ROYAL HASKONING

Appendix C
Baseline Process Understanding

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C1 Assessment of Shoreline Dynamics

C1.1 Introduction

This Appendix comprises the outline of the baseline coastal process understanding for the SMP coast.

The first report, C1.2 General Overview, describes the large scale geology and coastal processes along the coast between South Shields and Flamborough Head. It is compiled from a desk study of data, reports and peer-reviewed literature, and the interpretation of this information in the context of the SMP.

The later section of the Appendix, C1.3 provides a more localised coastal process description outlining the sediment sources, transport and sinks, and the controls and sensitive points influencing the coastal processes within local coastal process units. The local coastal process units have been defined as:

Unit 1 – Tyne Estuary South Groyne to South Pier
Unit 2 – South Pier to Trow Point
Unit 3 – Trow Point to the north end of Marsden Bay
Unit 4 – Marsden Bay
Unit 5 – South end of Marsden Bay to the north of Souter Point
Unit 6 – North of Souter Point to Souter Point
Unit 7 – Souter Point to South Bents
Unit 8 – South Bents to Roker Pier (Whitburn Bay)
Unit 9 – Roker Pier to north Hendon Sea Wall (Sunderland Docks)
Unit 10 – South Hendon Sea Wall to Grangetown
Unit 11 – Grangetown to Seaham Harbour North Pier
Unit 12 – Seaham Harbour
Unit 13 – South end of Seaham Harbour to Blackhall Rocks
Unit 14 – Blackhall Rocks to Crimdon Park
Unit 15 – Crimdon Park to north end of Hartlepool Headland (North Sands)
Unit 16 – Hartlepool Headland (to Pilot Pier)
Unit 17 – Pilot Pier to South Pier
Unit 18 – South Pier to Seaton Carew
Unit 19 – Seaton Carew to North Gare Breakwater
Unit 20 – Mouth of Tees Estuary
Unit 21 – South Gare Breakwater to west end of Coatham Rocks (Coatham Sands)
Unit 22 – Redcar Sands
Unit 23 – East end of Coatham Rocks to Saltburn-by-the-Sea (Marske/Saltburn Sands)
Unit 24 – Saltburn-by-the-Sea to Skinningrove Jetty
Unit 25 – Skinningrove
Unit 26 – Skinningrove to Staithes
Unit 27 – Staithes
Unit 28 – Staithes to west end of Runswick Bay
Unit 29 – Runswick Bay
Unit 30 – East end of Runswick Bay to west end of Sandsend Wyke
Unit 31 – Sandsend Wyke

Unit 32 – Whitby Sands
Unit 33 – West/East Pier to north end of Robin Hood's Bay
Unit 34 – Robin Hood's Bay
Unit 35 – South end of Robin Hood's Bay to Scalby Ness
Unit 36 – Scalby Ness to north end Castle Cliff (North Bay)
Unit 37 – Castle Cliff
Unit 38 – South end Castle Cliff to Holbeck (South Bay)
Unit 39 – Holbeck to Osgodby Point
Unit 40 – Cayton Bay
Unit 41 – South end of Cayton Bay to Filey Brigg
Unit 42 – Filey Brigg to Speeton (Filey Bay)
Unit 43 – Speeton to Flamborough Head

C1.2 General Overview

Introduction

This section describes the large scale geology and coastal processes along the coast between South Shields and Flamborough Head. It is compiled from a desk study of data, reports and peer-reviewed literature, and the interpretation of this information in the context of the SMP. Geomorphologically, the coast can be divided into three distinct units. The Tyne and Wear/Durham coast comprises Magnesian Limestone overlain by glacial till and importantly, has been heavily modified by anthropogenic coal mining activity. The northern part of the Yorkshire coast is dominated by Jurassic sandstones and mudstones overlain by glacial till and has been sculpted into a headland-bay form. Many of the bays are deeply incised into the general trend of the coast. The southern part of the Yorkshire coast comprises high chalk cliffs ending in the promontory of Flamborough Head.

Bedrock Geology

Permian

The solid geology of the coast between South Shields and Hartlepool is dominated by the Upper Permian Seaham Formation (commonly known as the Upper Magnesian Limestone, British Geological Survey, 1965, 1978; Taylor *et al.*, 1971). The Upper Magnesian Limestone forms 15-30 m high, flat-topped and often vertical cliffs, behind shore platforms and beaches of varying composition and width. The limestone was deposited in a warm shallow sea (the Zechstein Sea) located between Britain and Poland. The modern Durham coast is close to the west coast of this ancient sea where a long barrier reef formed. The reef is composed of bryozoans and other marine animals and outcrops at the present coast at Blackhall Rocks. The reef is also particularly well displayed in and around Sunderland and forms prominent hills at Tunstall and Humbledon.

Triassic

The solid geology between Hartlepool and the southern bank of the Tees Estuary comprises a relatively narrow outcrop of Triassic Sherwood Sandstone Group overlain by Mercia Mudstone Group (Kent, 1980; British

Geological Survey, 1987). During the Lower Triassic all the continents had moved together to form the super continent of Pangaea and Britain became an arid desert. In the Hartlepool area, rocks from this period of continental conditions comprise red and grey fine-grained sandstones and siltstones belonging to the Sherwood Sandstone. The Sherwood Sandstone was deposited on a large desert plain across which large braided rivers intermittently flowed.

