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Dunwich coastal defence demonstration project

Assessing the effectiveness of geomembrane structures filled with locally won beach shingle or sand material to reduce cliff erosion

Report – SC050071/R

Flood and Coastal Erosion Risk Management Research and Development Programme

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Miranda Kavanagh

Director of Evidence

Executive summary

Innovative, low-cost and environmentally sensitive coast protection methods are required in locations where other traditional methods of defence are not justified for economic or environmental reasons. This demonstration project aimed to evaluate an innovative and potentially economically viable alternative to current low-cost options by testing how effective it is to retain beaches using geomembrane structures filled with locally won beach shingle and sand material.

About the project

The Dunwich Coastal Defence Demonstration Project sought to develop a low-cost technique to stabilise the beach in front of the coastal cliffs protecting Dunwich village on the Suffolk coast against erosion. As the area between Dunwich and Walberswick is a Site of Special Scientific Interest (SSSI), it was desirable to find a coastal management option to suit and work with these important habitats and natural coastal processes. The cliffs at Dunwich come under basal attack when the beach is comparatively low, allowing wave energy to reach the toe. The goal was therefore to stabilise existing beach slope angles and levels.

The basis of the project was the encouragement of the natural processes which enable the beaches to perform their function of energy dissipation with the construction of low-cost, low impact ‘soft defences’. It was also necessary to protect these soft defences against the occasional storm conditions that can cause considerable damage to the beach. The project consequently consisted of eight ‘humps’ running down the beach in a pattern similar to that used in a conventional timber groyne field. The humps were created by placing geotextile bags filled with shingle and sand from the beach in trenches, wrapping and covering them in a geotextile membrane to anchor them to the beach and to contain the beach material. The aim was for the humps to protrude above normal beach level by about half a metre. Geomembranes were used to allow for flexibility in the structures, allowing them to adjust to variations in the host beach while ensuring that no vertical edges would be exposed. A wave wash wall, or backwall, was constructed forward of the toe of the existing cliff such that extreme wave conditions would wash over but not breach the beach material anchored beneath.

The joint Defra and Environment Agency Flood & Coastal Risk Management (FCERM) R&D programme supported the trial to investigate the functioning and possible benefits of this new approach. Monitoring was undertaken for five years following the completion of the works in March 2007 to investigate the hydraulic performance and the condition of the various elements of the project. The monitoring regime consisted of a series of beach cross-sections, aerial photographs and visual inspections.

This report describes the development of the concepts behind the demonstration project, the construction techniques used to build the ‘humped’ groynes, monitoring procedures and the performance of the scheme to date.

Results

Analysis of the monitoring data indicated that the structures may have influenced the shape and condition of the beach up to around early 2010 by slowing the transfer of material across the works frontage. The volumes of change involved are small but overall there is a consistent trend of increasing volume in all zones within the demonstration project site.

The cross-sections suggest that the structures may not influence the shape and condition of the beach itself significantly. Ridge formations were continuous through the site and response to storm conditions seems to be unaffected by the lateral humps. A comparison of

the plots of the sections of the beach taken outside the works, with their relative neighbouring section, shows the beach height and shape to be very similar on each occasion. This suggests that the main geomorphological features in the beaches to north and south of the scheme site have usually been continuous through the site, albeit with some localised effect around the structures themselves where they are clearly interacting with incoming waves.

One of the most satisfactory aspects has been the accumulation of material on the landward side of the backwall. However, this is in effect a redistribution of beach material and hence not shown in the volumetric analysis. This material has built with each successive storm event with the wall itself forming a limiting threshold on the height of the upper beach material. There is now a substantial height of material at the toe of the cliff as a result of which there has only been one minor surface slippage, caused by surface water run-off.

The dune creators have helped to retain the beach material that has accumulated at the toe of the cliff. Initially, the tops of the creators were almost 900mm above the beach but were level with the beach by the end of the demonstration project. However, some people have criticised their visual appearance.

Photographic evidence shows that the overall beach shape within the site appeared to respond to the forcing conditions in much the same way as the beach to the north and south. However, the volumetric analysis does not appear to support this view. Ridge formations were continuous through the site and response to storm conditions seems to be unaffected by the lateral humps. The main geomorphological features in the beaches to the north and south of the scheme site are generally continuous through the site with some localised effect around the structures themselves where they are clearly interacting with incoming waves.

The aerial photographs give a clear indication of the condition of the beach and the degree to which the humps are covered or exposed. They also show the shingle ridges running through very clearly. A series of montages of the cliff top panoramic photographs give a good representation of the condition of the beach and the structures.

The groynes are substantially buried and have been for most the project period. This may be because the frontage has not seen the same degree of overall retreat during the last century compared with previous periods.

Conclusions and recommendations

The five-year demonstration project showed that the use of geomembranes and local beach material can provide a low-cost option for constructing structures intended to stabilise eroding beaches. Careful selection of plant is required to recognise the discrete operations associated with schemes of this type. In particular, further development work is required to handle and position the geotextile without jeopardising the designed shape of the humps.

The monitoring data indicate that the structures may have been in place during a period of relative calm, when the beach has been accreting naturally. The loss of the beach to the south was a temporary situation and there appears to be no detectable evidence that the structures are having a major impact of the condition of the SSSI or interrupting shoreline processes. As the groyne humps have not experienced long periods of pressure for retreat, it is recommended that they remain in place so that the continued monitoring can judge the longer-term impacts and effectiveness.

Acknowledgements

The financial contributions and support for the project from the partners is acknowledged, without which this demonstration project would not have proceeded. The partners were the Crown Estate, Dunwich Parish Meeting, Dunwich Town Trust, Natural England, the Environment Agency, Stephen Hawes Associates, Suffolk Coastal District Council (latterly in conjunction with Waveney District Council), Suffolk Coast & Heaths AONB, The Adnams Charity and Terry Oakes Associates Ltd.

Contents

1 Background

The village of Dunwich lies on the Suffolk coast, some four kilometres south of the town of Southwold and the River Blyth estuary. Dunwich was historically a large port, although coastal erosion caused much of it to be lost in the 13th to 16th centuries. In 1286, a large storm swept much of the town into the sea and the Dunwich River partly silted up. Residents fought to save the harbour, although this was finally destroyed by an equally fierce storm in 1328, which drove the sea against the spit of land known as Kings Holme, shifting the shingle so that it blocked the entrance to Dunwich harbour. As a result, the ships, goods and therefore revenue from the harbour moved up the coast to Walberswick. The 1328 storm also swept away the entire village of Newton, which was located a few miles up the coast. Another large storm in 1347 destroyed approximately 400 more houses in Dunwich. A quarter of the city had been lost in one event and much of the remainder of Dunwich was lost to the sea through continued erosion over a period of about two to three hundred years.

Figure 1.1 Aerial view of Dunwich village and Walberswick Bay

Today, Dunwich contains the ruins of a church and a friary, both of which are of national heritage importance. Small commercial fishing boats launch off the beach, although the fishing industry has declined in recent years. Figure 1.1 shows an aerial view of the village.

The area between Walberswick and Dunwich is ecologically important, with Site of Special Scientific Interest (SSSI) status. It also provides a natural setting for the two villages and has been identified as important for walking and painting, activities that reflect the character of the villages and form a major part of their attraction for tourists.

It is also thought that the Roman ''Stone Street' runs from Dunwich to Caistor St Edmund near Norwich, indicating the area's historical significance.

The *Suffolk Coastal Local Plan – First Alteration* (2001) recognises that Dunwich is important to the local economy and that the tourist industry needs protection.

The littoral drift along the shore is weakly in a net southerly direction, but with a higher degree of variation to both the north and south under specific wave conditions. The entrance to the River Blyth and its structures act as the updrift control to the coast, the downdrift control being determined by the cliffs at Dunwich. Between these hard points, the coast comprises a curving narrow shingle ridge. Although there is significant northerly and southerly movement of sediment under specific wave conditions, actual drift erosion along the ridge is relatively small. Overall, the alignment of the beach appears to be dominated by cross-shore sediment movement as opposed to longshore movement.

There are no built defences along this stretch of coast. The 10–15m high Dunwich Cliffs are formed of layers of Kesgrave Formation Till underlain by older Westkapelle Crag. The cliffs are eroding slowly and irregularly. They are fronted by a narrow beach consisting of mobile marine sand and gravel. The erosion of the cliffs is a significant source of material for beaches. In addition to the direct impact on the village, the erosion tends to influence the alignment of the shingle bank to the north. Figure 1.2 shows part of the cliffs and beach.

At the start of the project, the current management policy for the frontage was 'retreat the line' to allow the continuation of natural processes and at the same time maintaining some erosion and the feed of sediment to the shore and offshore banks (*Lowestoft to Harwich Shoreline Management Plan*, May 1998). The shoreline management plan (SMP) states that soft engineering measures to limit the rate of erosion would reduce the extent of any losses to Dunwich, while maintaining the high natural landscape value of the unit. This policy was reviewed and confirmed as 'management realignment' (*Lowestoft Ness to Felixstowe Landguard Point Shoreline Management Plan,* January 2010).

Figure 1.2 View of Dunwich cliffs and beach

2 Project aims

Innovative, low-cost and environmentally sensitive coast protection methods are required in locations where other traditional methods of defence are not justified for economic or environmental reasons. This demonstration project aimed to evaluate an innovative and potentially economically viable alternative to current low-cost options by testing how effective it is to retain beaches using geomembrane structures filled with locally-won beach shingle/sand material.

The Dunwich Parish Meeting, in conjunction with consulting engineers Stephen Hawes Associates, had been working since 1997 on a proposal to stabilise the beach fronting the eroding cliffs in order to reduce the frequency of dangerous cliff falls. The consulting engineers wished to encourage the natural processes which enable the beaches to perform their function of energy dissipation with the construction of low-cost, low impact 'soft defences'. However, it is also necessary to protect 'soft defences' against the very occasional storm conditions which can cause so much damage to the beach itself. The project therefore consisted of the construction of eight 'humps' running down the beach in a pattern similar to that used in a conventional timber groyne field. The intention was that, on completion, the humps would protrude above the normal beach level by approximately half a metre.

The overall aim of the project was to test and evaluate the success of retaining beaches using geomembrane structures filled with locally won beach shingle or sand material.

Specific project objectives referenced in the legal agreement between Suffolk Coastal District Council (SCDC) and the Environment Agency were:

- To investigate and trial the performance and effectiveness of a novel, cost-effective method of beach control in order to improve the range of available options
- To develop the design details for synthetic geomembrane structures filled with existing natural shingle for use as low-cost defences for coast protection
- To test the effectiveness of these low-cost synthetic geomembrane structures in retaining beach material under a range of sea and storm conditions
- To monitor and compare their effectiveness by comparing the performance of adjacent protected and unprotected beaches over a five-year period
- To analyse and produce a report on the results which facilitates their appropriate generic use in low-cost coast protection and beach control projects

During the project another objective was added:

- To learn lessons about this innovative approach and whether it may have merit for wider application

3 Partnership arrangement

The Dunwich Parish Meeting had originally intended to implement the demonstration project developed by Stephen Hawes Associates and supported by financial contributions from a number of organisations. However, legal advice obtained showed that the Parish Meeting had no coast protection powers and could not legally carry out the project. As a result, the Parish Meeting asked Suffolk Coastal District Council, as the relevant coastal protection authority, to take over the project, to which the Council readily agreed. The funding, consents and so on were transferred to the Council to enable the work to proceed under its control and direction.

In addition, the Council agreed to let a contract (managed via Suffolk Coastal Services Ltd) with Stephen Hawes Associates, the designer of the scheme, to act as project manager and a further contract with the appropriate engineering contractors to undertake the works. A contract for the engineering consultancy services of Stephen Hawes Associates was completed on 19 February 2007.

The Environment Agency contributed £27,000 towards the cost of the project to investigate the functioning and possible benefits of this new coastal management technique.

The engineer for the works was Stephen Hawes Associates and the principal contractor was Tobin Plant Limited. Survey work was carried out by Anglia Survey and Design.

Terry Oakes Associates Ltd was appointed as project manager to monitor and assess the effectiveness of scheme on behalf of the joint Defra and Environment Agency Flood and Coastal Erosion Risk Management (FCERM) research and development programme.

4 Geofabric ‘humps’ concept

What is a geo-hump?

