4 DATA EVALUATION, ANALYSIS AND DISCUSSION

The key to identifying an appropriate Strategy for future coastal management of Walney Island is an understanding of coastal and geomorphological processes and how they are likely to change in the future. In order to achieve this, a review of all the available historical and recently collected data has been completed and an overview of relevant characteristics is provided. Each specific topic is considered in isolation and the section is completed with an overview of coastal process/shoreline interaction and future shoreline evolution.

4.1 Coastal Processes

4.1.1 Wave Climate

Analysis of the wave data derived from the Met. Office wave model shows that there is little change from offshore to inshore during storm conditions apart. The only feature is a general reduction in height as waves progress landward, as would be expected due to changes in the level of the seabed. Furthermore, as the sea bed contours are essentially parallel to the line of the coast, particularly south of Walk Haw Scar, there is only a small change in the overall direction of waves as they approach the shoreline, with, if anything, a narrowing of wave energy to within the predominant directional sector (225-255° WCB).

The main difference between the annual and storm conditions is that the annual results show a greater spread of directions, as might be expected. Nevertheless the 225°-255° sector accounts for the dominant wave direction sector and the direction sector in which the highest waves occur. See table 3.1

The data from the NRA wave recorder in the Walney Channel provides details of significant wave heights (H_s), zero crossing periods (T_z) and wave steepness (H_s/T_z). No directional data is provided. In the majority of cases H_s, which is approximately the average of the highest third of the waves, is less than 1.0m and generally less than 0.5m. In total significant wave heights in excess of 1.0 metre was only recorded 1.15% of the time.

In the Met. Office wave model, offshore peak wave periods associated with the storms analysed vary from 10.1 to 4.6 seconds with a mean value of 6.7 seconds. Inshore the range is 9.7 to 4.7 seconds, with a mean value of 6.3 seconds.

The Walney Channel wave recorder provided mean wave periods of between 6.3 and 1.36 seconds.

The results of this wave climate analysis, comparison with other available data and effects on shoreline behaviour are discussed in the geomorphological overview provided in Section 4.2.

4.1.2 Water Levels and Flooding

Analysis of tidal levels indicates that there is a 0.3m difference in predicted spring tidal range between the north and south ends of the island. Furthermore predicted levels on the inside face are higher again due to the restriction in the tidal prism between the island and the mainland.

As the west coast of Walney Island effectively shelters the Walney Channel, Barrow Docks and east coast of the island from significant wave activity (as confirmed by the limited wave heights recorded in the channel, as shown in the table above), water level provides the primary criterion for coastal defence evaluation.

Predicted extreme levels (table 3.3 refers) are based on observations taken at Barrow. Hence, whilst these may provide appropriate criteria for examining the risk of flooding on the east facing coast, they may be slightly conservative for use on the west coast. Notwithstanding the above, it is the combination of waves and water levels that provides the criteria for evaluation on the west coast.

However, as well as changes in elevation of the tides due to atmospheric conditions, i.e. surges, there are other factors that may affect the level of the water, particularly:

- Wind set-up - Shear stress exerted by wind on the water surface causes a slope in the water surface as a result of which wind set up and set down occur at downwind and upwind shorelines respectively.
- Wave set-up/down - The level of water is increased or decreased by wave set up/down caused by energy dissipation due to shoaling of the incoming waves.

These factors will not only determine the degree of overtopping that would occur at the shoreline but will affect how the beach / shoreline reacts to the forcing coastal processes applying.

Flood Risk

The Environment Agency have provided a series of maps based on the Ordnance Survey 1:10,000 series and utilising known OS topographic data for the island have identified areas of land at risk of flooding from a predicted 1 in 200 year water level occurrence. This information is reproduced on Figure 4.1. Particular anomalies in this data are defined below:

- The land between the west coast and Wylock Marsh, where the width of the island is at a minimum, has been raised by the landfill operations and is significantly higher in elevation than indicated on the EA mapping, particularly on the west coast side.
- The whole of the area north of the airfield is shown to be below the 1 in 200 year level. This is considered to be unrealistic given the general relief of the dune area in the locality.

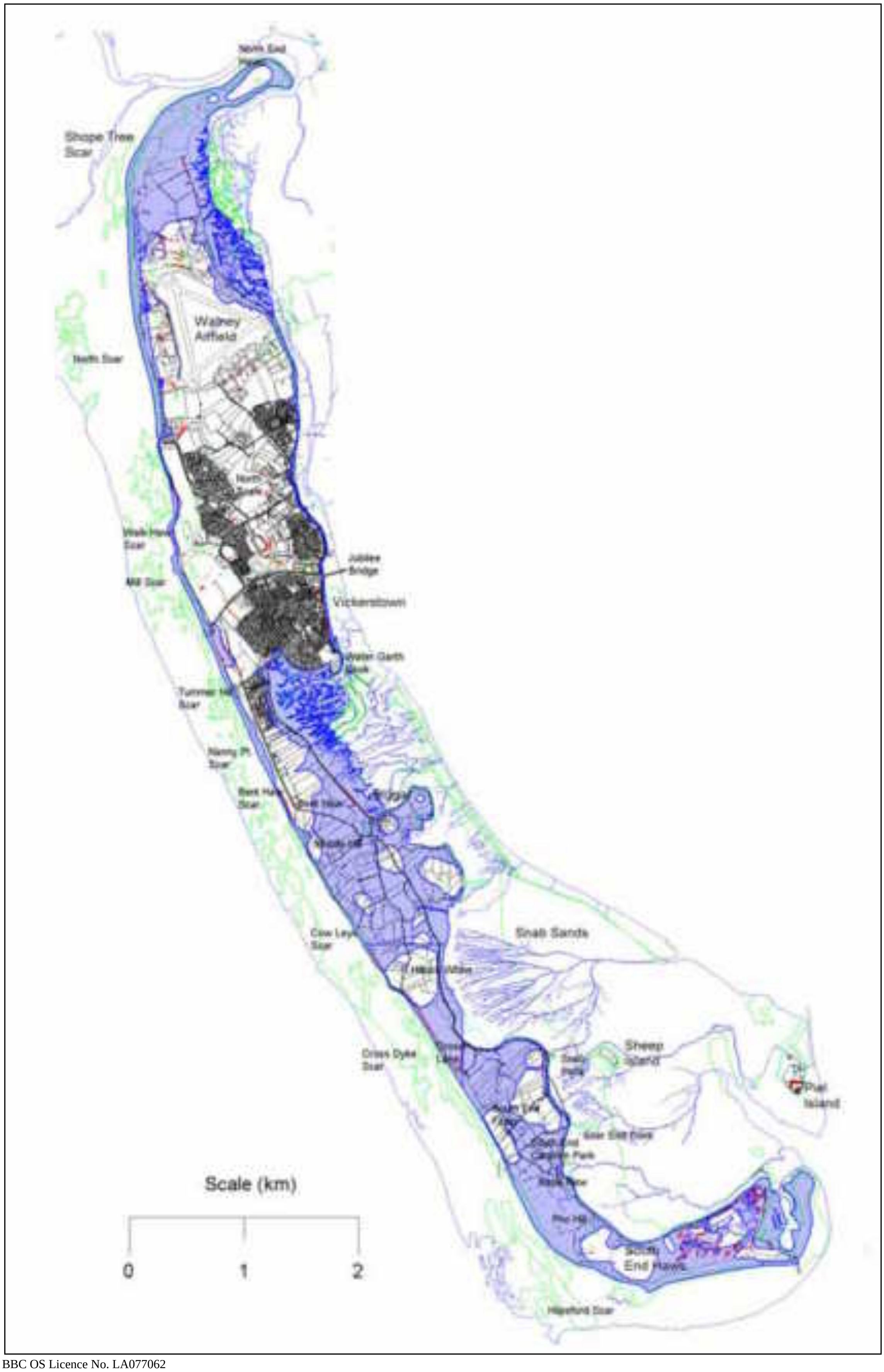

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Figure 4.1 – Environment Agency 1 in 200 Year Flood Outline

4.1.3 Currents

The are three primary types of current that may be acting:

Tidal Currents

From the data available, it is clear that Morecambe Bay heavily influences the behaviour of tidal currents off the south end of Walney Island and, to a lesser extent, the Duddon Estuary does the same to the north. Morecambe Bay represents the meeting point for two distinct tidal streams:

- The SE/NW stream that flows generally parallel to the Cumbrian coast, and
- the south eastern Irish Sea stream that flows north/south off the coast of the Fylde.

