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Erosion along the Holderness Coast

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ABSTRACT

Coastal erosion is the process of wearing away material from a coastal profile due to imbalance in the supply and export of material from a certain section along the shore. It takes place in the form of scouring in the foot of the cliffs or dunes or at the sub-tidal foreshore as a result of high waves, high tides and storm surge conditions, and results in coastline retreat along with loss of land due to sediment relocation. This can be a cause of concern for coastal communities, or the coast of an entire nation.

In response to the problem engineers within the field of coastal management have developed various methods that aim to reduce erosion and maintain, restore, or improve specified qualities of coastal ecosystems. Managers and decision makers have been challenged to balance the trade-offs between protection of property and potential loss of landscapes, public access, recreational opportunities, and natural features. England has faced particular challenges within the realm of coastal erosion, the Holderness coastline in particular has borne the brunt of the effects.

This paper will cover the challenges faced along the Holderness Coastline within the field of coastal management and focus on the traditional and emerging techniques used to control erosion while taking into costs, benefits, and environmental impacts of each alternative.

1 INTRODUCTION

Holderness is an area of the East Riding of Yorkshire, on the east coast of England with a population of 312,000 split among several communities. The areas main centres are related to tourism, fisheries, agriculture, energy, and nature and conservation.

The Holderness coastline is positioned between the towns of Flamborough Head and Spurn Head (Figure 1). It has the reputation of having some of the highest rates of coastal erosion in Europe, at 1.5m a year on average which equates to roughly 2 million tons of removed material a year

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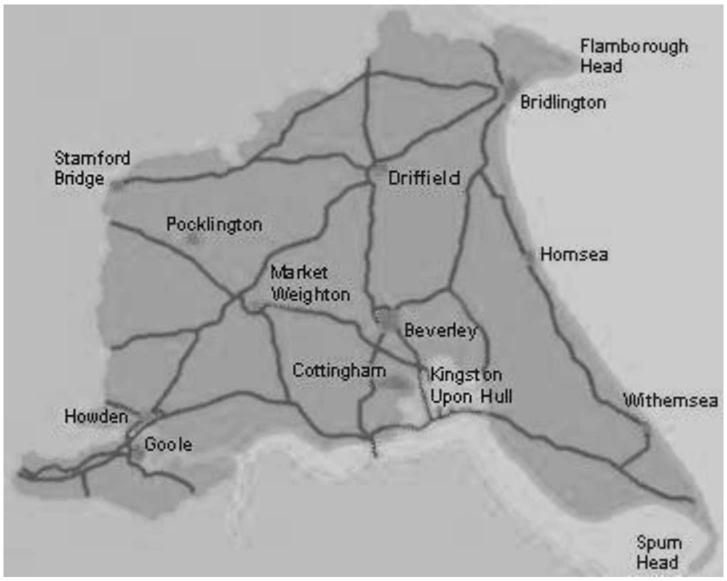

Figure 1: Holderness Coast

Various coastal management techniques have employed to reduce erosion and maintain, restore, or improve specified qualities of coastal ecosystems. Hard defences in the form of a concrete seawall and timber groynes have given some protection. However, one or more such groynes have had a detrimental effect further along the coast.

2 CAUSES OF EROSION

Coastal erosion is usually the result of a combination of factors - both natural and human induced - that operate on different scales. Most important natural factors are: geology, geomorphology, winds and storms, near shore currents, relative sea level rise (a combination of vertical land movement and sea level rise) and slope processes. Human induced factors of coastal erosion include: coastal engineering, river works (especially construction of dams), dredging, vegetation clearing, gas mining and water extraction.

2.1 Natural Processes

In the case of Holderness the responsible natural processes are most related to geology, geomorphology and wave action.

Geologically, the lithology of the coast is dominated by glacial till and boulder clay deposited in a lake basin during the Devensian glaciation period (Figure 2). These materials are easily eroded due to their softness, permeability and unconsolidated structure. The cliffs along Holderness are underlain by Cretaceous chalk but in most places it is deeply buried beneath the glacial deposits that it has little to no influence on the majority of the landscape.

