Coastal Trends Report
North Norfolk (Holme-next-the-Sea)

RP009/N/2009
March 2009
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We operate at the place where environmental change has its greatest impact on people’s lives. We reduce the risks to people and properties from flooding; make sure there is enough water for people and wildlife; protect and improve air, land and water quality and apply the environmental standards within which industry can operate.

Acting to reduce climate change and helping people and wildlife adapt to its consequences are at the heart of all that we do.

We cannot do this alone. We work closely with a wide range of partners including government, business, local authorities, other agencies, civil society groups and the communities we serve.
Holme-next-the-Sea

(Photograph: Environment Agency)
Glossary

Accretion The accumulation of sediment on a beach by the action of natural forces or as a result of man-made artificial structures

Bathymetry The topographic relief of the seabed

Beach Dewatering System A system used to drain the upper beach by lowering the water table in the swash zone, reducing sand fluidisation and encouraging suspended sediments to be deposited more readily

BPIT Beach Profile Inspection Tool – SMG bespoke software for QA and analysis of beach profile data which uses Matlab functionality

Chainage The distance along a topographic survey transect line, measured in metres

Chart Datum The level to which all soundings on a marine navigational chart are based

Dragons' tooth defences Soft sea defences consisting of fencing posts inserted at intervals in a zig-zag formation on the foreshore immediately in front of eroding dunes to encourage sand deposition at the foot of the dune and dune face

Ebb delta The bulge of sand formed just seaward of an estuary mouth by the deposited sediment of an ebb current

Embryo dunes The initial build up of wind blown sand around sediment and vegetation. The first type of dune in a dune system which can be easily washed away by high tide

Erosion The loss of material from a beach by the action of natural forces or the result of man-made artificial structures interfering with coastal processes

FCP Foreshore Change Parameter

Foreshore The area of beach lying between high water and low water

Foreshore rotation Foreshore steepening or flattening resulting in the convergence or divergence of high and low water marks

Grey dunes Also known as Fixed dunes. Established dunes found landward of the yellow and embryo dunes characterised by more varied turf than just marram grass and are completely covered. Grey dunes are no longer involved in the cyclical beach/dune sediment exchange
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longshore drift</td>
<td>Movement of sediment along the shoreline</td>
</tr>
<tr>
<td>Matlab</td>
<td>MATLAB is a platform for technical computing, integrating computation, visualisation and programming in an environment where problems and solutions are expressed in mathematical notation</td>
</tr>
<tr>
<td>MHWS</td>
<td>level of Mean High Water Spring tides</td>
</tr>
<tr>
<td>MHWN</td>
<td>level of Mean High Water Neap tides</td>
</tr>
<tr>
<td>MLWN</td>
<td>level of Mean Low Water Neap tides</td>
</tr>
<tr>
<td>MLWS</td>
<td>level of Mean Low Water Spring tides</td>
</tr>
<tr>
<td>MSL</td>
<td>Mean Sea Level</td>
</tr>
<tr>
<td>Ordnance Datum</td>
<td>The mean sea level (as derived from 6 years of observation at Newlyn, Cornwall) used as a datum for calculating the absolute height of land on official British maps.</td>
</tr>
<tr>
<td>SANDS</td>
<td>Shoreline and Nearshore Database - software developed by Halcrow for the analysis of beach profile data</td>
</tr>
<tr>
<td>SMP</td>
<td>Shoreline Management Plan</td>
</tr>
<tr>
<td>Soft defences</td>
<td>Engineering options which are non-rigid (like sea walls) and which work with the natural coastal processes of wave action and sediment movement</td>
</tr>
<tr>
<td>Swash</td>
<td>The movement of water (uprush and backwash) after an incoming wave has broken</td>
</tr>
<tr>
<td>Swash zone</td>
<td>The limit of the movement of uprush and backwash after an incoming wave has broken</td>
</tr>
<tr>
<td>Tidal prism</td>
<td>The amount of water that flows into and out of an estuary or bay with the flood and ebb of the tide (excluding any contribution from freshwater inflows)</td>
</tr>
<tr>
<td>Yellow dunes</td>
<td>Also known as Mobile or Marram dunes. Dunes on the foreshore with well established marram grass coverage. These dunes have sediment exchange processes with the upper beach during constructive or erosive conditions</td>
</tr>
</tbody>
</table>
1.0 Introduction

1.1 Background

The Shoreline Management Group (SMG) based within the Environment Agency's (Anglian Region) Flood Risk Management section has undertaken regular strategic coastal monitoring of the Anglian coast since 1991. The rationale behind the programme is to assist the implementation of appropriate and sustainable works on the coast, whether undertaken by the Agency for the purpose of flood risk management or works undertaken by various maritime district council partners for erosion control purposes.

An additional output from the monitoring programme is the assessment of coastal dynamics to inform long term strategic plans for the coastline. The vehicle for this is the Shoreline Management Plan (SMP) process, which is currently being reviewed along the entire Anglian coast.

The Anglian Coastal Monitoring programme is now in phase VII (2006/07 to 2010/11) and collects a variety of data including:

- Annual aerial photographs
- Bi-annual strategic topographic beach surveys (winter and summer) at 1km intervals
- Bathymetric surveys (extension of beach survey lines out to approximately 10 metre depth offshore)
- Continuous wave and tide recording (nearshore and offshore). As part of Phase VII this includes a suite of five offshore, and twenty nearshore continuous wave and tide recorders.
- Scheme specific beach topographic surveys

Beach topographic profiles have been undertaken at 1km intervals, twice yearly in summer and in winter, along the coast since 1991. Generally speaking the main aspect of interest is the average rate of beach erosion or accretion along the coast. In addition to this, gradual change to the gradient or steepness of the beach is of particular interest to coastal managers.

The positional accuracy of the Anglian Coastal Monitoring profiles is +/-0.05m vertical and +/-0.02m horizontal.

Now, with a continuous record of seventeen to eighteen years of beach topographic data, it is therefore possible to analyse these to determine reasonably robust initial indicators of longer-term trends. Last year, the SMG produced a series of Coastal Trends Analysis reports based on the SMP sub-cell boundaries: Essex, Suffolk, North Norfolk, Norfolk, The Wash and Lincolnshire. Data collected in the future can be readily added to this analysis to further ascertain the validity of the trends.

Scheme specific monitoring addresses specific sea defence scheme requirements in greater detail at a variety of locations along the coast. More in-depth analysis such as at Holme-next-the-Sea is now taking place. Scheme specific profiles, at roughly 160m intervals, have been surveyed at Holme since winter 1998, with strategic profiles since winter 1992.
1.2 **Analysis methodology**

The profile data presented in this report is in the form of tide level analysis, beach profile analysis and aerial photography comparisons.