A geo-hump is constructed by placing existing, natural beach shingle and sand in a series of 90cm x 90cm x 90cm geotextile bags, which are then wrapped and covered in a geotextile envelope to create a low profile, parabolic cross-section structure. The fabric envelope is taken down on each side of the structures into trenches, not only to anchor the structures in the beach but also to form a containment ‘curtain’ around the beach material on which each structure is to be founded. The geo-hump can be laid parallel or perpendicular to the coast.

The requirement at Dunwich was the development of a technique that would restrict the erosion of the cliffs to a manageable rate. Because of the limited number of properties remaining at risk in the village, a low-cost solution was needed. The environmental interest of the site demanded minimal impact on the geological and habitat interest as well as on the natural coastal processes.

The cliffs at Dunwich come under basal attack when the beach is comparatively low, allowing wave energy to reach the toe. The purpose of the technique which was the subject of this demonstration project was therefore to stabilise existing beach slope angles and levels. The thinking behind the design was borne out of observations of wave action on beaches within Suffolk and the interaction with traditional steel and timber groynes.

As well as the high capital cost of constructing such groynes, it was noted that reflected energy from the vertical faces of the groyne upstand was causing scour under certain conditions. Adjusting the groyne board levels to optimise performance was becoming impractical and increasingly costly.

Given that the beach needed to be ‘reinforced’ in order to restrict whole scale downdrift movement of sediments, the need for some form of shore normal structure was recognised. To restrict the amount of reflected wave energy, a low profile section was proposed with a minimal projection above the designed beach level.

The use of geomembranes was proposed to allow for flexibility of the structures, permitting them to adjust to variations in the host beach while ensuring that no vertical edges would be exposed. The intrinsic stiffness and strength of the construction would be achieved by containment of the beach material itself.

Thus the concept of lateral structures embedded in the beach, consisting of beach shingle and sand contained within a geotextile envelope and with a low profile, parabolic cross-section, was proposed as a potential solution to the continuing problem of cliff erosion at Dunwich. The fabric envelope would be taken down on each side of the structures into trenches, not only to anchor the structures in the beach but also to form a containment ‘curtain’ around the beach material on which each structure was to be founded.

The groyne-like structures or ‘humps’ were to be tied into a shore-parallel structure at the head of the beach. This was to be of a similar form of construction and cross-sectional profile.

5 Construction details and sequence

The construction of the works took place during February and March 2007 using a gang of two operatives and two small excavators with operators. The site plan prepared by the project engineer is reproduced in Appendix A.

Construction of the lateral 'humps' began on 27 February 2007. The original design length of 30m had to be modified so that the geofabric could be buried securely at the seaward end clear of the low water mark on the day of construction. This reduced the length to 20–25m.

A wave wash wall, or backwall, was constructed forward of the toe of the existing cliff such that extreme wave conditions would wash over but not breach the beach material anchored beneath. This hump wall was 240m long and extended 15m beyond the outside humps. The engineer's scale drawing of the form of construction is reproduced in Appendix B.

Figure 5.1 Filling and placing of the flexible intermediate bulk containers

The 'placed beach material' comprising existing natural shingle, was contained within a series of 90cm x 90cm x 90cm high flexible intermediate bulk containers (FIBCs) (Figure 5.1), as new but misprinted. The use of FIBCs enabled the material to be placed over the existing 'virgin beach material' to be shaped and contained. It had the added advantage of ensuring that, by forming cellular enclosures within the length of the wave wash backwall, the placed material was prevented from migrating along its length. This enhanced the stability and consistency, as well as improving stability and the speed of construction. The FIBCs were placed in pairs and their open tops then laced together using heavy duty cable ties prior to encapsulation.

A hopper arrangement was developed for filling the fabric bags, which were to form the compartments of the structure, with beach shingle. The double row of bags was filled with beach shingle using a hopper device which filled both bags simultaneously. The amount of material used in each bag was measured carefully to ensure that the designed profile could be achieved.

Figure 5.2 Placing geomembrane on top of bulk containers

After the FIBCs were positioned, trenches were excavated along the entire length of each hump on either side. The six-metre wide Geofabrics HP17 geomembrane encapsulating material was then wrapped around the hump of contained material (Figure 5.2) and secured in 1.6m deep trenches. These were then back filled and consolidated. Jointing of the geotextile was achieved by means of a hot air gun, forming a continuous welded seam. Figure 5.3 shows a partially completed hump.

In addition, eight groynes were formed from a 30-metre length of 1.5m x 2m geofabric filled with beach material. These groynes were spaced 30m apart and buried approximately 0.7m into the beach.

Figure 5.3 Partially completed 'hump'

Eight dune creators (Figure 5.4), a modern form of faggoting, were placed to intercept wind-borne sand and topsoil. To avoid the need for vertical support of the plastic mesh by vertical posts, they were shaped in plan in a figure of eight. The lower 300mm was buried in the beach, with the remaining 800mm being left to reduce wind velocity and cause the blown material to drop out to form the dunes. In March the dune creators were installed behind the backwall. These comprised Tensar geogrid panels folded into figure of eight plan shapes and buried along their long edges to an initial depth of 300mm.

Figure 5.4 Completed and filled dune creator

Finally, sections of UltraRib drainage pipe were installed vertically behind the backwall at the mid-point between each hump and trimmed off at 5.0mAOD. These formed reference points for the photographic surveys.

The initial estimate for the total cost of the project was £70,855 for a 240-metre long 'groyne' field. Post-construction essential repairs carried out during 2007-2008 increased expenditure to £78,065.

6 Monitoring regime

A monitoring regime was established to measure the performance and effectiveness of geo-humps in controlling the height and depth of the beach. It was also necessary to test the effectiveness of these low-cost, synthetic geomembrane structures in retaining beach material under a range of sea and storm conditions. In view of the importance of the adjacent SSSI, it was also necessary to monitor and compare their effectiveness by comparing the performance of adjacent protected and unprotected (SSSI) beaches over a five-year period.

The methodology and cost of the monitoring were influenced by the small scale of the project. As a result, the main basis of the monitoring regime was a monthly visual inspection of the condition of the beach and structures, supported by a set of photographs taken from pre-defined locations. A series of beach cross-sections were taken nine times during the five-year life of the project. Full colour, stereographical 1:5000 aerial photographs for 2005 to 2010 were obtained from the Environment Agency.

6.1 Beach cross-sections

The main basis of the agreed monitoring regime was a series of beach cross-sections. These were carried out prior to construction and immediately afterwards. The locations of the beach cross-sections are shown in the plan reproduced in Appendix C.

Topographical surveys continued twice a year for the first three years, with the proviso that additional surveys should take place following significant storm events. The surveys were carried out using global positioning system (GPS) linked techniques and result in the creation of a Digital Ground Model (DGM) from which seven cross-sections could be prepared. Two of these sections indicated beach levels to the north and south of the project site. The other five sections were equally spaced throughout the site itself. In total, these surveys were repeated a further nine times during the five-year life of the project. Table 6.1 lists the dates of the topographical surveys.

Two transects, 50m and 100m beyond each end of the backwall, were established to monitor conditions of the beach away from the intervention zone of the scheme. Intermediate transects were originally established at the anticipated mid-point between the humps. Following construction, however, it was noted that there was a slight misalignment of the actual mid-point with the predicted position. The initial re-surveys following construction produced cross-sections for both mid-points. Subsequently, only sections for the 'as-constructed' mid-points were produced.

From the DGM, volumetric calculations were performed to assess the overall condition of the beach and to enable comparisons to be drawn between the current and previous surveys. The computed technique is straightforward and has produced consistent and believable results since the beginning of its use on the project.

6.2 Beach photographs

Immediately prior to construction, but once the setting out had been carried out, a series of photographic viewpoints was established. These consist of a series of 57 repeated views of the humps and intervening bays for comparison over time. The viewpoints are augmented by individual photographs of damaged areas. The series is completed by a set of views taken from the cliff top giving an overview of the site and the embayment extending to Walberswick in the north and Minsmere in the south. Some of the photographs are included in Appendix I.

6.3 Anglian Regional Coastal Management Programme data

The Environment Agency leads the Anglian Region Coastal Monitoring Programme (ARCMP) covering the coastline from the Humber estuary to the Thames estuary. The programme provides a sound scientific basis to inform strategic coastal management, including shoreline management plans and beach management activities. The programme provides continuous and consistent monitoring as data collection provides the base information for all coastal management. It highlights where beaches are eroding and accreting and therefore how they should be managed for best effect and for best value for money.

Plans extracted from the data analysis report are included in Appendix D.

6.4 Historic data

The Environment Agency provided the aerial photograph in Appendix E, on which are marked the positions of the cliff top line along the Dunwich frontage *c.*1880, 1905 and 1925 as interpreted from the old County series historic maps. It can be seen that the location of the demonstration project on the cliff top position remained stable between 1880 and 1905. There followed a 20-year period of extensive erosion when the cliff top receded by 60m – likely to be the result of a few extreme events but on average three metres per year. Since 1925 the cliff top position has receded a further 20m (average of 0.24m per year). Apart from for a few localised failures resulting from surface water run-off, the cliff top position remained stable during the period of the demonstration project.

6.5 Environment Agency aerial survey photographs

As part of the ARCMP, SCDC receives full colour stereographical 1:5000 photographs annually. The photographs are usually taken in the summer. Using these photographs, officers of Waveney District Council (WDC), which manages the Dunwich frontage on behalf of SCDC, plotted the line at the bottom of the shingle bank (as the most obvious feature to plot) for the period 2005 to 2010 onto the 2010 aerial photograph (Appendix F). An additional plot of the most extreme positions of this edge was plotted on to the 2010 aerial photograph.

The first photograph in Appendix F shows that the location of the bottom of the shingle bank did not move very far up the beach, confirming it remained fairly stable and full. The second photograph, which shows the outer limits of the shingle bank, gives a clearer indication of the limited range in the movement of this point.

6.6 Mike Page's aerial photographs

Mike Page is a local pilot who records changes along the Norfolk and Suffolk coastlines on digital photographs taken from his plane. His photographic library recorded the condition of the Dunwich beach during the period of the demonstration project. Appendix J shows the photographs obtained. Table 6.1 shows the dates of these photographs versus those for the topographical surveys.

Table 6.1 Dates of Mike Page's photographs compared with dates of topographical surveys

Date of Mike Page's aerial photograph	Date of topographical surveys
	07 February 2007
11 March 2007	
	24 April 2007
	23 May 2007
	26 June 2007
	19 September 2007
	06 March 2008
11 May 2008	
	02 June 2008
23 June 2008	
	15 January 2009
29 October 2009	15 September 2009
	8 February 2010
10 October 2010	
14 March 2011	
2 December 2011	
	16 January 2012

7 Review of monitoring data

The main basis of the agreed monitoring regime was a series of beach cross-sections, monthly photographs and visual inspections. Full details are given in Section 6.

7.1 Beach cross-sections

Beach profile surveys were carried out on the various dates and the volumes of each of the five beach zones were calculated. Appendix C shows the location of the monitoring points and the volumes measured are given in in Appendix H (Table H1).

The zone beach volumetric data were analysed to identify trends (Tables H2 and H3). These tables should be read in conjunction with the charts in Appendix G, which show a comparison of the volume of beach material at various locations along the frontage:

- Zone 04 is to the north of the works
- Zones 01, 02 and 03 are within the works
- Zone 05 is to the south of the works

The charts are based on the data in Table H1.

An analysis of the tables and charts indicates the following.

- The data suggest that the structures may have influenced the shape and condition of the beach up to around early 2010 by slowing the transfer of material across the works frontage. This is one possible explanation for the trends of accretion in Zones 4 and 3 and erosion in zone 5 to that date. The volumes of change involved are small and so any effect beyond the works frontage is unlikely to have been significant.
- Data from Zone 1 are at odds with the visual evidence that the volume behind the backwall has increased. This may because material has steepened to be higher at the cliff toe.
- Zone 2 only acquired additional material late in the project
- Zone 3, which is closest to the wave zone, is the most volatile but it appears to have acquired significant material. The trend line is consistent with other profiles.
- Zone 01 is least variable in volume and has the lowest volumetric change rate. Again this is as expected as it covers an area at the back of the beach location.
- It is likely that these effects are broadly similar in the control zones (and beyond), but as there are no equivalent 'sub-zones' in Zones 4 and 5, it is not possible to comment on distribution in the upper, mid, low parts of the control zones.
- Taking the hump zones (1–3) as a whole, they have consistently accrued more material than Zone 5 to the south, but less than Zone 4 to the north. There could be many reasons for this unconnected with the structures, the variances are not great and Zone 5 has not depleted in absolute terms. Nonetheless, continued monitoring of this aspect is recommended.
- Overall there is a consistent trend of increasing volume in all zones within the demonstration project site.

