The geology and landscape of the Isle of Sheppey

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Summary

Sheppey is a small island off the north coast of Kent at the mouth of the river Medway formed primarily of a ridge of London Clay overlain to the south by alluvium of the Medway estuary and the Swale marshes. Studies have shown that over time sea level change, coastal erosion and coastal sedimentation have created a landscape with two contrasting environments that will need very different management strategies in the future. The question is how will these processes change the landscape in the future? Will climate change increase coastal erosion along the north Sheppey coast and help to support marsh accretion, or will the rate of sea level rise increase to outstrip the ability of marsh sedimentation to keep up? Past, present and possible future changes are discussed since the consequences for the ecology and natural history of Sheppey could be serious.

Introduction

The Isle of Sheppey is a small island in the Thames estuary off the northern coast of Kent, approximately 65km east of central London. It is 16km long, 7km wide and has an area of approximately 90km^2. It is the largest of several low islands at the mouth of the river Medway, separated from the mainland by the Swale, a tidal creek that over time has silted up. Sheppey itself consists of three main islands that protrude through marshes which developed as sea levels rose: Sheppey, the Isle of Harty and the Isle of Elmley (Fig. 1). The marshes, which form most of the southern part of the island, are a significant component of the North Kent Marshes which form an almost continuous coastal marshland fringe from Gravesend in the west, across the Isles of Grain and Sheppey to Whitstable in the east (Fig. 2).

This paper provides a general overview of the geological and geomorphological history of Sheppey to provide the context for the natural history of the island – the focus of the current volume.

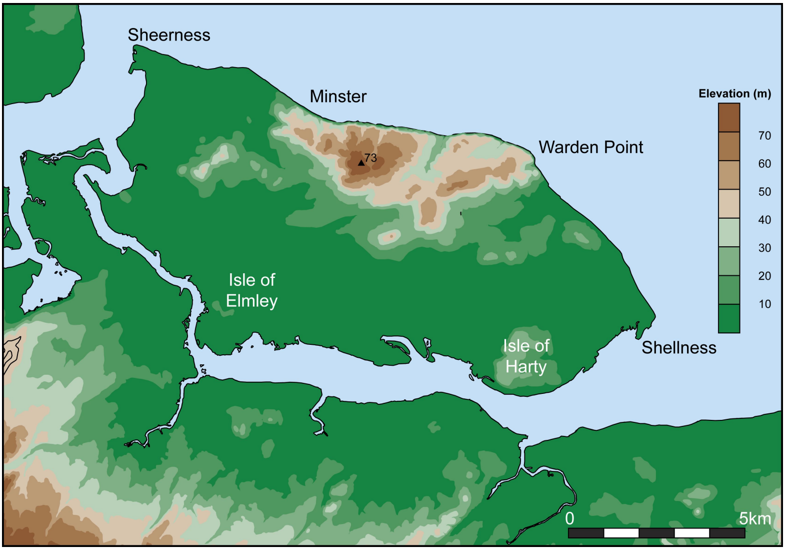

Fig 1. The Isle of Sheppey. Relief – showing the Isle of Harty reaching 27.5m and the Isle of Elmley (12m). The highest point of 73m occurs between Minster and Eastchurch.