The mudstones of the succeeding Mercia Mudstone probably represent wind-blown dust that settled in large shallow salt-lakes and mudflats on the desert plain. These mudstones occur at the mouth of the Tees Estuary and underlie Middlesbrough.

Jurassic

The coastal cliffs and shore platforms between Redcar and Speeton are composed of Jurassic rocks (Kent, 1980; British Geological Survey, 1998a, b, c). The lowermost belong to the Lower Jurassic Lias Group and are exposed along the coast between Redcar and Blea Wyke. Towards the end of the Triassic and into the Lower Jurassic a shallow marine sea invaded much of the continental landmass, resulting in the flooding of the desert plain. In this shallow, tropical sea a series of mudstones and limestones were deposited known as the Redcar Mudstone Formation (more commonly the Lower Lias). These are in turn overlain by a series of shales, limestones, thin sandstones and ironstones, belonging to the Middle Lias (Staithes Sandstone Formation, Cleveland Ironstone Formation). The Lower and Middle Lias outcrop along the coast between Coatham and Staithes and in Robin Hood's Bay. The Upper Lias (Whitby Mudstone Formation) comprises mudstones and shales that outcrop along the coast from Staithes to Blea Wyke. The Upper Lias rocks of the coast east of Whitby are the richest source of fossil marine reptiles (including many plesiosaurs, ichthyosaurs and crocodiles) of this age anywhere in Britain.

Following a period of gradual uplift of the land, the succeeding Middle Jurassic sandstones and mudstones of the Ravenscar Group were deposited on a low-lying coastal plain crossed by large rivers. Periods of marine inundation over the coastal plain are marked by beds of more calcareous-rich rock. The Middle Jurassic rocks are exposed along the coast between Blea Wyke and Scarborough. Gradual marine inundation led to deposition of the Upper Jurassic Corallian Group comprising alternating shallow water calcareous sandstones and limestones exposed on the coast between Scarborough and Filey Brigg. Overlying the Corallian are the marine mudstones of the Kimmeridge Clay Formation, which underlies the Vale of Pickering, but coastal exposures are poor (at Reighton).

Cretaceous

The end of the Jurassic and the beginning of the Cretaceous was marked by a global fall in sea level and the retreat of the sea from the area now occupied by north-east Yorkshire. This led to the formation of land and a period of erosion began. After a considerable interval, the early Cretaceous sea invaded this land area from the east. The first sediments deposited in this shallow sea are represented by the Lower Cretaceous Speeton Clay which is exposed along the coast at Speeton (Kent, 1980; British Geological Survey, 1986). Overlying the Speeton Clay is the Red Chalk, a pink limestone and brick red marl. A major phase of sea-level rise and deepening of the Cretaceous sea marked the beginning of the Upper Cretaceous. In this warm, sub-tropical sea, the almost pure limestone of the Chalk Group was deposited, which forms the headland and shore platforms of Flamborough Head. The highest chalk cliffs in Britain are at Bempton, their height perhaps reflecting the fact that the Chalk in this area is much harder than the Chalk of southern Britain.

Pleistocene Geology

Over the last two million years the climate of Britain has varied tremendously with periods of temperate climate interrupted by repeated advances and retreats of glaciers and ice sheets. Collectively these periods have become known as the Ice Age and the actions of the ice sheets have been instrumental in forming the modern landscape of Tyne and Wear, Durham and Yorkshire. Around 115,000 years ago a severe cold phase known as the Devensian glaciation caused an ice sheet to spread across northern Britain. As the ice advanced it eroded the ground over which it passed (including deposits of previous glaciations), the eroded material then deposited at the base of the ice to form sheets of till (boulder clay). Associated with the till are suites of sand and gravel formed at the edge of the ice sheet.

The entire coastal strip between South Shields and Flamborough Head is overlain by Late Devensian glacial till, comprising clays, gravelly clays, sands and gravels (Taylor *et al*., 1971; Kent, 1980). The relationship between the bedrock and the till is an important factor in the form and stability of any particular stretch of this coastline. The till varies in thickness depending on the surface of the underlying bedrock. Along the Durham coast the thickest deposits are preserved in channels cut by glacial melt water through the Upper Magnesian Limestone (e.g. Hawthorn Hive) (Smith, 1981; Hughes *et al*., 1998). The Jurassic rocks of the coast between Redcar and Speeton rise and fall producing a coastline of headlands composed of rock outcrops (capped by till) and wide bays (e.g. Filey Bay) where a cover of glacial till occurs at sea level. The near vertical cliffs of chalk are overlain by a thin cap of till which increases in thickness from Speeton towards Flamborough Head. Where the till is at the coastline (exposed at the top of the beach), it is subject to fairly rapid erosion, and is a major source of local beach sediment.

Evidence of higher sea levels during the Pleistocene is provided by raised sand and gravel beach deposits such as those found in Shippersea Bay and Filey Bay. Bowen *et al*. (1991) showed that the Easington Raised Beach rests on a bevelled limestone platform at around +32 m OD. It appears to be overlain by glacial sediments of supposed Late Devensian age and contains marine shells with a radiocarbon age exceeding 38,000 years. Bowen *et al*. (1991) ascribed it to an interglacial high sea level event dated to Oxygen Isotope Stage 7 between the Hoxnian and Ipswichian stages. The Upper

Speeton Shell Bed in Filey Bay occurs at around +32 m OD and contains estuarine molluscs probably of Hoxnian age.