1.2.1 **Tide level analysis**

Beach level/tide analysis data was analysed using a function of ‘SANDS’ software with tidal parameters, derived from harmonic analysis, supplied by Gardline Environmental Ltd. Generally, the accepted definition of the foreshore is the intertidal region between the highest and lowest tide level. In this report the area between the MHWS (Mean High Water Springs) and MLWN (Mean Low Water Neaps) level is used as there was little MLWS data with which to form any relevant trends.

Figure 1 below demonstrates the principle of beach profile change over time along with changes to beach gradient and the corresponding lateral movement of the high water and lower water marks.

![Figure 1](image)

*Figure 1 – Conceptual diagram of a beach profile showing shoreline advance/retreat relative to Mean High Water and Mean Low Water and associated foreshore gradient change.*

Figure 2 demonstrates how the analysis was performed and a trend is obtained. The example used in Figure 2 is from an eroding beach, which is retreating with an average trend of -3.86m/yr. However, in any single year the actual erosion observed varies considerably. For example, between 1996 and 2000 very little erosion occurred, whereas between 2000 and 2001 the beach retreated by almost 20m.
Another important factor in coastal risk management policy decision making is foreshore steepening. This is because a wide flat beach can dissipate incoming wave energy much more readily than a narrow steep beach.

Changes in the gradient of the beach between MHWS and MLWN are expressed in the form of the ‘Foreshore Change Classification system’ (Halcrow, 1988) and shown in Appendix 2. Positive Foreshore Change Parameter (FCP) values indicate a beach system advancing seaward and negative values show a system retreating landwards. The individual FCP numbers indicate flattening, steepening or no rotation.

As no pair of MHWS and MLWN trendlines were likely to possess exactly the same gradient, every profile could be described as either flattening or steepening. In order to eliminate insignificant rotational changes any change of less than 1.0% of the mean width of the foreshore was considered to be ‘no change’. In addition to this, judgement was used where some apparent rotational changes were deemed to be unreliable due to high degrees of foreshore variability.

1.2.2 Beach profile cross sections

Beach profile cross sections were also analysed using the Beach Profile Inspection Tool (BPIT) which uses Matlab functionality. Analysis of the beach profile cross sections were used for the alongshore comparison over time and important for a number of reasons.

Firstly, beach profile survey cross sections which showed irregular horizontal datum shifts or obvious errors in the survey profile could easily be identified and rejected from the tidal and beach profile analysis. Secondly, analysis of the beach above the tidal extent such as the dune height and morphology and marshes on the backshore could be undertaken. The beach profiles also displayed the substrate type at various locations alongshore.
Figure 3 – example of temporal cross-section comparisons – summer and winter from 1998 to 2008 – at survey profile N1C1C showing movement of sand bars on the foreshore above MLWN and changes in dune morphology above the MHWS mark. Note that the ‘y’ axis, height, is greatly exaggerated in relation to the ‘x’ axis, length across-shore.

Figure 4 – envelope plot of temporal cross sections at same survey profile, N1C1C, showing minimum and maximum heights of beach levels over 10 over period with 2008S (summer) profile shown (black line).
Finally, evidence of cyclical changes and patterns in the beach profile such as rhythmic sand bars, were easily identifiable on the profile cross-sections, which were not evident in the tide level analysis.

Tidal levels of MHWS, MSL and MLWN provided by Gardline Environmental Ltd were also plotted against the beach profiles and the position of sandbars and areas of erosion/accretion in relation to these water levels were easily identified. Comparisons of winter and summer profiles for any seasonal trends was also undertaken.

1.2.3 Aerial photography

Aerial photography comparisons were made between 1992 and 2007 and were particularly valuable in confirming the amount of dune retreat or accretion during this period. Areas of vegetation type, for instance saltmarsh/sand dune interchange at either end of the study area could also be observed and tied in with the beach profile cross-sections.

Figure 5 – comparisons of aerial photography between 1992 and 2007 showing areas of dune accretion or erosion indicated by the 1992 (purple) and 2007 (yellow) polylines.
Map 1 – Holme location. The orange lines denote the area of coastal analysis undertaken.
Map 2 – Holme profile locations. There are four strategic profiles (longer lines) together with eight scheme specific profiles (shorter lines) used in this study.
2.0 Holme-next-the-Sea

2.1 Introduction

Holme is situated on the north Norfolk coast 4km east of Hunstanton. The shoreline morphology here is characterised by a natural sand dune system with ridges set out parallel to the shoreline and separated from each other by marked troughs or dune slacks. These dunes lie above the mean high water levels and extend up to 100m from the shoreline in some places. Behind the dunes and sand ridges lie areas of natural saltmarsh, reclaimed marshland and freshwater lakes.

![Figure 6 – established dunes near to profile N1C1C looking eastwards.](Photo: Environment Agency)

The dunes constitute a natural coastal defence and can exceed 10m in height in places. There are few artificial structures at this site and therefore the beach can be said to be behaving naturally and rolling back in response to coastal processes acting upon it. However, their exposed nature has led to persistent erosion of the foreshore, particularly in the area adjacent to The Firs where there is a small shelter belt of pines.

Holme is situated within a high energy wave environment with mean annual alongshore wave energy values of 1000 – 1500 kN$\text{s}^{-1}$ (Halcrow, 1988). The foreshore displays a dissipative beach morphology of a wide flat sandy beach extending several hundred meters offshore. Holme is located within a macro-tidal environment with a mean spring tidal range of >6m. The tidal system is NE-SW orientated as well as receiving locally generated waves from The Wash.

‘Dragons' tooth' dune fencing, running for a length of 450m adjacent to the nature reserve at the Firs, was installed in early 2004 to protect the base of the dunes from erosion and to build up beach levels. Previously a different design method was used on the dune fencing which involved the use of horizontal telegraph poles in addition
to the uprights but these were uprooted and washed away during a storm event in 2003.

The current design of the dragons’ tooth fencing is of smaller posts in a zig-zag fashion alongshore with posts inserted vertically, at alternate heights, and with gaps to allow for sediment interchange processes. Geotextile material previously used on this new design (to ‘aid’ sediment entrapment) was not replaced during the maintenance works in 2005 which repaired damages suffered in the previous winter. However, material still remains on some of the fencing at the western end which is in a state of disrepair.

These small scale, soft defences represent a short term strategy with a 1 in 10 year design standard.

Figure 7 – Dragons’ tooth dune fencing at N1C1.