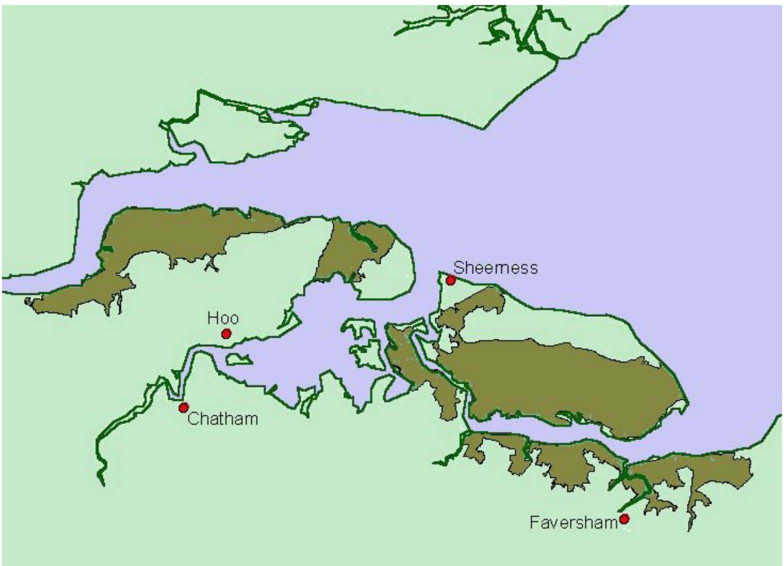

Fig. 2. The North Kent Marshes

The Geology and Relief of Sheppey

The present day environment of the Isle of Sheppey is, like so many other areas, controlled predominantly by its geological and geomorphological history. Like much of north Kent between the Isle of Grain in the west and Reculver in the east, the Isle of Sheppey is underlain by a series of Tertiary deposits which rest unconformably on the northeast dipping Chalk of the Upper Cretaceous which forms the North Downs of Kent - the northern margin of the Weald (Fig. 3). The stratum which forms the predominant geological exposure of the north Kent coast and which underlies the alluvium of the Medway Estuary and the Swale marshes and the heart of the London Basin, including the Isle of Sheppey, is the London Clay.

The London Clay was laid down during the Eocene between approximately 52 and 48 Million years ago on a shallow shelf of a semi-tropical sea near the estuary of a major river system (Holmes, 1981; Jones, 1981; King, 1984). It is a homogeneous, stiff, fissured clay, bluish-grey in colour when fresh and weathering brown (Dines, Holmes & Robbie, 1954; Whittow, 1992). It reaches its greatest thickness in Kent, estimated to be 146 to 157 metres near Minster on the Isle of Sheppey (Davis, 1936; Davis & Elliot, 1957; Gallios, 1965; Holmes, 1981; King, 1981, 1984), where it is overlain by two apparently protective outliers of transitional sands and clays of the Claygate Beds (up to 3 metres thick on average) and the fine sands with flint pebbles of the Bagshot Beds (10 metres or less – Holmes, 1981) (Davis & Elliot, 1957; Gallois, 1965).

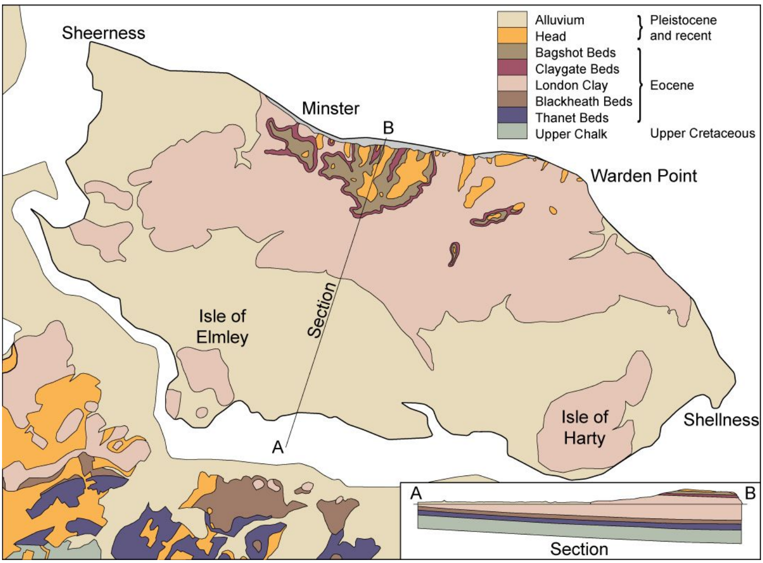

Fig. 3. The Geology of Sheppey.

Quaternary gravels and brickearth are also locally developed. Away from Minster, however, the London Clay thins towards Medway in the west and towards the Swale to the south, the latter due to denudation (Davis, 1936). The greatest exposure on the island occurs at Warden Point on the north coast where it forms unstable cliffs 42 to 46 metres high (Fig. 4a & 4b) (Davis, 1936; Dines, Holmes & Robbie, 1954, Badmin, 2014). The London Clay is richly fossiliferous (Gallois, 1965) and Sheppey is internationally renowned for the quality and diversity of the fossils found on the beach due the rapid erosion of the north coast cliffs. Fossils *in situ* are rare (Davis, 1936).

The topography of Sheppey is predominantly low-lying marsh (generally below 4 metres O.D.; Fig 1), but rises up the approximately west-east trending spine of London Clay to a high point (c. 73 metres O.D.) between Minster and Eastchurch where the London Clay is capped by the Claygate silts and sands and Bagshot sand Beds (Fig. 3) (Holmes, 1981). Prominent outcrops of London Clay also rise above the marsh in the south of the island, forming the Isles of Elmley (c. 12 metres O.D.) and Harty (reaching 27.5m O.D – Fig. 1 - Hutchinson, 1968; Steers, 1981). These are likely to have been isolated islands before alluvial sedimentation infilled the intervening channels and allowed the marshes and mudflats to develop as sea level rose.