Coastal Geomorphology

Magnesian Limestone/Till

Between South Shields and Hartlepool, differential erosion along faults within the relatively hard Upper Magnesian Limestone cliffs has created an indented coast comprising a series of headlands with bays between them. These bays vary in size and geomorphology. From north to south these bays are:

Marsden Bay (Camel Island to Lizard Point);
Whitburn Bay (Whitburn Steel to Porson's Rocks);
Ryhope Bay (Ryhope Nook to Pincushion);
Seaham Beach (Pincushion to Featherbed Rocks/Seaham Harbour);
Dawdon Bankside Beach (Seaham Harbour to Nose's Point);
Blast Beach (Nose's Point to Chourdon Point);

Hawthorne Hive (Chourdon Point to Hive Point/Beacon Point);
Shippersea Bay (Hive Point/Beacon Point to Shippersea Point);
Easington Beach (Shippersea Point to Fox Holes/Horden Point);
Horden Beach and Blackhall Beach (Fox Holes/Horden Point to Blackhall Rocks);
Crimdon Beach and North Sands (Blackhall Rocks to Parton Rocks/Hartlepool).

Stacks, sea caves and arches are frequent along the Upper Magnesian Limestone coast. Arches are created by differential erosion of pockets of softer limestone, and stacks form when the arch collapses isolating them from the cliff. The stacks will eventually be lost and the process will begin again with new arches being formed. Some of the best known stacks are Marsden Rock between South Shields and Sunderland and those at Blackhall Rocks north of Hartlepool. During the 20th century a large arch formed at one end of Marsden Rock. This collapsed in 1998.

Between Seaham and Crimdon, steep sided, heavily wooded valleys or denes, dissect the cliff line. They are incised into the till and sometimes into the underlying limestone. The valleys are partially filled and they are likely to extend for some distance offshore. As the Devensian ice sheet melted, huge volumes of water were released as rivers and streams began to flow again. Combined with isostatic uplift, these meltwaters cut deep gorges through the till and limestone to form the denes. Denes include (from north to south) Seaham Dene, Hawthorn Dene, Foxholes Dene, Castle Eden Dene and Crimdon Dene.

The Upper Magnesian Limestone cliffs become less pronounced south of Blackhall Rocks, at which point the beach widens and an accumulation of wind blown sand forms links extending to Hartlepool. The dunes are situated on a southwards growing spit which connects to a Magnesian Limestone outlier at Hartlepool Headland. The mouth of the Tees Estuary and lowlands are also fringed by wind blown sand. Tees Bay has large areas of mudflat, which have been subject to extensive land-claim.

Jurassic Bedrock/Till

The effect of wave action and differential erosion on the variably resistant Jurassic shales and sandstones between Redcar and Speeton has been to produce a bay and headland (cliff) coastline. The cliffs are subject to landslip activity including a variety of processes; large fallen blocks on the foreshore, slumped areas and erosion fans, which are then removed by wave action at their toes. The Lias shales are relatively weak and can be subject to high erosion rates depending on local conditions, such as orientation and the presence or absence of a shore platform. East of Whitby, the oblique jointing in the Lias has been exploited by waves to form caves. In places, extensive undercliffs have developed as a consequence of ground instability. They are characterised by a sudden drop from stable ground at the landward edge of the cliff and a steep drop at the coastal edge of the undercliff. Examples of undercliffs (Mouchel, 1997) include:

Rosedale Cliffs
Seaveybog Hill
The Coombe and Common Cliff
Cayton Cliff
Gristhorpe Cliff

The cliffs of Jurassic rocks are frequently capped by till which in places has slumped to cover the *in situ* rock strata. Where this has occurred the resulting cliff generally has a near vertical lower section and a lower angle upper profile. Often the upper sections of the cliff are scalloped in appearance due to differential rates of landslip activity.

Where the coastal Jurassic rocks are at lower elevations, the cover of glacial till approaches sea level. Here differentially high erosion rates result in the formation of bays (with sand beaches) located between more resistant rock headlands (up to 200 m high) and shore platforms with a veneer of coarser sediment. Differential erosion of the till (relatively fast) backing the bays and the Jurassic rocks (relatively slow) to either side is continuing to lead to an increasingly incised coastline. In Filey Bay, for example, the till has been eroding at a fairly constant rate to form a gently curving sandy bay between the harder rocks of Filey Brigg and Flamborough Head. This crenulate-shaped bay indicates that the beach plan shape is tending towards an equilibrium form. Examples of these bays are (from north to south):

- Marske Sands/Saltburn Sands
- Cattersty Sands
- Runswick Bay
- Sandsend Wyke
- Hayburn Wyke
- Cloughton Wyke

- North Bay, Scarborough
- South Sands, Scarborough
- Cayton Bay
- Filey Bay

Although similar in shape to other bays, Robin Hood's Bay is not 'till controlled' but formed in an anticlinal structure where the less resistant Lias shales have been eroded. This is clearly seen in the pattern of rock ledges of more resistant sandstone and limestone exposed at low tide. The till forms low cliffs surrounding the bay. The combined action of wave attack and rain wash on the till matrix has produced many major slumps and slides (e.g. Stoupe Brow) and resulted in talus fans and pinnacle formations.