Adjacent to The Firs a raised earth embankment known as Thornham West Bank runs south-eastwards past Hun Outfall Sluice and to the footbridge at Staithe Lane. In some places it has been reinforced and forms the track of the north Norfolk coastal footpath. It offers protection to exceptionally high tides and also has a 1 in 10 year design standard.

Environment Agency defences and natural defences protect a cell of land that includes forty properties, including the villages of Holme next the Sea and Flaxley, as well as farmland and the freshwater marshes of Hun Pool, Christie’s Pool and Broad Water which lie immediately behind the dune system and The Firs. The villages lie seaward of an ancient raised beach.

The River Hun runs west to east behind and parallel to the dunes, cutting to the south of Hun Pool to reach Hun Outfall Sluice where it then flows into the marshlands at Thornham Harbour.
Figure 8 - Thornham West Bank looking SSE showing the River Hun flowing through saltmarsh before reaching Thornham Harbour.

The dune system along this 2km frontage is a designated National Nature Reserve (NNR) and provides a valuable natural habitat resource. There are also a number of other designations at this site and along the entire North Norfolk coast from Old Hunstanton to Kelling. These include the North Norfolk Site of Special Scientific Interest, Special Protection Area, Special Area Conservation, Ramsar site and an Area Of Outstanding Natural Beauty.

Holme Dunes Natural Nature Reserve is owned by Norfolk Wildlife Trust and is of national and international importance for wildlife conservation including a number of important conservation habitats; grey and yellow dunes; sand slacks with breeding natterjack toads and birds; saltmarsh (east and west ends), freshwater grazing marsh; reed beds and sand and mud flats (east).

Sand bars exist at either end of the dune frontage, east at Thornham Harbour and west towards Gore Point. These are relatively small compared to those found further east along the coast which may be due to their exposed position and the change in orientation in the coast at this point.

2.2 Thornham Harbour

Erosion of the dunes at Holme is thought to be an indication of the evolution of a larger system that incorporates the ebb delta of Thornham Harbour and the associated sediment pathways.

Ebb-tide deltas are the bulge of sand formed just seaward of an estuary mouth by the deposited sediment of an ebb current and are known to contribute to wave energy dissipation. The extent of the ebb delta is related to both the tidal prism within an
estuary and the incident wave energy on the ebb tidal delta. A large delta therefore indicates a relatively low amount of incoming wave energy expended to move the sand shoreward and the ebb delta storage of sand will increase with increasing tidal prism.

In Thornham Harbour however, historic land reclamation has reduced the tidal prism resulting in a decrease in the ebb delta area and volume (moving landward and upward) over the past few hundred years.

It is thought that the interaction of the delta with the adjacent shoreline is based on its sheltering effect, reducing wave and tidal energy inshore, and also its diversion of the sediment transport paths. It is therefore believed that the ebb delta erosion at Thornham Harbour is related to shoreline adjustment along the adjacent open coast and the erosion in the dunes at The Firs.

2.3 Sand dune systems

The creation of a sand dune system is dependent on an abundant sediment supply, dominant onshore winds and the establishment of a vegetation cover. These factors are also helped by a low nearshore slope combined with a large inter-tidal range providing wide expanses of sand which will dry at low tide.

Coastal dunes accumulate sand blown inland from the beaches in front of them by onshore winds (accretion). Ideal conditions for the transport of sand from a beach to the dunes occur after constructive (i.e. low height, long period) waves have deposited sand on the upper beach and inter-tidal foreshore. At low tide the sand dries and onshore winds can carry substantial volumes of sand onto the dunes. Conversely, they lose sand by a process of deflation of the surface caused by wind action and by marine erosion of the toe and seaward face of dunes, mainly by waves.

Figure 9 – backshore dunes in excess of 8m AOD at N1C1C.
As part of the long term evolution of the dune system, embryo dunes on the foreshore develop into foredunes or yellow dunes when they have reached a significant height and established with marram grass coverage. With the formation of new dunes further seaward of the existing yellow dunes, the yellow dunes are no longer involved in the sediment exchange processes with the upper beach during cyclical constructive and erosive conditions and over time become grey dunes established on the backshore, landward of the yellow dunes.

From the perspective of coastal management, dunes protect low lying coastal areas from flooding and also act as a buffer against erosion: they form a reservoir of sand under fair-weather conditions, replenished when upper beach levels are high and released to nourish the foreshore during storm erosion events, giving the dunes an eroded appearance.

However, long-term patterns of dune evolution although producing underlying trends of change, are often difficult to detect because of substantial and rapid changes in dunes in the short-term (i.e. over days or weeks). These cyclical changes in appearance are usually due to broadly seasonal weather patterns with severe short-term erosion events, occurring either singly or cumulatively over a few years. However, there may not be any long-term erosional trend which might require coastal management attempts to influence the natural processes and therefore a continuing programme of coastal monitoring is essential to determine the ‘health’ of the dunes.

2.4 Beach dewatering scheme

A trial beach dewatering scheme was installed at Holme in February 1997 to try to stabilise the beach levels without introducing permanent hard structures. The scheme operated for a period of seventeen weeks and covered a 200m length adjacent to the Firs.

Beach Drainage Systems (BDSs) were originally designed by the Danish Geotechnical Institute (DGI) in the 1980s to combat problems on eroding beaches with a high water table, where sediment transport is diminished by wet sand.

The technique used in beach dewatering schemes attempts to drain the beach by lowering the water table in the swash zone, reducing sand fluidisation and therefore encouraging suspended sediments to be deposited more readily. A wet sandy beach erodes more quickly than a dry one partly because wave scour is more effective on saturated sand, whereas dry sand absorbs swash water.

This system therefore aims to reduce the loss of material from the beach by reducing its mobility and encouraging accretion. The subsequent drying of the foreshore leads to available sand being blown inland with deposited sand forming an upper beach berm that protects the dune face during storm events that might otherwise cause erosion.

A Beach Drainage System involves the insertion of perforated drainage pipes connected to a pump and discharge system buried beneath the upper beach surface. This system accelerates seepage and the sand will tend to accrete if the beach surface is permeable due to the artificially lowered water table.

A successful beach drainage system will increase the elevation and width of the upper beach, providing an improvement to amenity value and encouraging the formation of foredunes. The raised upper beach will provide storm protection to the
dunes. Recycling or nourishment can initiate beach level increases, and fencing, thatching and transplanting can encourage dune growth.

The benefits of Beach Drainage Systems are, however, thought to be greatest in micro-tidal (<2m range) environments, and not effective during storms. The BDS at Holme was thought not to be effective due to increased exposure of wave attack on the frontage as a result of the eroding ebb delta; and not because of its high water table.