The Pleistocene Development of Sheppey

During the early to mid-Pleistocene, when sea levels were considerably lower than they are now, the major rivers in Kent (the proto-Medway and proto-Great Stour) formed part of a large river system that flowed out across what is now the North Sea (D'Olier, 1972, 1975; Bridgland, 1988, 2003; Bridgland & D'Olier, 1995). Although in the Early Pleistocene the Medway was probably independent of the River Thames, by the mid-Pleistocene the proto-Medway probably flowed north to join the River Thames in what is now Essex (Fig. 5a) (Bridgland & D'Olier, 1995; Bridgland, 2003). The migration south and east of the River Thames and its final diversion during the Anglian Glaciation/Cold Stage (MIS12, about 450ka) shortened the Medway by about 50km (Bridgland & D'Olier, 1995; Bridgland 2003). Sheppey at this time will probably have been part of an interfluve between the proto-Medway and the proto-Swale (Fig. 5b). Over the next 400ka the River Thames continued to migrate south and east.

The intricate pattern of the buried offshore contours (D'Olier, 1972, 1975; Bridgland & D'Olier, 1995) indicates that there were probably 3 north-east flowing rivers in Kent: the proto-Medway in the west, the proto-Swale and the proto-Great Stour in the east (Fig. 5c). Each was a tributary of the Thames, which flowed east after being joined by the proto-Medway, roughly parallel with the present coast of Sheppey. It was then joined by the proto-Swale from the southwest which may have been influential in turning the Thames sharply to the northeast where it was eventually joined by the proto-Great Stour and its tributaries, which during the Pleistocene drained north from the Wantsum Channel (Fig. 5c) (D'Olier, 1975).

Fig.4 (a) The London Clay of the north cliffs of Sheppey; (b) The eroding cliffs at Warden Point.

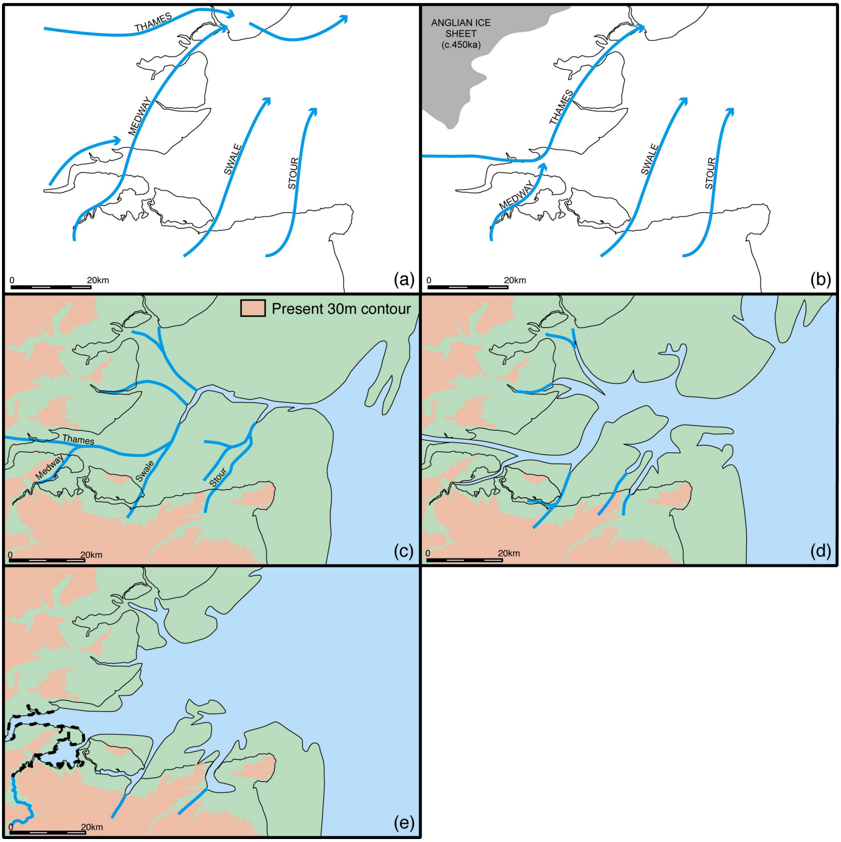

Fig. 5. The river system of South East England (a) just prior to the Anglian ice advance; (b) The Anglian diversion of the River Thames (after Bridgland, 2003); (c) 10,000 BP – Sea level -45 to -40m OD; (d) 9,000-8,600 BP – Sea level -30 to -28m OD; (e) 8,000 BP – Sea level -18m OD.