Currents off the Cumbrian coast to the north of Walney (Table 3.4, point D refers) generally flow toward the south east on the flood and north west on the ebb. However, it is interesting to note that the change of direction on the flood occurs 2 to 3 hours before High Water (HW) and on the ebb at 4 to 5 hours after HW. Overall, the flood flows are marginally stronger than the ebb.

Further south, off the southern tip of the island (Table 3.4, point A refers), the currents are more influenced by the effects of Morecambe Bay and are generally flow toward the east on the flood and west on the ebb. Here, changes in direction occur within an hour of high and low water respectively.

In the vicinity of the channel (Table 3.4, point C), the flows are, as would be expected, more aligned with the channel orientation. Point B, which is on the south side of the Walney Channel, shows signs of the ebb dominated south east Irish Sea current that flows into and out of Morecambe Bay.

Wave Induced Currents

Wave induced currents are caused by wave interaction with the shoreline. There are two main causes of these:

- Firstly, when waves break on the shoreline a longshore current is induced whose strength depends on how oblique the waves approach the shore.
- Secondly, variations in the breaking wave heights along a beach due to varying nearshore sea bed contours.

However, with the direction of wave attack being predominantly at 90^{o} to the shoreline (ref. Sections 3.1.1/4.1.1) and the sea bed contours being essentially uniform, the production of wave induced currents is unlikely to be significant in the movement of sediment along the shoreline, apart from perhaps at the southern end of the island where the orientation of the coast changes.

Wind Induced Currents

Wind drag on the water surface results in a build up of water against any downwind coastline. This results in a simple transport of water ‘dragged’ along the surface and a consequential reversal of flow toward the bed.

Inshore, across the Walney frontage, there is little quantitative data. However, the float tracking work carried out in the 1960's that identified surface currents provides some useful data, although only covering the southern half of the island, as follows:

- Apart from approximately 1-2 hours either side of HW, flows near the island are generally toward the south east (Morecambe Bay).
- Maximum surface flows of up to 1.0 m/s occur over high water.
- South easterly flows along the island frontage occur concurrently with ebb flows out of Morecambe Bay

Work by Aldridge (1997) on the effects of tidal asymmetry and its effects on sediment paths may be important in this respect, as the results of float tracks across the southern half of the island suggest that south westerly flood flows over this section occur for up to 60% of the time. Conversely, however, for the times when mobilisation and movement of nearshore sediments is likely to be greatest, i.e. either side of high water, the maximum surface currents apply in a north westerly direction.

This information tends to support the hypothesis that wind induced drag across the surface under storm conditions are producing currents near the bed that are acting in the opposite direction to that indicated by the float tracks and that these currents in combination with the tidal currents are instrumental in moving sediment along the shoreline.

A number of previous studies comment on the behaviour of tidal flows in the vicinity of Walney Island, but only in general terms and, apart from reference to the Admiralty data recorded above, without identification of the specific data on which assumptions have been made.

The 1950's paper "How long will Walney remain one island" (Ref. Proceedings of the Barrow Naturalist Field Club, 1971), states

" The tidal streams in the Irish Sea meet opposite Morecambe Bay, thus causing the very high rise and fall of tide in the vicinity. The southern stream runs northerly along the Lancashire Coast and into Morecambe Bay. The northerly stream runs into the Cumberland Coast and is deflected south easterly and then sets up the Duddon Estuary. From about Sandy Gap on the west shore of Walney it is also south-east until it runs into Morecambe Bay. There is however, a weak counter current north of Earnse Point running north-east into the Duddon. These currents denude the shore."

Bullen and Partners Preliminary coastal survey report of May 1986 provides the following description:

" The main tidal current in the Irish Sea off Barrow is from a west-north westerly direction. Off Walney the current divides, and a weak current flows northerly round North End Haws into Scarth Bight, while south of Earnse Point a strong current flows southwards round Hilpsford Point into Walney Channel. The littoral drift on the west coast of Walney Island is therefore, northerly, north of Earnse Point, and southerly, south of Earnse Point."

4.1.4 Beach Plan Shape Behaviour

The historical movement of the mean high and low water marks has been analysed by extraction of offsets for each data set along the lines of the beach profiles that have been recorded since 1992. This information has then been used to establish rates of movement between surveys and average rates of movement per annum over the same timescale. This work was partially carried out during preparation of the Shoreline Management Plan, but has been extended to cover all profiles across the island's west facing coast. The results of this analysis are provided in Appendix K.

This data generally confirms the landward retreat of the shoreline over the southern part of the west facing coast, south of Hillock Whins, since the middle of the 19th century. One particular anomaly is that the high water mark between Sandy Gap (XS 6) and Hillock Whins (XS 12) appears to have moved to seaward in the latter part of the 19th century, but that during the 20th century it has started to retreat to landward. This behaviour cannot be explained for the type of shoreline that exists and clearly highlights the dangers in using such data sets to define absolute figures

North of Sandy Gap, behaviour appears to have been more cyclical, although there was landward retreat of the high water mark at Earnse Point (XS 3) from the mid 50's to the 70's. This is likely to have been the catalyst for increased shoreline exposure at this point and the subsequent need to refurbish the defences here.

At the northern end of the island the position of the high water mark appears to have been generally stable or moved to seaward over the past 150 years. What is more intriguing is the dramatic changes that appear to have occurred in the zone between high and low water during this period. In the latter half of the 19th century the width of inter tidal zone appears to have increased at up to 25m per annum.

On first examination in the more recent past, the far north end appears to have experienced a reversal in this trend in even more spectacular fashion. Closer examination of this, however, identifies this as a secondary low water channel that has split from the main Jubilee Channel that feeds tidal waters between the island and the mainland, north of the Jubilee Bridge. This feature is only shown on the most recent OS map and, therefore, has only formed in the past forty years. Map and photographic evidence suggests that it formed from the sea rather than from the land, although most recent aerial photographs (1997, see below) suggest that it has now largely infilled again.

Whilst the above assessment can provide generalisations on historical behaviour that can be linked, where appropriate, to past behaviour and events, the beach profile data that has been collected may provide the following additional information:

- Confirmation or otherwise of historical trends over the recent past
- Correlation with wind, wave and tide data to identify specific conditions that have caused particular behaviour in the past.

4.1.5 Examination of Beach Profile Data

1963-1965

The primary purpose of the collection of beach profile data for two years between 1963-65 was to obtain an understanding of how different exposure conditions altered the profile of the beach and therefore affected the vulnerability of the shoreline on the west facing coast to erosion.

The key points obtained from this data, extracted from the geomorphological overview carried out by Dr. Ada Pringle (reproduced in Appendix G) are:

- Three types of features tend to develop on the upper beaches (0-60m). Constructive wave action associated with offshore winds led to the building of swash bars up to 0.6m high near HWM as the beach profile was steepened. Conversely, and more rarely, the profile was cliffed up to 0.6m, with shingle below being combed down as the gradient was reduced by waves formed by onshore winds. Also associated with onshore winds was a smooth equilibrium profile, which was either evenly sloping or convex.

- As the lower beach characteristics varied on the different profiles, the changes surveyed need to be examined separately. At North Point, the main changes were associated with the steady landward migration of the sand ridges and runnels producing a height variation of up to 1.8m. On three surveys the features were partially smoothed and on one survey they were totally smoothed following strong onshore winds from 185º-265º across the maximum Irish Sea fetch. The ridges and runnels were re-established by the following surveys.

- The lower beach at Earnse Point showed an almost featureless low gradient throughout the 2 years, except on one survey when a ridge and runnel developed following a period of strong onshore winds from 185º-265º.

- At Biggar Bank, the even gradient of the lower beach also showed little change. On one survey the profile was lowered by about 0.6m and the till underlying the scar was extensively exposed following moderate onshore winds. On another survey, the profile was lowered by up to 0.5m following stronger onshore winds. Neither of these losses was regained subsequently. However, on a further survey, a loss of 0.5m was restored by the next monthly survey.