2.5 Dune fencing

The construction of semi-permeable fences along the seaward face of dunes, like the dragons tooth defences at Holme are used to encourage the deposition of wind blown sand, reduce trampling and protect existing or transplanted vegetation.

Figure 10 – Dragons’ tooth dune fencing taken from N1D7B looking eastwards. The fencing is characterised by a zig-zag formation of spaced posts with landward spurs all aimed at maximising accretion rates.

Fencing has minimal impact on the natural system and can enhance natural dune recovery. At the same time they can control public access and reduce erosion caused by trampling. They are most effective where they are above the normal limit of wave run-up and where there is available wind blown sand.

Dune fencing, however, cannot prevent erosion where wave attack is both frequent and damaging, ie during storms, but they will encourage foredune growth and resist some erosion. Fences reduce wind speed across the sand surface and encourage foredune deposition. They also act as a modest barrier to wave attack, reducing the erosion potential of waves near the limit of uprush.
Other factors depending on the success of dune fencing are thought to be the ‘void to solid ratio’ of the fence, where a solid ratio of 30% to 50% is required. The amount of vegetation available to stabilise the accumulated sand is important. Landward spurs at right angles on the fencing are also thought to increase accretion rates.

Dune fencing is relatively low cost but requires regular maintenance and has a limited life span. Where erosion is severe they are thought to be unsuccessful.

![Figure 11 – Damaged dune fencing with remains of geotextile material near N1D7B.](Photo: Environment Agency)

### 2.6 Shoreline Management Plan

The first generation North Norfolk Shoreline Management Plan (SMP) 2006, acknowledges that the dunes at Holme may need to be allowed to roll back naturally. Land behind the eroding section of dunes is low lying and a breach could occur if the dunes were left undefended. This would lead to the loss of one property and freshwater habitats in the hinterland at Broad Water, Christies Pool and Hun Pool.

The properties in the villages of Holme-next-the-Sea and Flaxley at risk of flooding are protected to the east by the Thornham Bank, to the north by the dunes and to the west by the rock groynes along the Hunstanton golf course. Apart from the central section of dunes, defences are in good condition.

The SMP recommended a preferred defence policy of a combination of ‘hold the existing line’ to be adopted in the short to medium term (involving strengthening the eroding section of dunes at the Firs) and maintaining other existing defences. This was to be followed by a longer term policy of ‘retreat the existing line’ if maintaining the receding dune frontage in their present location became unsustainable.
Retreating the existing line would involve creating a new defence line slightly landward of the existing line by encouraging the development of new dunes and by foreshore recharge or the construction of a new defence line.

The second generation North Norfolk SMP is currently under consultation and due to be published in summer 2010.

2.7 *Historic OS maps*

Historic Ordnance Survey maps for Holme dated 1887, 1905 and 1939 are shown below along with current OS mapping centring on the area of The Firs. The maps have been overlaid with the aerial polylines from 1992 and 2007 along with the present location of the dragons’ tooth dune fencing to give an idea of location and changes over time.

The accuracy of the historic maps should be viewed with some caution especially with regard to the precise shape of the coastline. However, what is interesting is that the historic extent of the shoreline overall is not much further seaward of the current coastline and in some cases is in fact further landward of the current dunes. Of particular note are the structures shown in the 1905 map including breakwaters and some kind of sea wall or embankment to the west of N1D7A. The remains of the two breakwaters can still be seen today (Figure 11).

![Figure 12 – Remains of breakwaters first shown in 1905 ordnance mapping. The photograph is taken looking south-eastwards towards The Firs.](Photo: Environment Agency)
Map (series) 3 – Series of OS maps at Holme showing the central section adjacent to The Firs for 1887, 1905, 1939 and present day.
3.0 Analysis

3.1 Outline observations

A number of surveys were rejected from the analysis process due to horizontal datum shifts and other errors and these are listed in Appendix 1.

Table 1 and Figure 13 show the general results from the 12 strategic and scheme specific profiles at Holme. Appendix 4 lists the results in more detail.

<table>
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<tr>
<th>General Trend</th>
<th>No. of profiles</th>
<th>Percentage</th>
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<tr>
<td>Accretion</td>
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<tr>
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Table 1 – general results of analysis showing general (mean) trends, foreshore gradients, alongshore defences and dune movement by number of profiles and percentage.

![Figure 13](image_url) – graph of trends for Holme showing MHWS, MSL and MLWN for all survey locations.

*This figure relates to actual long-shore structures at the location of the profile determined from 2007 aerial photography and National Flood and Coastal Defence Database (NFCDD).*
All Holme profiles show a mean erosional trend of the foreshore over the past 17 years. In the case of one profile (N1D6) this erosional trend is minimal (-0.1m/yr) and therefore classified as ‘no change’. These erosional trends are most significant at the eastern end of the study area at N1C1C where mean rates are -5.6m/yr.

Other significant erosional trends were located at N1C2 (Thornham Harbour) of -2.9m/yr and at N1D7A just to the west of the dragons’ tooth dune fencing where erosion trends were -2.8m/yr.

Three quarters of profiles showed a no rotation trend of the foreshore. Three profiles showed a steepening trend and only one profile showed a flattening trend.

At either end of Holme, at Gore Point and at Thornham Harbour, the foreshore extends around a kilometre seaward of MHWS so rotational changes here in the order of several tens of meters have been regarded as insignificant and shown as ‘no rotation’ although erosion trends of the foreshore are represented.

In terms of dune erosion/accretion there was an even split with half of profiles displaying eroding dunes mostly in the central area around The Firs from N1D7 to N1C1A and again at N1C2 (Thornham Harbour). The six accreting dunes were mostly located to the west at Gore Point and with two profiles to the east just before the Thornham Harbour profile.

At all locations the beach is behaving naturally in response to coastal processes. Thornham West Bank on the backshore at N1C1C and N1C2 does not affect the natural beach processes on the foreshore. In addition the profiles adjacent to the ‘dragons’ tooth’ dune fencing are working with the natural processes and not inhibiting them in any way.

The two profiles located at the dragons’ tooth soft defences – N1D7B and N1C1 – show mean erosional trends of -0.8m/yr and -2.3m/yr respectively.
Map 4 – Mean erosion trends along with FCP scores for the twelve profiles at Holme overlaid onto 2007 aerial photography. Appendices 2 and 3 give a definition of the Foreshore Change Parameter scores and key to the trend and level of change.
Map 5 – Holme 2007 aerial photography overlaid with polygons showing areas of dune accretion since 1992 (green) and dune erosion since 1992 (red). Areas of accretion are observed at either end of the study area, compared to the central area adjacent to The Firs where erosion of the dunes is evident. Dragons’ tooth dune fencing (soft defences) are shown as a brown line adjacent to The Firs. Exact figures for dune erosion/accretion are outlined in the detailed profile observations in Section 3.2.
3.2 Detailed observations

N1D6 – West Sands, north of Flaxley.