Robinson (1977a, b, c) studied the shore platform between Saltburn-by-the-Sea and Robin Hood's Bay. It is 300 m wide in places at mean low tide, and cut into Lias shales (with occasional more resistant sandstones), which have low resistance to marine erosion. The presence or absence of relatively resistant sandstone debris on its surface mainly controls platform morphology. Where debris is absent the platform is called the plane, slopes at around 1^{o} and is smooth. Where a beach exists at the cliff toe, the platform is inclined at $2.5\text{-}15^{o}$ (mode 6^{o}) and known as the ramp. The ramp may occupy the whole platform but it is more usually present at the cliff toe with the plane extending from it to the sea and occupying most of the platform's width. Different erosive processes act on the ramp and plane because debris lies on the ramp but not on the plane.

Chalk/Till

The Cretaceous rocks between Speeton and Flamborough Head are dominated by chalk, having a greater resistance to erosion than the Jurassic rocks creating characteristically tall steep cliffs (up to 30 m high) with very slow rates of recession fronted by a chalk shore platform (Mouchel, 1997). The platform extends for up to 1 km from the headland providing an important marine habitat.

Processes are limited to occasional rock falls and landslip activity in the till cap, the latter having only minor importance to overall morphology. Pebble and cobble beaches formed of chalk are found at the foot of the cliffs as a product of cliff erosion. There is little evidence for mobile sediment on the foreshore. The chalk is well jointed and wave action has created numerous features on the north side of the headland. King and Queen Rocks, High Stacks and Adam and Eve (now collapsed) pinnacles are examples of stacks while arches are found between Chatterthrow and Little Thornwick and at North Landing. Small coves such as North Landing, South Landing and Selwick Bay have been formed at local weaknesses in the chalk and contain beaches of sand.

Impact on Durham Coastal Geomorphology of Colliery Waste

An important aspect of the geomorphology along the Durham coast is the unique legacy left behind by coal mining activities. Mining activity in the Durham Coalfield exploited the productive seams of the Coal Measures, which underlie the Magnesian Limestone at a depth of 300 m or more. Mining was active at collieries at Dawdon, Easington, Horden and Blackhall. Much of the mine waste was tipped directly on to the beaches of the Durham coast, particularly at Blast, Easington and Blackhall Beaches.

Colliery waste was first tipped in large quantities in the early 1900s. At the height of production (after the 2nd World War), some 2.4 million tonnes of waste was tipped on the beaches every year. The tipping resulted in 12 km of waste-choked beaches, which in places were up to 10 m in depth and advanced by several 100 m in places. During the 1980s the tipping was progressively reduced, and in 1990, British Coal was informed that the licences permitting the dumping of colliery waste on the beaches would not be renewed. Waste tipping ceased in 1994.

The waste raised beach levels and extended the high water mark seaward, leaving the original cliffs isolated from the sea. Although landslipping of these cliffs still takes place, the slumped material is not transported away, allowing many of the backing cliffs to become vegetated (e.g. Hawthorn Hive and Horden Beach).

Now the tipping has ceased, coastal processes are eroding the waste. Morphologically, the waste comprises two components; a wide consolidated terrace of chemically altered waste extending out from the foot of the limestone cliffs to the wave run-up limit, and a lower unconsolidated active beach in the intertidal zone. The terraces appear to be of two types. The first type are formed by erosion of the waste at the tipping point (e.g. Blast Beach and Easington Beach) and are characterised by an eroding low cliff (2-3 m high) along their seaward edge. Erosion, forming these terraces, has resulted, to date, in a drop in their surface levels of 7-8 m in places (Babtie, 1999), from the cliff top to their present level. The second are formed by redeposition of the eroded waste onto beaches further down the longshore transport system (e.g. Hawthorn Hive and Horden Beach). These terraces lack a sharp seaward boundary merging more gradually with the fronting beach. Both types of terrace are typically at elevations of +5-6 m OD and are up to 150 m wide.

The waste contains brick rubble and lenses of fine laminated sediment deposited in artificial lagoons created by pumping of water out of the mines. It may also contain unusual minerals such as sideronatrite and natrojarosite, which form where the minerals in the waste react with seawater.

Beaches

Posford Duvivier Environment (1994) divided the coast between Sunderland and Hartlepool into three sections. Between Sunderland and Seaham Harbour, the beaches are generally of natural composition (uncontaminated by colliery waste) and consist of sand and shingle. Between Seaham Harbour and Blackhall Rocks they are contaminated with colliery waste. The intertidal area is steep (4-9^{o}, Humphries, 1996) and narrow, and consists of both natural sediments and shingle-size colliery waste. Humphries (1996) carried out particle size analyses of the colliery-waste affected beaches between March 1991 and June 1993. She found poorly sorted sediments with mean particle sizes in the fine to medium-fine pebbles range. Between Blackhall and Hartlepool, the beaches are sandy with particles of coal interspersed in the sand. The beaches are comparatively wide and more gently sloping (2-3^{o}, Humphries, 1996) than those to the north.

Along the open coast between Redcar and Speeton, small pocket beaches composed of pebbles and boulders can occur resting on the shore platform. Wider sand beaches are present in most of the bays.

Offshore

The sea bed sediments offshore are characterised by sand and gravel, resulting from Holocene reworking of glacial deposits and erosion of bedrock by marine processes. These sediments form a veneer over bedrock; there is no evidence for Pleistocene sediments preserved offshore (Cameron *et al.*, 1992).

