Coastal Defence Sefton Council

Climate change and the Sefton Coast: Implications for coastal geomorphology.

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Executive Summary

This document is aimed at highlighting some of the potential impacts to the Sefton Coast of the predicted climate changes. The document is by no means fully comprehensive but tries to compile information from a number of relevant reports and to present it in an informative manner and doesn't attempt to quantify the impacts. This report focuses on the physical aspects of the coast and not the biological and ecological aspects.

Introduction

The earth's climate is constantly changing, however, some of the changes seen during the latter part of the twentieth century cannot be explained by natural variations alone. Box 1 highlights some of the recent changes to the UK climate. The climate for the next 30-40 years has more or less already been determined (UKCIP, 2006b) due to a time lag in the response of the global climate system to change. This time delay inherent in the atmosphere and oceans means that reducing global greenhouse-gas emissions now could play an important role in mitigating against climate change in the second half of the 21st century. However, the action needs to be taken now to achieve this.

BOX 1. Summary of recent changes in North West (or UK) Climate

- Average mean temperatures have risen by 0.4°C at Manchester Airport between 1988 and 1997 when compared to the 1961-1990 average. This equates to 2.65°C over a century (SNW, 1998).
- Globally the 1990's were the warmest decade in the last century, with 1998 being the hottest year on record and 2001 the third hottest (UKCIP, 2002).
- The thermal growing season for plants in central England has lengthened by about one month since 1900 (UKCIP, 2002).
- Seasonal rainfall has varied by as much as 15% from the average in the last 30 years (SNW, 1998).
- A decrease in summer rainfall during the last century of up to 20% (SNW, 1998).
- Increases in high intensity winter rainfall have been experienced since the 1960's (SNW, 1998).
- An increase in flooding of some major rivers in the region in the last few decades (SNW, 1998).
- Sea level around Liverpool has risen by about 6cm in the last 50 years (SNW, 1998), over the last 100 years the UK average has risen by about 10cm (UKCIP, 2002).

The UK Climate Impacts Programme (www.ukcip.org.uk) has produced a series of potential climate change scenarios based on four different global emission rates: Low; Medium low; Medium high and High, that run until the 2080s, Box 2 shows some of the predicted changes to the Northwest's climate. However, there are a large number of uncertainties associated with predicting the outcomes of the scenarios. There are three main uncertainties relating to the emissions and scientific understanding. It is unknown how the global emission patterns will continue in the rest of this century. Scientific knowledge and modelling about the sensitivity of how the global climate will continue to react and change has its limits and any natural variation in the climate systems could significantly alter any predicted outcomes. These limitations must be fully appreciated before any plan or policies are made. A more detailed description of the uncertainties is available on the UKCIP website at:
http://www.ukcip.org.uk/scenarios/guidance/uncertainty.asp

BOX 2. Summary of predicted changes to the North West (or UK) Climate.

- The warming in the North West varies between 0.7°C and 2.1°C by the 2050's (Holman *et al*, 2002) when compared to the 1961-1990 average. Average annual temperatures across the UK may rise by between 2ºC and 3.5ºC by the 2080s, depending on the scenario (UKCIP, 2002).
- There may be more warming in summer and autumn than in winter and spring (UKCIP, 2002).
- A small increase in annual rainfall of 3-4% is predicted but winters will become wetter than at present by between 10 and 35 % whilst the summers may become drier (UKCIP, 2002).
- By the 2080s across the UK snowfall amounts will decrease by between 50 and 90% (UKCIP, 2002).
- More depressions may cross the UK in winter which could lead to stronger winds especially across the central and southern part of the country. However, predictions for changes in wind are very uncertain and must be treated with caution (UKCIP, 2002).
- The contrast between winter and summer climate will increase for all scenarios. Winters will become wetter and summers may become drier (UKCIP, 2002).
- Sea level rise predictions give a change of 7 and 36 cm by the 2050s, and by between 9 and 69 cm by the 2080s (UKCIP, 2002).
- Extreme sea levels, occurring through combinations of high tides, sea-level rise and changes in winds, may be experienced more frequently in many coastal locations (UKCIP, 2002).

The Sefton Coast

The Sefton Coast is a dynamic coastline which has always changed and will continue to change due to the influences of the forcing factors such as the wind, waves, tides, currents and human impacts. Regardless of climate change the coast will continue to change as it attempts to reach a state of equilibrium.

Summary of potential impacts of climate change on the Sefton Coast

Beaches and mudflats

Beaches and mudflats may be re-shaped and eroded (SNW, 1998) due to predicted increases in sea level and increases in winter depressions potentially causing more storms. This may also lead to a change in the sediment composition of the foreshore with muddier areas potentially becoming sandier due to changing energy regimes; this in turn may exclude certain species whilst becoming more favourable to other species (Cook and Harrison, 2001).