- Changes on the lower beach at Hilpsford were associated with sand ridges separated by a scar. As at North Point, the sand ridges tended to move landward, with the landward ridge becoming attached to the upper beach at times.

- The similarities between the lower beach evolution at North Point and Hilpsford were to be expected because of the similarity of beach material and ridge and runnel morphology. The small changes recorded at Biggar Bank relate to the relatively coarse size of the pebbles and the closeness of the till platform beneath it. The small changes at Earnse Point in fine sand, however, appear to result from the proximity of Earnse Scar to the south, which affords some shelter from south-west winds and waves.

1992-2000

The beach profile data collection that was commenced in 1992 was set up primarily to identify long term changes in the position of the beach and therefore assist in defining appropriate management actions. Analysis of the beach profile data recorded was commenced as part of the South Cumbria Annual Monitoring Work (Ref. Shoreline Management Partnership, 1993-95) and, as detailed in section 3.1.5, involved recording offsets from the origin of each profile to four tidal contours.

During this initial work the first six sets of profiles were recorded. Since completion of these monitoring arrangements a further six surveys have been undertaken and a similar analysis has been carried out on the results.

The levels chosen for the tidal contours are generally representative of predicted tidal levels along the South Cumbria shoreline, and whilst they may be considered to reasonably representative figures for the eastern shoreline of the island, they do not accurately represent predicted tidal levels along the western frontage. Notwithstanding this level differential, it was considered appropriate to use the previously defined levels to negate the need for reworking the first six survey sets. Furthermore, as the main purpose is to define changes in beach behaviour, the levels chosen encompass the typical range of tidal conditions.

The offsets recorded for all eleven surveys have been extracted and tabulated for each tidal contour in turn, with movement between consecutive and across ranges of surveys calculated from this data. The changes in gradient between adjacent contours for each survey are then calculated to provide an indication of changes in beach composition across specific sections of the beach.

Comparison plots for each of the sections are provided in Appendix L, with tabulated and graphical presentation of the offset analysis carried out provided in Appendix M.

A preliminary assessment has identified significant variation in the position of contours, particularly of the upper beach contours, which is probably indicative of the mobility of the shoreline sediments and their ability to be moulded into different profiles as dictated by the prevailing condition. The most recent surveys provide only a snapshot of behaviour and are therefore difficult to correlate against known conditions. As such, analysis of the data does little to confirm, or otherwise, specific trends in shoreline behaviour.

It is considered that due to the variation in beach shape that occurs, cliff recession data obtained from the aerial photographs will provide more useful data for use in examination of the Do-Nothing scenario (see section 5.3) and the development of strategy options.

4.1.6 Aerial Photographs

The aerial photographic archive provides a rich source of data, but due to the limited time to review this data it has not been possible to carry out extensive analysis of the information contained on them.

The following key points have been extracted from an initial examination:

13th July 1950 (Whole Island)

- Groynes visible between Bent Haw and Middle Hill with a small development on the site of present car park at Bent Haw
- No linear defences visible across Mill Scar and Earnse Point, faint outline of groynes
- North Scale less developed
- West Shore Park smaller than present day
- No caravan site at South End
- Functional jetty at South End serving sand and gravel pit
- Buildings etc. on west coast opposite Coastguard Cottages at south end - Hilpsford Point (Ring of four pill boxes, with control building?) intact
- Evidence of track across marsh between Snab Point and Scar End Point on east coast

1st June 1963 (Whole Island)

- Area on south side of Bent Haw being used as active tip area
- West Shore Park well developed

4th June 1970 (Whole Island)

- New Tip Active on south side of Hillock Whins
- Groynes still in evidence at Bent Haw Scar (less development apparent)
- No caravan site at South End
- Earnse Point to Mill Scar protected (zig-zag breastwork or groynes across point)
- West Shore Park more developed
- Evidence of tip on west side of airfield
- Split in low water channel off North End evident
- Slipway at Earnse Point
- Buildings etc. on west coast, opposite Coastguard Cottages at south end, eroded (two structures on beach)
- Track across marsh between Snab Point and Scar End Point still in evidence

28th May 1976 (South of Scar End Point only)

- First signs of caravan park development at South End - a few vans and some empty bases
- No buildings associated with Oyster Farm, but some booms across one of the adjacent lagoons
- Buildings etc. on west coast, opposite Coastguard Cottages at south end, erosion continuing (further structure on beach)
- Loading jetty still in evidence

22nd June 1983 (South of Jubilee Bridge only)

- Remnants of sand and gravel loading jetty at south end (now disused)
- Oyster farm developed
- No ring of structures at Hilpsford Point, Control building? Near edge.
- South end caravan park established
- Tip area increased on north side of Cross Lane
- Low lying hinterland between Middle Hill and Hillock Whins and between Cross Lane and Hare Hill shows signs of shingle bank being washed landwards. This is probably as a result of the severe storm that occurred at the end of January that year and potentially provides evidence that tidal waters met across the island on that occasion. Significantly the low lying land to the south of Hare Hill, that might of expected to have similar conditions applying due to the low levels of the hinterland, does not show exhibit the same signs
- Groynes still evident across Bent Haw frontage. Development has gone and linear defence is in place.
- No groynes between Middle Hill and Bent Haw
- Track across marsh between Snab Point and Scar End Point still in evidence

<u>11th June 1992 (Whole Island) / 25th August 1992 (Whole Island)</u>

- Remnants of sand and gravel loading jetty at south end still evident
- Cow Leys, Middle Hill and Bent Haw linear defences evident an last remnants of groynes across Bent Haw
- Some buildings at Hilpsford Point still evident
- Track across marsh between Snab Point and Scar End Point still in evidence
- Active tip area now south of Cross Lane. Area to north landscaped. And rock armour toe protection in place.
- Emergency toe bund in place across Earnse Point.
- Tip on west side of airfield still active
- Low water channel off North end filled in

<u>22nd October 1997 (Whole Island)</u>

- Remnants of sand and gravel loading jetty at south end still evident
- Some buildings at Hilpsford Point still evident
- Track across marsh between Snab Point and Scar End Point still in evidence
- Tip south of Cross Lane still active, partially landscaped. Rock armour defences in place
- New Earnse Point defences in place

The above photographs have been used in examination of historical rates of recession along the west facing coast and also the definition of potential future rates (see section 5.3.4).

4.1.7 Coastal Process / Shoreline Interaction

It is clear from the data examined that the interaction of the forcing coastal process parameters and the shoreline gives rise to behaviour that is governed by the following criteria:

- Wave climate
- Water levels
- Tidal and wind induced currents
- Geomorphological formations
- Hinterland topography

The available historical evidence suggests that the west coast of the island has certainly been eroding over the past 150 years and probably for much longer. The geomorphology of the island is reasonably uniform along the majority of its length, as might be expected from an island formed from glacial and post glacial deposition, with glacial till cliffs and post glacial alluvium deposits forming the shoreline over the majority of the island. The only differences to this formation are the sand dunes that have formed, at the extremities of the island, from blown sand deposition.

As a result of these formations the island is particularly vulnerable to attack from the sea on its western coast, but less so on the east facing shoreline where water levels present the main threat to the hinterland and erosion is minimal.

West Coast Behaviour

On the west facing coast the shoreline can be split into two discrete lengths:

- North of Walk Haw Scar - the shoreline is generally orientated north/south for about 3km before it curves to the east on the approaches to the Duddon Estuary.

- South of Walk Haw Scar - the orientation approaches south-east/north-west for approximately 7km before it also curves eastwards on the entrance to Morecambe Bay

Historically, erosion of the west facing coast has been concomitant with accretion at the extremities of the island. The pattern of erosion appears to have been defined from the relative susceptibility of the shoreline formations to erosion.

Forcing Parameters

The mechanisms that cause erosion result from the behaviour of waves and tides.