Three lines of dunes interspersed with marsh/mud are backed by a larger expanse of saltmarsh which is dissected by a channel. Aerials show a seaward advance (around 7m) of low, sparsely vegetated embryo dunes from 1992 to 2007 as a result of the onshore accretion of sand ridges. These new dunes are now around a height of 4.7mAOD at 390m chainage.

The original foredune peak at around 380m chainage in 1992W moved landward and increased in height by half a meter, becoming steeper at its present position of 360m chainage with a height of 4.5mAOD at 2008W.

Vegetated saltmarsh and mud/sand between the foredunes and backdune at 257m chainage has shown vertical accretion of between 15 – 20cm. The back dune at 257m chainage is very stable but highest in 1998W at 6.3mAOD but in recent years this has lost height by around 12cm.

A 200m stretch of saltmarsh separates the backdune with the higher ground at zero chainage. This saltmarsh suffered erosion in 1995, 1996 and 1997 but by 2001 the surface elevation had increased again by around 30cm. The intervening period between 2001 to 2008 saw further downward fluctuations in height with 2008 levels accreting to near 2001 levels.

Figure 14 - N1D6 showing summer profiles only for clarity: 2008S highlighted yellow shows accretion in saltmarsh, stable backdune and vertical accretion of a new foredune. The pink survey line in 1996S shows the lowest level of saltmarsh (winter profiles are all above this line but below most of the other summer profiles).
The beach is 330m wide between MLWN and MHWS. Just above the MHWS mark in front of the foredune a berm has formed which gained height up to 2001S after which it then began to decrease in height.

MHWS shows a significant mean accretion trend of 4.6m/yr (showing cyclical patterns) and which has extended 60m seaward in the period 1992 to 2008 due to the accretion of a foreshore berm. The upper beach in front of the dunes has become more convex in shape. The lower beach displays rhythmic sand bars moving onshore.

In contrast MSL shows a significant mean erosional trend of -4.2m/yr, also with cyclical patterns, moving landwards by around 100m since 1992. A lower erosion trend exists at MLWN of -0.8m/yr. The mean trend of movement at this profile is -0.1m/yr (classed as ‘no movement’) and because of the advance seaward at MHWS the profile can be said to be steepening.

**N1D6A – West Sands.**

Three lines of dunes are separated by a small channel at around 112m chainage, which flows from the inland behind Gore Point. There is an area of saltmarsh between this channel and the foredune at 277m chainage. Aerial photos show that there has been no overall movement in dune extent at this particular point.

![Figure 15 - N1D6A envelope plot with 2008S profile highlighted.](image)

The foredune at 280m chainage is accreting vertically at around a height of 6.10m AOD in 2008S as is the dune face, it is therefore becoming steeper. No horizontal movement in dune extent. Leeward slope of foredune is very stable.
Figure 16 – The channel and outlet at N1D6A. Mean erosion rates are small and there is no movement in dune extent. However the course of the channel now meanders and crosses back through the profile.

Figure 17 – Channel and outlet at N1D6A, looking west.
There is no change in height or movement of the small dune immediately behind the channel at 67m chainage which has a height of 4.4mAOD or in the backstop dune at zero chainage (height 6.7mAOD).

Profiles show the landward and upward movement of a sand bar 80m in front of foredune which built up to 2007W and which then lost height of 1m by 2007S. Profiles show this berm rebuilding by 25m but with much steeper foreshore which has moved landward by 50m since 1998S. There is beach steepening in front of this berm to form concave beach shape. The channel which flows onto the beach at Gore Point flows seaward in front of this berm.

At MSL the beach has again become convex and moved seaward by 100m (summer 2008). However profiles show an erosional trend at MSL mark displaying cyclical changes.

Overall the beach foreshore displays rhythmic sand bars moving up the beach – with a concave/convex/concave pattern from in front of the foredune down to MLWN.

MHWS shows a cyclical pattern of between 300 – 400m offshore, although the mean trend figure is erosional at -1.2m/yr. MSL shows a very strong accretion trend of 3.3m/yr extending up to 600m offshore. MLWN also show a strong erosional trend of -2.9m/yr varying between 625 – 700m offshore.

The beach as a whole shows a no rotation trend and a mean erosional trend of -0.3m/yr, the second lowest trend along the Holme frontage.

**N1D6B – Gore Point.**

This profile is characterised by three lines of dunes decreasing in height towards the foreshore.

The backstop dune at 10m chainage has shown a lowering in height since 1998W when it was 10.9mAOD to a height of 10.3mAOD in 2008W with the dune crest moving seaward by 1.1m in the same period.

The dune at 36m chainage shows fluctuations in height and position over the same period with an elevation of 20cm in crest height from 1998 – 2008 to present height of 7.2mAOD. The 1m horizontal seaward movement in the crest position and the accretion of sand on the dune face is evident from winter profiles.

The foredune at 80m chainage has accreted since 1998 with a 2m elevation in the foreshore to create a crest height of 5.8mAOD together with an elevation of over 1m at the toe of the new dune. Aerial photography shows this dune has accreted seaward by 42m since 1992. Sediment has also accreted in the new trough between the new dune and the second dune at 36m chainage.

The accretion of this new dune is a result of the lowering of the foreshore at MHWS levels by a similar 1m in height and resulting in the present MHWS level moving landwards by around 60m since 1998.

The beach between MHWS and MLWN is around 30m in width and displays rhythmic sand bars moving onshore with the 2008S profile showing these sand bars at MSL and MHWN mark. These sand bars give a convex/concave/convex beach pattern along the profile.
Mean trends in tidal levels all show moderate erosion with a mean erosional trend for the profile of -2.3m/yr with no beach rotation. MHWS in particular shows cyclical patterns within the trend.

Figure 18 - N1D6B where new dunes have accreted at 80m chainage. 2008S is highlighted in yellow.

Figure 19 - Backdunes between profiles N1D6B and N1D6C near Gore Point which exceed 10mAOD in places.
N1D6C – Gore Point.

Three lines of dunes with decreasing crest heights towards the foreshore back a wide sandy beach. Aerials show a seaward advance in dunes of 26m from 1992 to 2007.

The backstop dune at zero chainage has been stable height at 9.6mAOD since 1998.

The first foredune at 38m chainage with a crest height of 8.6mAOD has shown steady accretion of the backslope and seaward face of the dune. This accretion seaward by 20m since 1998 and 26m since 1992 (shown by aerials) has created a new foredune at a height of 6.7mAOD at 67m chainage, the seaward face of which is relatively steep.