Sand dunes

There are likely to be several significant impacts on the dunes. Sea level rise will cause more erosion of the dunes as the tide will rise higher and impact more frequently on the frontal dunes. The consequence of this is that the dunes will roll back releasing sediment onto the beach. This landward realignment could be intensified due to increased wave energy and frequency impacting on the dunes due to the potential increase in winter depressions (storms) (UKCIP, 2002).

There are likely to be several physical changes within the dune system as well. Changing precipitation patterns will affect the level of groundwater within the dunes and availability of water will alter. A potentially lower water table could lead to large blowouts developing and increased mobilisation of sand.

Salt marsh

Sea level rise will cause more erosion of the marsh and the tide will rise higher and impact more frequently on the frontal marshes. The marsh will also be flooded for longer. The consequence of this is that the vegetation will change (Holman *et al*, 2002) and the marsh will realign landward with the loss of the front edge of the marsh. This realignment isn't a problem except where the back of the marsh has been fixed by development.

Sea walls

The areas of coast that are fixed by sea walls, Crosby and Southport, will see a different type of reaction to climate change. The changes to the beaches are likely to remain fairly similar to those of the other beaches across the coast. However, the standard of service of the sea wall is likely to decrease. This means that there are likely to be more overtopping events due to increased sea level and increased storminess. Overtopping is when water comes over the top of the structure but the structure itself has not failed. E.g. waves splashing over the sea wall.

Conclusions

There are clearly a large number of potential consequences to climate change that have a differing degrees of likelihood associated with them. One thing we can be sure of is that there is going to be change as a result of climate change. One of the most likely changes is the increase in sea level rise which could significantly alter the topography of the coastline. This is likely to include a landward realignment of the coastal dunes and the salt marsh. Where the coast is backed by hard defences there is likely to be an increased frequency of over-topping.

These changes to the physical dynamics of the coast will have a knock on effect on the species and communities of the coastal system. The most obvious would be habitat loss.

Way Forward

It is essential that the threat of climate change be taken into account in any future works on the Sefton Coast. Developing an adaptable and sustainable approach to planning and management on the coast will reduce spend and prevent future problems from occurring due to inappropriate planning and management decisions being made.

The continued monitoring of the coastal processes and the response of the geomorphological aspects of the coast will be critical to ascertain the scale and rates of change. Analysis of this data will be used to aid the predictions of the future evolution of the coastline. Coupled with this information will be the continued development of the Sefton Coast Database, which will compile data, both historic and modern, and analyse this information to improve our understanding of the Sefton coastal system, thus further increasing our ability to refine the predictions of the future evolution of the coast.

Climate change will be incorporated into coastal defence policy when the second round of Shoreline Management Plans (SMP) are developed, this process is due to begin in 2008. The SMP will develop strategic policy options looking up to 100years into the future.

Work has begun on quantifying the changes to the coastal defences along the Sefton Coast that may occur as a result of climate change. Projects identified include predictions for changes to the sand dunes and assessing the amount of overtopping of hard defences. A report for assessing Southport's hard defences is available at www.sefton.gov.uk/page&4606 .

Contents

1. Introduction

This report aims to highlight some of the potential impacts of predicted climate change on the Sefton Coast. The report is by no means fully comprehensive but tries to compile information from a number of relevant reports. The main focus for the report will relate to potential changes to the geomorphology of the coast.

2. Background

2.1 Sefton Coast

The Sefton Coast (Figure 1), which extends over 34 kilometres (21 miles), is comprised of soft and granular estuary deposits of sand, silt, clay and peat. There are no outcrops of rock on the shoreline. Hence, the forces of nature readily mould it, so the shoreline is constantly changing in response to the fluctuating influence of wind and water and as a result of human activity. Its overall shape derives from two major river estuaries, the Mersey and the Ribble. Two other much smaller rivers, the Alt and Crossens, each have important local zones of secondary influence.