The majority of storm wave energy impacting the west facing shoreline is focussed to 15° either side of 90^{o} to the shoreline (WCB 225-255°), particularly over the southern half of the island (i.e. south east of Walk Haw Scar). Under typical annual conditions the focussing is less pronounced, but over 50 % of waves still impact the shoreline from between 195 and 255° WCB.

The sea bed contours off the west-facing coast is generally uniform with the seabed contours roughly parallel to the shoreline orientation. As a result, very little refraction of waves occurs from the predominant directions (195- 285°WCB). Due to the relatively flat sea bed of the near sub tidal and lower inter tidal zone (typical gradient of 1 in 100-200), waves can impact the shoreline, mobilising sediments on the beach and causing the erosion of the cliffs that provides further material to the inter-tidal zone.

However, waves will generally only cause damage if the water levels are higher than the predicted astronomical levels and, therefore, the water depth available can sustain the larger wave heights. Without this additional water depth, the waves will break further offshore and dissipate most of their energy on the beach rather than impacting the cliffs and causing erosion.

Beach Profile Behaviour

The form and profile of the beach varies along the west facing coast from narrow shingle upper beaches with wide expanses of sand across the lower beach exhibiting ‘ridge and runnel’ features at the north end to wider shingle upper beaches with boulder scars interspersed with sand areas across the lower beach. The form of these foreshore features is dependent on both the historical shoreline geomorphology and that which is present today.

The action of the waves and tides mould the beach to different shapes, dependent on the particular features of the beach and the wind, wave and tide conditions applying. On the upper beaches, wave action associated with offshore winds leads to the building of bars near high water mark. Conversely, onshore winds can create a cliffed effect. Due to the variations that exist in the formation, behaviour of the lower beach can vary more widely.

On the sand only sections, strong onshore winds tend to smooth the ridge and runnel features, which return in periods of calmer weather. At times the sand ridges move landward, with the landward ridge becoming attached to the upper beach.

Where scars exist, there is generally little change, as would be expected, in the beach formation but strong onshore winds can strip sand away from between the boulders that form the scars with the potential for the underlying till to be exposed and, in some cases, irreversibly eroded.

The inter-tidal scars were originally formed from large boulders eroded from the till which were generally too large to be moved under tidal conditions and therefore have remained in place. As the shoreline has recessed, the scars have extended to landward, supplemented by fresh erosion from the cliffs. In some places, however, the scars have not extended to landward and a sand beach has formed between them and the upper shingle beach. This appears to be indicative of softer deposits behind the original till cliffs.

The behaviour of the scars is influenced by a number of factors, with the following mechanisms thought to apply:

- Extreme tide and wave conditions can move even the larger boulders, which de-stabilises the formation. However, boulders may be moved under certain conditions, but return during other conditions.

- The scars can alter in level. In times of high energy fine material (sand etc.) that fills the gaps between the boulders can be removed which exposes the underlying till, which itself is susceptible to further erosion, causing the level to drop. Such behaviour is irreversible.

- The scars can become filled with sand and this aids their integrity. In such cases, subsequent losses can be recovered.

Notwithstanding that the combination of waves and water level provides the mechanism for sediment mobilisation and changes, primarily to the on/offshore profile of the beach, it is the behaviour of currents that provide the forces to move sediment away from the area of wave influence. Available data on currents does not provide a clear understanding of the relative importance of the various currents that may be acting. However, it appears that a combination of tidal and wind induced currents are likely to be the key forcing parameters in the movement of sediments once they have been mobilised by the tide/wave/shoreline interaction.

Shoreline Reaction

Along the shoreline, erosion susceptibility is linked to the type of material that is forming the shoreline at any given time, which is known to vary with location.

Generally, the post glacial alluvium deposits have eroded more quickly than the glacial till of the drumlins, although it is the latter feature that has provided the material to form the inter tidal scars. The most noticeable feature in this respect is the frontage between Bent Haw and Hare Hill. Up to the end of the 18th century, the shoreline along this section was predominantly straight. Excessive erosion of the alluvium over the southern half of this length, between Hillock Whins and Hare Hill, at the end of the 19th century caused a significant set back of the shoreline that has prevailed to the present day. The material from this formation is generally the smaller fraction that is removed offshore by wave action.

The erosion of the glacial till cliffs on the other hand provides a number of different material fractions, as follows:

- Fine clay and silt, which is easily eroded and rapidly transported away from the erosion zone offshore
- Sand and shingle, which is sorted across the foreshore profile by wave action but will be subject to disturbance and may be transported longshore to feed the extremities of the island.
- Cobbles and boulders that drop out of the cliffs and supplement the heavier material that forms the boulder scars (as described above).

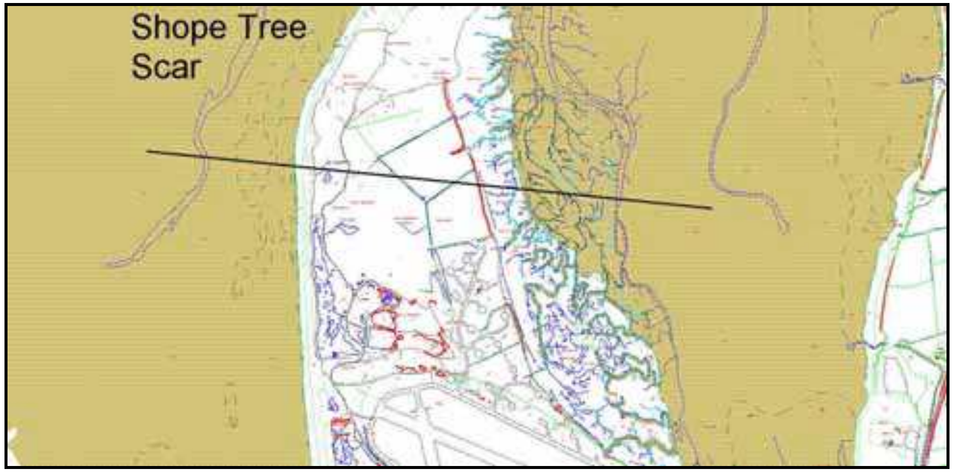
Figure 4.2 a to d provides a series of schematic sections through the island, showing the relative levels of the shoreline and hinterland to the water levels applying, beach and shoreline geomorphology, aswell as the typical land use and development close to the coast.

East Coast Behaviour

The shelter from wave attack that the island provides to the east coast results in different conditions on the east coast and water levels are the primary criteria for coastal defence evaluation along this shoreline Here, the shoreline is low lying over the southern half with only a short length of cliff frontage south of Biggar. Further north, higher land occurs, but it is largely covered by development.

The shoreline on the east facing coast is heavily indented and the shelter provided has enabled new habitats to form between headlands. Upper beaches of shingle tend to be of the ribbon variety. The shoreline on this coast can effectively be split into three sections:

- Between South End Haws and Water Garth Nook: where four embayments have formed and areas of saltmarsh have developed.
- Between Water Garth Nook and the airfield: where the gap between the island and the mainland is narrowest. The beaches are largely formed of shingle and mud across this stretch and coastal defences have been erected to support the hinterland infrastructure.
- North of Walney Airfield: where saltmarsh has developed behind the North end Haws spit