Coastal Erosion

Magnesian Limestone/Colliery Waste

The coast north of Seaham harbour comprises limestone cliffs with a bevelled layer of till backing a sand and shingle beach. The till is prone to substantial slumping, and massive falls. Most of the slumps are likely to be related to previous heavy rainfall events and most will occur in the winter months when rainfall is heavier. Rain falling on the immediate coastal hinterland is absorbed by infiltration and seeps towards the cliffs where the additional weight overcomes the resistance to shearing and the slope fails.

The section of coast between Seaham harbour and Blackhall Rocks is contaminated with consolidated colliery waste. Here, the supply of sediment to the nearshore zone from erosion of the natural cliffs is negligible, because they are stranded, landward of the waste, and waves do not reach the toe of the cliffs.

Posford Duvivier (1993) argued that the colliery waste would erode in two stages. An initial phase of rapid erosion (10-20 m per year) would remove the unconsolidated seaward edge. This would be followed by a second, slower phase of erosion (0.5-2 m per year) of the main body of the colliery waste (the terrace), which has become consolidated since being tipped. They suggested most of the waste is transported and deposited offshore (70-90%). The waste that now makes up the beaches between Seaham and Blackhall Rocks is thus a small proportion of the waste that has been tipped. During storms this offshore sediment may be resuspended, transported onshore and deposited on the beaches.

In some areas the waste has been removed artificially as part of a regeneration programme along the coast (Turning the Tide). The colliery land-claim sites at Easington and Horden had large cliff edge spoil heaps. As part of the regeneration, these heaps were removed and the waste spread over the sites, capped and covered with soil to create public open space at Easington and for habitat recreation at Horden. In total 1.3 million tonnes of waste was removed and 80 ha of land reclaimed by this process.

Easington District Council has repeat-profiled (1990s-2001) nine beaches between Seaham and Crimdon as part of the Turning the Tide project. These profiles record lateral erosion rates for the two different types of terrace (Posford Haskoning, 2004).

Beach profile data captured between 1994 and 2001 describe lateral erosion of the waste terrace cliff and beach at Blast Beach (waste from Dawdon colliery which stopped in 1991) of around 17-18 m per year. Comparison of the 1989 and 1993 OS maps showed an erosion rate of 20 m per year. The Easington Beach (waste from Easington Colliery) data is more difficult to interpret, but suggests an erosion rate of around 12 m per year. These data suggest that in these areas, where the terrace is formed by erosion, a high rate of erosion has continued after waste tipping ceased.

The beach profiles from Hawthorn Hive and Horden Beach, where the terrace is formed of redeposited waste, suggest a more stable beach regime. Over the period 1996-2001 (Hawthorn Hive) and 1994-2001 (Horden Beach) the terrace has eroded little. This may suggest that these beaches and terraces are still being fed with an adequate supply of sediment from further up the longshore transport system. Hawthorne Hive receives sediment eroded from Blast Beach and Horden Beach receives sediment from erosion of Easington Beach.

Shippersea Bay and Blackhall Beach appear to be intermediate between the two regimes described above. Both beaches have laterally eroded over a 5 year period (1996-2001) by 2.5-3 m per year.

Based on these data, it is possible to divide the Durham coast into two ‘erosion cells’, which appear to be controlled by the location of the waste tipping points along the coast (Blast Beach and Easington Beach), and the subsequent erosion and redeposition of this waste. Considering the northern ‘cell’, after cessation of tipping at Blast Beach, the waste has eroded rapidly (17-20 m per year) through natural processes. Much of the fines in this waste will have been transported offshore. However, longshore transport to the south has led to redeposition of some of the waste and formation of terraces in bays to the south such as Hawthorn Hive and Shippersea Bay. Although diminished through time, the Blast Beach source continues to supply Hawthorn Hive (the first bay south of Blast Beach) and hence the terrace of waste is presently stable and not eroding. In Shippersea Bay (the second bay south of Blast Beach and separated from Hawthorn Hive by a wide headland), the initial pulse of eroded material was deposited on the beach to form the terrace. However, because the bay is further down the longshore transport system from Blast Beach, the diminished supply through time means the beach is now eroding. South of Shippersea Bay to the next tipping point at Easington Beach the beaches appear to be relatively clean with respect to redeposited mine waste (Halcrow, 2002), indicating that bypass of this material beyond Shippersea Bay is limited.

The same logic can be applied to the southern 'cell' involving tipping of waste on Easington Beach, redeposition and continued supply to Horden Beach, and redeposition followed by erosion of Blackhall Beach. South of Blackhall Rocks the beaches are relatively clean. The effect on Blackhall Beach of tipping at Horden has been negated because of its artificial removal. The tipping of waste at Blackhall occurred to the south of the Blackhall Beach profile.

Jurassic Bedrock/Chalk

The coastline from Redcar to Flamborough Head exposed to erosion is comprised of cliffs and shore platforms of three main rock types; Jurassic shales and sandstones, Cretaceous chalk and Pleistocene till. Each of these lithologies has a different resistance to erosion by subaerial and marine processes. The Jurassic rocks, particularly the Lias shales, are relatively easily eroded, whereas the harder Cretaceous chalk is relatively resistant. Cliffs cut into till are subject to the highest rates of erosion. Mouchel (1997) quoted estimates of erosion in Filey Bay (till) of 0.15 m per year between 1850 and 1928 and double this between 1928 and 1964. Agar (1960) suggested average cliff toe erosion rates for Jurassic shales of medium toughness of 0.09 m per year and for glacial till of 0.28 m per year and negligible for chalk.