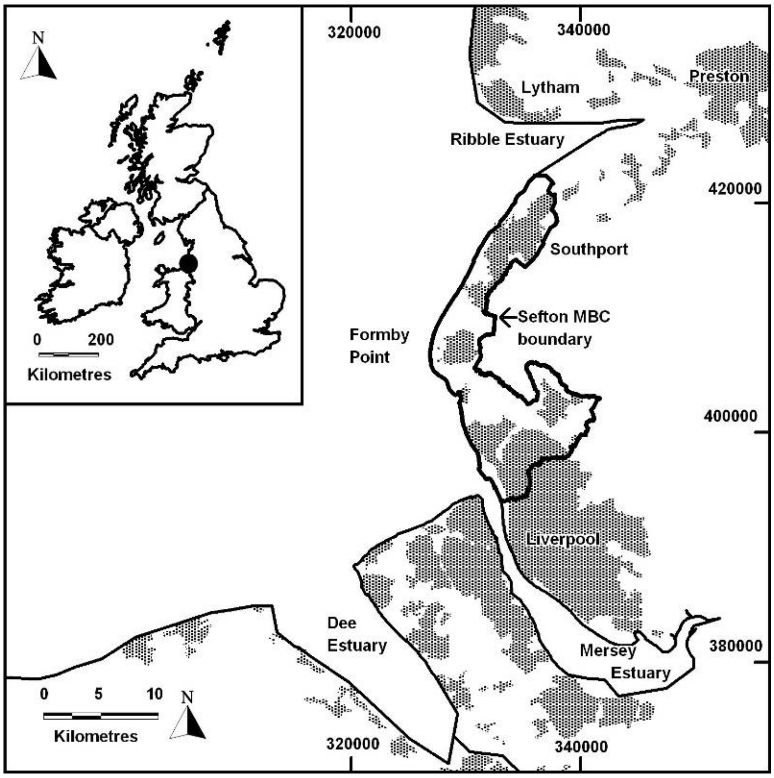

Figure 1. Sefton Coast location plan © Crown Copyright.

The coast is a long, wide arc of sand, with a hindshore dune system, which at one time would have stretched from the Mersey Estuary to the Ribble Estuary (Figure 2). Human use of the dune system over several centuries has created a dune landscape of great variety. Several towns have developed along the coast and at Crosby, to the south, and Southport, to the north, artificial defences have been put in place.

The sand dunes, beaches and marshes of the Sefton Coast are one of the most important areas for nature conservation in Europe. The Sefton Coast is also an important visitor destination with popular bathing beaches, open countryside, and the seaside resort of Southport.

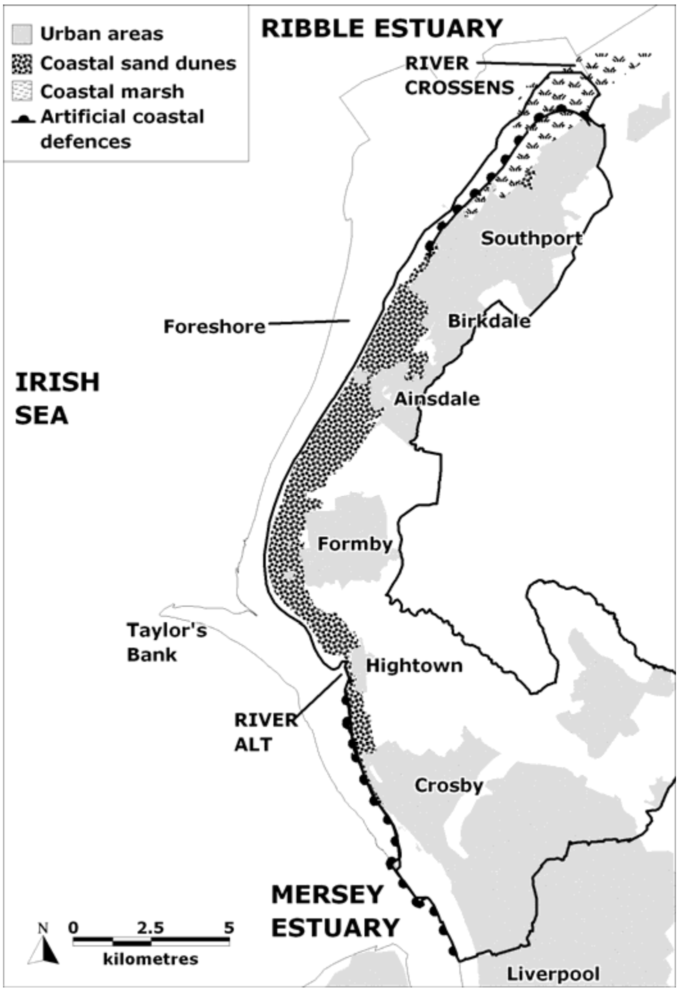

Figure 2. Generalised Sefton Coast landscape type.
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2.2 Background to climate change

The earth's climate is in a constant state of change; however, some of the changes seen during the latter part of the twentieth century cannot be explained by natural variations alone (UKCIP, 2002). Mankind is impacting on the climate through the combustion of fossil fuels, emissions of other green house gases and urbanisation to name but a few. Reducing global greenhouse-gas emissions could play an important role in mitigating climate change in the second half of the century. However, the time delay inherent in the atmosphere and oceans means that action needs to be taken now to achieve that.

3. The Global response to Climate Change

Recognizing the problem of potential global climate change the Intergovernmental Panel on Climate Change (IPCC) was established in 1988 to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation (IPCC, 2006). The IPCC has so far produced three assessment reports looking at the global climate change perspective. These reports have been taken forward by the UK Climate Impacts Programme (UKCIP) to produce a more detailed assessment of the potential impacts to the UK Climate.

The UKCIP has produced a series of potential climate change scenarios based on four different global emission rates: Low; Medium low; Medium high and High, initially in 1998 and updated in 2002. These predictions run until the 2080s. However, there are a large number of uncertainties associated with predicting the outcomes of the scenarios.