- There are differences between the trends in the change of beach volume and the photographic evidence. The difference in Zone 1 and between Zones 4 and 5 may be explained by a rotation of shoreline bathy or by the works introducing a temporary block to north to south drift which, once filled, allowed overspill to resume to fill Zone 5.

7.2 Beach cross-sections

The topographical survey results included a series of cross-sections at seven locations taken on 12 separate occasions covering a period of six years from just prior to construction. These sections are drawn using an exaggerated scale. Appendix G contains plots of the data.

The sections give a good visualisation of the beach shape over the period of the works. They confirm that the early storms pushed material, previously sitting in a shingle ridge, further up the beach towards the toe of the cliff where it has remained. The sections also illustrate the volatility of the beach between the high and low water marks. The range of beach level height and the rise and fall of the shingle ridges are evident. There has been a difference in localised mid-beach height of almost 2m.

The last survey shows the beach level to be at its highest at any time over the demonstration project period.

A review of the volumetric data (see Appendix H) confirmed that, while the beach shape may change, the amount of material on the beach is fairly consistent – see plots for June 2008 and January 2012, the two occasions when the beach volume was at its highest.

The sections suggest that the structures may not influence the shape and condition of the beach significantly. Ridge formations were continuous through the site and response to storm conditions seems to be unaffected by the lateral humps. A comparison of the plots of the sections of the beach taken outside the works (that is, 100m to the south and north) with their relative neighbouring section (that is, at each end of the works) shows the beach height and shape to be very similar on each occasion. This suggests the main geomorphological features in the beaches to north and south of the scheme site have been usually continuous through the site, albeit with some localised effect around the structures themselves where they are clearly interacting with incoming waves.

7.3 Beach photographs

The cliff top panoramic photographs stitched together to create a series of montages (last set of photographs in Appendix I) give a good representation of the condition of the beach and the structures. The regular low level photographs were used to review the condition of the beach and the structures.

7.4 Historical maps

The historical maps show that the beach as fairly stable between the 1880s and 1900. However, approximately half (around 25m in depth) of the cliff and land known as 'Maison Dieu Hill' eroded sometime between 1900 and 1920. A comparison with the 2010 aerial photograph provided by the Environment Agency (Appendix E) shows that the toe of the cliff has not retreated very much further. It is apparent that, other than loss of beach material experienced during irregular storms, the frontage has not seen the same degree of overall retreat during the last century. This suggests that the trend for erosion along the frontage has temporarily slowed.

7.5 Anglian Coastal Management Programme data

The Environment Agency supplied data from its Anglian Coastal Management Programme's *Suffolk Coastal Trends Analysis Report* (2011). The profile data presented in this report are mainly in the form of beach level analysis which examines the movement of the foreshore between high and low water together with aerial photography between 1991 and 2010. The detailed observations along the Walberswick to Dunwich frontage are summarised in Table 7.1.

Table 7.1 Detailed observations for Walberswick to Dunwich frontage

Site No.	Location	Comments
S1C1	South Pier, Walberswick	Cyclical periods of erosion and accretion within an overall low erosional trend of -1.4m per year with water levels moving by around 50m on and offshore. 2010 levels are 50m further onshore than 1998 levels.
S1C2	Corporation Marshes, Walberswick	Small and steady accretional trend of 0.5m per year with no beach rotation.
S1C3	Walberswick	Significant erosion trend of -2.2m per year with slight beach flattening.
S1C4	Dunwich	Stable frontage, no movement.
S1C5	Dunwich	Mean trend of 0.4m per year due to steady accretion since 2005. No beach rotation.
S1C6	Dunwich, East Friars House	Slight erosional trend of -0.3m per year, though since 2003 levels have shown a slight accretion trend.
S1C7	Dunwich, Cliff House Caravan Park	No movement, stable frontage.

7.6 Environment Agency aerial survey photographs

While it is acknowledged that the edge of the shingle ridge is somewhat an arbitrary feature, it is interesting to note that the plots show that its location does not vary greatly. Even the plots of the two most extreme locations of the ridge show a fairly limited range in their location. This is in agreement with the location of the ridges as shown on the cross-sections. Furthermore, the plots do not suggest a trend for the edge to retreat towards the cliff line. These photographs could be used for trend analysis.

7.7 Mike Page's aerial photographs

The photographs in Appendix J cover a four and a half year period from just post-completion of the humps. The photographs give a clear indication of the condition of the beach and the degree to which the humps are covered and/or exposed. The site fencing and track marks of the equipment used to place the humps can be seen in the March 2007 photograph. The healthy state of the beach is clear in the last photograph taken in December 2011.

8 Scheme performance

This section provides an outline of the behaviour of the scheme and the main learning points, as measured through the monitoring regime.

8.1 Construction techniques

During the initial construction it was clear that the range of operations required in a relatively small site made the careful selection of plant critical. Small machines, rated at five tonnes, were initially successful in filling the FIBCs and excavating the anchor trenches for the backwall in the relatively dry conditions of the upper beach. Upgrading one of these machines to a 13-tonne rating gave benefits when excavating the trenches for the humps lower down the beach where the saturated conditions made it more difficult to keep the excavations open.

One of the significant problems was in achieving a satisfactory depth of anchorage at the seaward ends of the humps. Despite the upgraded machine it proved difficult to excavate to the 1.5m depth originally proposed. The saturated sand was generally fluidised close to the low water mark and this, together with the difficulties in handling the free end of the geotextile, led to a number of locations where the extreme edge of the fabric broke surface following installation.

Spreading out the geomembrane to cover the bagwork was problematic throughout the original construction phase. The considerable weight of a roll of the fabric precluded manual handling and, again, the modest size and reach of the machines prevented a satisfactory method of handling the rolls on a pole threaded through the central tube without taking the weight on the bags. As a result, it was difficult to achieve the optimum shape of the domed top of the humps.

Preliminary development work had taken place to achieve a safe, economic means of filling the bags with shingle/sand mix. Minor modification to the hopper took place on site and the operation became reasonably efficient.

8.2 Structural aspects

A consistent problem occurred during construction whereby difficulty was experienced in securing the geomembrane at the seaward end of each lateral 'hump'. This was caused by the limited time available to work at the bottom of the tide and by the difficulty in achieving the required depth of trench excavation in the saturated beach material. As a result, a severe storm shortly after the completion of construction loosened fabric in two of the hump groynes. When exposed, it is considered that these pose a hazard to bathers.

During the same event, some of the FIBCs collapsed. This was attributed to the lack of containment and possible fluidisation of the beach material constituting the underlying formation. It was also noticed that a number of the cable ties lacing the bags together had snapped. The loss of shape on the structures seems to derive from the ability of the shingle in the FIBCs to move within the containing geomembrane. Examination of the original cross-section shows that there is little in the way of tensile capability to restrict the lower outside edges of the FIBCs from spreading. The complete encirclement of the FIBCs by means of the reinforced geomembrane in the revised section should provide such a restraint.

The backwall remained intact and continuous with no significant loss of material because, from the photographic records, it was apparent that the zone behind the backwall had built progressively following construction. The back edge of the wall was consistently buried and the dune creators were only just showing above the shingle. However, during the project some of the front edge of the backwall developed a more vertical face. It is probable that loss of beach level immediately in front of the backwall led to loss of support to the front edge. The tendency then appeared to be for the weight of saturated material behind the backwall, as well as the material contained in the backwall itself, to push the front edge forward. The vertical face thus formed then encouraged wave reflection and increased scour. However, this feature was considered transient as beach material did return and cover the front face of the fabric.

There were a small number of locations where the geomembrane has been holed or torn, with a suspicion that some of the damage may have been caused maliciously. In other instances, some tearing and fraying of the fabric edges indicated an abraded or tensile failure. In each case, a simple patch of fabric was welded over the damage with the repairs continuing to prove satisfactory over the subsequent period.

8.3 Hydraulic performance and effect on beach

What did become apparent from observations made over the winter of 2007/8 was the build-up landward of the backwall. This was particularly evident following the storm event on 9 November 2007 but had been progressive since the construction of the dune creators. These high beach levels behind the backwall were sustained during the project and the dune creators remain substantially buried in the accumulation of shingle. Levels have been such that there has been no undercutting of the cliff by tidal or wave action. Minor, localised cliff falls were experienced, usually following periods of heavy rain.

During the second year the accumulation of material on the landward side of the backwall continued, forming a limiting threshold on the height of the upper beach material. There was a substantial increase in the height of material at the toe of the cliff as a result of which there was only one minor surface slippage, caused by surface water run-off.

A storm in September 2009 with strong onshore winds caused a substantial lowering of the beach, sufficient to expose the seaward ends of the lateral humps and the edges of the fabric.

Following the September 2009 storm event, there was a low area between the backwall and the ridge which had built up between the low water and half tide marks. This was most prominent in the southern part of the site and was completely filled at the northern section. This feature was the exception to the general condition whereby beach shaping was consistent through the site and to the north and south. It was clear that some influence on the waves and localised currents had been exerted by the exposed structures and this had led to the development of this ‘valley’. The feature was quite shallow and did not give rise to any concerns about the stability of the various structures.

Overall throughout the project, the beach within the site continued to respond to the forcing conditions in much the same way as the beach to the north and the south. Ridge formations were continuous through the site and response to storm conditions seems to be unaffected by the lateral humps. In effect, the main geomorphological features in the beaches to north and south of the scheme site have usually been continuous through the site, albeit with some localised effect around the structures themselves where they are clearly interacting with incoming waves. This impression is confirmed by the cliff top photographs (the location of which had been specifically chosen to try to demonstrate any impact the scheme site might be having on the wider embayment between Walberswick and Minsmere), the topographical surveys and the aerial photographs.

9 Findings

One of the significant problems was in achieving a satisfactory depth of anchorage at the seaward ends of the humps. Despite the upgraded machine it proved difficult to excavate to the 1.5m depth originally proposed. The saturated sand was generally fluidised close to the low water mark and this, together with the difficulties in handling the free end of the geotextile, led to a number of locations where the extreme edge of the fabric broke surface following installation. The limited time available to work at the bottom of the tide contributed to the difficulty in achieving the required depth of trench excavation in the saturated beach material. As a result, a severe storm shortly after the completion of construction loosened fabric in two of the hump groynes. When exposed, it is considered that these pose a hazard to bathers. Refinement of the design to minimise work at or near the low water mark will lead to improved construction standards.

Spreading out the geomembrane to cover the bagwork was problematic throughout the original construction phase. The considerable weight of a roll of the fabric precluded manual handling and, again, the modest size and reach of the machines prevented a satisfactory method of handling the rolls on a pole threaded through the central tube without taking the weight on the bags. As a result, it was difficult to achieve the optimum shape of the domed top of the humps. Therefore, careful selection of plant is required to recognise the discrete operations associated with schemes of this type. In particular, further development work is required to handle and place the geotextile without jeopardising the designed shape of the humps.

During a post-construction storm event some of the FIBCs collapsed. This was attributed to the lack of containment and possible fluidisation of the beach material constituting the underlying formation. It was also noticed that a number of the cable ties, lacing the bags together, had snapped. The loss of shape on the structures seems to derive from the ability of the shingle in the FIBCs to move within the containing geomembrane. Examination of the original cross-section shows that there is little in the way of tensile capability to restrict the lower outside edges of the FIBCs from spreading. The complete encirclement of the FIBCs by means of the reinforced geomembrane in the revised section should provide such a restraint.

Preliminary development work had taken place to achieve a safe, economic means of filling the bags with a shingle and sand mix. Minor modification to the hopper took place on site and the operation became reasonably efficient.

One of the most satisfactory aspects of the project so far has been the accumulation of material on the landward side of the backwall. It may be that this is, in effect, a redistribution of beach material and hence is not shown in the volumetric analysis. This material has built with each successive storm event, with the wall itself forming a limiting threshold on the height of the upper beach material. There is now a substantial height of material at the toe of the cliff as a result of which there has only been one minor surface slippage, caused by surface water run-off.