Agar (1960) showed that rates of cliff erosion in the Jurassic rocks are generally higher at the toe than at the top, leading to a steepening of the profile. However, the nature of the shale and the till that caps it restricts the extent to which steepening takes place before slope failure occurs. Clark (1991) recognised four stages to the erosion of Jurassic cliffs at Whitby. First, the base of the cliff is eroded by waves creating a wave-cut notch. Second, the cliff collapses producing oversteepened slopes. Third, there is further cliff failure involving initial remobilisation of displaced blocks. Finally, the failed material is removed from the base of the cliff by marine action and the cycle starts again.

In addition to marine processes, subaerial processes such as saturation by groundwater leading to failure are also important. The importance of this process is highlighted by the cliff collapse at Holbeck, Scarborough where increased pore water pressure promoted failure. An important parameter in this process is the nature of precipitation. Staithes village is bounded by rock headlands and has developed on the steep sides of a rocky gorge. There is severe erosion, mainly due to subaerial weathering, at the Cowbar promontory west of the harbour. Runswick is situated in a sheltered position in the west end of Runswick Bay. The village is protected by a concrete wall built between 1950 and 1970 which is in a generally sound condition. However, the till cliffs to the south are weak and this end of the wall is at risk as are a number of houses along the unprotected part of the bay.

An important facet of coastal evolution, particularly along the Lias coast is the downcutting of the shore platform. Robinson (1977c) found that the main process of erosion on the plane is desiccation of the shale, which causes contraction of the clay lattices (in swelling clay minerals) during low water and expansion by wetting during high water. These movements crack the shale bedding laminae into polygons about 20 mm in diameter, which are removed by waves. Desiccation is enhanced in well-drained areas and there is a positive correlation between altitude and erosion rate producing the smooth near horizontal plane. The process is most effective when desiccation is most intense which is during summer and at high levels where the drying period is longest. Erosion averages 1 mm per year, but ranges from zero in pools to 9 mm per year at the cliff foot, where wave turbulence, drainage and the period between successive high tides reach their maximum values.

Robinson (1977a, c) indicated that the main erosive process on the ramp is abrasion of the platform surface by the movement of debris over it. This conclusion was supported by high erosion rates in winter when waves could move more debris more vigorously. He suggested that beach particle size and thickness are important influences on the rate of erosion. A shallow sand and pebble beach less than 5 cm thick allows erosion at all times. Wave energy is the most important variable if the beach is more than 13.5 cm thick since only high-energy storm waves can agitate particles on the ramp at these depths. Erosion rates for the zones of 0-5 cm depth, 5-13.5 cm depth, and greater than 13.5 cm depth were 3.94×10^{-3} cm per tide, 3.26×10^{-3} cm per tide and 1.13×10^{-3} cm per tide, respectively.

Extensive monitoring and research has been undertaken by Durham University of this section of the coast. This work has been carried out concurrent with the development of the SMP2; results based on the initial 18 months monitoring having been published as a PhD. Thesis (M. Lim, 2006) and further discussion of the full 35 months research programme is presented in a report commissioned by the Staithes and Cowbar Association (personal communication with Mr. C. Mann and Dr. N. Rosser. Oct 2006). The findings of this research indicate both from the monitoring results and from further examination of historical evidence that erosion rates of the Cowbar frontage may be of the order of 0.025m/yr. The research provides an exceptional degree of accuracy in assessing erosion rates over the period of monitoring and this is supported by the result of the analysis of historical records. Even so given the relatively short time period of the monitoring in relation to the SMP, it is necessary to take a precautionary approach. As such, the continuation of erosion at this rate cannot be assumed to necessarily apply over the full period of the SMP. At present this is the best available evidence.

Sediment Transport

Waves

The north-east of England is subject to high energy wave conditions, dominated by north and north-easterly winds, promoting a net longshore transport of sediment to the south. The majority of waves approach the coast from 0-120^o with the highest waves between 0-90^o. (Mouchel, 1997; Babtie, 1999; Posford Duvivier, 2000; Halcrow, 2002). Although exposure to waves is high and hence potential rates of sediment transport are high, the actual rates are likely to be low due to partial trapping of the sediments within the bays along the coast. Although the net longshore movement of sediment is south, the direction can be reversed during storms. In addition, where there is shelter from northerly waves there may be a reversal in direction.

Tides

Along the English east coast, the tidal current streams are generally north to south on the flood and south to north on the ebb. Spring tidal current velocities are about twice as fast as neap tidal current velocities. The maximum flood flow is generally higher than the maximum ebb flow and so the residual tidal current is south flowing. Both transport by waves and tidal currents is therefore generally southward. The magnitude of the tidal currents increases in a southerly direction proportionally with increasing tidal range in the same direction.