4. Uncertainty in predictions of future climate changes

Before any decisions can be made based on the climate change predictions it is necessary to understand the limitations inherent in them. There are three main areas of uncertainty associated with them; firstly emissions uncertainty; secondly modelling uncertainty; and thirdly natural climatic variability. The amount of emissions uncertainty is relatively small associated with climate change impacts up to around 2040's. It is noticeable that the warming until around 2040 is very similar across all four UKCIP02 scenarios. This is mainly due to the considerable time delay of the climate system; much of the warming over the next few decades is already built into the climate system due to past and current emissions (UKCIP, 2006a). However, beyond this time, the emissions uncertainty increases rapidly with the UKCIP02 results giving only an indication of the range of possible climate futures (UKCIP, 2006a). A more detailed description of the uncertainties is available on the UKCIP website at: http://www.ukcip.org.uk/scenarios/guidance/uncertainty.asp

Emissions Uncertainties- It is unknown how society will react to the threat of climate change and consequentially how the patterns of greenhouse gas emissions will develop. As a result the climate prediction models are based on four different emissions scenarios ranging from low emissions through to high emissions to compensate for this. Depending upon how society reacts can give significantly different results. How technology and energy use will change in the future, which could also impact on the rates of greenhouse gas emissions, is also unknown.

Modelling Uncertainty- The immense complexity and chaotic nature of the global climate is difficult to replicate in a computer model. It is likely that some of the interactions are not yet know or fully understood. Different global climate models represent the ocean-atmosphere system and its many interactions and feedbacks in different ways. Each model has a different structure and each model contains different representations of important climate processes such as clouds, ocean eddies and soil moisture. Each model will therefore simulate a different global climate change and a different regional response even when forced by an identical emissions scenario (UKCIP, 2006a). Basically if you put the same variables into different models you will end up with a range of possible outcomes.

Natural Climatic Variations**-** There are also issues relating to the natural variation of the climate. The climate varies naturally on a wide range of timescales, at any given point in time the natural variations may either add or subtract from any man made climate change (Handley Centre, 2004)**.** The UKCIP predictions ran the model several times but starting with different initial conditions. The outputs of these models were averaged to produce a single output for each emission scenario.

5. Recent changes in the North West and UK Climate

The earth's climate has been changing since it first came into being. The climate varies on a number of scales both spatially and temporally. However, some of the changes to the climate seen during the latter part of the twentieth century cannot be explained by natural variations alone. There is now clear evidence that humans are having an impact on the earth's climate. A summary of the changes for North West England is show in box 1.

BOX 1. Recent changes to the North West Climate

- Average mean temperatures have risen by 0.4^{o}C at Manchester Airport between 1988 and 1997 when compared to the 1961-1990 average. This equates to 2.65^{o}C over a century (SNW, 1998).
- Globally the 1990's were the warmest decade in the last century, with 1998 being the hottest year on record and 2001 the third hottest (UKCIP, 2002).
- The thermal growing season for plants in central England has lengthened by about one month since 1900 (UKCIP, 2002).
- Seasonal rainfall has varied as much as 15% from the average in the last 30 years (SNW, 1998).
- A decrease in Summer rainfall during the 20th century of up to 20% (SNW, 1998).
- Increases in high intensity winter rainfall have been experienced since the 1960's (SNW, 1998).
- An increase in flooding of some major rivers in the region in the last few decades (SNW, 1998).
- Sea level around Liverpool has risen by about 6cm in the last 50 years (SNW, 1998), over the last 100 years the UK average has risen by about 10cm (UKCIP, 2002).
- There is now strong evidence of a human-induced warming in the world's oceans approximately 84% of the total heating of the Earth system over the last 40 years has been absorbed by the oceans (Barnett *et al*, 2005).

6. Climate change predictions

Using the UKCIP scenarios a number of predictions of how different aspects of the climate may change in response to climate change have been made, a summary of these, for the northwest, are shown below in table 1. More detailed descriptions of the predicted changes are made in the subsequent text.

	2020s (2011-2040)	**2050s (2041-2070)**	**2080s (2071-2100)**
Change in average annual temperature	0 to 1°C	1 to 3°C	1 to 5°C
Change in maximum summer temperature	0 to 2°C	1 to 4°C	2 to 6°C
Change in summer rainfall	0 to 20% decrease	10 to 30% decrease	10 to 60% decrease
Change in winter rainfall	0 to 10% increase	0 to 20% increase	0 to 30% increase
Change in annual snowfall	10 to 30% decrease	30 to 60% decrease	40 to 100% decrease
Change in summer and autumn soil moisture content	Not available	Not available	20 to 50% decrease
Change in sea level	4 to 14cm	7 to 36cm	9 to 69cm

Table 1. Summary of climate changes to the North West (Glynn, 2005) – Sea level from UKCIP, 2002.

6.1 Temperature

It is widely accepted that global temperatures are changing as a result of human induced climate change. The rates of change vary from day to night, from place to place and from season to season.

The effects temperature changes could have are wide ranging, most obviously on seasonal temperatures and flora and fauna but will also affect wider aspects of the physical dynamics of the coast. The following list is a summary of some of the key changes.

