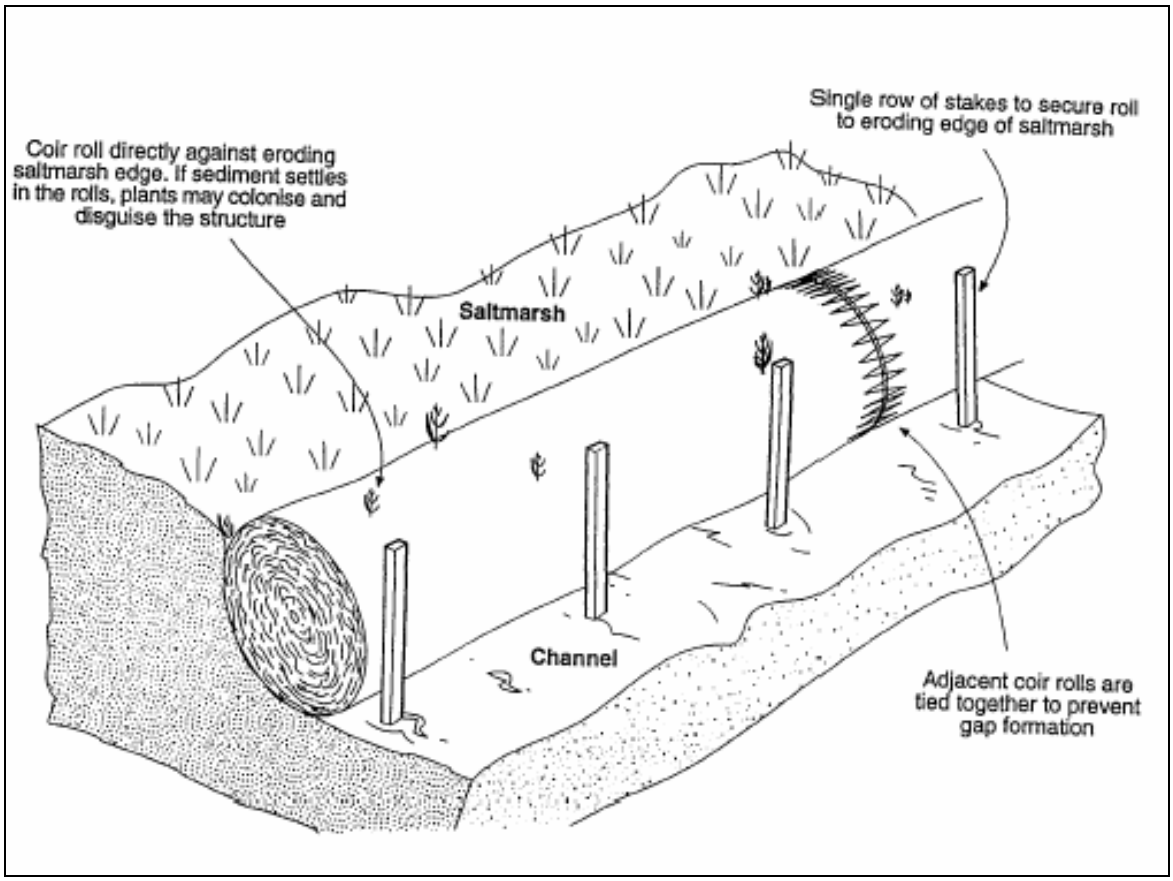

Figure D.6 Possible improvements to the use of coir rolls (from Carpenter and Brampton, 1996)

In recent years a significant amount of research has been undertaken by NFDC to determine the rate and extent of saltmarsh loss over the last 60 years in their district, and how this may impact on the shoreline, existing defences, the economy of the towns and region, and nature conservation. The culmination of this research will result in a coastal defence strategy for the Western Solent which will explore the various options for coastal management between Hurst Spit and Calshot Spit. The strategy is due for completion towards the end of 2005.

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D.6 Technique: foreshore sediment recharge

D.6.1 Horsey Island, Hamford Water (northeast)

Description

Horsey Island lies within the inlet of Hamford Water and is part of the Walton Backwaters and Essex Estuaries SAC. The island is strategically important in that it provides protection against wave action to the Backwaters, thereby reducing erosion. Recharge of the foreshore was first carried out in the early 1990's and represented the first application of dredged material for beneficial purposes in the UK. In total, a volume of 18000m^3 of coarse dredged material was sprayed onto the mid intertidal area by rainbow discharge from a self-load, self-empty discharge vessel at high water on spring tides. The material was used to fill the gaps between a line of disused Thames Lighter barges that were grounded on the foreshore.

Monitoring

Pre- and post-monitoring surveys were carried out to ascertain the effects of the scheme. Five replicate 10cm diameter cores were sampled before and after mud placement on the upper, middle and low shore and on an adjacent control site. As predicted, the coarser nature of the recharge material led to a complete change in the sediment character of the site. Similarly, the deposition of material led to localised changes in foreshore bathymetry and benthic invertebrate surveys showed marked changes in the community type, resulting in a switch in dominance from species associated with muds to those associated with coarser material. In particular the king ragworm, *Nereis virens*, was shown to significantly increase in abundance. Pollution surveys revealing no increase in sediment contaminant levels.