While tidal current flow offshore is more or less northward or southward, the flow inshore is affected by coastal and sea bed topography (Motyka, 1986). Tidal streams run strongly off prominent headlands (1.5 ms^{-1} off Flamborough Head, giving rise to turbulence and eddies on both sides of the Head). Tidal streams in some large embayments (e.g. Filey Bay) are barely perceptible. In other places they may cause local problems (e.g. at Whitby where streams may reach 2.5 ms^{-1} across the harbour entrance under westerly and south-westerly gale conditions). In Hartlepool Bay a clockwise tidal circulation is developed with recorded current velocities of the order of 0.7 ms^{-1}.

Sediment Transport – Sunderland to the Tees Estuary

Motyka and Beven (1986) estimated that longshore transport between Sunderland and Seaham is probably no greater than 10,000 m^3 per year. The lack of large-scale beach accretion north of Seaham suggests that the longshore rate must be modest. Between Seaham and Blackhall Rocks, the net longshore rate is also modest (again estimated as less than 10,000 m^3 per year by Motyka and Beven, 1986), supported by the fact that relatively small volumes of sediment bypass the Blackhall Rocks headland. These figures are very different from those quoted in Babtie (1999). Babtie (1999) indicated net potential sediment transport southwards between 333,400 m^3 per year and 1,376,800 m^3 per year. These values were based on average annual wave climate and a 90-micron sand size.

Motyka and Beven (1986) do not quote the source of data for sediment size used in their work, so it is not possible to explain the discrepancy between the two studies. However, based on the qualitative evidence (ie, the lack of significant accretion north of Seaham and the partial blocking of transport by the headlands), the Motyka and Beven (1986) results for transport rates are considered to be closer to reality than Babtie (1999). The particle size used in Babtie (1999) seems very small compared with observations made on site. Particles as small as 0.09 mm would tend to be transported in suspension, not as bedload, thus making the Babtie (1999) calculations erroneous. Overall, the beaches are composed of medium to coarse sand. Indeed, the modelling carried out by Posford Haskoning (2004) to determine potential transport rates, has used a particle size of 0.6 mm (which is more realistic). The results show a sediment transport potential of between 2,000 and 30,000 m^3 per year. This is similar to the Motyka and Beven (1986) results. If up to 1.3 million m^3 was moving along that coast, as indicated by Babtie (1999), morphological indicators of massive bedload sediment movement would be observed, which is not the case.

Motyka and Beven (1986) also argued that under maximum wave heights experienced along this coast, beach sediments are effectively trapped inshore of the 10 m isobath. They suggested that, for this reason, the movement of sediment around the entrance to the harbour at Seaham is negligible. The harbour structures extend a long distance seawards and into water depths of greater than 10 m. However, sediment of various sizes is regularly dredged from within the harbour, providing evidence of sediment at this lower level bypassing the piers. This is confirmed by the modelling studies completed by Posford Haskoning (2004) which show sediment travelling both north and south at depths beyond the piers.

Sediment Transport - Tees Estuary to Flamborough Head

The open coast between the Tees Estuary and Flamborough Head is dominated by sparse rocky beaches. For this reason, the net longshore transport, which is from north to south, is weak and fragmented (Motyka, 1986). Movement of beach sediment is generally contained within individual bays and because of their strong indentation the action of waves tends to push sediments towards the centre of the bays, so they act as almost independent coastal cells (Motyka, 1986). For example, Motyka (1986) suggested that it is likely that very little beach sediment moves south out of Hartlepool Bay and Tees Bay. Indeed, they tend to act as sediment traps, and there has been much infilling throughout the Holocene in both bays, enhanced by land-claim.

There are several large promontories such as Scarborough Ness, Filey Brigg and Flamborough Head which also reduce the longshore sediment transport to a low level. More extensive accumulations of sand have developed where headlands provide sufficient shelter from northerly winds, and south-east exposure may result in local reversals of transport direction (e.g. Filey Bay). At Skinningrove, there is a small mining village set in the bottom of a steep river valley and situated a short distance upstream of the river mouth. There are no coast protection problems here because of the shelter against northerly waves provided by a jetty. A sand and shingle ridge has developed across the river mouth and gives protection against waves from the north-east. This build up of sand and shingle to the east of the jetty indicates a local reversal in the direction of longshore transport, due to the sheltering effect of the jetty.

The harbour at Whitby also effectively stops longshore sediment transport. The beach to the west is wide and sandy while the rock platform east of the harbour is free of beach sediment. What little sand is transported across the harbour tends to be swept into the outer harbour area. Here it has settled out to form a beach on the east side of the entrance. There are no sand beaches east of the harbour entrance.

An important aspect of sediment transport along this coastline is a small but important exchange of sediment around Flamborough Head. Flamborough Head represents a partial or 'one-way' sediment divide in longshore transport terms. The Flamborough Head foreshore is free of mobile sediment and its existing integrity and stability is not dependent on a longshore source of sediment. Along the northern side of Flamborough Head, longshore transport by waves is low and tidal currents in the nearshore zone are thought to dominate the southward transport of sediment. However, it is believed that north-easterly wave activity during extreme storm events (1 in 50 return period) can cause a southerly movement of sediment from an extensive sand deposit located offshore in Filey Bay (Stapleton, 1994). During such an event, it is estimated that 40,000 m^3 of sand is transported south around Flamborough Head and swept offshore by tidal currents and deposited on Smithic Shoal. Smithic Shoal occurs as a solitary near-coastal sand bank in the lee of Flamborough Head and appears to be maintained by the tidal residual currents south of the headland. Stapleton (1994) also considered that this sediment was gradually returned to Filey Bay by transport on tidal residual current flowing north around Flamborough Head. According to Mouchel (1997), there is a residual tidal current from the south during spring tides of 0.11 ms^{-1}, and a residual current from the north during neap tides of 0.09 ms^{-1}. Hence, sediment is able to move around the headland from Smithic Shoal into Filey Bay, and, according to Stapleton (1994) is sufficient to balance the losses.