- Average annual temperatures across the UK may rise by between 2°C and 3.5°C by the 2080s, depending on the scenario (UKCIP, 2002). For the North West the change is more variable from 1° to 5°C (Glynn, 2005).
- There may be more warming in summer and autumn than in winter and spring (UKCIP, 2002).

- The temperature of UK coastal waters will increase, although not as rapidly as over land, with the greatest warming in the south of the UK (UKCIP, 2002).
- The UK's thermal growing season for plants is now longer than at any time since the start of the record in 1772 by about one month (UKCIP, 2002).
- By the 2050s, typical spring temperatures may occur between one and three weeks earlier than at present and the onset of present winter temperatures may be delayed by between one and three weeks (UKCIP, 2002).

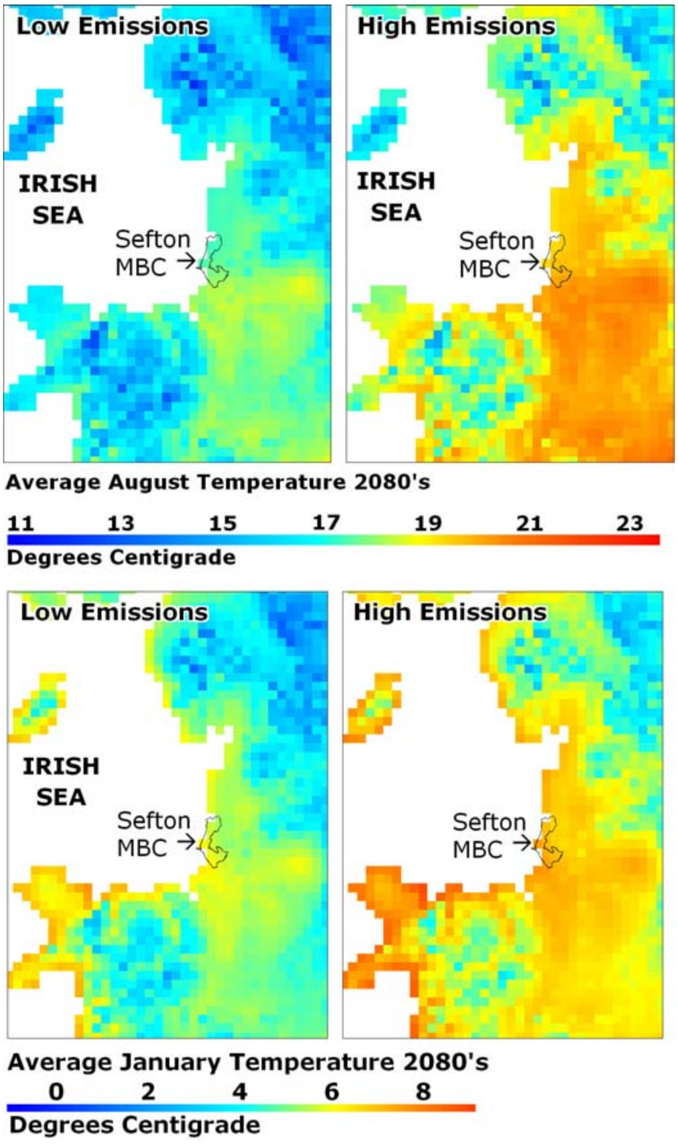

Figure 3 Top- Average August temperatures in the 2080s under the low and high emissions scenario for the North West UK. The images show a difference of 1.5°C and 3°C between the scenarios.

Bottom- Average January temperatures in the 2080s under the low and high emissions scenario for the North West UK. The images show a difference of 1.5°C and 3°C between the scenarios.

6.2 Precipitation

The predictions show little change in the annual average rainfall, however, there are significant changes to the seasonal and location of rainfall (McEnvoy, 2005). In the Northwest by the 2050s, average summer precipitation is likely to decrease by between 10-30% and by 30%-50% by the 2080s. Winter precipitation is expected to increase, with a 10-30% increase by the 2080s (McEnvoy, 2005). As the winters become wetter and the summers become drier, there will be a greater contrast between summer and winter seasons. (McEnvoy, 2005). The winter precipitation is likely to fall in heavy bursts more frequently (UKCIP, 2002).

Under all scenarios, snowfall is set to decrease over time. Even under the low scenario average snowfall could decrease by 10–30% by the 2020s, becoming a 30 - 40% decrease by the 2050s. In the high scenario case, a 50-60% decline by the 2050s is expected. Large areas of the UK will experience long periods of snowless winters by the 2080s (McEnvoy, 2005).

Linked to both precipitation and temperature the whole country experiences a decrease in average soil moisture, with the highest summer reductions of 40% or more by the 2080s, occurring in the high emissions scenario. In winter, by the 2080s for the high emissions scenario, a decrease of up to 10% over England is expected, in spite of increased winter precipitation over England.