Since the end of the last ice age (c.11,500 BP - Before Present), the geomorphology of the north Kent coast has been radically modified by generally rising sea levels. Approximately 10,000 years ago, sea level was 40 to 45 metres below the present (D'Olier, 1972; Devoy, 1979) and a land bridge existed between southeast England and Europe (D'Olier, 1972; Bridgland & D'Olier, 1995). What is now the Isle of Sheppey was probably part of the interfluve between the western-most of these (Bridgland & D'Olier, 1995). If the topography of the buried offshore contours can be taken to indicate the spatial extent of the river bluff between the Medway and the Swale, then the original size of the Isle of Sheppey was probably double that it is now, extending at least 6-7km northeast from the present coastline

(Fig. 5c) (Bridgland & D'Olier, 1995). As sea level rose, the North Sea flooded and the sea advanced up the River Thames/Medway estuary complex so that by about 9000-8,600BP, when sea level was about -30 to -28 metres O.D. (D'Olier, 1972; McRae & Burnham, 1973; Devoy, 1982), the river Medway must have been tidal (its base being 32m below O.D.)(Fig. 5d). By 8,000BP, with sea level at approximately -18 metres O.D. (Devoy, 1982; Long, 1995), the spur of land that now forms Sheppey may have started to become isolated as the Swale (with a maximum depth of 15 metres) probably began to flood. The coastline is likely to have been similar to today (McRae & Burnham, 1973), if perhaps 6-7km further north (Fig. 5e). This basic morphology was still evident in c. 1840 (Fig. 6).

The drowning of the Thames and Medway valleys resulted in changes to the hydrological processes that were operating. From about 6,000BP, deposition of sediment from both river erosion and erosion of the London Clay coastline led to the infilling of the drowned valley system and the development of tidal mudflats and fragmented salt marshes up to 30 metres thick (Evans, 1953; Gallois, 1965; Kirby, 1990), creating what are now the North Kent Marshes. At that time, the marshes of North Kent were probably almost contiguous with marshes that formed the wetland regions of Essex and Suffolk. Today, the marshes of Sheppey are separated from those of mainland Kent by the Swale, an 18.4km long channel about 3km wide at its eastern end, narrowing to about 300 metres in the west (Fig. 2). In Kent, the marshes must have been reasonably dry by 50-400A.D., since the marsh clay was used by the Romans for pottery and for stock raising (Evans, 1953;

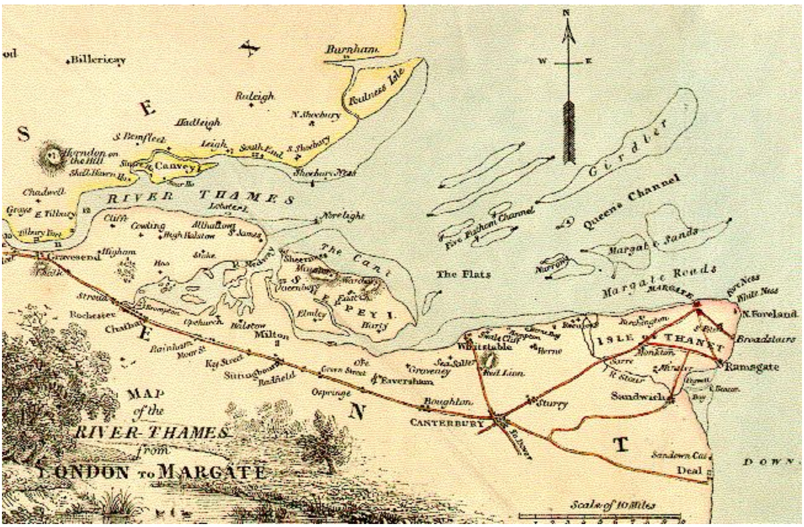

Fig. 6. Sheppey and northern Kent in c.1840 (Mapmaker unknown). (http://img.tfd.com/wiki/b/b9/Map_of_the_River_Thames_downstream_from_London_1840.jpg).