The dune creators have helped to retain the beach material that has accumulated at the toe of the cliff. Initially, the tops of the creators were almost 900mm above the beach but, at the end of the demonstration project, the tops were level with the beach. However, ways in which their aesthetic quality could be improved would be welcomed by some people.

Photographic evidence shows that throughout the project the overall beach shape within the site appeared to respond to the forcing conditions in much the same way as the beach to the north and the south. However, the volumetric analysis does not support this view.

The cross- sections give a good visualisation of the beach shape over the period of the works. They confirm that the early storms pushed material, previously sitting in a shingle ridge, further up the beach towards the toe of the cliff where it has remained. The sections also illustrate the volatility of the beach between the high and low water marks. The range of beach level height and the rise and fall of the shingle ridges are evident. There has been a difference in localised mid-beach height of almost 2m.

Ridge formations were continuous through the site and the response to storm conditions seems to be unaffected by the lateral humps. In effect, the main geomorphological features in the beaches to north and south of the scheme site were usually continuous through the site, albeit with some localised effect around the structures themselves where they are clearly interacting with incoming waves.

The aerial photographs give a clear indication of the condition of the beach and the degree to which the humps are covered or exposed. The photographs also show the shingle ridges running through very clearly. Extending their area of coverage would give information on the condition of the beaches or habitats to the south of the site. The cliff top panoramic photographs, stitched together to create a series of montages, give a good representation of the condition of the beach and the structures.

The trend analysis report produced as part of the Environment Agency's Anglian Coastal Management Programme, which looks at a much longer length of shoreline, indicates a trend for long-term accretion to the north of the site. It also suggests that the southern part of the beach is more volatile but with a current minor trend of accretion.

The cliff top panoramic photographs, stitched together to create a series of montages, give a good representation of the condition of the beach and the structures. The regular low level photographs were used to review the condition of the beach and the structures.

It is apparent from the historic maps that, other than loss of beach material experienced during irregular storms, the frontage has not seen the same degree of overall retreat during the last century. This suggests that the trend for erosion along the frontage has temporarily slowed.

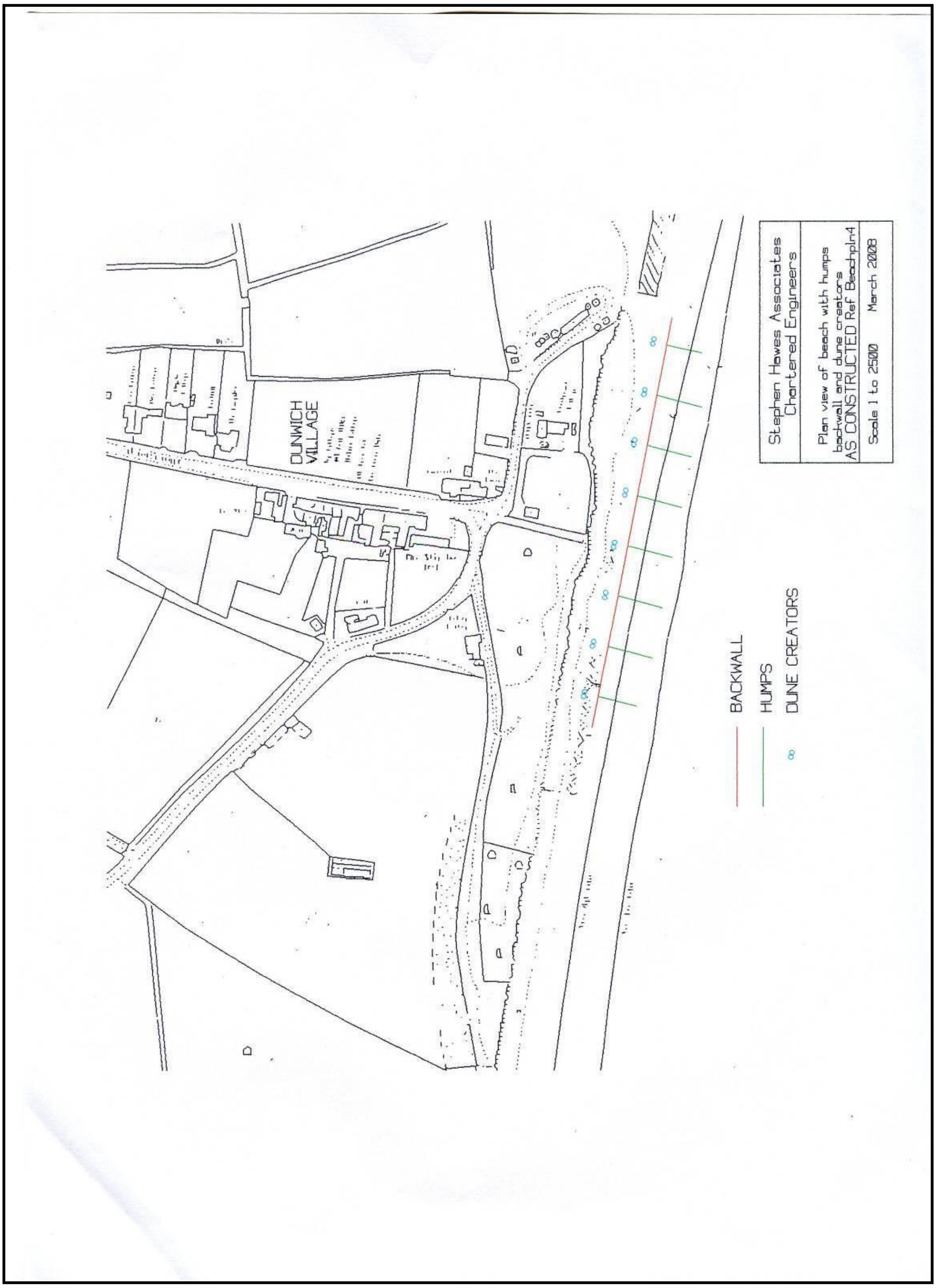
The data suggest that the structures may have influenced the shape and condition of the beach up to around early 2010 by slowing the transfer of material across the works frontage. The volumes of change involved are small and so any effect beyond the works frontage is unlikely to have been significant.

10 Conclusions

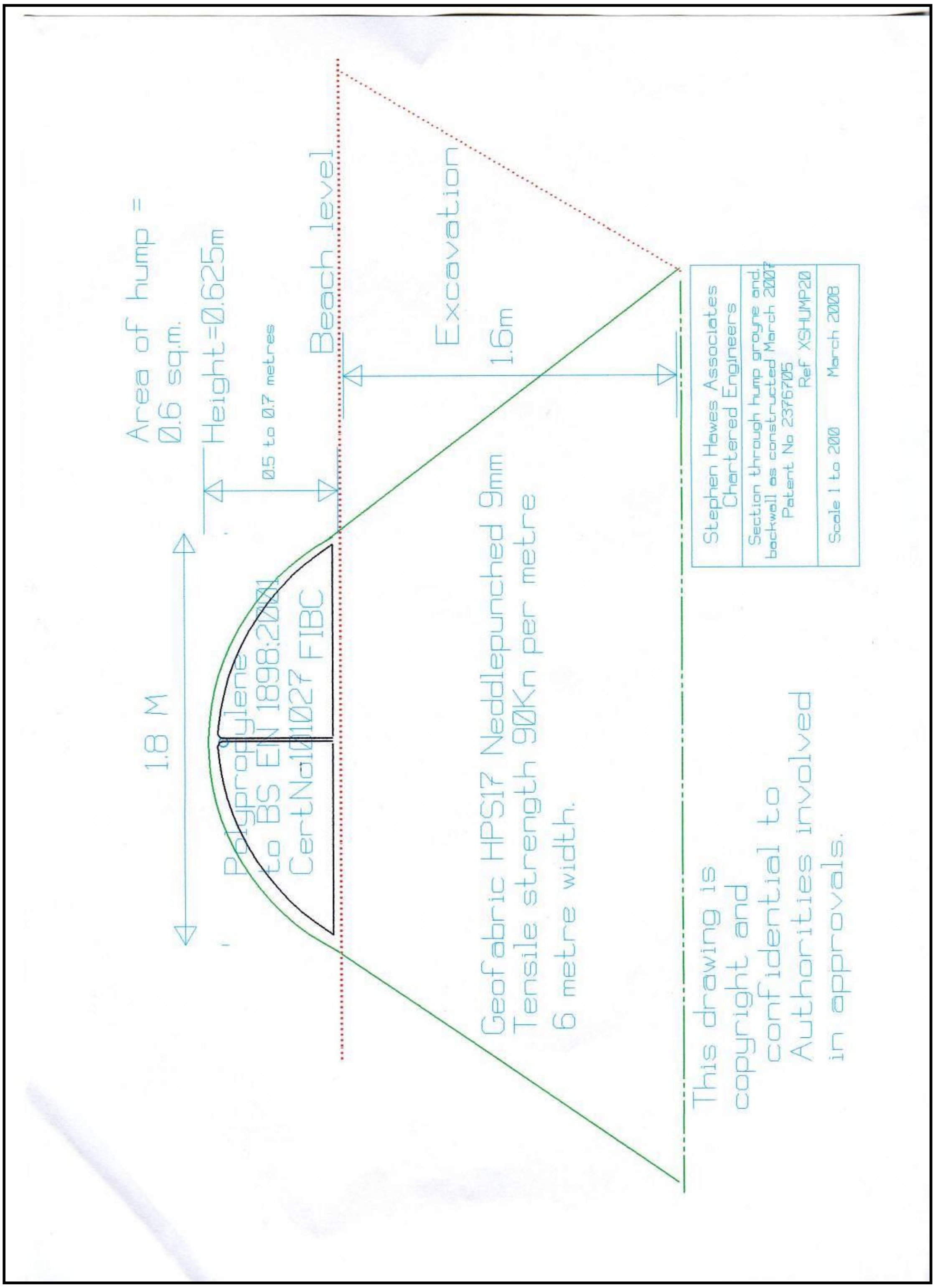
The five-year demonstration project showed that the use of geomembranes and local beach material can comprise an effective, low-cost option for constructing structures intended to stabilise eroding beaches. However, the monitoring data indicate that the structures may have been in place during a period of relative calm when the beach has been accreting naturally. The loss of the beach to the south was a temporary situation and there appears to be no detectable evidence that the structures are having a major impact of the condition of the SSSI or interrupting shoreline processes. In addition, the groyne humps have not experienced long periods of pressure for retreat.

The project team therefore considers that more data, obtained over a longer period of time, are required to test the scale of impact of the structures in order to inform new projects and to demonstrate that the project’s aims have been examined in full. The team recommends that the structures remain in place so that the continued monitoring can judge the longer-term impacts.