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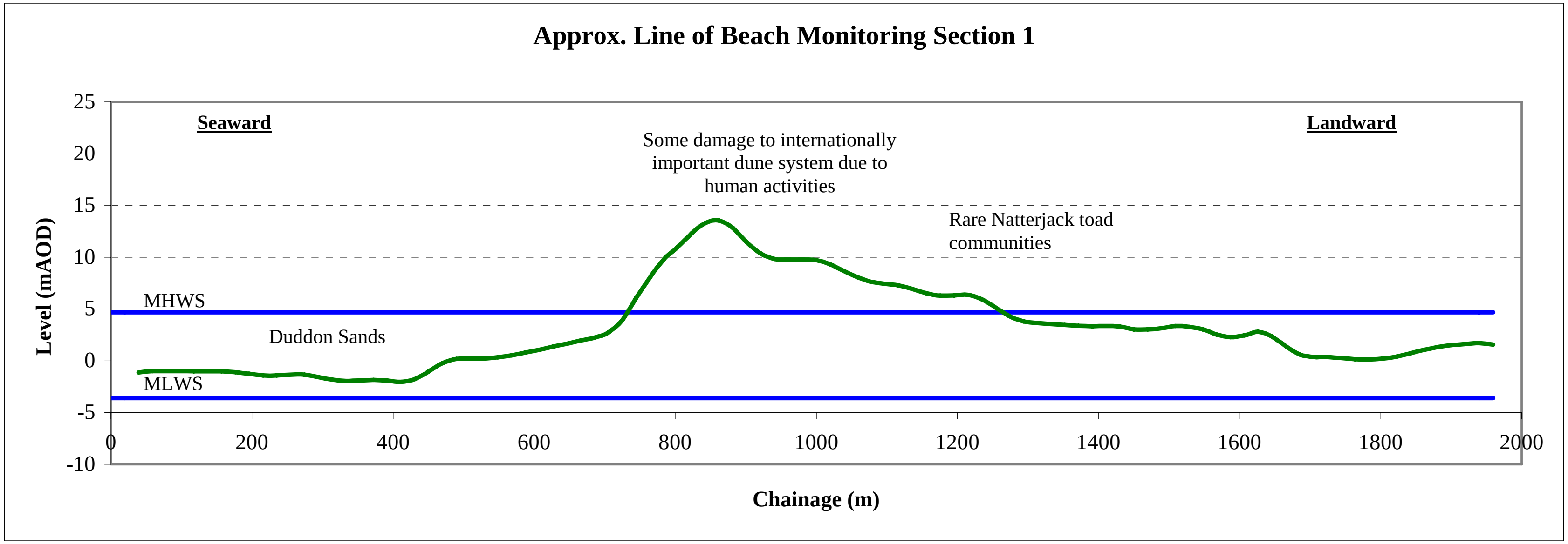

Figure 4.2a – Schematic Section Between Walney Airfield and North End Haws

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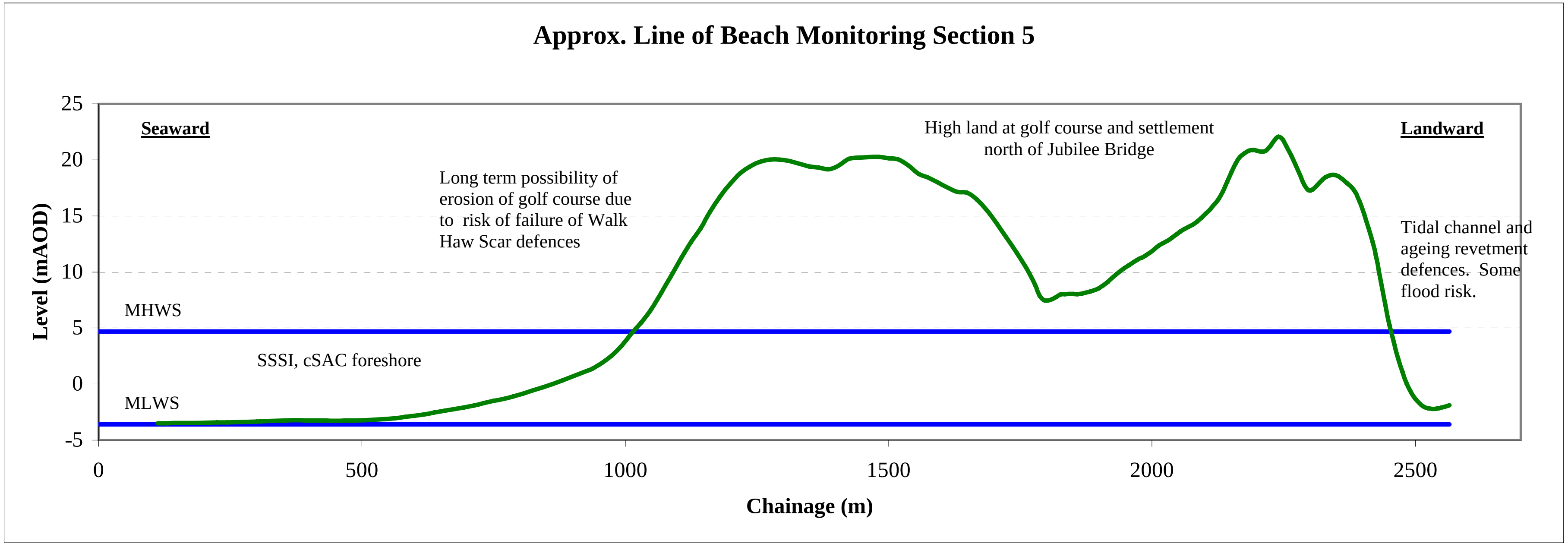

Figure 4.2b – Schematic Section Through Vickerstown

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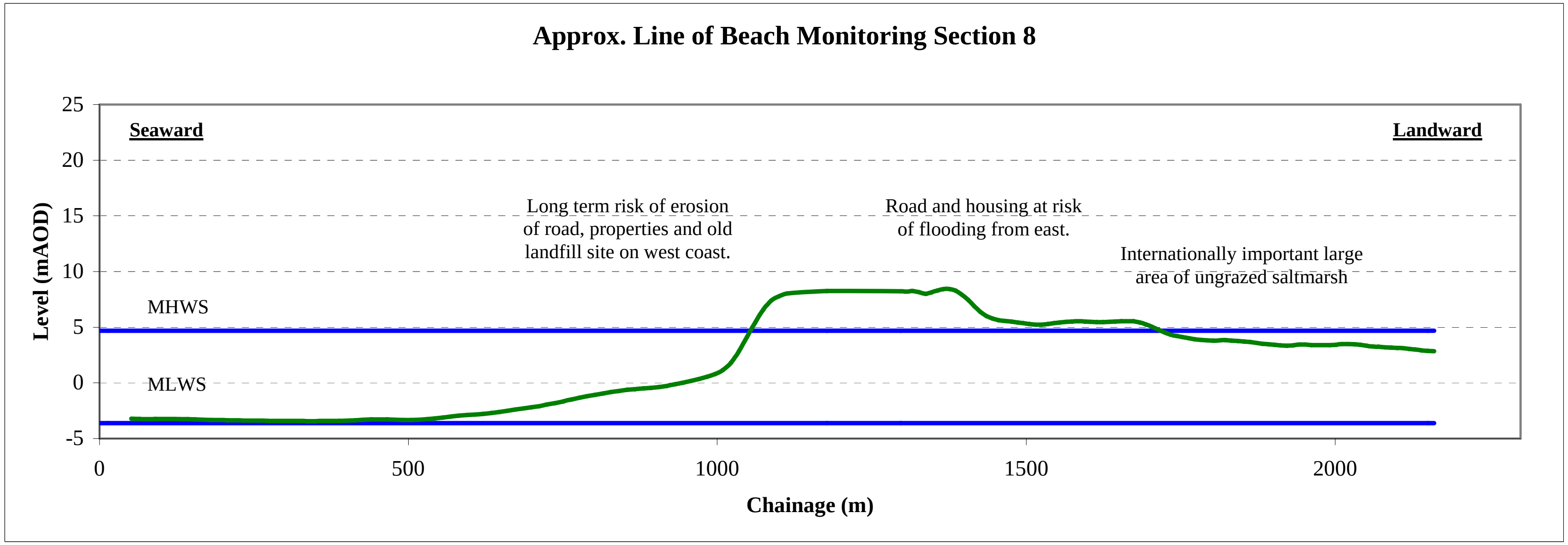
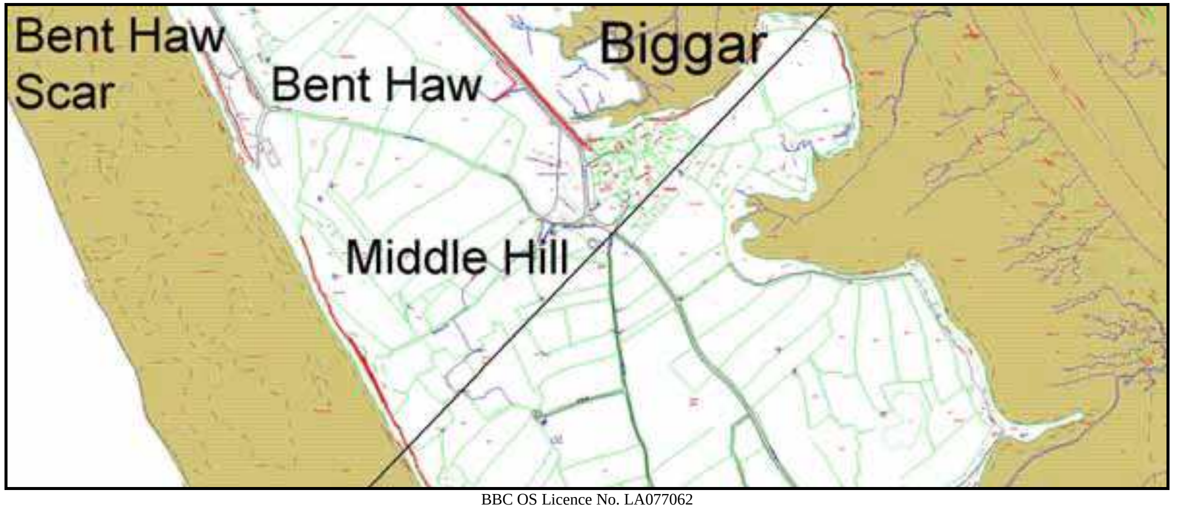