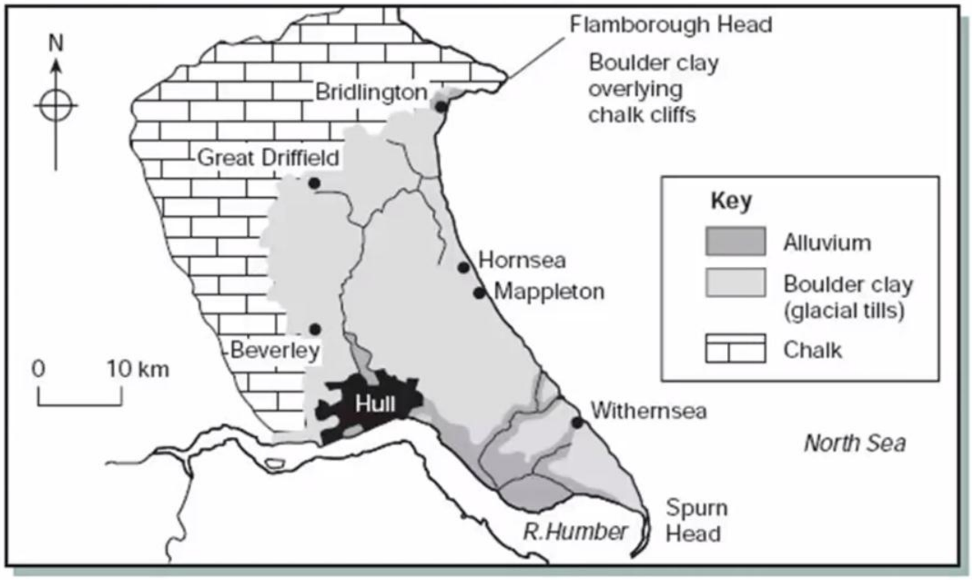

Figure 2: Holderness Coast Geological Composition

In terms of geomorphology, it is important to recognize wave break point and beach presence when considering the impacts of coastal erosion. Along Holderness waves break at the foot of the cliffs and the the majority of the beaches are composed of sand. Sandy beaches absorb less wave energy than cobble or stone alternatives, which means that the foot of the cliffs are receiving the brunt of the wave forces. This combination can partially explain the high erosion rates.

At Holderness the environment leads to the development of fetch-limited wind waves as a result of the dominant north-easterly wind direction. Waves occurring storm events can reach up to 4 m, and the tidal range at the Holderness coast is relatively high and can reach up to 7 m. The waves interaction with the coast then creates north-south orientated long shore currents (Figure 3).

The waves and current combined are trying to re-shape the coast between Flamborough and Cromer into a smooth bay. The waves produce southward bound long shore currents. The chalk headland of Flamborough Head prevents transport of materials from the north, thus little beach material is transported southward to the beaches of Holderness. The cliffs south of Flamborough Head are made up of loosely consolidated glacial till (there is no relationship between rates of erosion and type of till, nor with the height of the cliff). The sea attempts to build up an equilibrium gradient by eroding these soft cliffs behind the beach, to which the strong waves have easy access. This ultimately means that a portion of the Holderness coast will be eroded in order to achieve a more efficient, long term coastal shape. Other major sources of erosion are large storms and high tidal surges. These forces typically result in a series of small slumping type landslips, which can take a 10– 20m bite out of the cliff top at one time followed by a period of several years in which no further movement takes place at that point.