Generally, however, the erosion of the foreshore has been arrested and the wetland is being restored.

Figure D.7 Recharge scheme at Horsey Island (source: Environment Agency)

Effectiveness of the scheme

The Horsey Island recharge scheme is considered to be one of the most successful projects of its type carried out in the UK in terms of providing the coastal defence function for which is was designed. The abundance of the ragworm *Nereis*, supports a thriving Sea Bass fishery and bird populations. A new marsh habitat also formed behind the recharged material.

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Environment Agency (1999). *Monitoring foreshore recharge works, Essex 1998-2002.* Contract 0031: Post-placement monitoring studies. Unpublished report.

D.6.2 North Shotley, Orwell Estuary

Description

In December 1997 a trial recharge scheme on the Orwell Estuary at Shotley was undertaken by the Harwich Haven Authority and the Environment Agency. Here, a 2km earth wall, protecting low lying grazing land, had undergone severe erosion

following the near complete loss of fronting saltmarsh. Several unsuccessful attempts were made to halt the erosion using hard engineering techniques, such as gabions and concrete facing.

Consequently, approximately 22000m^3 of maintenance dredgings, mostly silt (20µm in size), was pumped behind a retaining bund of coarse, poorly sorted gravel. The placement extended over 450m of the foreshore with a maximum width of 70m. Mud was pumped at a density of approximately 1.3g cm^{-3}, leading to an initial elevation of between 1.0 and 1.3m above Ordnance Datum (OD). For comparison, the level of local Mean High Water Neap (MHWN) and Mean High Water Spring (MHWS) was 1.4m and 2.0m respectively, with the remnants of the old marsh system lying between 2.0 and 2.2m OD.

Monitoring

Monitoring was undertaken at the site from January 1998 until the scheme was subsumed into the larger Shotley Foreshore Habitat Enhancement Scheme (see Case Study D.6.3) in 2003. Monitoring was undertaken on a quarterly basis to determine the *in situ* stability and morphodynamics of the deposited mud and enclosing gravel, and the extent of invertebrate and halophyte colonisation. Results have shown that due to the low elevation of the raised surface relative to MHWN and MHWS limited colonisation of saltmarsh plants occurred. Although very sparse *Salicornia* and isolated *Spartina* plants have established, the recharge is clearly not direct replacement for the saltmarsh fringe, whose remnants lie above MHWS.

Figure D.8 Recharge scheme at North Shotley (source: Environment Agency)

Prior to recharge, the sediment infauna of the site was impoverished relative to other foreshores elsewhere in the estuary. Post-recharge monitoring, however, showed that the site was rapidly colonised by benthic invertebrates, such as polychaete and oligochaete worms, gastropods such as *Hydrobia* and a few bivalves. As expected, substantial short-term and seasonal variability was evident on the site. However, it seems clear that the pumped recharge mud quickly acquired sufficient structure to support the recruitment and development of a varied infauna.

Effectiveness of the scheme

The establishment of a diverse sediment infauna at substantially higher elevations compared to the pre-existing tidal flat led to an increase in its use by wading birds. Although no quantitative bird monitoring was undertaken, it is clear from qualitative observations that birds are able to feed on the recharge mud until much later into the tidal cycle than was previously the case. For example, Brent Geese were observed at the Shotley site in 1999 along with small numbers of shorebirds, including Ringed Plovers, Oystercatchers, Grey Plovers, Dunlin, Redshanks and Turnstone; whereas, prior to the scheme, only two shorebirds (Grey Plover and Oystercatcher) and no geese were recorded on the site.

The recharge scheme was unsuccessful in raising the height of the mudflat surface sufficiently enough to allow saltmarsh vegetation to colonise. In addition, the gravel bund that protected the lower margin of the site subsequently rolled landward under wave action (raising its height) and provided suitable conditions for a second phase of recharge at a higher elevation over the inner region of the site.

Further information

French, J.R., Watson, C.J., Moller, I., Spencer, T., Dixon, M. and Allen, R. (2001). *Beneficial use of cohesive dredgings for foreshore recharge*. Proceedings 35th MAFF Conference of River and Coastal Engineers. 5th-7th July 2000, Keele.

Posford Duvivier Environment (2000). *North Shotley mud placement: analysis of effects on benthic invertebrate community*. For the Harwich Haven Authority.

D.6.3 Shotley and Trimley Habitat Enhancement Schemes, Orwell Estuary

Description

In October 2004 The Port of Felixstowe (POF) completed the extension of an additional 270m of quayside at its Trinity III berths. The scheme also involved dredging of the main approach channel to enable larger ships with deeper draughts to berth at the newly extended quay. At the same time, the Stour and Orwell Estuaries SPA is currently being degraded in the lower Orwell due to underlying erosion of the intertidal areas that have been ongoing since the 1920s. In parallel with this the seawalls at Trimley and Shotley were both in a very poor state of repair, thereby threatening the integrity of the freshwater sites behind them due to the likelihood of a breach.