Coleman & Lukehurst, 1967). The continual rise of sea level, however, caused numerous marine incursions, which from 1014 A.D. began to put the human use of the marsh under threat. The consequence was that by the end of the 12th Century, clay embankments started to be constructed on the Medway marshes to protect and reclaim the marsh (Evans, 1953; Kirby, 1990). This 'inning' process was most intense between AD1250-1450, increasing the marsh level by about 3 metres (Kirby, 1990), burying the Romano-Saxon surface near the main Medway channel which was in its present position by at least AD 1600. Over the last 400 years, unusually, marsh accretion has not been able to keep pace with the sea level rise and in the last 200 years the marsh edge has retreated and the tidal flats have lowered by over 2 metres. Unlike modern losses, however, this loss is not due to natural processes, but is due largely to extraction for brick and cement manufacture, which started in 1860 and was at its peak between 1895 and 1905 (Evans, 1953). While digging stopped in 1963, the marsh does not appear to have recovered yet and most current losses are probably natural.

The History of Coastal Instability

Of major importance to the Isle of Sheppey, and a major focus of geomorphological research (Steers, 1964; So, 1966; Hutchinson, 1968; Holmes, 1981, Jones, 1981, Nicholls, Dredge & Wilson, 2000), is the erosion of the London Clay cliffs along the north coast. While the cliffs have been stabilised in the west to protect Minster and in the east to protect Leysdown, between Minster and Warden there is about 7km of actively eroding coast (Fig. 1 & Fig. 4b). These cliffs range from 30 to 46 metres in height and reported average rates of cliff retreat between Sheerness and Herne Bay, where marine undercutting and landslides attack the London Clay, range between 1 to 5 metres per year, although it is recognised that the rate varies over time (Steers, 1953, 1964, 1981; May, 1966; So, 1966; Coleman & Lukehurst, 1967; Hutchinson, 1968; Holmes 1972, 1981; McRae & Burnham, 1973, Jones, 1981; Nicholls, Dredge & Wilson, 2000). Where the London Clay is overlain by the Claygate and Bagshot Beds, springs and cliff-top ponds exist. These can be a major contributor to seepage erosion and landslides along the coast. Where there is active marine erosion at the cliff base, and no coastal sediments for protection, large deep-seated rotational landslides occur, usually involving base failure (Hutchinson, 1968):

> "Considerable portions of the cliff, sometimes half an acre, will slip seawards, carrying intact trees, fences and tracks." (Davis, 1936, p330) (see Fig. 7).

After a slide, the rapid removal of debris by marine action leads to progressive steepening of the cliffs, such as those at Warden Point (Fig. 4), where cliff recession is reported to be up to 3 metres per year (Steers, 1964, 1981; McRae & Burnham, 1973; Badmin, 2014), until slides occur again. This leads to a cyclic

Fig. 7. Rotational slide, Warden Point 2014 (note the pond at the back edge of the slide) © Chris Young.

erosional process which at Warden Point has a period of about 30 to 40 years (Nicholls, Dredge & Wilson, 2000). The seriousness of the loss is demonstrated by Steers (1981) who notes some 42 hectares were lost between Scrapes Gate and Warden Point jetty (a distance of about 10km) between 1865 and 1966. In what has become one of the most frequently reported examples of cliff erosion on the Island, Warden Church in 1769 was over ¼ mile (400 m) from the cliff top (Fig. 8) that engulfed it between 1872-1898 (Holmes, 1972, 1981) – an annual rate of erosion that must have been between 3 to 4 metres a year.

Where the cliff is fronted by saltings and the removal of debris by marine action at the foot has ceased, the London Clay slopes are affected by shallow landslides re-grading over time to a stable angle of approximately 8^{o}, as can be seen on the Isle of Harty (Hutchinson, 1968). Here salt marsh protection, and thus slope degradation, has existed for less time to the south (Fig. 9) and slopes have reached 11.5^{o} – 12.5^{o} compared with the northern margin (Fig. 10), where slopes have re-graded to 8^{o}.