Figure 4.2c – Schematic Section at Tummer Hill Marsh



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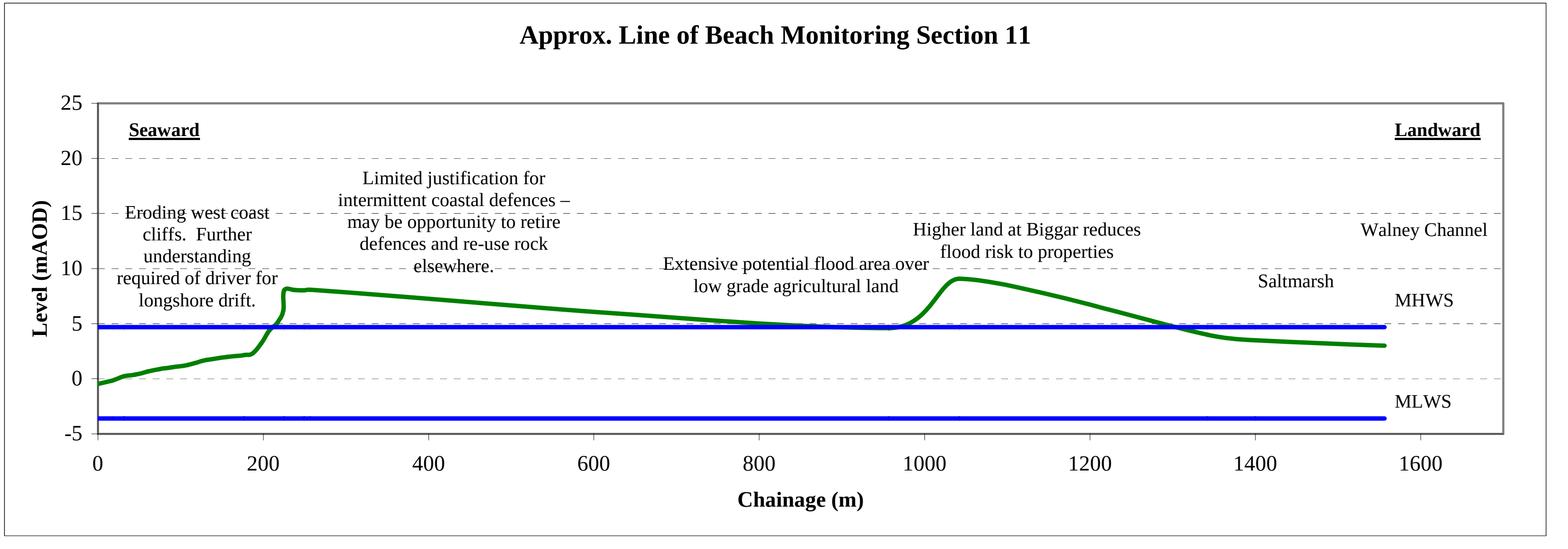

Figure 4.2d – Schematic Section Through Middle Hill and Biggar

4.1.8 Future Coastal Geomorphological Evolution

Effects of Present Human Intervention

Much of the Walney Island coastline remains in a natural state and in these parts is likely to continue to evolve in much the same way that historical records have shown. The coastal defences described in section 3.3 are localised and may be expected to have a range of effects, some desirable but others detrimental to the island's natural evolution.

Wooden groynes have been built at various times where till cliff erosion has been especially rapid, sometimes coupled with short sea walls of various type. Whilst this protects the land behind from wave attack, it prevents the natural supply of sediment from the cliff to the beach below. Where there is pronounced longshore drift of beach sediment, as occurs on Walney Island, this is likely to cause beach depletion and lowering. This may expose the underlying till shore platform to an increasing rate of erosion and lowering. In turn this will increase wave attack on the artificial defences. Furthermore, to the north and south of the artificially protected coast, natural erosion will continue, eventually resulting in the protected coast jutting seaward of the natural coast and becoming the focus of more concentrated wave attack.

Historical recession of the shoreline has taken place south of Sandy Gap and north of Walk Haw Scar, with the section in between generally showing only minor movement and/or cyclical behaviour. This can be particularly seen by the shingle headland at the top of the beach at Mill Scar. With the shoreline to the south susceptible to erosion and southerly longshore drift, the opposite is in evidence on the north side of Walk Haw Scar. The shoreline is orientated differently north of this point providing, if anything, a greater potential for wave induced longshore drift than to the south.

The recently constructed 'T' groyne at Earnse Point provides evidence, by the build up of shingle on its south side, that upper beach shingle drift is occurring. Furthermore, the build up of a predominantly sandy beach on the north side of the groyne indicates that waves, which are being diffracted around the head of the groyne on the north side, are pumping finer sediments that are in motion across the lower beach into the lee of the structure. This confirms that the groyne is helping to build the beach across the point but is also, in the short term, depleting downdrift beaches and potentially exacerbating erosion across the West Park frontage. Specific erosion across the launching ramp may not be a direct result of the groyne construction, as the ramp is itself a low barrier to drift and is likely to have caused a step in beach level across it in the past. This requires short term monitoring to confirm future management actions.

At the southern end of the island, the single groyne at South East Point causes an artificially sharp angle to this coast whilst still allowing shingle to pass over it. If it were removed the natural more rounded coastline shown in 1847 on Figure 3.8 would be more likely to evolve. However, the short term effect of this on the lighthouse would need careful assessment, although in the longer term this accreting coastline should extend south-eastwards.

Potential for a Breach in the Island

The concept of a breach occurring in Walney Island is one that has been discussed for over a century and a half, once historians, scientists and engineers started examining the data regarding recession over the west facing coast. In 1866, Mr. R.A. Peacock presented a paper on the changes occurring to the south end of Walney and extrapolated the data then available to identify that if the rate of erosion continued, the width of the island between Hilpsford Point and Hare Hill which was up until then recessing at a rate of 8 feet per annum, would be reduced to zero by the year 2050. Whilst recession of this frontage has continued, the width of the island at the present time appears to be only 50 metres or so less than it was 170 years ago.

The Applicant in the proposed development of land at South End Farm as a landfill tip in 1992 also presented the argument that this breach was going to occur. What is more realistic in this particular location is the potential for extreme water levels to cause flooding of the hinterland that effectively links the east and west coasts and maroons the south end of the island.

Reference to Figure 4.1 shows the area of land that is below 6.5 metres AOD or the equivalent of a 1 in 200 year return period tidal level. Whilst this information requires more detailed confirmation it clearly identifies that significant sections of this part of the island can be flooded by tidal waters overtopping the natural defences and that there is the potential for linkage of tidal waters across the island, particularly at:

- South End Haws
- Around Pho Hill and Rape Haw, as described above
- Between Biggar Bank, Hillock Whins, Biggar Village and Long Rein Point

The addendum to the environmental statement for the above Planning Application provides photographic evidence to this effect.