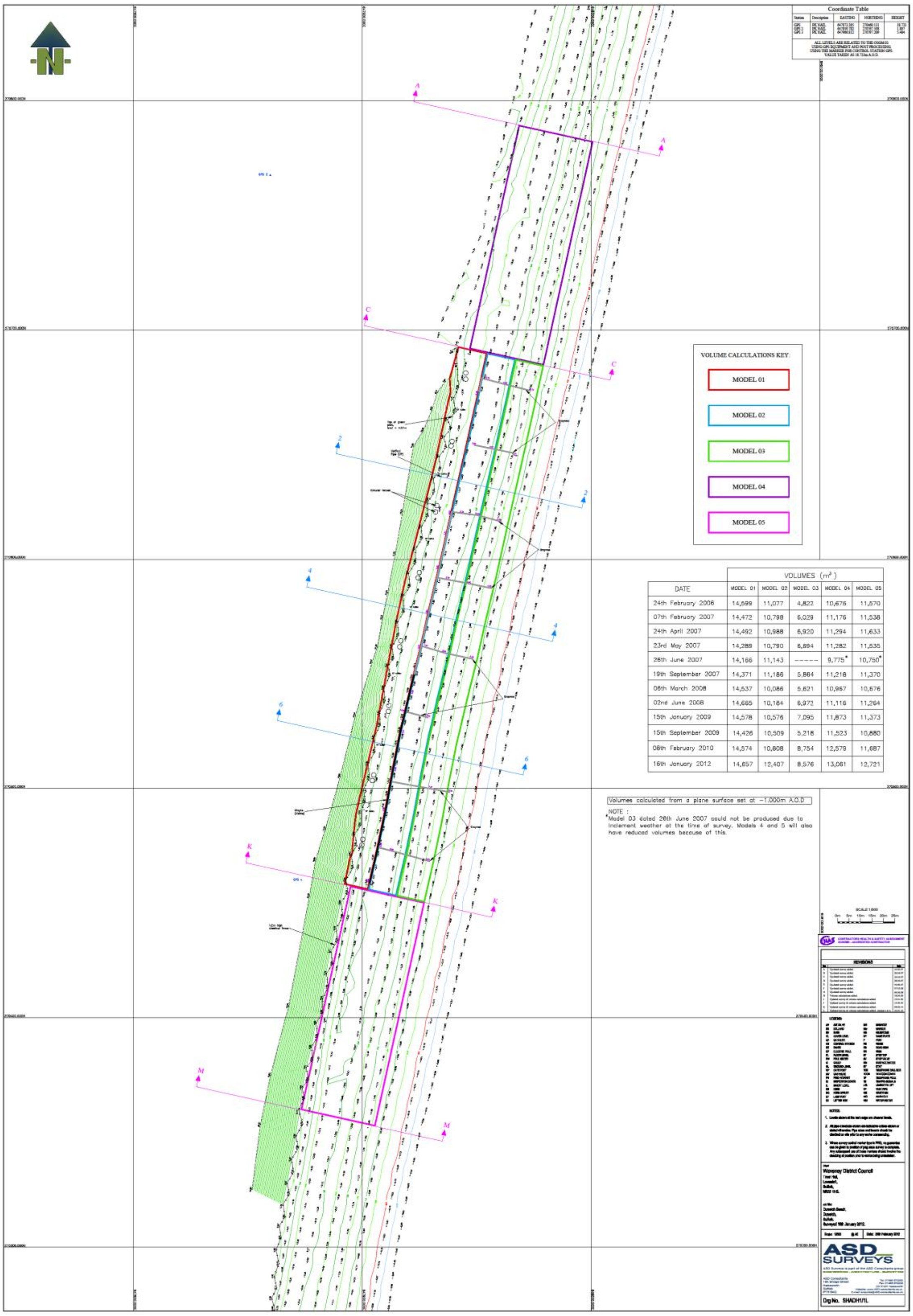
Appendix A: Site plan



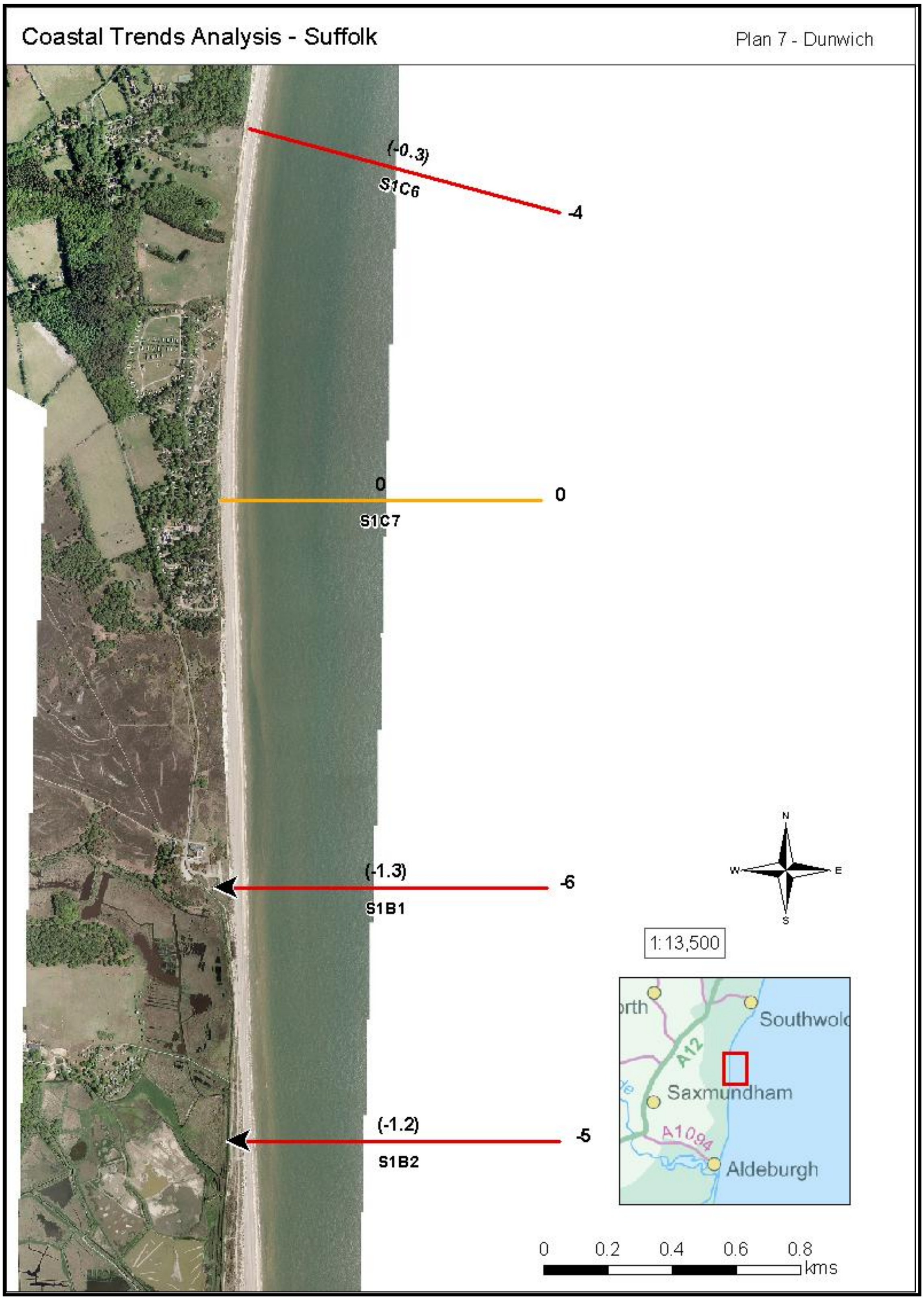
Appendix B: Form of construction

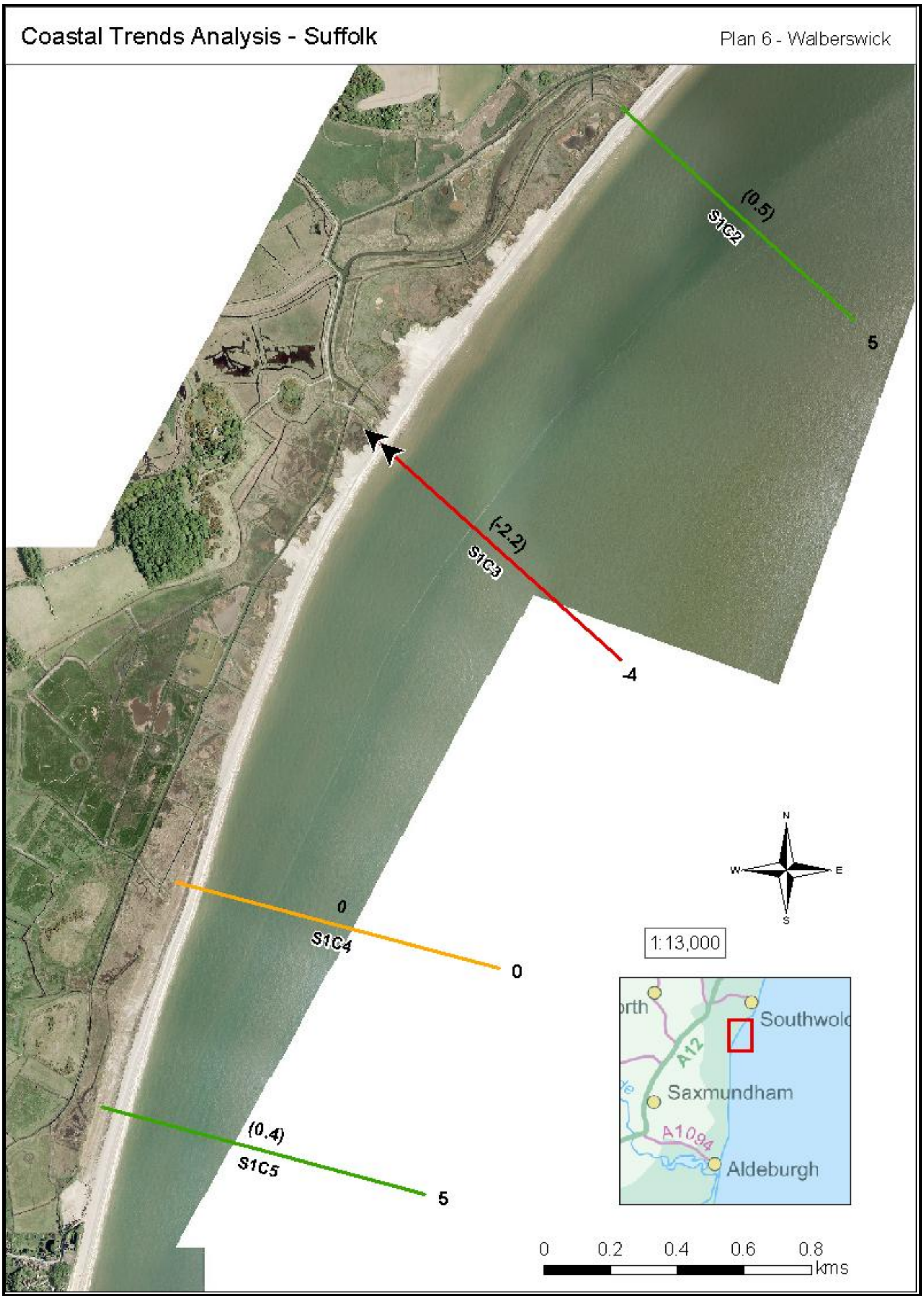


Appendix C: Monitoring locations



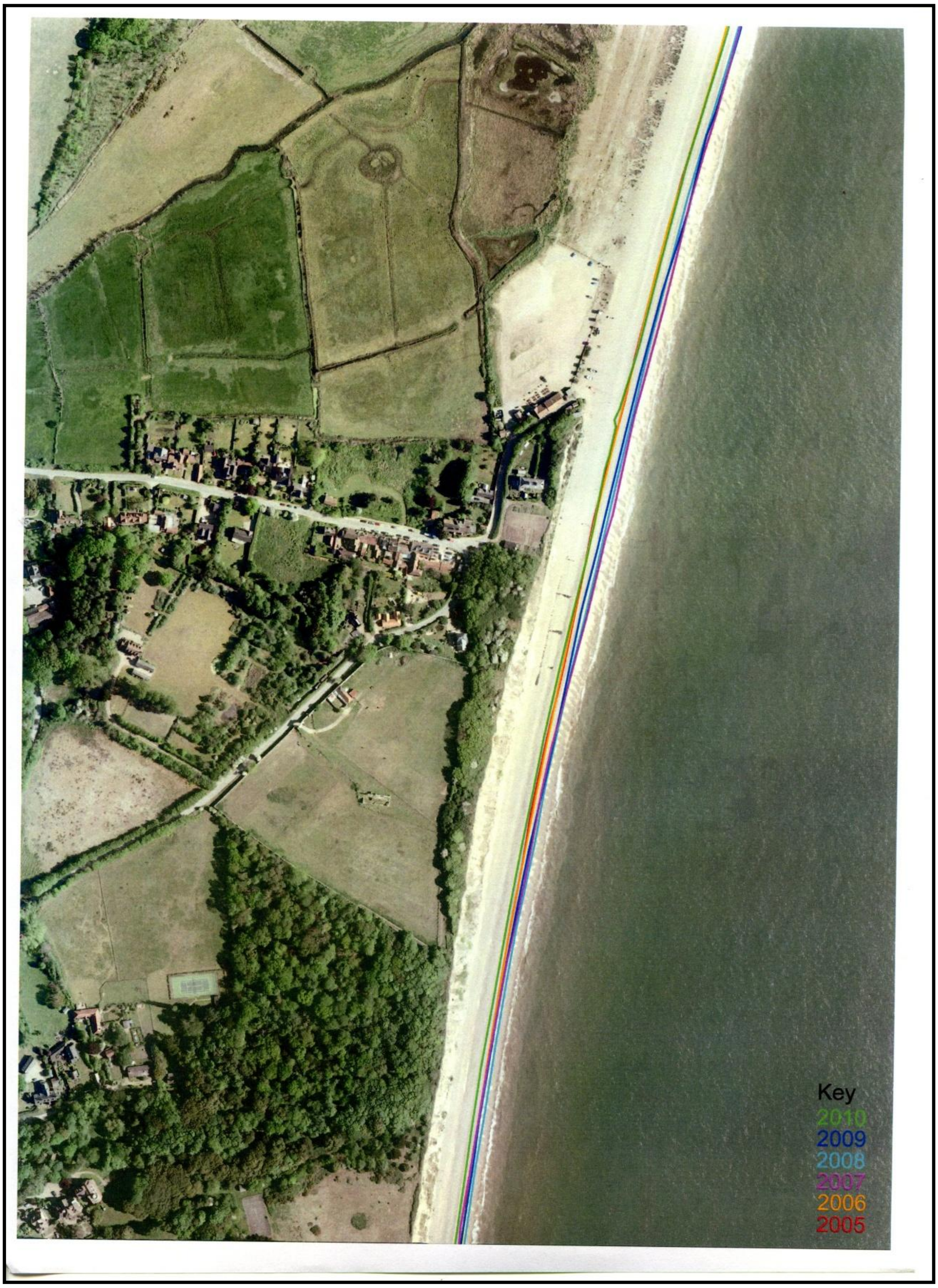
Appendix D: Coastal trends analysis plans