As well as mitigating for the effects of the project on the adjacent SPA the scheme was also seen as an opportunity to improve the stability of the existing lower Orwell flood defences and to provide intertidal habitat of enhanced value for feeding waterfowl. More specifically, it was hoped that 3 ha of saltmarsh habitat would develop following the completion of the habitat enhancement.

Shotley

On the Shotley foreshore (Fig D.9) the schemes involved the construction of clay bunds around Shotley Marina, and backfilled with silt. Further north, two areas of existing gravel were topped up (see Case Study D.6.2) with silts and another scheme was constructed based on bunds created using in-situ material backfilled with 0.3m of silts.

Trimley

On the Trimley side of the Orwell, schemes were implemented that utiised both clay and gravel for the bunding. Following the removal of silt from the approach channel, gravel was dredged from the new approaches and placed in the quay construction zone and onto the Trimley foreshore in order to construct the habitat enhancement bunds, including a gravel island for nesting little terns. Approximately 22,000m^3 of gravel was placed on the Trimley foreshore for the bunds and 80,000m^3 stored for the gravel island, which covers approximately 1 hectare above high water.

Figure D.9 Shotley habitat enhancement scheme

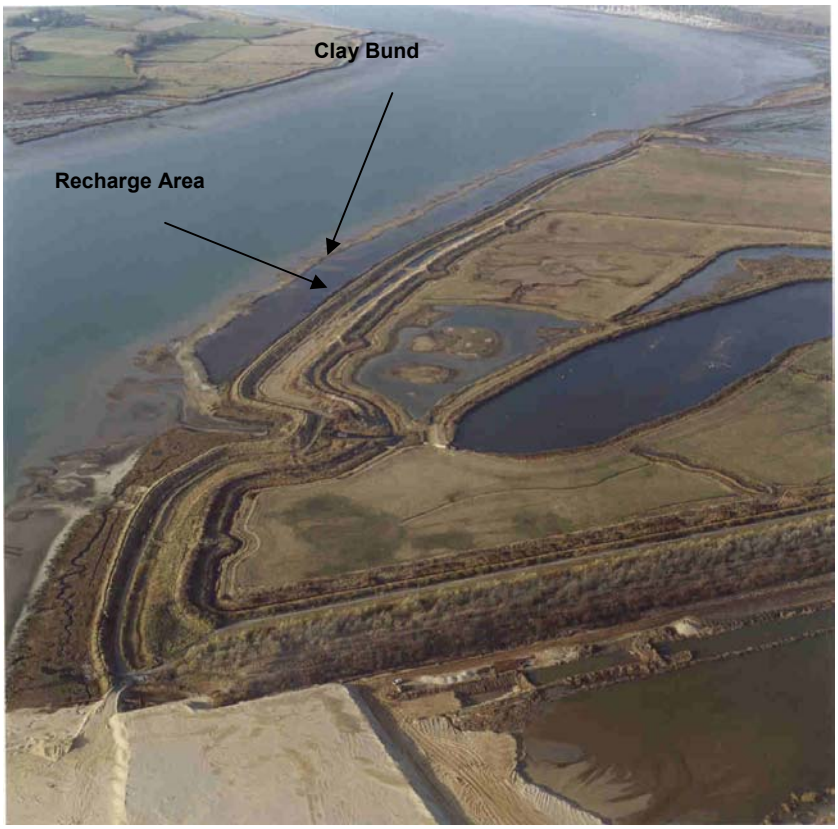

Figure D.10 Trimley habitat enhancement scheme

Effectiveness of the scheme

Surveys of the habitat enhancement bunds have been carried out on behalf of HHA in November 2003, March 2004, July 2004 and March 2005.

In terms of saltmarsh development, colonisation has occurred at both sites with small patches of *Salicornia* recorded at Shotley and localised *Spartina* colonisation recorded at Trimley.

Topographic surveys of both sites have revealed marked differences in the behaviour of the bunds. Whereas the Trimley placements have remained relatively stable the clay bunds surrounding Shotley have been highly mobile with the backfilled material remaining soft. The original backfill level of this area was about 2.4m CD which has reduced by up to 0.6m in places. The reductions in elevation here are likely to have been associated with both consolidation and mass erosion/loss of the placed material. The original North Shotley scheme (Case study D.6.2) levels have fallen by up to about 0.3m, with the centre of the site remaining high

Benthic monitoring of invertebrates show that in November 2003 (one month after completion of the bunds) the benthic community was, in general, very impoverished. For example in many of the cores only 1 to 2 species were found, which is far less than for cores taken from the adjacent muddy foreshore. However, this finding is to be expected given the timing of the mud placement (one month earlier). Results from the previous monitoring surveys are still being analysed and are due to be reported towards the end of 2005.