Immediately in front of the new dune there is erosion of the foreshore of around 1m in height, at just above MHWS level, resulting in a concave beach shape.

At MHWS the beach takes a convex shape for 40m due to the first sand bar moving onshore where beach levels are up to 1m higher, therefore moving MHWS levels further offshore. This pattern of convex/concave beach shape in repeated down the beach with another sand bar accreting at MSL.

The beach between MHWS and MLWN is 250m wide. All tide levels show a moderate erosional trend of between -1.9m/yr to -2.6m/yr. The mean trend of erosion is -2.1m/yr and there is no rotation in beach profile.

Figure 20 – N1D6B and N1D6C profiles showing dune accretion from 1992 to 2007.
Figure 21 – N1D6C showing a seaward advance of dunes since 1992 of 26m.

**N1D7 – Nature Reserve**

Three lines of dunes back a sandy beach. There is little movement in the crest on the backstop dune at 11m chainage with a crest height of 9.4m AOD.

The dune at 48m chainage has showed narrowing/steepening (especially on the backslope, around 4m) with fluctuations in height since 1992 in the order of 1m from 8m AOD to present height of 9.8m AOD.

The foredune at 57m chainage has shown progressive retreat by around 13.5m but maintained relative height of 8.9m AOD since 1992 with steepening of dune face. The most significant events were between 1996W to 1996S where the dunes retreated by 5m and between 2005W and 2005S where they retreated by another 2m.

There are rhythmic sand bars moving onshore with sand bar accretion at the foreshore in front of the receding dunes at MHWS mark creating a convex beach shape for 20m. There is also a sandbar present just above MSL mark. Beach lowering of around 1m in height is present at MLWN at 250m chainage. These areas of accretion/erosion form patterns of convex/concave/convex along the beach.

At between 340 to 380m chainage there is a stationary sand bar just below MLWN. The beach between MHWS and MLWN is 250m wide.

Tidal analysis shows erosion trends at all levels which appear cyclical at MWNS (-0.5m/yr) and MLWN (-1.0m/yr). MSL shows more significant erosional trends at -2.3myr. From 1997S onwards MSL levels have moved onshore by around 70m in a steady trend. There is no rotation in beach profile with mean rates of erosion of -1.3m/yr.
Figure 22 – Dune retreat of around 12m since 1992 at N1D7 with sandbars moving onshore. 2008S profile is highlighted.

**N1D7A – Nature Reserve**

This profile shows two lines of dune ridges at 8m chainage and 23m chainage – and is situated just west of where the dragons’ tooth dune fencing starts. The back dune at 8m chainage has fluctuated considerably in height and horizontal movement but in 2008 has built to a height of 9.5mAOD and has moved seaward with a steeper seaward facing edge.

The foreshore dune at 23m chainage has retreated by 12m in the period 1996 – 2008 losing height of over a meter to its present 9mAOD. Aerial photographs (2007) show a retreat of 19.5m since 1992.

The dune face and dune toe have eroded at a similar rate to maintain profile and immediately in front of the eroding dune is a sand bar around 20m in width just above MHWS level. At MHWN there is an area of erosion of around 1m in height immediately in front of another sand bar. This pattern of sand bars is repeated down the beach with another area of erosion (or lowering) of MLWN level and which is evident of rhythmic onshore movement of sand bars.

The width of beach between MHWS and MLWN is 250m. At MLWN beach shape is convex for another 100ms.

Tide level analysis shows a significant trend of erosion at MSL of -7m/yr, with more cyclical and slight trends of erosion at MLWN and MHWS of -0.6m/yr. Mean trends of erosion are therefore significant at -2.8m/yr and there is no rotation in beach profile.
Figure 23 – The western limit of dune fencing at N1D7A where geotextile material is still in place.

Figure 24 – Envelope plot of N1D7A with the foredune showing significant landward retreat and lowering since 1996. The 2008S profile is highlighted.
N1D7B – West of The Firs.

A single line of dunes at 17m chainage is fronted by dragons’ tooth dune fencing. The dunes have retreated by 8m since 1998W when they were a height of 10.3m. Aerial comparisons from 1992 show dune retreat of 28m up to 2007. The present height of the dunes is 8.4m AOD, however the land behind them is up to 1m lower and lowest at -17m chainage where land height is 7m AOD.

Figure 25 – Envelope plot of N1D7B, the single line of dunes has shown lowering and retreat since 1998. 2008S profile is highlighted with dune fencing shown at 35m chainage.

Figure 26 – Back dunes at N1D7B looking east towards The Firs.
The largest single erosion event was between 2004S to 2005S where the dune retreated by 3m in a single winter. Old dune fencing is evident on this profile in 2002S at 38m chainage, the same location as the present dragons’ tooth fencing but this seemed to have little effect of the dune retreat.

Dune fencing introduced in 2004 has built up beach levels in front of the dune. From MHWS level, which is 8m seaward of the fencing, beach levels have decreased by around 1m forming a concave beach shape. Beach levels slope down towards MSL at an even level when it then becomes concave for around 100m and up to 1.5m lower than previous years. The beach builds up again at MLWN with convex beach shape. This gives evidence of shallow rhythmic sand bars moving onshore.

The width of beach between MHWS to MLWN is just over 200m. Tidal analysis shows a very strong erosional trend at MSL of -4.8m/yr. MHWS displays a small erosional trend of -0.6m/yr. However, MLWN appears more cyclical with an erosional trend from 1998W to 2005W. Following this, in 2005S, MLWN accreted seawards by around 100m from when it then shows cyclical patterns to 2008. Because of these patterns MLWN shows a mean accretion trend of 3m/yr and results in giving the beach a flattening beach profile.

N1D7B is the only profile at Holme to display a flattening profile. Mean trends of erosion are relatively small at -0.8m/yr.

**N1C1 – The Firs.**

A single line of low dunes, height 5.5mAOD is fronted by dragons’ tooth dune fencing. The dunes have receded by 26m since 1991S when they were a height of 9.9mAOD to their present position at 26m chainage. The single biggest erosion period was between 1996W and 1997S when the dunes receded by 10.3m.

Between 2001S and 2002W the dunes had reduced to their lowest height at 5.3mAOD. By 2002S the dunes had rebuilt to a height of 7.4mAOD 8m further seaward. Pre-dragon tooth fencing was also evident on this survey. Following 2002S there was a gradual retreat and erosion of dunes with significant erosion between 2004W to 2004S of 2.5m. Another large erosion event took place between 2005W and 2005S of 4m when dunes reduced to near 2008S levels.