6.3 Wind

The North Atlantic Oscillation is a strong climatic influence on the UK winter climate and it is thought that winter depressions will become more frequent, with the UK subject to more wet, windy and mild weather in winter months (McEnvoy, 2005). Stronger winds in southern and central Britain are also predicted (UKCIP, 2002). However, the climate models do not produce consistent estimates of wind speed changes (UKCIP, 2002).

6.4 Sea Level Rise

Sea level rise could be one of the most apparent and significant impacts of climate change to the Sefton Coast having effects on the physical structure of the coastline, increased frequency of tidal flooding and knock on consequences to local communities and tourism.

The predictions of sea level change can be complicated due to the Glacial Isostatic Adjustment (GIA), which is the response of the land to the weight of the glaciers, from the last ice age, being removed. However, Sefton experiences almost zero GIA (UKCIP, 2005); thus any recorded changes in sea level are clear reflection of sea level rise. Table 2 shows the predicted sea level rise for the North West.

	Low Emissions			High Emissions		
Year of Prediction	2020s	2050s	2080s	2020s	2050s	2080s
Net sea level change (cm)	4	7	9	14	36	69

Table 2 Predicted sea level rise of the North West (UKCIP, 2002)

Defra has since issued supplementary guidance to authorities responsible for flood and coastal defence on climate change impacts (Defra, 2006). These new guidelines give a rate of sea level rise for each time band (Table 3).

Administrative or Devolved Region	***Assumed Vertical Land Movement (mm/yr)***	Net sea level rise (mm/yr)				***Previous allowances***
		1990-2025	***2025-2055***	***2055-2085***	***2085-2115***	
NW England, NE England, Scotland	+0.8	2.5	7.0	10.0	13.0	4 mm/yr* constant

*Updated figures now reflect an exponential curve, and replaces the previous straight line graph representations.

Table 3 Defra supplementary guidance on sea level rise.

7 Impacts of climate change on the Sefton Coast

This section describes in broad terms some of the potential impacts climate change will have on particular features of the Sefton Coast. These descriptions are by no means fully comprehensive but focus on the key changes that could affect the coastal defence function and the key habitats of the coast. Each section begins with a brief description of the feature, then the details of climate change impacts and finishes with potential ways forward.

7.1 Sand Dunes

The sand dunes on the Sefton Coast are one of the largest areas of dunes in Britain. They stretch for approximately 17km and cover 2100ha and are protected with local, national and European conservation designations. The dunes provide a vital coastal defence function and protect the towns of Formby, Ainsdale and Birkdale as well as the low-lying hinterland of farmland.

The sand dunes are a very dynamic landform and habitat. They are principle made of sand gains that are generally non cohesive (i.e. don't stick together), only becoming slightly cohesive when they are wet. Due to this mobile nature of the sand, the dunes are readily moulded by physical processes such as the tide, waves and wind. The amount of energy these processes have is reflected in the structure of the beach and dunes. The dunes, especially the frontal dunes, are constantly fluctuating in response to changes in the physical processes. The dunes along the Sefton Coast have seen periods of rapid accretion and erosion as well as quieter periods of change. The dunes at Formby Point have been very mobile over the last century and half, up to the early 1900's the dunes had accreted by several hundred metres. After the early 1900's the process reversed and the dunes began eroding. This process of erosion is still continuing at about 4m per year. Both accretion and erosion are natural dune processes, however, they are often given a positive or negative bias due to the way mankind interacts with the coast.

Due to the nature of a soft coast it will readily respond to any changes in the physical processes that affect it. It is clear that there will be several significant changes to the dune system as climate change affects these physical processes. The most significant effect is likely to be as a result of sea level rise which will cause a retreat of the dunes, as will increased storminess although we are not in a position to quantify this yet. What is also apparent is the difficulties in predicting how the coast will respond to the variety of potential changes, for example the impact of changes in rainfall upon the groundwater will have an impact on the geomorphology of the dunes but because of the interaction with soil and plant development this is currently to complex to assess. Box 2 provides more details of the predicted changes and their effects on the dunes

It is crucial to regularly monitor the position and condition of the frontal dunes to ensure the coastal defence function is maintained. It would also be beneficial to better understand the relationship between the beach and dunes and this may provide an early warning system of potential changes to the patterns of accretion and erosion.