Further information

Posford Duvivier Environment (2001) Trinity III Terminal (Phase 2) Extension. Compensation, Mitigation and Monitoring Agreement. Unpublished report to Port of Felixstowe.

D.6.4 Horsey Island, Hamford Water (southeast corner)

Description

This scheme involved the direct application of dredged material on top of an eroding saltmarsh in the southeast corner of the island. The objectives of the experiment were to assess the impacts of dredged material on saltmarsh vegetation and to see whether a high marsh community would develop in place of a low marsh community. In 1992, 1000m^3 of dredged silt from Harwich Harbour was deposited on a 0.5ha plot of heavily grazed saltmarsh dominated by *Spartina* and *Puccinellia*. The work was carried out during the late summer of 1997 so that the sediment had time to consolidate before the main release period for the seeds of saltmarsh plant species. Material was deposited on the marsh via rainbow discharge using a fixed distributing nozzle.

Monitoring

Unfortunately no pre- or post-monitoring data is available for this scheme. However, it has been confirmed by Ian Black (English Nature Site Manager) that most of the applied silt was washed off the sites during the first set of spring tides following the placement. Due to the lack of monitoring data, however, it is not known what quantity silt was washed away or remained.

Effectiveness of the scheme

As most of the sediment was washed off on the following spring tides the scheme was generally regarded to have been unsuccessful. Recommendations which followed the initiative included the potential use of retaining bunds to trap the fine silt material. A possible suitable material for this would be rolls of coconut matting, similar to those used in Case Study D.5.1, secured onto the saltmarsh surface to form a continuous low wall around the receiving area. The bund may also serve to enhance accretion.

The Environment Agency has scheduled further saltmarsh recharges at Horsey Island for October 2005. Following on from the original trial scheme, the use of a retaining bund will be used in an attempt to retain the sediment (Gemma Costin, *pers. comm*.).

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D7 Technique: rock sills

D.7.1 South Ferriby, Goxhill and Barrow Haven, Humber Estuary

Description

Rock sills were placed in front of eroding saltmarshes at three locations along the Humber estuary. At all three sites, the top of the mounds were level with the saltmarsh surface. However, the Barrow Haven scheme (1991) differed to those at South Ferriby (1986) and Goxhill (1988), as the mounds in the latter two cases were positioned approximately 0-15m from the eroding saltmarsh cliff edge, whereas the rock barrier at Barrow Haven (following recommendations from English Nature) was constructed so that it abutted the leading edge.

Monitoring

At each of the three sites, the rate of accretion behind the rock mounds was monitored. This was achieved by pushing 2m lengths of metal tube about 1m into the sediment. The change in level was recorded every 2 weeks for over two years by measuring the distance between the top of the tube and the surface of the mud.

Over the two year monitoring period all three sites showed a net increase in sediment accretion. At South Ferriby, where the rock sill was placed at a distance of 0-15m from the saltmarsh cliff edge, an increase of 30cm on the leeward side of the barrier was measured. However, levels did not increase further as the system reached equilibrium in relation to the height of the rock mound. Three years after the first placement of rocks, a second scheme was initiated where additional rocks were placed on the rock mound, resulting in an additional increase in level of 25cm. Subsequent colonisation by saltmarsh plants between the rock mound and cliff edge has been successful in widening the saltmarsh and, hence, increasing the degree of protection to the earth embankment.

Accretion at Goxhill was greater with over 80cm being deposited in the two year period. This resulted in reducing the height of the saltmarsh cliff from 1.5m to 0.8m, which would have a significant effect on supporting the toe of the seawall. Saltmarsh plants also colonised the accreted mud between the mound and the saltmarsh cliff. Monitoring carried out at Barrow Haven also revealed an increase in sediment levels.

Figure D.11 Construction of the rock beach sill, Goxhill on the Humber (from Toft et al., 1995)

Effectiveness of the scheme

The schemes do appear to have been successful in that sediment has accreted in between the mound and the saltmarsh cliff, and this has been colonised by various species of saltmarsh plants. However, as the monitoring program did not include an adjacent control site, it is not possible to conclude what proportion of this accretion was due to the presence of the rock mound (although a significant proportion is likely to have been). The schemes would have benefited from a more extensive post-operation monitoring program based on the following:

- Burial/exposure stakes arranged in a transect to include sites on the saltmarsh surface, the accreting mud between the saltmarsh cliff and rock mound, and the foreshore on the estuary side of the rock mound.
- A similar transect on a control site
- Measurements of the change in the position of the saltmarsh cliff behind the rock mound and at the control site.

When the schemes were originally constructed concerns was expressed by English Nature that the rock mounds could decrease the potential feeding area available for foraging wading birds. Although the schemes were successful in meeting their objectives (i.e. halting saltmarsh erosion/promoting accretion), English Nature were of the opinion that mudflat habitat was more desirable than the saltmarsh which replaced it and that if saltmarsh loss was a 'natural' process they did not favour intervention. Subsequently, there have been no further attempts on the site to halt saltmarsh erosion using hard engineering techniques.