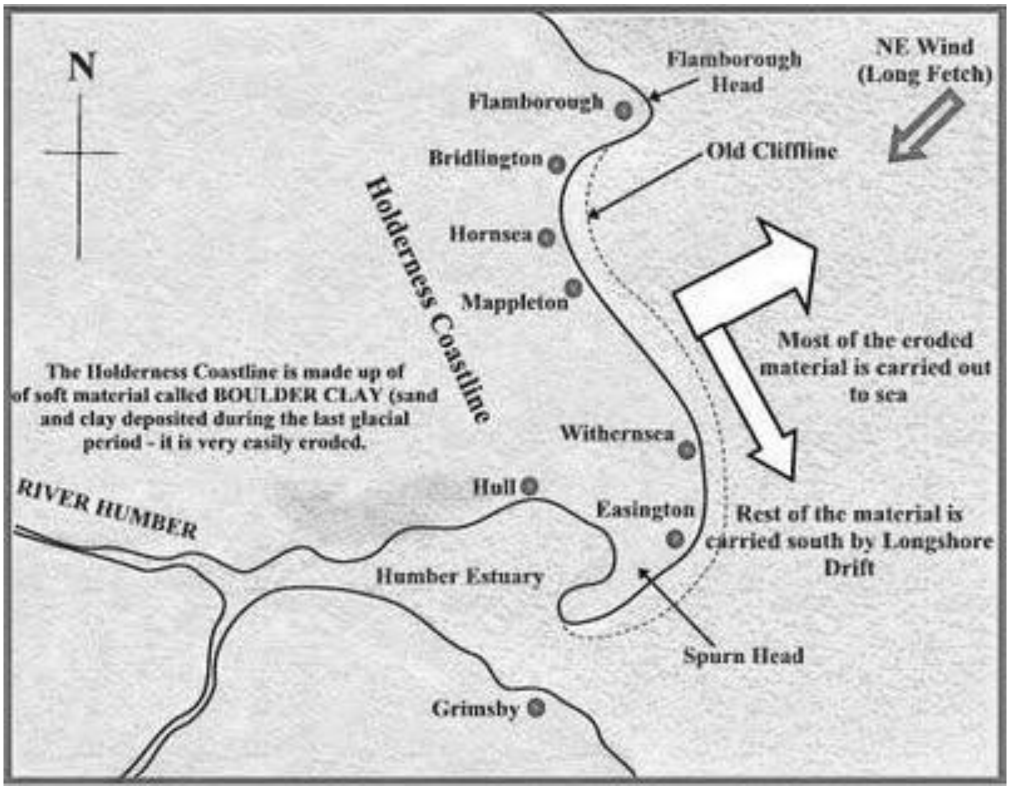

Figure 3: Wind Direction and Longshore Drift

2.2 Human Interaction

Hard engineered structures like seawalls, dykes, breakwaters, jetties, and rock-armoured structures, modify wave and flow patterns in the near shore zone and can cause a redistribution of coastal sediments. The net volume of sediments in the coastal zone may not be intensely affected, but the sediment redistribution can induce heightened erosion in some places and accretion in others. Modification of wave and flow patterns and coastal sediment transport are related to the trapping of sediment transported alongshore and a sediment deficit downdrift. Another result of hard structures near is that incoming waves can be reflected and hamper energy dissipation which can then in turn augment turbulence which results in increased cross-shore erosion. Hard structures can also create wave diffraction, which is the alteration of the wave crest direction due to the vicinity of seaward structures and can result in wave energy being either diluted in some places (reduced impact on the coastline) or concentrated in others (increased impact on the coastline and subsequent erosion).

An example of the unintended effects of hard engineering would be the residents living in to the south of Mappleton. The groynes at Mappleton have altered the natural movement of long shore drift, trapping the coastal sediments and preventing sediment resupply further to the south. This process has resulted in a significant increase in the rate of erosion south of Mappleton, beaches have become increasingly narrow leaving the cliffs unprotected.

Another human influence on coastal erosion is dredging. Dredging activities have intensified in the past 20 years for navigational and industrial purposes. Along the coast of Holderness, 4 million tons of material has been removed by dredging which has increased the steepness of the seabed, leading to larger wave height and increased wave energy. Not only has dredging increased seabed slope, but it has also removed foreshore materials (small stones and pebbles) which protect the coast against erosion and contributed to the sediment deficit in the coastal sediment cell.

3 EFFECTS OF EROSION

The effects of erosion are felt along the length of the Holderness coast in different ways and in different magnitudes. The processes of coastal erosion have been impacting the area for several hundred years.

3.1 Environmental Impact

The first effect of erosion along the Holderness coast is that of mass movement, also known as rotational slumping. During prolonged rainfall, water is absorbed by the glacial till which reduces the internal friction of the soil. Movement will occur once the waves have removed enough of the lateral support from the bottom of the cliff to create an imbalance. The figures below reveal the physical process of rotational slumping.

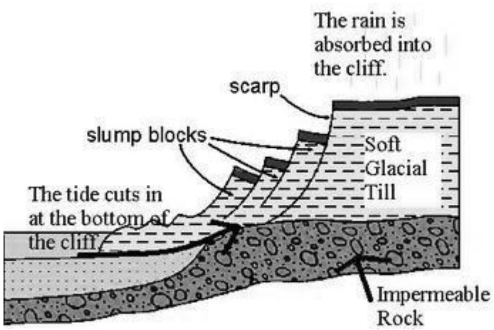

Figure 4: Process of Rotational Slumping

Figure 5: Rotational Slumping at Flamborough Head

One of the more gradual impacts is that of cliff retreat, it is caused by the forces of erosion as cliff materials are carried away from the shore and not replenished. Over the years, several coastal communities have been lost to the slow but eventual retreat and the process continues today at a rate of 2m per year.

The final disruption due to erosion is to local wildlife. Biodiversity has gradually declined along sections of the coast as the local environment cannot support as many species due to reduced supply of sediment.

3.2 Socio-Economic Impact

The socio-economic impacts of coastal erosion are simple to asses and can be broken down into three categories: settlement loss, economic loss and cost of coastal defences.

In over 2000 years, 4km of coastline has been lost to erosion. This has resulted in least 30 settlements marked on maps disappearing (Figure 6) and with more at risk if current trends are maintained. The major population centres along the coast are adequately protected but many some communities and homesteads are rapidly losing land.