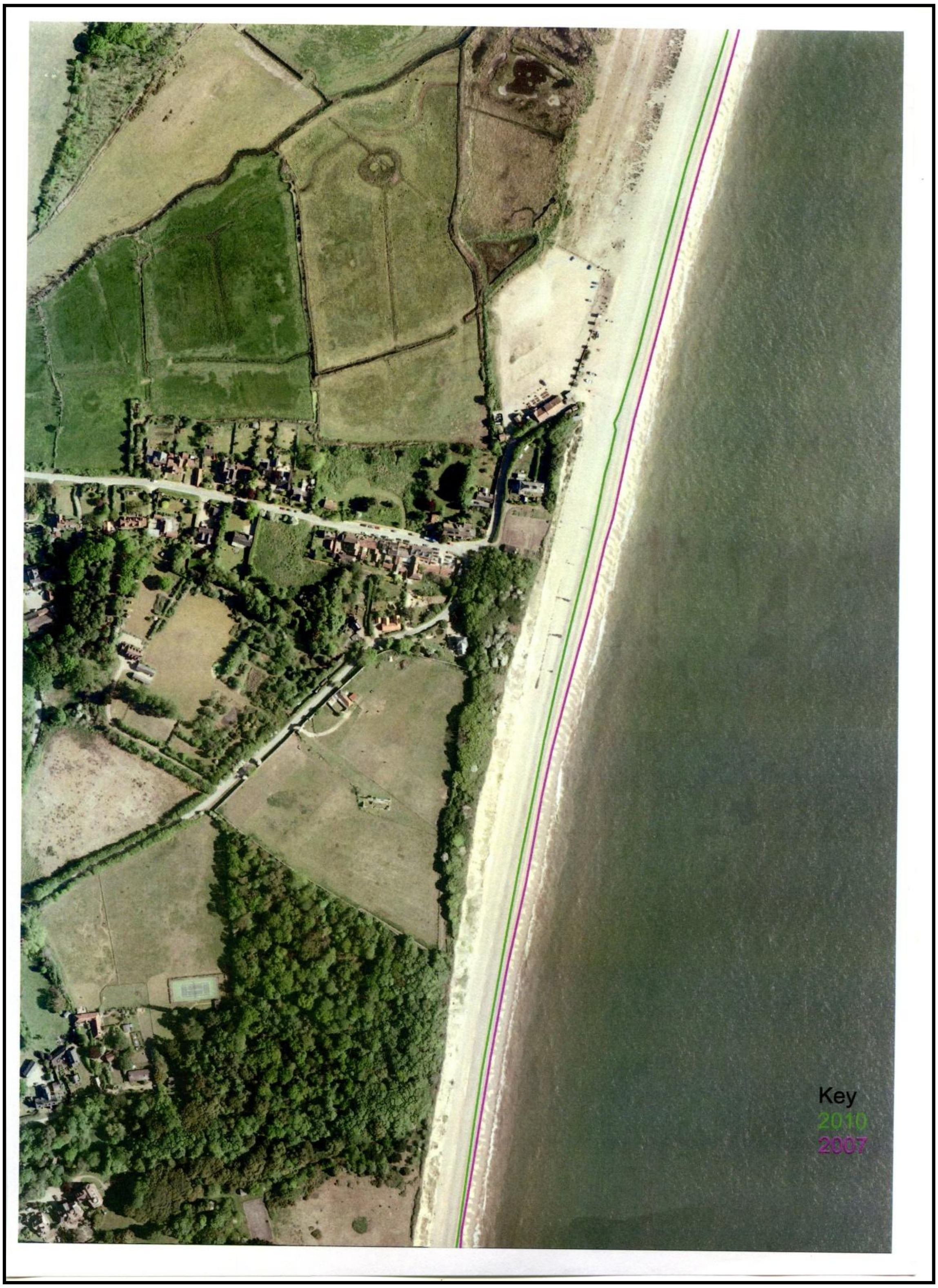



Coastal Trends Analysis - Suffolk
Plan 6 - Walberswick
(0.5)
S1C2
5
(-2.2)
S1C3
-4
0
S1C4
0
(0.4)
S1C5
5
N
W
E
S
1:13,000
Southwold
A12
Saxmundham
A1094
Aldeburgh
0
0.2
0.4
0.6
0.8
kms

Appendix E: Cliff top positions

Appendix F: Beach shape aerial photographs



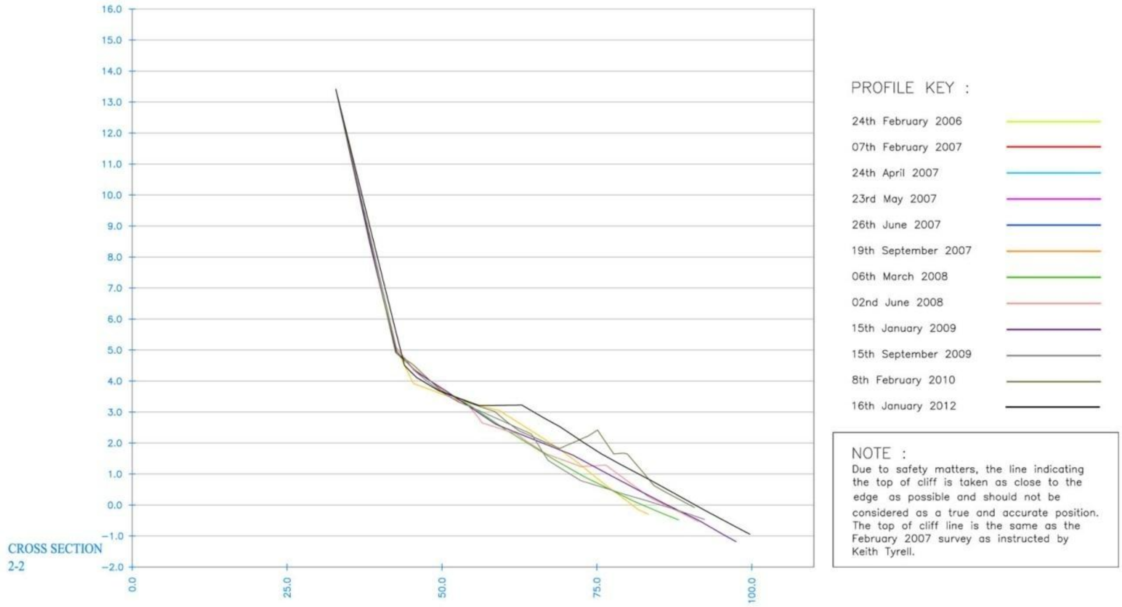

Key
2010
2007

Appendix G: Beach cross-sections

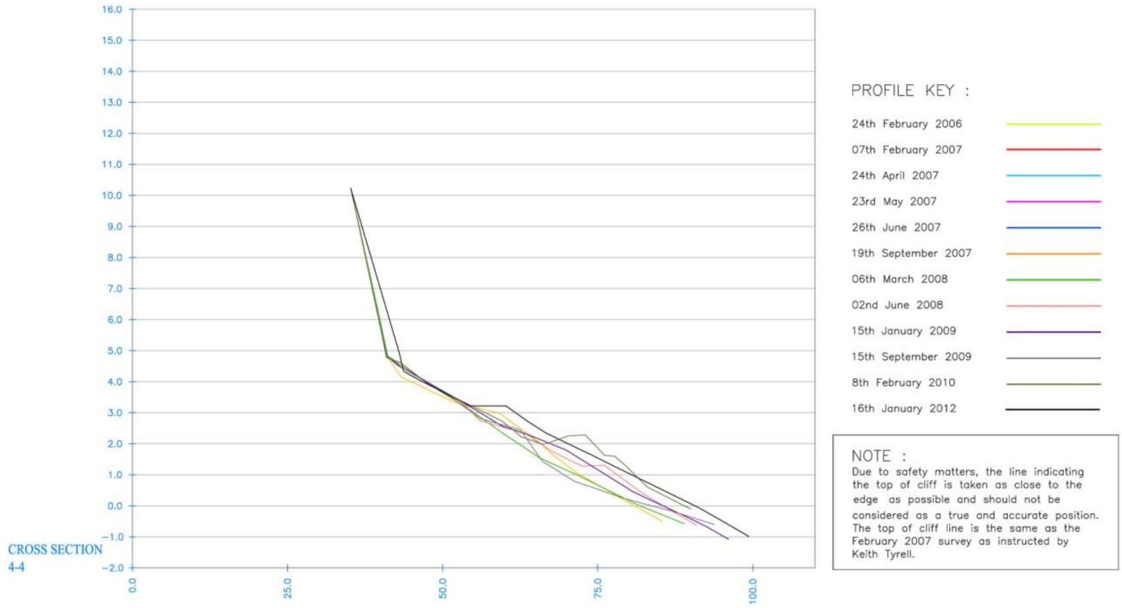
The following charts are cross-sections of the beach, from low water, to the top of the cliff. The sections are an interpretation of the topographical surveys listed in Table H1.

The *y*-axis is the vertical distance (that is, height) of the beach or cliff in metres above Ordnance Datum (mAOD). The *x*-axis is the horizontal distance in metres. For ease of interpretation the scales have been exaggerated. Chainage zero is at the northern end of the backwall.