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D.8 Technique: managed realignment

D.8.1 Abbotts Hall Farm, Salcott Estuary

Description

Abbotts Hall farm is situated on the northern bank of the Salcott estuary, a tributary of the Blackwater estuary in Essex. The managed realignment scheme developed from a regulated tidal exchange scheme initiated in April 1996. Abbotts Hall is an 80ha site and was purchased in 2001 with the assistance of the following: a legacy from the late Joan Elliot, Trust Members, WWF, English Nature, Environment Agency and the Heritage Lottery Fund. It represents a multifunctional flood management scheme incorporating ecological, compensatory habitat creation, conservation, flood defence and economic functions.

Figure D.12 Abbots Hall Farm, before breach (source: Environment Agency) **Abbots Hall Farm, after breach**

The scheme involved breaching the existing defences at 5 strategic locations in September 2002 to create intertidal mudflats, saltmarsh and saline lagoons and also freshwater, brackish water and grazing marsh habitats. No new defences were created as the naturally higher ground behind provided an adequate secondary defence. However, two small walls were constructed at the edges of the site to protect adjoining sites from saline intrusion. The largest breach was taken down to 1.65m ODN, enabling it to act as a sill at the end of the receding tide and to reduce

the amount of sediment “stirred up” near low water on the adjacent mudflat and, thereby, reduce the suspended sediment levels potentially arriving at the oysterbeds downstream.

The site has a natural creek system and sloping topography suitable for saltmarsh development; the 3-4m contour is reached on high spring tides, and mud and silt is deposited with every tide, successfully contributing to saltmarsh and mudflat development.

Monitoring

Baseline monitoring began in the autumn of 2000 in anticipation of breaching taking place in 2001. Due to delays in acquiring the necessary permits and the outbreak of Foot and Mouth disease, breaching did not occur until 2002. Consequently, baseline monitoring continued for a further year, giving two years of pre-breach data.

The program of monitoring work involved the following:

- Hydrographic parameters (tides, waves, currents and suspended solids).
- Bathymetry.
- Bed sediment characteristics.
- Scour monitoring.
- Meteorological data.
- Bird counts.
- Macroinvertebrate counts.

Effectiveness of the scheme

No major hydrodynamic changes have been observed in Salcottt Channel in the period immediately following breaching of the sea defences; this being the time when such changes would be expected to be most apparent were they to have occurred. By spring 2003 the site had become colonised by several pioneer saltmarsh species and over 10 different species of fish were using the site. On one occasion, approximately 2,000 Herring/Sprat were caught using a seine net in one tidal pool, some of which are commercially fished. Ongoing monitoring by the Environment Agency continues.

Further information

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Environment Agency (2003). *Sustainable Flood Defences – Monitoring of the Managed Realignment Scheme at Abbots Hall, Essex*. Unpublished report.

D.8.2 Orplands Sea Wall, Blackwater Estuary, Essex

Description

The site forms part of the St Lawrence Bay and is situated on the southern side of the Blackwater estuary in Essex. The site includes two retreat areas - tidal mudflats and an area of saltmarsh to seaward - and has two distinct parts; Site A and Site B, which are next to each other along the coast, but separated by a counterwall. The two sites had different pre-inundation characteristics:

- Site A was rough grassland before it was reopened to tidal flooding, it had not been ploughed and the line of the original major creeks can still be seen as shallow, linear depressions.
- Site B was used for cereal production and clay pipe land drains had been installed approximately 1m below the land surface to lower the water table in the field.

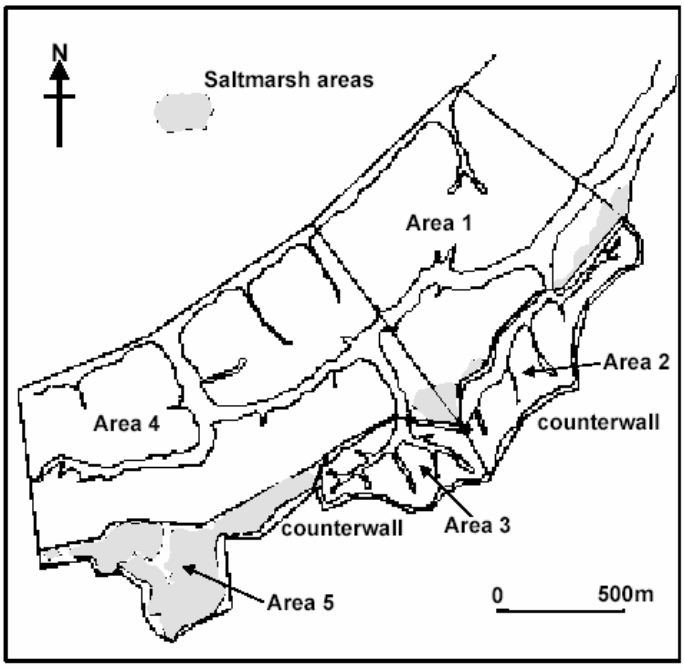

Figure D.13 Map of the Orplands study areas. Area 1 - mudflats seaward of the managed retreat sites; Area 2 - Orplands A retreat site, Area 3 - Orplands B retreat site, Area 4 - mudflat seaward of the control saltmarsh; Area 5 - saltmarsh (source: Environment Agency).