Dragons’ tooth dune fencing was completed in early 2004. Since 2005S to 2008S dunes have only receded by 1m horizontally and by 20cm in height.

There is an overall flattening of the dunes and beach profile with rhythmic sand bars moving onshore with a shallow pattern of concave/convex/concave beach shape alongshore from in front of the dunes down to MLWN. There is a shallow trough of erosion in front of the dune fencing with a sand bar accreting at MHWS just seaward of this. A sand bar is also currently building above MSL. Beach levels from MSL down to MLWN have built up again in recent years.

The beach extends 200m between MHWS and MLWN. Tidal analysis shows cyclical patterns within definite trends of erosion at all levels. MLWN showed a trend of retreat of 165m between 1991S and 1999S following which there were then cyclical accretion patterns. MSL water levels have retreated by 50m and MHWS by 30m since 1991.

Mean rates of erosion are high at -2.3m/yr with no overall beach rotation.
Figure 27 – ‘Dragons’ tooth’ dune fencing in front of eroding dunes at N1C1.

Figure 28 – Envelope plot of N1C1 showing landwards movement (24m) and vertical lowering (over 4mAOD) of dunes since 1992. 2008S profile is shown with dragons’ tooth fencing evident at 30m chainage.
Figure 29 – Dune erosion just east of N1C1 before dune fencing starts.

**N1C1A** – East of The Firs.

A single line of dunes has maintained relative height at 10.6 - 10.8m AOD since 1998. However, the dunes have retreated landwards by 16m. The dune has a flat crest for 20m with a slight trough in the middle. The largest erosion period occurred between 2002S to 2003S where the dunes retreated by 3.5m.

The winter profiles show a more progressive retreat of the foredune. There is overall erosion at the toe of the dune, but which accreted in 2008W. There is little movement to dune backslope.

The dunes have showed a retreat of 28m between 1992 and 2007 according to aerial photographs.

The beach currently extends 160m between MHWS and MLWN with evidence of sand bars moving onshore just above MSL (where there is a double sand bar feature) and MHWS. From MLWN the beach runs offshore for 200m at an even level.

All tidal levels show slight to moderate erosional trends although these are more cyclical at MHWS, MHWN and MSL. At MLWN levels (with the exception of 2001-2002) levels are showing significant erosion with the MLWN mark moving from 375m to 260m offshore.

Mean erosional trends are -1.2m/yr with no overall rotation in beach shape. However, if the MLWN accretion spikes for 2001S and 2002W were removed MLWN would be said to be eroding significantly and therefore displaying a steepening beach profile.
Figure 30 – Dune retreat at N1C1A by around 16m since 1998 but maintaining relative height, with 2008S profile highlighted.

Figure 31 – Eroding dune face near to N1C1A.
N1C1B – Broad Water.

This profile shows five lines of dunes stretching from zero to 85m chainage. The three backdunes are stationary with little variation in height over time with a height of around 11m.

A new foredune has accreted since 1998 moving upwards and seawards to its present position with a crest height of 9.2m AOD. The new foredune foreslope has accreted seawards by around 25m. Aerial photographs show an advance of dunes by 18m from 1992 to 2007.

The middle dune at height of 11m shows variations in the order of 0.5m and with horizontal movement in crest of about 3 - 4m.

Accretion has also take place on the backslope of the second dune, behind the new dune, by around half a metre.

The foreshore displays rhythmic sand bars moving onshore forming a concave/convex pattern along the beach profile. The most pronounced sand bar is currently accreting just above MSL mark. Variations in moving sand bar height are in the order of 1.5m.

The beach extends 225m from MHWS to MLWN. MLWN level shows a strong erosional trend of -7.3m/yr with MSL and MHWS showing a slight to moderate accretional trends which could be due to cyclical patterns. The beach here therefore shows a significant steepening trend with a mean erosion rate of -1.9m/yr.

Figure 32 – Dune accretion at N1C1B with new foredune at 85m chainage.
This profile runs from the Thornham West flood embankment with up to six lines of dunes separated by saltmarsh in some places. Comparisons in aerial photography showed seaward accretion of the dunes by a total of 61m in the period 1992 – 2007.

A newly created foredune, 1998W to 2008W reached a height of 5.6mAOD at 224m chainage before being swept away in 2008S. This dune has now been replaced by a flat foreshore in front of second (current foredune).

The current foredune at 185m chainage has also built up since 1998W to a height of 6.1mAOD accreting seaward by 21m.

The highest dune at 157m chainage showed vertical accretion from 1998W to 2008S of 80cm to a maximum recorded height of 8.5mAOD, which then fluctuated in level to reach its present height of 8.2mAOD. The smaller dune peak behind this at 150m chainage has also accreted in height over the same period to 7.7mAOD.

The area behind these dunes is characterised by smaller dunes interspersed with a stretch of saltmarsh for 36m which are all maintaining a relative height and position. The backstop dune at zero chainage is a height of 8.2 – 8.4mAOD.

The foreshore between MHWS and MLWN is 375m wide and characterised by rhythmic sandbars moving onshore. The present profile (2008S) shows accretion at MHS mark and a convex beach profile followed by erosion and concavity at MHWN mark. MSL shows an accreting sand bar and MLWN shows a shallow concave beach shape.
Figure 34 – Dunes at N1C1C showing foredune that accreted at 225m chainage in the period 1998W – 2008W which was then washed away before the survey of 2008S (black line). Dunes have also accreted seawards by 21m now at 185m chainage. See also Figures 3 and 4 on page 4.

Figure 35 – Comparisons of 1992 and 2007 aerial photography. The blue circled area represents the foredunes that built up in the period 1998 – 2008 (winter) which were then washed away before the survey of 2008S.
Tidal analysis shows a slight erosion trend at MHWS. MSL displays a strong accretion trend of 3.67m/yr, however this is skewed due to an accretion jump in summer 2003. Since then there has been significant erosion of over 100m to 2008. MLWN shows a significant erosional trend of nearly -20m/yr with the levels moving landwards by over 100m in a six year period. The foreshore beach profile is therefore steepening significantly. Mean erosion trends at Holme are the highest at this profile due to the significant erosional trend at MLWN.

N1C2 – Thornham Harbour.

Thornham West Bank flood defence backs an extensive saltmarsh which is separated from the beach by two lines of low dunes. The channel formed in the saltmarsh at 238m chainage is the River Hun which emerges from Hun Outfall Sluice further northwest on the embankment and flows into Thornham Harbour.

2007 aerial photographs show a loss of up to 41m of dunes since 1992.