Box 2. Potential impacts to Sand dunes

- Changes to evaporation rates could affect the amount of dry sand on the foreshore and consequently the amount available to be blown into the dunes.
- Changes in species composition may occur due to increases in temperature with species migrating in a northerly direction. This could see species with a more northerly distribution losing out whilst species with a southerly distribution becoming more common.
- Earlier and longer growing seasons are likely to occur (UKCIP, 2002) but the increased likelihood of extreme summer temperatures (UKCIP, 2002) may increase stress on vegetation during the summer.
- With increased summer temperatures and longer sunshine hours there are likely to be more people visits to the coast. The increased visits could, however, negatively impact on the fragile frontal dunes and increase the erosion and amount of mobile sand if not correctly managed (McEvoy *et al*, 2006).
- Changes in the rainfall patterns could significantly affect the groundwater table and thus dune slacks and the species reliant upon them. It is likely that the water table will have an increased variability both within and between seasons and possibly for long periods it could be 1m lower than at present. However, there could also be occasions with a very high water table but becoming less frequent. The groundwater table in the dunes is vital for many plant species and wet slack habitats.
- With predicted increases in heavy winter rain events there could be more localised flooding.
- With lower rainfall in summer the foreshore and dunes will become drier making more sand available to be blown into the dune system.
- Similarly to changes in temperature, changes in rainfall could alter species composition in the dunes, with more drought tolerant species becoming dominant.
- Linked to both rainfall and temperature the reduced availability of soil moisture in the dunes could create a more stressful environment for vegetation.
- Rising sea levels could cause a landward realignment of the sand dunes (Cook and Harrison, 2001). Under all climate change scenarios coastal erosion will increase (Office of Science and Technology, 2004). Coastal squeeze could be a problem for the sand dunes in certain areas.
- Rising sea levels could potentially alter sediment supplies and process patterns by changing estuary dynamics (Cook and Harrison, 2001).
- An increase frequency of storm events could have significant impacts on sand dunes (Cook and Harrison, 2001) by preventing the sand dunes recovering sufficiently between the events and increasing rates of erosion.

7.2 Salt Marshes

The main area of salt marsh along the Sefton Coast is located in the mouth of the Ribble estuary to the north of Southport there are also small areas around Birkdale and the mouth of the River Alt at Hightown. The marshes are protected by a number of local, national and European designations. Many of the implications of climate change impacts that apply to sand dunes also apply to salt marsh.

Salt marshes are almost flat areas of the intertidal area that are comprised of fine sediment that supports plants and animals that are very tolerant to the extreme conditions that are present there. Salt marshes are important areas for sea defence and as they significantly reduce the wave energy that passes over them.

Salt marshes form in the landward area of the intertidal zone that is only covered by the sea for relatively short periods of time at high tide, and is uncovered for the majority of the tidal cycle. Marshes form in relatively low energy environments where fine sediments can deposit. Changes to the amount of energy coming into the system will affect deposition rates. They are very slow growing habitats.

As with the changes to the sand dunes the salt marsh is dependent on the forcing factors for its pattern of evolution. Again sea level rise and increased storminess are likely to have a significant impact on the position of the salt marsh and cause a land ward retreat of the marsh edge. The increased sea water inundation will also affect the plant community distribution across the marsh; again a landward retreat of the communities is likely. The other predictions of climate change are likely to impact more on the vegetation and soil development which is closely linked to the development of the extent of the saltmarsh. Box 3 provides more details of the predicted changes and their effects on the salt marsh.

Box 3. Potential impacts to Salt marshes

- Changes to evaporation rates that could affect the amount of moisture maintained in the marsh and dry it more often creating a more stressful environment for vegetation.
- Changes in species composition may occur with species migrating in a northerly direction. This could see species with a more northerly distribution losing out whilst species with a southerly distribution becoming more common. It is predicted that salt marsh grass will begin to lose climatic space, this loss is more evident on the East coast with the areas of loss extending from the Thames to the Humber (Cook and Harrison, 2001). However, it is expected that sea purslane will increase its range (Cook and Harrison, 2001).
- Earlier and longer growing seasons are likely to occur (UKCIP, 2002) but the increased likelihood of extreme summer temperatures (UKCIP, 2002) may increase stress on vegetation during the summer.
- With predicted increase heavy winter rain events there could be more localised flooding.
- Similarly to changes in temperature, changes in rainfall could alter species composition in the marsh, with more drought tolerant species becoming more established.
- Rising sea levels could cause a landward realignment of the salt marsh (Cook and Harrison, 2001). Under all climate change scenarios coastal erosion will increase (Office of Science and Technology, 2004). Coastal squeeze could be a problem for the salt marsh in certain areas.
- The more frequent flooding of the marsh could lead to changes in species composition with more salt tolerant species becoming dominant.
- Potentially alter sediment supplies by changing estuary dynamics (Cook and Harrison, 2001).
- An increase frequency of storm events could have significant negative impacts on salt marsh (Cook and Harrison, 2001) by preventing the salt marsh recovering sufficiently between the events and increasing rates of erosion.

7.3 Beaches and mudflats

The foreshore on the Sefton Coast is dominated by sand along most of its length that only becomes progressively muddier as it approaches the Ribble Estuary. Some small localised areas of muddier deposits also occur at other sites across the coast. The foreshore at Crosby is restricted in width due to the sea wall on the landward side and the trained river channel on the other. North of the Alt estuary the foreshore is continuous up to the Ribble Estuary. To the north of the Alt Estuary is a large sand bank called Taylors Bank. Just to the north the shore is at it narrowest in the section at Formby, where the coast is eroding, and gradually widens up to the Ribble Estuary.