The seawall protected 40 hectares of agricultural land which was divided into SSSI grazing marsh and land in arable production. Land levels ranged from -1m OD to above +4m OD. The original line of the sea wall was constructed in the 18th century and until the 1950's was fronted by saltmarsh and a high level mudflat foreshore. Sea wall condition deteriorated as the fronting saltmarsh eroded and, despite extensive previous maintenance works, it was estimated in 1994 that in excess of £600k would be required to sustain the defence over a 20 year period; at 15k per

hectare it was determined that it was uneconomic to invest in conventional sea wall construction and repair techniques.

Breaching took place in April 1995 and involved demolishing the seawall to allow normal tidal exchange to take place. Breaching took place over a period of 4 days during neap tides. A series of nine meandering vertically sided 'creeks', one metre deep, were excavated within the site to facilitate tidal flow over the area.

Two new set back walls were constructed to the north and south of the site to protect adjacent areas from saline intrusion and flooding. Flapped pipes were laid on the site to allow freshwater drainage onto the new saltings. Material from the breach was re-deposited landward to act as a buffer to wave energy penetrating through the breach.

Tall vegetation at the rear of the site was left to decay naturally and provide organic material to the site and also to act as sediment trap for fine sediments.

Figure D.14 Orplands sea wall post breach; looking westwards along seawall from eastern end of site, showing badly eroding saltmarsh outside of the breached sea wall (to the right) and retreat site to the left of the picture (source: Environment Agency)

Monitoring

As Orplands was the first deliberate managed realignment site in the UK, a comprehensive pre- and five year post-construction monitoring program was undertaken to assess the effects of the scheme. The following items were monitored within the realignment site plus a control site:

- Vertical accretion / erosion rate on both foreshore and salting.

- Lateral erosion / accretion rates.
- Various physical parameters including cohesive strength and organic content.
- Various chemical parameters including pH, redox potential and nutrient content.
- Various hydrographic parameters, including wave energy and current speeds.
- Changes in saltmarsh morphology in terms of creek lengthening and areas of die back.
- Changes in plant vigour in terms of % species cover, plant height and plant community.
- Composition and abundance of benthic invertebrates, fish, mammals and birds.

Effectiveness of the scheme

Annual monitoring by the Environment Agency has shown that saltmarsh vegetation has developed on the higher elevations of the sites and is dominated by pioneer *Salicornia spp*. communities, with areas of intertidal mud becoming established on lower areas. The higher elevation of Site B (former arable land) led to the colonisation of *Salicornia* with larger expanses of mud developing on the lower Site A. This, in turn, led to the build up of soft muddy sediments at the seaward edge of the retreat site, which has been colonised by invertebrates. Mobile species, those that have a planktonic larval phase (such as *Nereis* and other polychaetes) and *Hydrobia* have colonised these muddy sediments; while bivalves and other species that have no planktonic larval phase, such as oligochaetes, have either not colonised or did not appear for a number of years.

The poorer groundwater drainage of Site A, which had not been ploughed or drained since enclosure, produced highly anoxic conditions. It is thought these conditions prevented plant colonisation below 2.5m ODN. For the same reason, bivalve mollusc species, though present in substantial numbers in the nearby mudflats, failed to colonise the same anoxic mudflats;

The speed of development of the waterbird assemblage followed that predicted from the changes in benthic fauna. The build up of fine muddy sediments led to the assemblage being initially dominated by Redshank, Dunlin and Grey Plover, which feed predominantly on *Hydrobia* and *Nereis* (the two main invertebrate species to colonise in the first few years following the breach). Knot was initially absent but their colonisation coincided with the appearance of the bivalve *Macoma* on the sites, a preferred prey item, approximately three years after the breach. Species such as Oystercatcher and Turnstone, which feed on molluscs and crustaceans, were very scarce on the sites during winter, although common on the surrounding estuary. In the short-term, it is unlikely that the retreat sites will develop in such a way that populations of these two species would be supported. The large molluscs, preferred by Oystercatchers, were virtually absent at least five years after the breach and it may take some years for these to colonise, if they ever do. However, experimental introduction of these species may speed up the colonisation process.

There are still extensive areas of bare mud and pioneer plant communites on the Orplands site, and in the south-west corner of the site there is a transition from saltmarsh to non-tidal grassland not interrupted by a seawall; a transition that is rather unusual in East Anglia because of the extensive land claim that has taken place on the upper edge of most saltmarsh sites in this region.