Earlier profiles in 1991 and 1992 show a high dune at 610m chainage and at a height of 7.5mAOD. Aerials (1992) also show a line of dunes at this location. From 1993S the dune had reduced to 5.5mAOD at 600m chainage. Then by 1997W the dune had rolled back to form a much wider and lower mound at 3.6mAOD from 480 – 580m chainage.

This mound showed fluctuations in height and position until 2003S when it then formed the two-crest dune with the present location/height of today, moving landward and upward to a height of 4.6 – 4.7mAOD at 470 – 526m chainage. These new dunes are backed by another saltmarsh channel at 425m chainage which has maintained relative position but moved landward slightly by 5m since 1991. Saltmarsh levels behind the dunes have remained static.

The foreshore between MHWS and MLWN, a distance of 700m, shows the rhythmic movement of onshore sandbars. The beach height in front of the current foredune is 3.4m at 650m chainage forming a convex beach shape at MHWS.

Tidal analysis shows a fairly strong erosional trend of -1.9m/yr at MHWS and significant erosional trend at MLWN (-6m/yr). There are however obvious cyclical patterns within these trends. There is no overall significant rotation in beach profile. Mean rates of erosion are strong at -2.9m/yr.
Figure 36 – Dune retreat (41m) and lowering (3mAOD) to 2008S at N1C2. The dunes are backed by extensive saltmarsh.

3.3 Summary

The beach at Holme is behaving naturally with all profiles showing some kind of foreshore erosional trend, at MHWS, MSL or MLWN, to a greater or lesser degree, although at N1D6 this is negligible (-0.1m/yr). The majority of profiles, three-quarters, showed no change in beach rotation so could be said to be retreating at an even rate.

All profiles displayed the gradual onshore movement of shallow sandbars. What could appear as areas of erosion or accretion between MHWS and MLWN were in fact the cyclical patterns of sandbar formations with the lowering and heightening of the beach being the troughs and peaks of the sequence of sand bars. For certain profiles it was therefore sometimes difficult to discern any definite long-term trend in foreshore movement. However, with tide level analysis more definite trends could be identified on some, but not all, of the tide levels. The onshore movement of sandbars did not necessarily equate to dune accretion above the MHWS mark as half of all profiles displayed dune erosion.

Erosion of the central area of dunes stretches from N1D7 to N1C1A (nearly 1km). Mean foreshore erosion trends here are in the main attributed to high erosional trends at MSL. Erosion continues despite the new style dune fencing put in place in early 2004, although beach levels have built up in front of the fenced dunes at N1D7B and N1C1. There have been no significant erosional events here since summer 2005.

Profile N1D7A situated just west of the dragons’ tooth dune fencing displays the highest rate of foreshore erosion (-2.8m/yr) along this section of coast (if you exclude
N1C1C and N1C2 at the Thornham end). In contrast, N1D7B, the next profile along is the only profile to show flattening. However this is due to an accretion trend at MLWN along with erosion at the MHWS mark. In some places along this section the land behind the dunes is lower and this would have significant consequences if the dune line was breached here in the future.

Dune accretion was evident at the eastern and western ends of the Holme frontage at Gore Point and adjacent to Thornham Embankment and was in contrast to the foreshore erosion trends at these locations. The pattern of dune erosion/accretion alongshore was equally mirrored by dune height, where low dunes coincided with dune retreat adjacent to The Firs and at Thornham Harbour and high dunes evident in areas of dune accretion at Gore Point and Thornham Embankment.

![Figure 37 – Dune retreat extent adjacent to The Firs from 1992 to 2007. The 2007 coastline is represented by the yellow polyline and 1992 the purple. Dragons’ tooth dune fencing runs from just east of N1D7A to mid-way between N1C1 and N1C1A.](image)

Erosional trends of the foreshore are the most significant at the Thornham Estuary end at N1C1C (-5.6m/yr) due to exceptionally high erosion trend at MLWN and where, incidentally, the new foredunes were washed away sometime before the 2008S survey. In addition, erosion is high at Thornham Harbour profile at N1C2 (-2.9my/yr), where mean erosion trends are again attributed to very high erosion at MLWN.

There was little evidence of any strong seasonal patterns or trends, (winter and summer profiles) although erosional events could be identified, such as 2008S for N1C1C which identified the loss of the 10-year old foreshore dune. This is due to the erosional event taking place either before or after the winter profile was surveyed (usually January).
Comparisons of historic (1887, 1905, 1939) and present day OS maps have revealed that there is comparatively little overall difference in coastal extent since 1887 although there are variations in the advance and retreat of the dunes in places. Some areas for instance appear further landward in the old maps, such as at the eastern end of the current dune fencing, indicating that significant dune accretion must have taken place in the intervening period.

This might suggest that there is not much of an overall long-term (ie >100 years) trend in dune retreat and that the erosion that is evident today may be part of a shorter term erosional cycle.

The old groyne system and shore embankment evident in the 1905 OS map at N1D7 and N1D7A indicates that erosional problems were encountered here at a much earlier date. These groynes are adjacent to an area of present day erosion which is significant at -2.8m/yr (N1D7A) and amongst the highest foreshore erosion along this frontage.

The erosion of the dunes at Holme is connected with the sediment availability and wave regime (wave energy and direction) along this frontage. The increased exposure of wave attack may be attributed to the adjacent eroding ebb delta within Thornham Harbour and therefore the result of the evolution of sediment pathways in operation in a much wider system.

Because of the lag that may exist in any system this response may be occurring many years since the causational effect (ie, land reclamation) took place. Other factors which would also influence the shoreline dynamics are the rate and level of sea level rise which at the moment is still uncertain.

It is important to appreciate that the dune retreat and foreshore erosion seen today may be a cyclical pattern within a much larger trend which might not be indicative of a steady state of erosional processes. Continued monitoring of beach profiles are therefore necessary to help determine future response.
Appendices

Appendix 1 – Surveys rejected from the analysis process due to horizontal datum shifts and other errors.

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Appendix 2 – Foreshore change classification system (adapted from Halcrow, 1988). The change is indicated in red.

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Appendix 3 – Key to trends analysis map
### Appendix 4 – Detailed Results

<table>
<thead>
<tr>
<th>Profile Name</th>
<th>Location</th>
<th>Defence</th>
<th>Meters per year</th>
<th>Mean Rate</th>
<th>FCP Score</th>
<th>Dunes</th>
<th>Beach</th>
<th>Notes</th>
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<td></td>
<td></td>
<td></td>
<td>MHWS</td>
<td>MSL</td>
<td>MLWN</td>
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<td>Score</td>
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<td>Gore Point</td>
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<td>dragons’ tooth fencing</td>
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<td>Thornham West Bank*</td>
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</tr>
</tbody>
</table>
Appendix 5 - References


Ground photos – Lucy North
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