The coastal erosion is significant for Sheppey. Firstly, even erosion rates as low as 1 metre per year are more than sufficient to remove the 6-7km of land that originally formed the 'river bluff' northeast of the present coastline 8000ka. This has left extensive, low gradient (0.5^{o}-2^{o}), foreshore exposures of inter-tidal mudflats 3-500 metres wide (Fig. 11) cut into the London Clay (Nicholls, Dredge

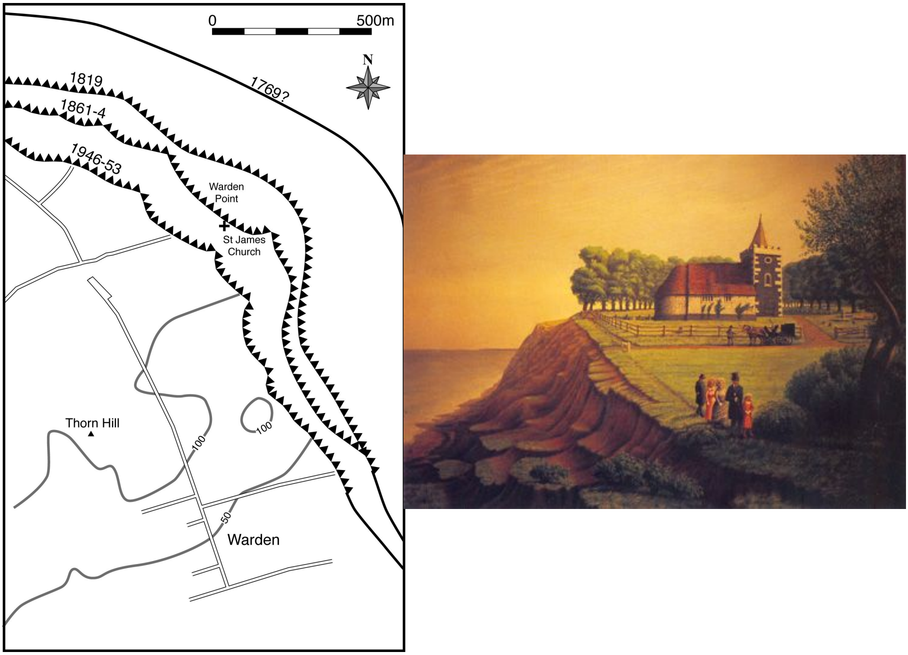

Fig. 8. Erosion at Warden Point, 1769-1953 and the destruction of St James' Church, Warden, in 1876 (Judge, 1997).

& Wilson, 2000). In addition, the erosion has truncated several small north or northeast-flowing streams which cross the London Clay (Holmes, 1981), many of which can be seen as areas of increased erosion.

Secondly, while coastal erosion is obviously important, deposition is also important along the Sheppey coastline. The erosion provided much of the sediment used to build up the North Kent Marshes. Nicholls, Dredge & Wilson (2000) suggest that between 1897 and 1998 somewhere between 450 000 to 500 000 t a^{-1} was added to the system. If this hundred-year period is even closely representative of the last 8000 years, something in the region of 3,600-4000 million tonnes of sediment have become available to the marshes as sea level rose. These marshes now lie up to 4 metres above sea level and are crossed by a network of channels (Fig. 12). Some are only a few metres wide, while others, such as Capel Fleet which once will have isolated the Isle of Harty from the rest of Sheppey, or Windmill Creek which separates Elmley from Sheppey (Steers, 1981, p159), are up to 20 metres across.

In addition, at Warden Point there is a clear sediment transport divide. West of Warden Point (Fig. 1), longshore drift to the west has created a narrow spit at the mouth of the River Medway which Sheerness occupies, while to the of Warden

Fig. 9. Isle of Harty - south: slopes have re-graded to 11.5° –12.5°

Fig. 10. Isle of Harty northern margin: slopes have re-graded to c. 8°

Fig. 11. Inter-tidal mudflats at Leysdown-on-Sea, Sheppey

Fig. 12. The marsh channel network south of the Isle of Harty

Point transport is to the southeast and a small sand, shingle and shell spit has developed at Shell Ness, extending into the mouth of the Swale and backed by marsh developed in the lee of Shell Ness. Here the beach consists of a steep ridge backing the shore platform. Since the proportion of shells in the London Clay is relatively small, the major sediment source must be from offshore. Both spits are important in helping to protect the marsh behind – but will this continue?

What of the Future?