Further information

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D.8.3 Tollesbury realignment site

Description

The realignment site is located on the Tollesbury fleet, a tributary of the Blackwater estuary, Essex. The site is owned by English Nature and is part of the Blackwater Estuary Nature reserve (www.english-nature.org.uk, for more details). In August 1995, a 60m breach was made in the sea defences and land previously under cultivation was opened to tidal inundation for the first time in over 150 years. Tidal inundation was limited to the 21ha site by the construction of a counter wall built on the 3m contour. The elevation of the site ranged from 0.96m OD to 3.0m OD, although most is less than 2.0m OD. The mean tidal range for Bradwell, the nearest reference point, in the Blackwater Estuary is 4.7m on spring tides and 3.0m on neap tides.

Monitoring

To record the development of saltmarsh vegetation a transect 20m wide was laid out in each of the three fields within the realignment site, starting at the foot of the counter wall on the highest part of the site and extending 125m to lower ground. Each transect was divided into 2500 $1m^2$ cells, where plant species presence and percentage cover were recorded. Monitoring started in 1997, two years after the breach, and took place in September each year.

Invertebrates were sampled at seven sampling sites within the realignment area annually from 1995 to 1998 and again in 2001. Nine 10cm diameter core samples were taken from each of the seven sites to a maximum depth of 15cm, sieved through a 0.5mm mesh and preserved in 5% formal saline.

Effectiveness of the scheme

By 2001, approximately 6ha of the 21ha site had been colonised by saltmarsh vegetation. The lower limit of the vegetation corresponded with the 1.5m contour. The dominant vegetation community established within the site was annual *Salicornia* saltmarsh, which composed of large strands of *Salicornia eurpaea* agg. (common glasswort) at high density, often with no other species. *Puccinellia maritima* (common saltmarsh-grass) and *Atriplex portulacoides* (sea purslane)

species that dominate the vegetation communities of the adjacent marshes were restricted to the highest land in the area near the foot of the new sea wall (>2.2m OD).

Figure D.15 Tollesbury realignment site at High tide (from Living with the Sea, 2003)

During the monitoring period, accretion rates showed no indication of declining, with an average of 23mm accretion per annum. However, there was considerable within-site variation, ranging from 8mm to 258mm of sediment build up over the original agricultural surface. Most of the variation was accounted for by differences in elevation.

Initial invertebrate colonisation of the site was rapid. Fourteen species of intertidal invertebrate were recorded within the site after two months of tidal inundation, with between 18 and 19 species recorded in each survey thereafter. Colonisation occurred only in the newly accreted sediment and not the original agricultural substrate. Numbers and distribution of most species increased year on year, with the most abundant species, the mud snail *Hydrobia ulvae*, occurring in every sample in 2001.

Further information

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D.8.4 North Trimley Marsh, Orwell Estuary

Description

In October 1998, the Harwich Haven Authority (HAA) commenced works to deepen the approach channel to the Haven Ports. As a condition of the various consents for the scheme a mitigating and monitoring package was agreed with English Nature, the Environment Agency and Defra to minimise the adverse impacts of the scheme on the Stour and Orwell Estuaries SPA. As a result, in November 2000 16.5 ha of intertidal habitat was created through managed retreat at North Trimley Marsh.

The site was created on former arable land. The western perimeter is made up of the seawall which formerly separated the Orwell estuary from the farm land. A new counter-wall was created around the north, eastern and southern perimeter of the land.

One of the required criteria for the site was that no more than 30% of its area should develop into saltmarsh. At least 70% of the retreat area was, therefore, designed to be below the level of +3.5m CD, as saltmarsh was estimated to develop at levels higher than +3.5m CD. The entrance (i.e. the breach in the sea wall) was designed at +1.5m CD so that the site would completely drain at low tide.

Figure D.16 Trimley Marsh Managed Realignment Site (Posford Haskoning, 2004)

Maintenance dredgings (fine mud) from the channel in the lower Orwell estuary were pumped into the site to provide a suitable substratum for colonisation of estuarine flora and fauna. Approximately 35,000m^3 of dredged material was dredged by a trailing suction hopper dredger and pumped via a floating pipeline through the breach to a floating pontoon where it was pumped onto the site. The material was deposited in four locations at high water, from where it was spread out over the site. The dredged material formed a layer approximately 30 to 50cm deep above the underlying soil.

Monitoring

Monitoring has been carried out on North Trimley Marsh since November 2000 and has involved the following:

Benthic invertebrates

Cores (11cm diameter by 15 cm deep) are taken from 12 stations. The sampling stations are mostly on the middle and lower shore, roughly evenly distributed over the site. Each station is marked with a labelled stake and the position recorded with GPS. Two replicate cores are taken from each sampling station (within an area of approximately 2m^2), giving a total of 24 samples over the whole site.

Particle size analysis

Single process particle size analysis is carried out on 8 of the samples and double process on the remaining 4. As the majority of the samples comprise silt (less than 63µm), the single process analysis is undertaken for the <63µm fraction only.