The potential for breaching of the island up until the 1970's was more acute south of Hillock Whins across to Wylock Marsh on the east coast. Here, the width of the island had almost halved in the previous 100 years, largely due to the erodable alluvium that formed the shoreline between the drumlins of Hare Hill and Hillock Whins. The width of the island had decreased to approximately 200 metres in 1969, when the decision to use the land as a landfill tip was taken. As shown on Figure 4.1, the land was low lying and susceptible to inundation and water linkage across the island during extreme tidal conditions. Tipping commenced in 1969 on the north side of Cross Lane and has gradually extended southwards to the present site across Low Bank. This has effectively raised the level of the land by typically up to 5m, reducing the flood risk but requiring the construction of artificial defences that both protect the landfill site and prevent the release of natural sediments to the inter-tidal zone. Notwithstanding this, the majority of material that was being eroded from this section is likely to have been fines that are unlikely to have contributed significantly to natural beach protection and which will probably have been lost offshore. Nevertheless, the construction of a hard defence is likely to have caused some beach lowering which would lead to increased exposure conditions and possible destabilisation of the offshore scar feature, which from visual evidence since the mid 19th century would not appear to have been supplemented with material from the shoreline.

Integrity of Coastal Geomorphological Features

Till Cliffs:

Under natural conditions these cliffs will continue to erode by both sub-aerial processes associated with rainwater and ground-water and by marine attack, which whilst generally concentrated at the cliff foot may affect much of the cliff face during westerly storm conditions. Sand and gravel deposits within the till may be liable to preferential erosion, which may undermine the clay cliff above. Generally wetter and stormier conditions during the winter will be likely to cause more rapid erosion than during summer months.

Beaches:

The integrity of the beaches depends upon the maintenance of a reasonably natural regime overall as discussed above. Erosion of the till cliffs will supply coarse and medium sand, and small and medium pebbles to the upper beach, which will afford protection to the cliff foot except at MHWST and during storm conditions. The scars are formed from the larger pebbles from the till cliffs and these protect the till shore platform from all but slow marine erosion. The fine sand which forms highly mobile sandbanks, which may form into ridges and runnels, is also derived from erosion of the till cliffs. This material may be supplemented toward the south by sand from the outer parts of Morecambe Bay and in the north by material transported into the Duddon Estuary.

Dunes:

The South Walney dunes form part of a nature reserve and access is by permit only. The mainly vegetated dunes are not under serious threat by human trampling, which can damage vegetation and cause erosion. The oyster farm, based in the pools left after earlier gravel working beneath the dunes, does not appear to impinge on the neighbouring dunes. The integrity of these dunes, therefore, seems assured in the foreseeable future.

The North Walney dunes are open to public access from Earnse Point and erosion of the seaward dunes has occurred since the 1960s. These dunes are vulnerable to vegetation damage by human trampling, resulting in development of blowouts. There appears to be no restriction on 4x4 vehicles using the sandy beach and these pose a serious threat if driven into the relatively fragile dunes.

Saltmarshes:

Again lack of data on recent evolution allows only general comments. The saltmarshes south of Vickerstown appear to be in a good condition and those at Wylock Marsh and Haws Bed Marsh appear be expanding as a result of colonisation by *Spartina anglica*. If these marshes behave similarly to those in other parts of Morecambe Bay in recent years, they may be expected to become consolidated as grasses higher in the natural succession, such as *Puccinellia maritima*, become established.

Effects of Increasing Sea Level and Storminess

Examination of tide gauges around the north-eastern Irish Sea (Emery and Aubrey 1985) confirms that absolute sea levels were rising by 0-2mm/year with higher values towards the south of this area. Flather (1992) suggested that a sea level rise of 1.5-2mm/year was a reliable estimate for this area in the medium term. Partly off-setting this is the isostatic rising of the land (Shennan 1989) across north-west England with the Walney Island area rising at about 0.3mm/year.

Under conditions of a net rise in sea level and possibly increased storminess, the till cliffs along the west coast of Walney Island would be expected to erode more rapidly by wave attack, assuming the storms are mainly from the west as now. More sediment would be supplied to the beaches, the scars would extend landward, whilst the more seaward parts were lowered, and accretion rates resulting from longshore beach sediment movement would probably cause increased growth of shingle ridges at the north and south ends of the island. Dunes would continue to form on these ridges. The integrity of the saltmarshes along the more sheltered east coast would probably depend on a sufficiently slow sea-level rise to enable the marsh to accrete upwards at a similar rate. With a faster sea-level rise the marsh might develop a seaward cliff, which would retreat landward reducing the saltmarsh area and conversely increasing the width of the bare mudbanks/sandbanks and increasing shoreline exposure.

4.2 Environmental Data

The data collated with regard to the natural environment and the conservation interest associated with Walney Island has identified the international, national and local importance of the area with regard to the features and habitats that are specific to the vicinity, with the following key interests applicable:

- Internationally important populations of regularly occurring Annex 1 birds.
- An internationally important assemblage of waterfowl and seabirds.
- Internationally important populations of regularly occurring migratory birds
- Inter-tidal boulder and cobble skear communities (west facing Coast)
- Sub tidal boulder and skear communities (Walney Channel)
- Coastal lagoon communities (south end)
- Inter-tidal mudflat and sandflat communities (island perimeter)
- Saltmarsh and Pioneer saltmarsh communities (east facing coast)
- Sand Dunes (north and south ends)
- Vegetated Shingle (west facing coast)

However, in order to provide an appropriate assessment with regard to development of a strategy, it is necessary to examine and analyse the particular importance of the specific key interests identified.

<u>Internationally important populations of regularly occurring Annex 1 birds</u>

The species listed in Annex 1 of the Birds Directive are the subject of special conservation measures concerning their habitat in order to ensure their survival and reproduction in their area of distribution. Species listed in Annex 1 are in danger of extinction, rare or vulnerable. Morecambe Bay is of importance for an internationally important population of breeding sandwich tern *Sterna sandvicensis.*

Sparsely vegetated shingle areas are an important nesting area for sandwich terns in the Bay. The main nesting areas are on Foulney and Walney Islands.

<u>Internationally important assemblage of waterfowl and seabirds</u>

The large areas of inter-tidal mudflats and sandflats in Morecambe Bay support dense populations of marine invertebrate species, which in turn provide a food source for large populations of waterfowl (wildfowl and waders). Morecambe Bay is one of the most important estuaries in the UK for wintering waterfowl regularly supporting over 20,000 birds (Cranswick *et al., 1995).* During severe winter weather Morecambe Bay assumes even greater national and international importance as waterfowl arrive from other areas further inland, as they are attracted by the mild conditions and the abundant food resource. The Bay also supports an internationally important assemblage of breeding seabirds.

Internationally important populations of regularly occurring migratory birds

Several of the species included in the wintering waterfowl assemblage also occur in internationally important numbers, and thus qualify for SPA status in their own right. The specific species are:

- Pink-footed Goose *(Anser brachyrhynchus)*
- Shelduck
- Pintail
- Oyster catcher
- Grey Plover
- Knot
- Dunlin
- Bar-tailed Godwit
- Curlew
- Redshank
- Turnstone
- Ringed Plover

Inter-tidal boulder and cobble skear communities (west facing coast)

Although the Bay is principally a region of soft sediments there are important areas of exposed boulder and cobble skears, which provide an important habitat for a range of marine organisms and thus contribute to the structure of the Bay. The boulder and cobble areas are mainly colonised by mussel beds *Mytilus edulis* and associated species (Woombs, 1997). The nationally scarce honeycomb worm *Sabellaria alveolata* has colonised the boulder and cobble skears off Walney Island.

Boulder and cobble skears provide a hard substrate for a different range of prey species including dense beds of mussels. These areas are very important bird feeding habitats. Small mussels are eaten by knot, dunlin and turnstone and larger specimens are taken by oystercatchers and eider. The skear areas are also used as important mid-tide roosting areas.

Sub tidal boulder and skear communities (Walney Channel)

The wave sheltered subtidal boulder and cobble skear sites in the Walney Channel are particularly important as they provide a habitat for a nationally scarce assemblage of cushion sponges, hydroids and sea squirts which thrive in these tide-swept waters (George, 1992; Cook, 1998). The subtidal boulder and cobble areas are also densely colonised by mussel beds *Mytilus edulis* and associated species (Woombs, 1997).