In terms of economic losses coastal properties which face these this type of aggressive erosion inherently lose value causing the property owners to end up with negative equity. Plenty of farms along the coast have been losing valuable acres of land yearly to erosion with little to be done to prevent it due to the cost-benefit of erecting coastal defences. There are industrial complexes at risk, with the main example being the Easington gas terminal. The tourism sector has been hit hard by erosion as several prominent beaches have either been reduced in size or blemished by unsightly coast defences. The diminished tourism industry has far reaching consequences as jobs are lost shops close followed by services, eventually towns are unable to sustain viable populations.

Coastal defences incur yearly expenses in order to maintain and expand. Hard engineering structures can be expensive to install and therefore are often only used around larger population centres. Some coastal defences have been abandoned due to mounting costs.

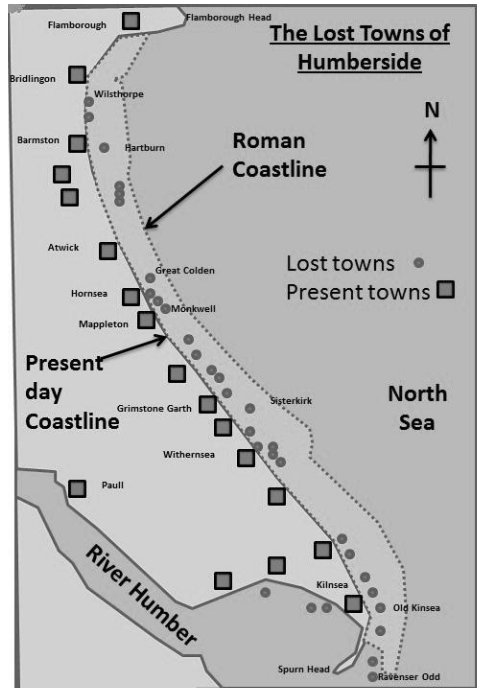

Figure 6: Lost Towns

3.3 Past Efforts

For the case of Holderness, hard sea defences have been built along the coast to stop the erosion in places where the sea threatens lives or important installations. Sea walls, Timber groynes and armour stone are three of the most common options used. Around population centers, cost effective timber groynes are used to protect sea walls by trapping sand moved by long shore drift in an effort maintain beaches that absorb wave energy. In other locations armour rock has been used to protect the base of cliffs and increase the resiliency of local beaches.

However these sea defences have a downside; they are visually unappealing, can be inefficient and in the long term can be found to encourage local erosion and erosion in other places. Furthermore, sea walls make access to the beach more difficult and can discourage tourism.

In the past, private sea defences have been put in place to protect assets. While these provide a short-term protection to the relevant properties, their nature and design can be of particular concern. Private defences are often built to the rigorous engineering standard of those publicly funded options, and pose health and safety problems risks to others.

3.4 Future Measures

Current and future efforts are being diverted to better understanding the processes contributing to the erosion in an effort to better plan and predict. One large scale experiment has been set up, the with the aim of understanding and predicting patterns of coastal erosion. The studies objectives were to quantify fluxes from a rapidly eroding coast to the adjacent sea and relate these fluxes to separate causative mechanisms via model simulations. To extend these simulations to predict wider scale, longer-term sediment motions and test against historical records of erosion and accretion, and to examine the associated impact of future and historical scenarios of climate change.

An important realization has been made that future management efforts will in some way depend upon cost benefit analysis and in order to evaluate different strategies and options, for example determining where managed retreat is most appropriate with those losing their homes and livelihoods being paid compensation.

Future efforts will also have to take into account existing sea defences are causing rapid erosion of the unprotected beaches and cliffs. To counter this, local regional authorities are now trying to set up integrated coastal zone management programs for the whole coastline. These measures include Dune, beach and near shore sand nourishments. These measures could prove to be as nourishment has proven to be successful as it is an efficient safety measure, cost effective; and it provides opportunities for other coastal uses. Another project being evaluated for Holderness includes a plan to create a large-scale underwater artificial barrier reefs made from concrete moulds.

4 CONCLUSION

The effectiveness of the measures taken along the Holderness coast are varying but in general the hard engineering measures are successful in stopping or at least reducing erosion locally. However, the hard structures often increase rates of erosion downstream of their use. Due to this relationship, areas in between the towns with a fixed coastline seem to be developing bays as a result of erosion. Essentially, the sea defences are creating artificial headlands as erosion on both sides of hard structures continues. As time progresses this could mean that the headlands become more and more exposed to the force of the waves, while the coast between the headlands will erode until a stable bay is formed.

The experiences along Holderness demonstrate the limits of disjointed response to coastal erosion and demonstrate the need for the adoption of a proactive approach to reduce erosion based on planning, monitoring and evaluation. In the future management strategies should depend upon cost benefit analysis and where the cost outweighs the benefits managed retreat may be the most appropriate option. The fact remains that it is important to remember that not only should the economics of each management strategy be considered but the long term effects have to be understood.

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