Sea level rise in Sheppey has been slowly accelerating since records began in 1834. From 1834 to 1900 sea level rise averaged about 0.4mm a^{-1}, while from 1900 to 1993 it averaged 2.2mm a^{-1} (Nicholls, Dredge & Wilson, 2000). Globally sea level is predicted to rise, on average, by up to about 0.5m by 2100 (IPCC, 2001, 2007, 2013). However, following the Third Assessment Report from the Intergovernmental Panel on Climate Change (IPCC, 2001), Defra suggested that sea level rises could increase exponentially in future. In south east England the rise could be 4mm a^{-1} between 1990-2025, 8.5mm a^{-1} between 2025-2055; 12mm a^{-1} between 2055-2085 and reaching 15mm a^{-1} between 2085-2115 (Defra, 2006), leading to a rise in sea level of up to 1 metre in the Thames estuary (Lavery & Donovan, 2005; Halcrow, 2010a, b). Predicting the impact of such a rise on the Isle of Sheppey is difficult, but some general points can be made.

In general, increases in sea level are widely regarded to cause several geomorphological responses. As water depths increase, wave height and tidal range increase resulting in an increase in energy at the coast. These are likely to increase coastal erosion, shoreline retreat and coastal squeeze which in low lying areas will increase the likelihood of coastal flooding (Shennan, 1993; Spencer & French, 1993; French, Spencer & Reed, 1995; Shaw *et al*., 1998; Boucher, 1999; Crooks, 2004; Lavery & Donovan, 2005; Goudie, 2013). In the case of the soft sediment cliffs of the north coast of Sheppey, where no coastal protection exists, unless changes are made to the coastal management strategy, sea level rise might be expected to increase basal erosion and cliff-top recession (see Bray & Hooke, 1997), and cause the Mean Low Water (MLW) to retreat. This is certainly consistent with map evidence from 1897-1974 provided for the 1998 Shoreline Management Plan (Halcrow, 1998) which shows that the MLW has retreated more than the cliff-top, suggesting that foreshore steepening has taken place as a result of coastal squeeze. Since the exact response will depend on the coastal management strategy (Leafe *et al*., 1998; Nicholls & Branson, 1998), it is worth noting that the new Shoreline Management Plans (Halcrow, 2010a, b) argue that between Minster slopes and Warden Bay, the unprotected slopes are important habitats and geological exposures, therefore the long term policy is to allow natural cliff retreat with no active intervention (i.e. a 'do nothing' response). While the rates of cliff retreat will depend on the location, the Shoreline Management Plan (Halcrow, 2010a) suggests erosion could be 45 to 180 metres by 2055 and 75 to 300 metres by 2105.

In addition to the changes in sea level it is widely suggested that, even if there is no change in annual precipitation, Global Warming will cause winter rainfall and the frequency of winter storms to increase (Hulme, Hossell & Parry, 1993; Hulme, 1997; Jones, Conway & Briffa, 1997; Wilby, O'Hare & Barnsley, 1997; Hulme & Jenkins, 1998; Collison, Wade & Griffiths, 2000; Marsh, 2001; Environment Agency, 2006). Although not statistically significant yet (Parker, Horton & Alexnder, 2000), there is some evidence from the UK that such changes have started (e.g. Wilby O'Hare & Barnsley, 1997; Conway, 1998). Increasing the frequency of storms will, in the Thames estuary, increase the likelihood of storm surges (e.g. Horner, 1984; Pratt, 1995; Lavery & Donovan, 2005), which will exaggerate increases in wave energy, tide level and the resulting erosion and flooding. Changes in rainfall or storm patterns could also increase the likelihood of landslide activity. While the exact impact on landslide activity is difficult to predict (Jones, 1993; Collison, Wade & Griffiths, 2000), increases in heavy winter rainfall is likely to resulting in an increase in large-scale slope failures on the soft cliffs of the south east (Jones, 1993) such as those of the north coast of Sheppey.

The erosion of the north coast is obviously of concern. However, this erosion could be extremely important for the marshes of south Sheppey. The fine-grained sediment released from the cliffs would probably be transported both offshore and into the Medway and Swale estuaries where it could contribute to the slow vertical sedimentation of the tidal flats and marshes. While rapid increases in sea level could outstrip the ability of marsh sedimentation to keep up, an increased sediment supply may allow the marsh to maintain its elevation relative to sea level (French, 1993; Pethick, 1993; Reed, 1995).

Unfortunately, with rising sea levels, areas where sea defences are in place may be more difficult to maintain. For example, at Minster and Leysdown-on-Sea the policy is to 'hold the line' (Fig. 13 & 14) (Halcrow, 2010a) and this is likely to lead to a narrowing of the coastal zone (Pethick, 1993; Nicholls & Branson, 1998). Over time, it is possible that eventually Minster will be left as an isolated promontory if erosion is allowed to occur to the east and the area of marsh between Minster and Sheerness floods. Here, in particular, the intention to hold the line may be a little ambitious. The marsh on which Sheerness stands could be very difficult to defend, since it will potentially require defences along the whole of the southern margin of Sheppey (Fig. 14).