Beaches and mudflats are an integral part of the coastal defences on the shore. They act as buffers to wave energy absorbing large amount of energy before it can impact on the coastal defence structures (Carter, 1999). The beach and mudflats respond rapidly to changes in the forcing factors and studying the change can assist in predicting coastal change (Carter, 1999).

Changes to the beach will be less obvious to the eye as there are no obvious features on the beach to compare against. There will, however, be a number of changes to the beach gradient and sediment composition. With increased sea level rise more energy will be transferred onto the beach. This will result in more sorting of sediments and potentially a coarsening of the sediments, this could result in a reduction of the muddy areas of the coast. Monitoring of changes in the beach sediments and topography could be used to identify the onset of erosion. Box 4 provides more details of the predicted changes and their effects on the beaches and mudflats.

Box 4 Potential impacts to beaches and mudflats

- Changes in species composition of the intertidal flora and fauna may occur with species migrating in a northerly direction. This could see species with a more northerly distribution losing out whilst species with a southerly distribution becoming more common. This could have a knock on effect on other species that feed on the foreshore.
- With predicted increase in heavy winter rain events there could be more localised flooding and scouring from run off.
- Linked to both rainfall, temperature and sea level rise there is the potential for the amount of interstitial water (the water that occupies the space between grains of sediment) to change and the salinity of this water to be altered, which could again affect the species composition within the sand and mud.
- Rising sea levels could increase the amount of energy coming onto the shore. This could alter the steepness of the foreshore and sediment composition. A higher energy environment would see less deposition of finer sediments, this could lead to mud flats becoming sandier and the sand on the beaches becoming coarser. This in turn could affect wader species with those favouring mudflats such as redshank and dunlin reducing whilst other such as oystercatcher increasing (Cook and Harrison, 2001).
- Potentially alter sediment supply by changing coastal and estuary dynamics (Cook and Harrison, 2001).
- Could deprive sand dunes of wind blown sand as the rising sea water floods more of the beaches and reduces the amount of time that the beaches are exposed to the air (Cook and Harrison, 2001).
- An increase frequency of storm events could cause more redistribution of sediment across the shore and more significant changes in the foreshore topography.

7.4 Hard defences

Both Southport and Crosby are protected from tidal flooding and erosion by hard, impermeable defences. They are predominately made of concrete and vary in design, reflecting on when they were built and the local physical conditions. The current management policy for these areas is to hold the line; this means that the defences will be maintained at their current position.

Sea walls are designed to a specific standard of service, this means that they will defend against the sea under a certain range of conditions. Normally this equates to a frequency of an extreme or storm event i.e. they will protect against a 1 in 20 years storm; a more extreme event (1 in 21 years or above) will over top the defences. This is where the sea will flood over the defences.

The impacts of climate change will not alter the position of the sea wall but will alter the standard of service. The standard of service is likely to reduce as a result of extreme weather events being predicted to become more common (UKCIP, 2002) and in conjunction with sea level rise will result in more over topping of defences. For example a seawall that would currently be expected to be overtopped once every twenty years may in the future overtop once every five years.

The function of the sea wall is also linked to the condition of the foreshore. However, the predictions for changes to the foreshore are limited in terms of physical structure. One possible change is the steepening of the foreshore which would allow more energy from the waves to impact higher up the shore and possibly onto the sea wall.

8. Conclusions

There are clearly a large number of potential consequences to climate change that have a differing degrees of likelihood associated with them. One thing we can be sure of is that there is going to be change as a result of climate change. One of the most likely changes is the increase in sea level rise which could significantly alter the topography of the coastline. This is likely to include a landward realignment of the coastal dunes and the salt marsh. Where the coast is backed by hard defences there is likely to be an increase frequency of over-topping.

There will also be an impact on the habitats and species found on the Sefton Coast. They will suffer from the loss of extent of habitat as well as all the other potential impacts associated with the climate occurring at their habitat changing.

9. Way Forward

It is essential that the threat of climate change be taken into account in any future works on the Sefton Coast. Developing an adaptable and sustainable approach to planning and management on the coast will reduce spend and prevent future problems from occurring due to inappropriate planning and management decisions being made.

The continued monitoring of the coastal processes and the response of the geomorphological aspects of the coast will be critical to ascertain the scale and rates of change. Analysis of this data will be used to aid the predictions of the future evolution of the coastline. Coupled with this information will be the continued development of the Sefton Coast Database, which will compile data, both historic and modern, and analyse this information to improve our understanding of the Sefton coastal system, thus further increasing our ability to accurately predict the future evolution of the coast.

Climate change will be incorporated into coastal defence policy when the second round of Shoreline Management Plans (SMP) are developed, this process is due to begin in 2008. The SMP will develop strategic policy options looking up to 100years into the future.

The UKCIP are due to produce an updated climate change impacts report in 2008, this and any other relevant reports will be incorporated into any plans and policies developed.

For further information about conserving energy and reducing your impact visit Sefton Council's Energy team at www.sefton.gov.uk/pages&2949

For more information about the UKCIP predictions visit www.ukcip.org.uk

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