Coastal lagoon communities (south end)

Coastal lagoons are bodies of water, natural or artificial, partially separated from the adjacent sea. The coastal lagoons at south Walney contain soft sediments, which support the macrophyte *Potamogetin pectinatus* and a range of other plant and animal species. These communities are fragile and contribute to the diversity of Morecambe Bay European Marine Site.

Coastal lagoons contain soft sediments, which can support tasselweeds and charophytes as well as filamentous green and brown algae. They provide an important feeding and roosting habitat for waterfowl, marshland birds and seabirds. Cavendish Dock in the Walney Channel is of regional importance as the largest coastal lagoon in north west England. The dock contains slightly brackish water, which is relatively warm because it receives cooling water discharges from the nearby power station. It supports a rich growth of plants including beaked tasselweed *Ruppia maritima* and is an important site for feeding and roosting wildfowl and roosting waders.

Inter-tidal mudflat and sandflat communities (island east coast perimeter)

Inter-tidal mudflats and sandflats are submerged at high tide and exposed at low tide. Their physical structure can range from the mobile, coarse sand beaches of wave exposed coasts to the stable, fine sediment mudflats of estuaries and embayments. This is a widespread habitat type that occurs throughout the UK. European Marine Sites were selected to encompass the ecological variation across the geographical range of this habitat type in the UK (Brown *et al.*, 1997).

Inter-tidal mudflats on the site support high densities of invertebrates that are important food for waterfowl. The high biomass of invertebrates includes species such as the Baltic tellin *Macoma baithica* (56,000 m^2 max. recorded density), cockles *Cerastoderma edule,* mud snails *Hydrobia ulvae* (1 0,000m^2 max. density), marine worms such as lugworms *Arenicola marina* and crustaceans such as *Corophium volutator* (9000 m^2 max record density). In general more sheltered areas with a relatively high silt content support a richer biomass than more exposed areas.

Pioneer saltmarsh communities (east facing coast)

Glasswort *Salicornia* spp and other annuals, referred to as pioneer saltmarsh, vegetation comprises a small number of species which are dominated by glasswort *Salicornia* spp. This vegetation occurs in a large number of saltmarshes in the UK and European Marine Sites were chosen to represent the geographical range of the habitat type. Generally the largest areas of pioneer saltmarsh have been selected, and since it occurs as an integral part of a sequence of habitats, from sand/mudflats to more stable saltmarsh vegetation, preference has been given to sites where it forms part of well developed successional sequences (Brown *et al.*, 1997).

Pioneer saltmarsh develops at the lower reaches of saltmarshes where the vegetation is frequently flooded by the tide. Wave exposure is particularly important in determining whether pioneer saltmarsh will colonise an area, as it is only able to do so in sheltered sites where it is protected from strong wave action. Pioneer saltmarsh is an important precursor to the development of more stable saltmarsh vegetation.

Pioneer saltmarsh covers extensive areas in Morecambe Bay and is dominated by glasswort *Salicornia* spp. Glasswort marsh occurs along the coastline of the Bay, forming a key stage in the transition from the extensive inter-tidal sand and mudflats to the distinctive saltmarsh of the site.

Saltmarsh communities (East facing coast)

Atlantic salt meadows *Glauco-Puccinellietalia* community, referred to in this document as saltmarsh, occur on North Sea, English Channel and Atlantic shores. There are more than 30,000 ha of saltmarsh in the UK and European Marine Sites were selected to represent the geographical range and ecological variation of the habitat. The European Marine Sites chosen are for the most part the largest examples of this habitat type, which support a well developed zonation of plant communities (Brown *et al.,* 1997).

Saltmarshes play a fundamental role in the life of an estuary, bringing stability to its margins and also operating as a source of primary productivity. They are a rare and specialised habitat in their own right and many of the plants which occur there survive nowhere else. Saltmarsh develops when vegetation colonises soft inter-tidal sediments of mud and sand in areas protected from strong wave action. Saltmarshes exhibit a zonation of vegetation which is influenced by the degree of tidal inundation, in turn related to the level, or height of the deposited sediment on which the saltmarsh has developed. This zonation is generally displayed as bands of characteristic vegetation communities. The lower levels of the saltmarsh, landward of the pioneer zone of glasswort, experience the greatest number of tidal inundations and are generally species poor. In the mid marsh zone, as the number of tidal inundations decreases the vegetation becomes more diverse with a more complex structure and a greater proportion of herbs. At the upper levels of the marsh, which the tide only reaches on the highest spring tides, the vegetation is diverse and includes some species which are restricted to this zone.

Morecambe Bay was chosen as being characteristic of saltmarshes in north-west England demonstrating large areas of closely grazed upper marsh (Brown *et al,* 1997). Grazing by domestic stock has been particularly significant in determining the structure and species composition of the habitat type and in determining its relative value for plants, invertebrates and wintering or breeding waterfowl. A wide range of saltmarsh community types is represented in Morecambe Bay and the saltmarsh covers large areas, especially where there has been little or no enclosure on the landward side. In the upper levels of the saltmarsh there are also important transitional habitats from saltmarsh to freshwater and grassland vegetation.

This habitat makes a vital contribution to the structure and function of the Morecambe Bay system. Saltmarshes and mudflats form two elements of an interconnected and dynamic system which is able to interact with the physical processes operating within the Bay.

Low marsh communities

The lower levels of the saltmarsh, landward of the pioneer zone of glasswort *Salicornia,* experience a great number of tidal inundations, usually more than 360 a year. Because of this, the vegetation communities of the low marsh and low-mid marsh are often species poor, composed of plant species which can withstand such conditions. Characterising species of this zone include extensive areas of saltmarsh grass *Puccinellia maritima* with smaller areas of sea purslane *Halimione portulacoides* in ungrazed areas.

Mid marsh communities

The mid marsh zone comprises a transition between low and upper marsh. As the number of tidal inundations becomes less frequent, the vegetation becomes more diverse with a more complex structure and a greater proportion of herbs. This zone is characteristically dominated by the saltmarsh grass/fescue *Puccinellia/Festuca* communities, of which over 1,000 ha occur in the Bay, and by smaller areas of saltmarsh rush *Juncus gerardii* community.

High marsh communities

At the upper levels of the marsh, tidal inundation only occurs on the highest spring tides and the vegetation reflects this with some species being restricted to this zone. The sea rush *Juncus maritimus* community is found in this zone and is more strongly represented in Morecambe Bay than elsewhere in England. Other important features of the higher saltmarsh communities include the saltmarsh flat-sedge *Blysmus rufus* and a few-flowered spike-rush *Eleocharis uniglumis* communities which are rare in Morecambe Bay (Burd, 1989).

Transitional high marsh communities

The higher marsh communities will grade into transitional communities at around extreme high water spring tide. Transitional communities are an important structural aspect of the upper saltmarsh. They may be freshwater transitional communities, such as the common reedbed *Phragmites australis,* common-club rush *Schoenoplectus tabernaemontanii* and sea club rush *Scirpus maritimus* communities, or grassland transitions include creeping bent *Agrostis stolon~fera,* red fescue *Festuca rubra* and tall fescue *Festuca arundinacea* communities. Historically, where the upper saltmarshes have been truncated by sea walls, these habitats have been lost.

Saltmarsh on the site provides important feeding, roosting and breeding areas for the Bay's bird life. The characteristic short sward height resulting from grazing pressure makes the saltmarsh an ideal habitat for roosting and feeding birds. On high spring tides thousands of wading birds concentrate on roost sites on the upper levels of the saltmarsh.

The primary objectives in respect of SSSI, SPA and cSAC features on Walney Island above the high water mark are the maintenance in favourable condition of:

- **Sand dunes,** particularly shifting dunes along the shoreline with Ammophila arenaria and fixed dunes with herbaceous vegetation.
- **Vegetated shingle,** particularly maintenance of the annual vegetation **of drift line (***Honkenya peploides-Cakile maritima* strandline community habitats).