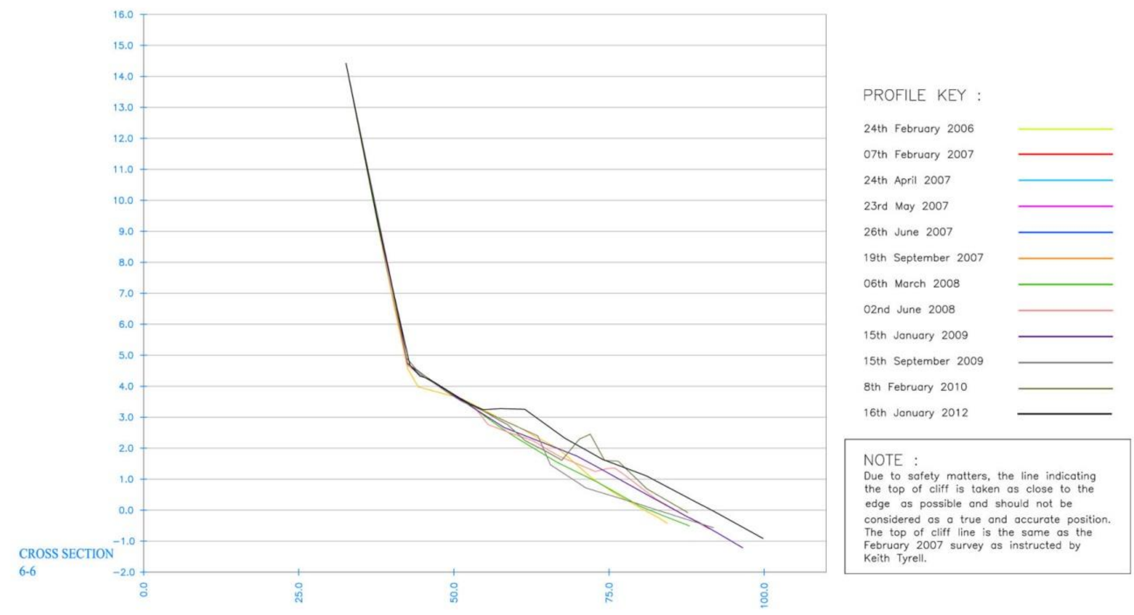
Section 2-2: Chainage 57m



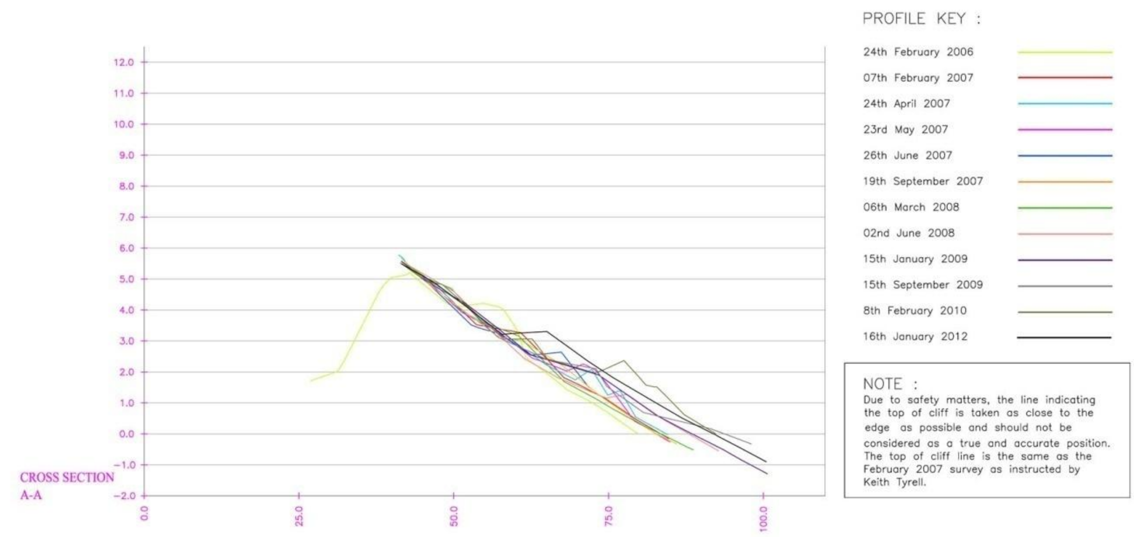
Section 4-4: Chainage 117m



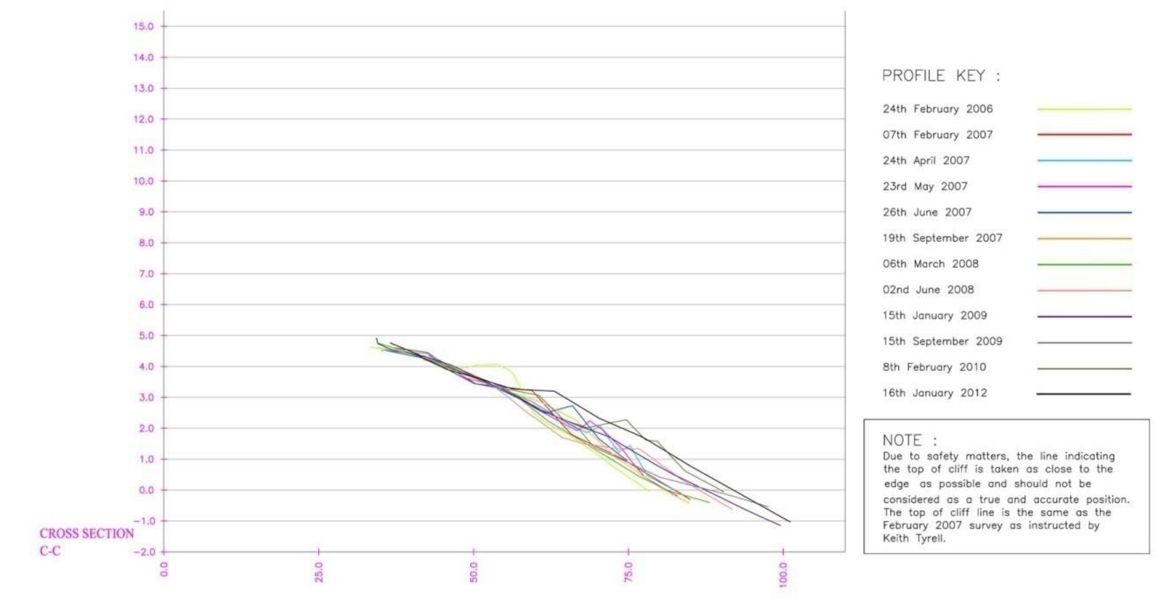
Section 6-6: Chainage 176m



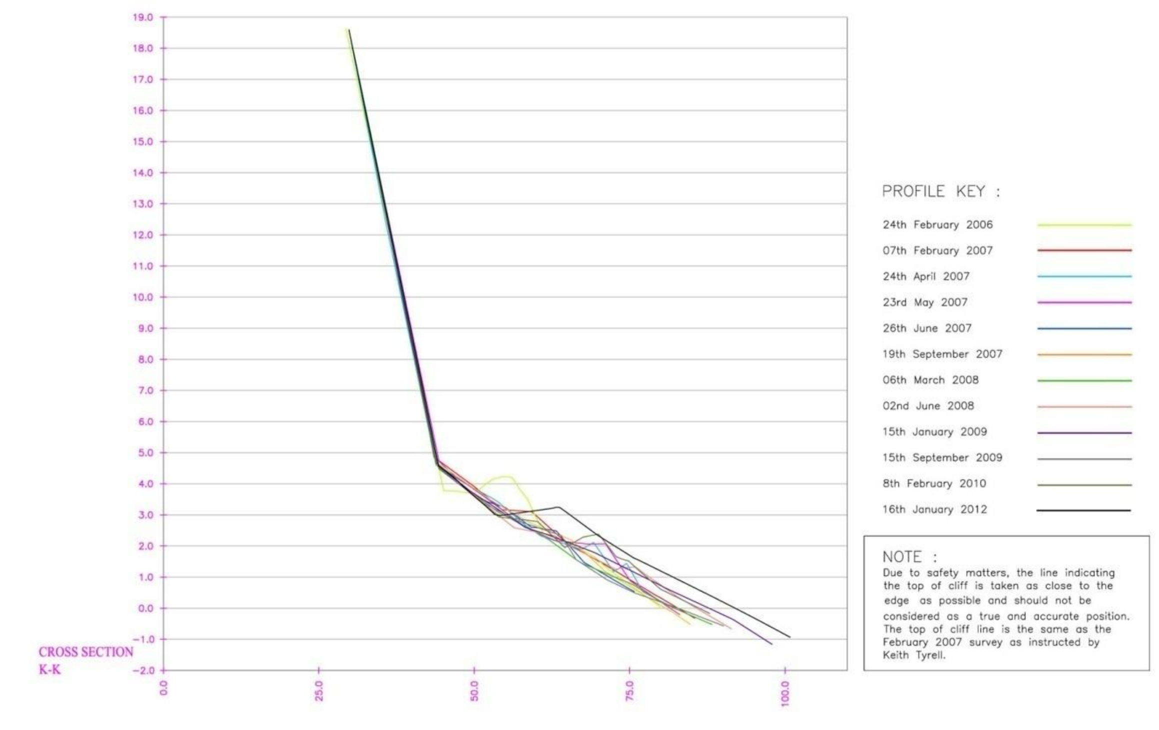
Section A-A: Chainage –100m (that is, 100m north of structure)



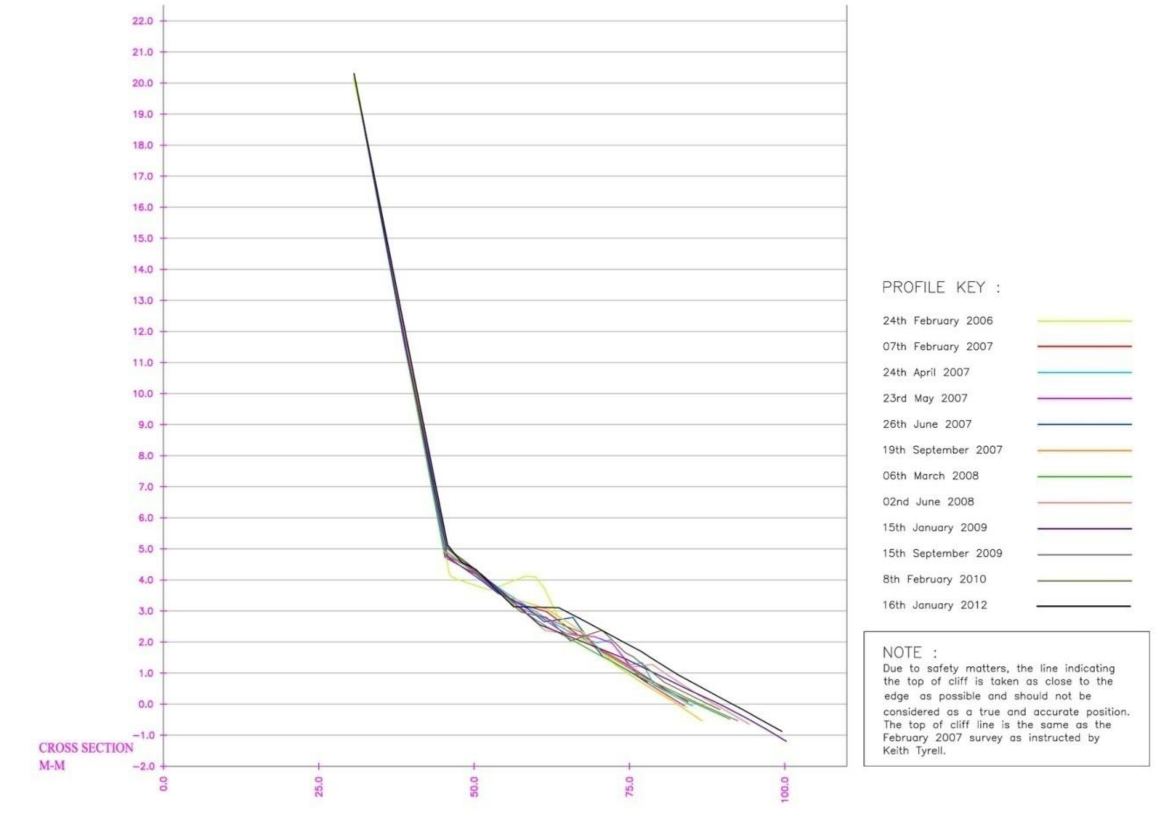
Section C-C: Chainage 00m (that is, at northern end of structure)



Section K-K: Chainage 240m (that is, southern end of structure)



Section M-M: Chainage 340m (that is, 100m south of site)



Appendix H: Comparison of beach volumes

Results of topographical surveys

Table H1 Beach volumes during project life

Date	Volumes (m^3)				
	Zone 01	Zone 02	Zone 03	Zone 04	Zone 05
24 February 2006	14,599	11,077	4,822	10,676	11,570
07 February 2007	14,472	10,798	6,029	11,176	11,538
24 April 2007	14,492	10,988	6,920	11,294	11,633
23 May 2007	14,289	10,790	6,694	11,282	11,535
26 June 2007	14,166	11,143	– *	9,775*	10,750*
19 September 2007	14,371	11,186	5,864	11,218	11,370
06 March 2008	14,537	10,086	5,621	10,967	10,676
02 June 2008	14,665	10,184	6,972	11,116	11,264
15 January 2009	14,578	10,576	7,095	11,873	11,373
15 September 2009	14,426	10,509	5,218	11,523	10,880
8 February 2010	14,574	10,808	8,754	12,579	11,687
16 January 2012	14,657	12,407	8,576	13,061	12,721

Notes: Zone 01 Toe of cliff – Backwall – an area within the works

Zone 02 Backwall – half way to LWM – an area within the works

Zone 03 Half way point – LWM – an area within the works

Zone 04 Area of beach between the toe of cliff and LWM for 100m north of the site

Zone 05 Area of beach between the toe of cliff and LWM for 100m south of the site

* Zone 03 calculation could not be made due to inclement weather preventing the lower beach being surveyed. Models 4 and 5 also have reduced volumes.