Similar problems may exist to the east of Sheppey. At Leysdown, the maintenance of fixed flood defences will result in a loss of the intertidal zone and it habitats unless the policy of coastal realignment is put in place (Crooks, 2004; Halcrow, 2010a). At Shell Ness while timber groynes have been used to reduce longshore drift and maintain and protect the shingle beach, as the cliff retreats, these groynes will become less effective, particularly if coastal protection continues to 'hold the line'. This is likely to cause the beach ridge to thin or even migrate landwards across the low lying backshore area. If sea level rise continues to cause coastal squeeze, the Shell Ness spit and the beach ridge will eventually be breached, opening the marsh behind to flooding and erosion. If this happens,

Fig. 13. Holding the line - Coastal zone narrowing is probable where the policy is to 'hold the line' (e.g. Minster, Leysdown to Shellness.)

extensive changes to the Swale are likely as coastal flooding increases (Shennan, 1993). The existing backshore would revert to an inter-tidal area and water ways such as Capel Fleet could be re-opened. Mudflats may erode as channels are widened and since mudflats are important ecologically, this could be a significant / important habitat loss (Pethick, 1993). One of two things may happen.

If the newly-created inter-tidal zone acts as sinks for fine-grained sediment and, if sheltered from wave activity and supplied with sufficient quantities of sediment, the marsh could potentially accrete vertically and Sheppey will not change drastically. However, if this accretion does not take place and if, as has been done in the past, the 5m contour is used as the area of expected risk (Department of the Environment, 1992; Shennan, 1993; Lavery & Donovan, 2005) there is the potential for large parts of the North Kent marshes to be completely flooded and the Isle of Harty and the Isle of Elmley to be separated from the Isle of Sheppey once more (Fig. 14). Sheppey itself would become an island approximately 7km off the north Kent coast.

The geomorphological evolution of Sheppey, with major potential changes in its coastal environment, will almost certainly alter the quality and quantity of associated habitats, and the nature of the ecosystem linkages. It is also likely to increase the vulnerability of wildlife, people and infrastructure (Crooks, 2004,

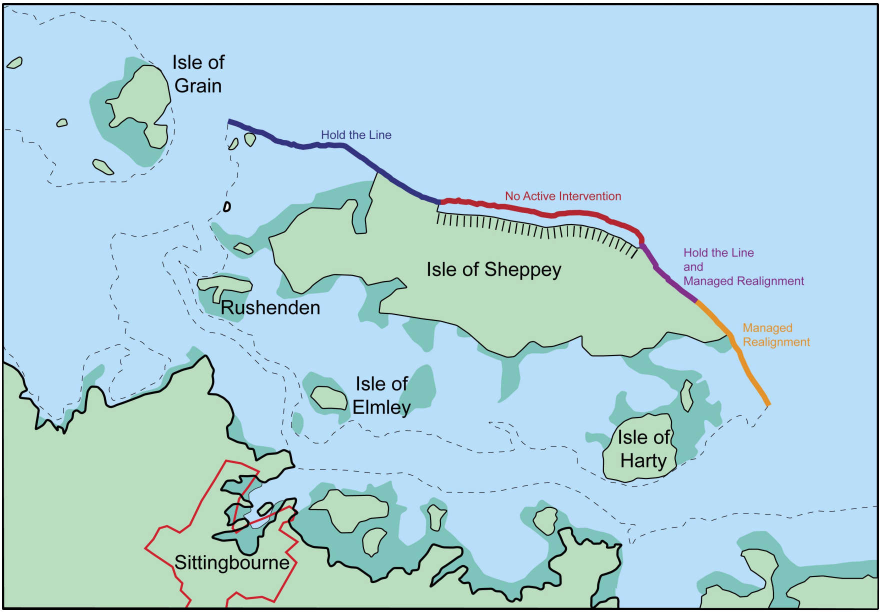

Fig. 14. Is this the future for Sheppey? Beach ridges may be breached, opening the marsh behind to flooding and erosion possibly flooding to the 5m line. The Shoreline Management Plans (2010) are also shown (after Halcrow, 2010).

Stanford, 2014). Changes in water level on the marshes of North Kent, including those of Sheppey, are likely to alter the species composition and to cause vegetation zones to migrate. The effect that this could have on Sheppey's wildlife requires further consideration.

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