Vegetation

Vegetation monitoring is undertaken using quadrat sampling. Fixed quadrats, each covering an area of 2m by 2m, were established at regular intervals around the perimeter of the site (where vegetation may be expected to colonise) and marked at two diagonal corners using stakes. The position of each quadrat was recorded using a GPS. Within each quadrat the percentage cover of each species is recorded and target notes made.

Waterfowl

The waterfowl usage of the site is monitored by means of counts undertaken around low water at monthly intervals throughout the over-wintering period (November to February) by the Suffolk Wildlife Trust. These low water counts form part of the ornithological monitoring of the whole of the Stour and Orwell estuary system being undertaken by Suffolk Wildlife Trust on behalf of the HHA. Counts of the rest of the estuary are taken at the same time, with the managed retreat site counted as a separate sector. Each count is started 1.5 hours before low water and continued, where necessary, to 1.5 hours beyond low water. All species present are identified and counted.

The second, third and future years of monitoring have been designed to be less intensive than the first. In the first year, benthic and vegetation surveys were carried out at roughly 3-monthly intervals up to June 2002. Since this time, surveys have been carried out approximately every six months.

Effectiveness of the scheme

The site has become more 'natural' over the first three years of monitoring. This is mainly due to the mudflats becoming 'smoother' in appearance, with more small creeks developing and the vehicle tracks (left from construction) evening out.

Monitoring carried out in the second year of monitoring (post breach) showed distinct changes in the benthic community of the site. Initially, during the first year of monitoring, the benthic community was characterised by a high degree of evenness between the numbers of each of the different species that make up the community and the community was dominated numerically by *Macoma balthica*. As the site has developed there have been marked increases in both biomass and number of individuals per core. However, the type of community has also changed. Between September 2001 and September 2003, the community was dominated by extremely high numbers of *Hydrobia ulvae*.

Around 1.6 ha of saltmarsh has developed around the fringe of the site and along the facing of the new sea wall. The saltmarsh community is mainly dominated by the pioneer species *Salicornia*, and appears to be behaving naturally, following distinct seasonal variation in growth and die-back. Overall, the saltmarsh is developing well and remains within the original target for its extent. The site continues to support high numbers of birds, particularly Dunlin and Ringed Plover.

Further information

Posford Haskoning (2004). Trimley Managed Retreat Site. 2nd Annual Monitoring Report (2002 -2003). Unpublished report for the Harwich Haven Authority.

D.9 Technique: regulated tidal exchange

D.9.1 Goosemoor, Devon

Description

Goosemoor is a six hectare grass field site on the edge of the Exe Estuary in Devon and is owned and managed by the RSPB. Although designated as part of the Exe estuary SSSI/SPA the site has no catchment contributing to the water balance and is therefore difficult to manage optimally as a freshwater wet grassland habitat. Bird usage within the area has also been low. It was felt by the RSPB to be typical of sites where RTE can be considered, with inland infrastructure vulnerable to flooding, ecologically poor habitat and where intertidal recreation would represent an enhancement.

The primary objectives of the Goosmoor RTE site were:

- To build an understanding of the potential uses of RTE in the UK, where Managed Realignment is not feasible;
- To demonstrate the flood defence/management benefits of RTE as a cost-effective source of compensatory habitat;
- To improve the biodiversity of a potentially important area; and
- To develop the project in partnership with the Environment Agency, Defra, English Nature, and other coastal decision makers.

Figure D.17 Internal creek network at Goosemoor (copyright AJ Bellamy)

Following the relevant permissions work commenced on the site to make it more suitable for tidal inundation. Work included:

- Excavation of existing drains and ditches to create the new creek system
- Reprofiling of ground levels to create the intertidal habitat areas
- Creation of a secondary bank along the foot of the railway embankment
- Installation of a 1.0m internal diameter pipe through the sea wall with a Self Regulating Tidegate (SRT) on the seaward side, and a sluice in the inland side, to retain on-site water
- Excavation of a channel to link the River Clyst with the SRT and pipe

Following completion of the engineering works the site was officially opened on 17th December 2004.

Figure D.18 Self regulating tidegate imported from the USA (copyright AJ Bellamy)

Monitoring

An extensive monitoring programme has been established involving the following:

Parameter	Method	Frequency
Water levels	Automated data logger	Weekly
Accretion rates	Measure depth of accretion at 40 random points	Annually (Aug)
Conductivity	Conductivity meter	Weekly
Vegetation	1x1m quadrats at 40 random points	Annually (Aug)
Habitats	Map extent of main habitats/NVC communities	Annually (Aug)
Bird usage (throughout year)	Regular counts	6 high tide per mth 6 low tide per mth
Bird usage (tidal cycle)	Count at 10 min intervals from high to low tide	6 through winter
Benthic Invertebrates	Record densities, species and size classes in benthic core samples from 40 random quadrats	Annually (Nov)

Effectiveness of the scheme

As the scheme was only completed in December 2004 no results as yet are available. However winter bird counts were carried out between January and March 2005 with Lapwing, Wigeon and Curlew numerically dominant. More comprehensive results on water levels, bird usage and overall site development will be available later in 2005.

Further information

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