Analysis of zone beach data

The analysis of the data in Tables H2 and H3 is based on the rationale that:

- the hump zones (Zones 1, 2 and 3) are lateral strips parallel to the cliff
- the control zones (Zones 4 and 5) are blocks, taking in the whole beach width from cliff to low water mark (see Appendix C)

Although conclusions can be drawn about each of Zones 1, 2 and 3 in isolation, the performance of the hump zones cannot be compared with the controls unless the data for Zones 1, 2 and 3 are combined, that is, as the 'Mean of 1–3' in Table H2.

A comparison of all the zone volumes is shown in Figure H1 and the volume of beam material in each zone on the date of each topographical survey in Figure H2.

Table H2 Zone beach data (m^3)

Survey date	Zone 1		Zone 2		Zone 3		Mean of 1–3		Zone 4		Zone 5	
	Raw	Var*	Raw	Var*	Raw	Var*	Raw	Var*	Raw	Var*	Raw	Var*
Feb-06	14,599	1%	11,077	3%	4,822	-20%	10,166	-3%	10,676	-4%	11,570	0%
Feb-07	14,472	0%	10,798	0%	6,029	0%	10,433	0%	11,176	0%	11,538	0%
Apr-07	14,492	0%	10,988	2%	6,920	15%	10,800	4%	11,294	1%	11,633	1%
May-07	14,289	-1%	10,790	0%	6,694	11%	10,591	2%	11,282	1%	11,535	0%
Sep-07	14,371	-1%	11,186	4%	5,864	-3%	10,474	0%	11,218	0%	11,370	-1%
Mar-08	14,537	0%	10,086	-7%	5,621	-7%	10,081	-3%	10,967	-2%	10,676	-7%
Jun-08	14,665	1%	10,184	-6%	6,972	16%	10,607	2%	11,116	-1%	11,264	-2%
Jan-09	14,578	1%	10,576	-2%	7,095	18%	10,750	3%	11,873	6%	11,373	-1%
Sep-09	14,426	0%	10,509	-3%	5,218	-13%	10,051	-4%	11,523	3%	10,880	-6%
Feb-10	14,574	1%	10,808	0%	8,754	45%	11,379	9%	12,579	13%	11,687	1%
Jan-12	14,657	1%	12,407	15%	8,576	42%	11,880	14%	13,061	17%	12,721	10%

Notes: * All variances are measured from the Feb-07 data.

Table H3 Restricted data, Q1 readings only (m^3)

Survey date	Zone 1		Zone 2		Zone 3		Mean of 1–3		Zone 4		Zone 5	
	Raw	Var*	Raw	Var*	Raw	Var*	Raw	Var*	Raw	Var*	Raw	Var*
Feb-07	14,472	0%	10,798	0%	6,029	0%	10,433	0%	11,176	0%	11,538	0%
Mar-08	14,537	0%	10,086	-7%	5,621	-7%	10,081	-3%	10,967	-2%	10,676	-7%
Jan-09	14,578	1%	10,576	-2%	7,095	18%	10,750	3%	11,873	6%	11,373	-1%
Feb-10	14,574	1%	10,808	0%	8,754	45%	11,379	9%	12,579	13%	11,687	1%
Jan-12	14,657	1%	12,407	15%	8,576	42%	11,880	14%	13,061	17%	12,721	10%

Notes: * All variances are measured from the Feb-07 data.

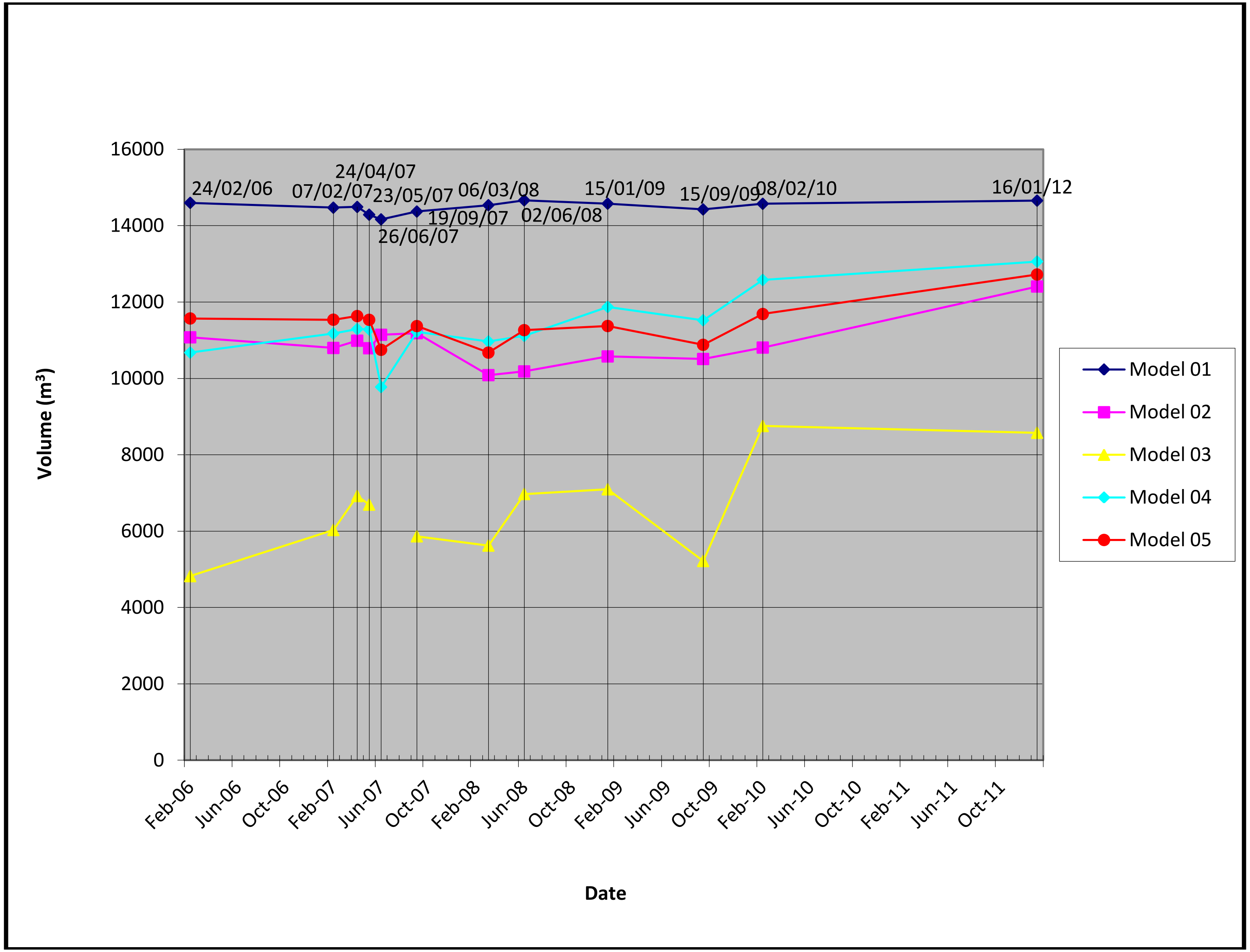


Figure H1 Comparison of all zone volumes (referred to as models in the key)

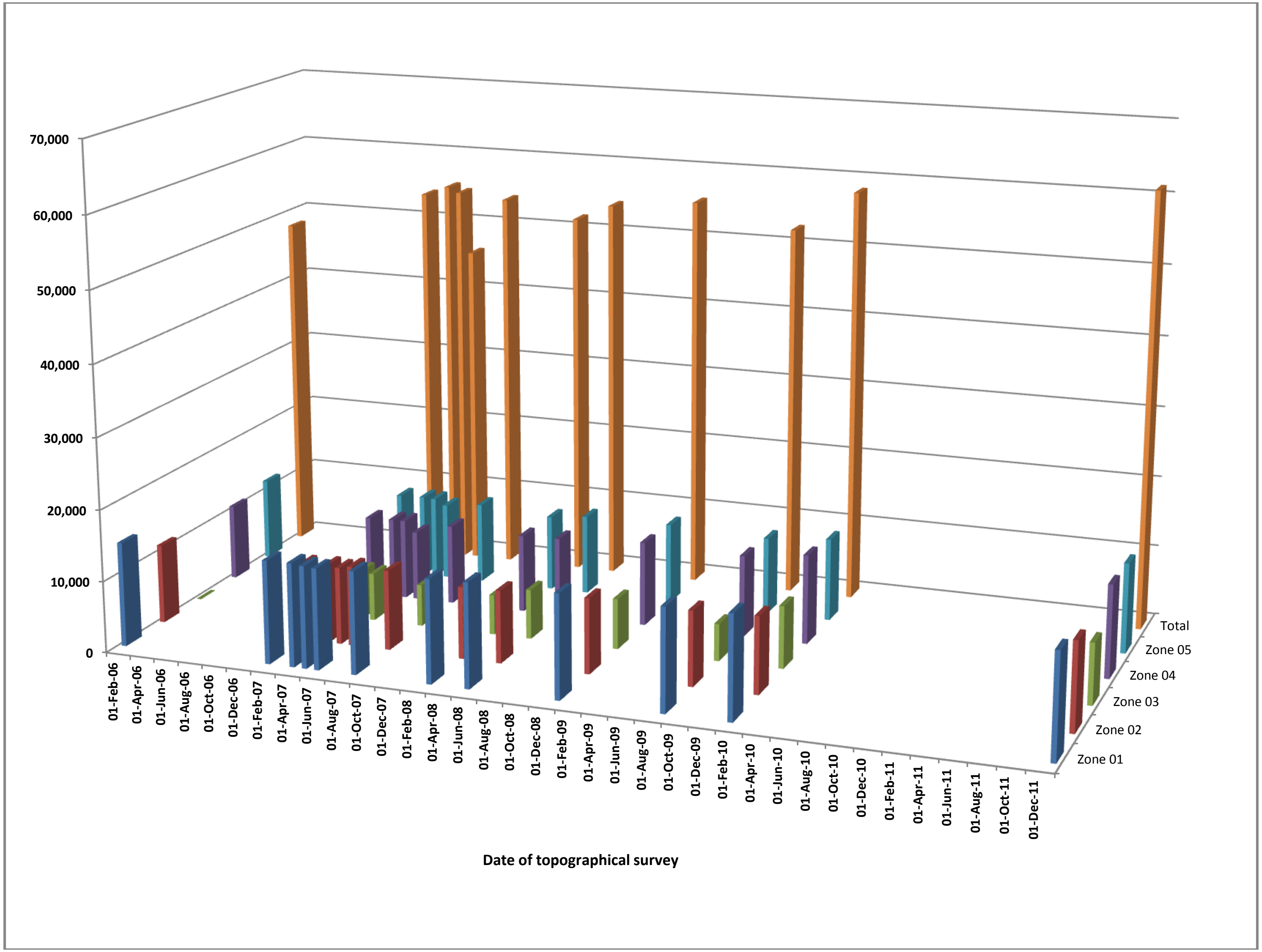


Figure H2 Volume of beach material (m^3) in each zone

Appendix I: Beach photographs

Comparison between 2007 and 2009

	18 March 2007	05 January 2009
ED4		
ED7		
HG1		
HG7		

	18 March 2007	05 January 2009
View from cliff top		
Damage to structures		
Backwall – July 2008		
Detached geomembrane at seaward end of 'hump' 2008		

Seaward end of 'hump' A 2008	

2009 photographs – position FG2

14 April 2009	**17 June 2009**
	
17 August 2009	**16 September 2009**
	
15 October 2009	**15 December 2009**
	

2009 photographs – site conditions 16 September 2009

14 April 2009	17 June 2009
	
17 August 2009	**16 September 2009**
	
15 October 2009	**15 December 2009**
	

2010-2011 montage photographs

March 2010

May 2010

June 2010

July 2010

September 2010

November 2010

January 2011

February 2011

2010-2011 photographs

4 March 2010	1 May 2010
	
4 June 2010	**6 July 2010**
	
22 September 2010	**15 November 2010**
	

25 January 2011	11 February 2011
	

Damaged fabric at February 2011

Appendix J: Mike Page’s aerial photographs

March 2007	May 2008
	
June 2008	**October 2009**
	
October 2010	**March 2011**
	

December 2011

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