Relative Sea-Level change

Plater *et al.* (2000) and Shennan *et al.* (2000) analysed sea-level index points from the Tees Estuary. The relative sea-level curve shows a rise of about 6 m over the last 8000 years (0.75 mm per year). Extrapolation of the data indicates that the late Holocene to present rate of relative sea level rise in the Tees Estuary is around 0.2 mm per year. This accords with the data of Shennan and Horton (2002) that shows the Durham/Yorkshire coast to lie around the 0 mm per year contour for crustal movement in Britain. The figure of 0.2 mm per year can be compared to historical sea-level change using tide gauge data (Woodworth *et al.*, 1999). The nearest gauges are North Shields and Immingham, where relative sea-level rises of 1.86 mm per year and 1.11 mm per year were recorded between 1901 and 1996, and 1960 and 1995, respectively. These figures are an order of magnitude higher than the figure calculated from long-term geological data. Woodworth *et al.* (1999)

suggested that, at North Shields at least, this might be due to localised submergence of the gauge, and that the value might be expected to be closer to 0.6 mm per year (c.f. Aberdeen).

Over the past century, the artificially increased input into the coastal sediment budget of the waste tipping has, until the closure of the mines, masked the impact of relative sea-level rise.

Mining Subsidence

Coastal dynamics may be complicated along the Durham coast by the possibility of local subsidence in response to the collapse of disused mine shafts at depth (Humphries, 2001). The mining subsidence is likely to be non-uniform along the coast, reflecting the irregularity of workings that underlie the coastline. Humphries and Ligdas (1997) suggested subsidence of around 4-5 m at Dawdon. Humphries (2001) suggested that land subsidence due to mining activities might exceed that of projected sea-level rise due to climatic changes. In this respect, the possibility of future mining subsidence may pose more of a threat to the long-term stability of the Durham beaches, than sea-level rise.

Future Behaviour of Colliery Waste Affected Beaches

One of the most important legacies with respect to this coast is the tipping of large volumes of mine waste on to the beaches between Dawdon and Blackhall Rocks, and the subsequent cessation of tipping.This has created a series of different artificial morphological elements along the coastline, which are responding in different ways to natural coastal processes. Terraces of consolidated mine waste extending out from the base of the limestone cliffs have been formed by erosion of the original tipped waste. These deposits are rapidly eroding at rates between 12 and 18 m per year. If this erosion rate continues into the future (and there is no reason to suspect it will not), then a terrace of waste 150 m wide will be completely eroded in 8 to 13 years.

A second form of terrace has been created from redeposition of the material released from erosion of the original waste. These terraces are found in bays to the south of the tipping points. They appear to be stable, and as long as an adequate supply of sediment reaches them from the eroding waste terraces, they will remain stable. However, in 8 to 13 years this supply is likely to be exhausted, and the terraces will then begin to erode. The erosion rate may be similar to that incurred by the tipped waste (i.e. 12-18 m per year).

The end result is likely to be complete removal of all the mine waste leading to re-exposure of the backing cliffs in those particular bays. Exposure will take place first at Blast Beach and Easington Beach (after 8-13 years) followed by later exposure at Hawthorn Hive and Horden Beach (up to 30 years). This supports the conclusion of Posford Duvivier (1993) that upon cessation of waste tipping the coast would recede to its original position of 1896, after 15-50 years.

It is possible that, based on the historical precedent of similar coastlines – such as Holderness, up to 2 m of coastal erosion can be anticipated per year for areas where glacial till is exposed at a low level at the coastline. Where Magnesian Limestone is exposed at a low level along the coast, recession of these cliffs will be low (i.e. <0.1 m per year to a maximum of 0.5 m per year). Scott Wilson (2001) also suggested similar erosion rates for the frontages north of Seaham.

The mouth of Castle Eden Dene (Horden Beach) is interesting because numerous changes have taken place here over time. In the past, high tides flooded the area, supporting active saltmarsh. More recently, longshore transport has caused colliery waste to be transported and deposited at the mouth of the Dene, forming a terrace behind the beach. This raised the beach level and prevented further inundation by tides causing the saltmarshes to disappear. However, with the cessation of waste tipping, the sea may eventually erode the waste and allow saltmarsh to form again.

C1.3 Localised Coastal Process Understanding

Unit 1 – Tyne Estuary South Groyne to South Pier

Sediment Sources, Transport and Sinks:
This short stretch of coast comprises a narrow sand beach located in a bay between South Groyne on the south side of the Tyne Estuary (to the north) and South Pier (to the south). The width of the beach increases in a southerly direction. The beach is backed by sand dunes partly defended by a sea wall and rock armour in front of a till hinterland. The supply of sediment to the beach is likely to be from the dunes and from sources offshore. Transport of sediment away from the beach is restricted by the controlling points. The underlying bedrock is Coal Measures.

This unit has been the subject of extensive land-claim of the beach and the coastline (dunes) has advanced between 0.4 m/yr and 1.8 m/yr over the last 100 years due to this land-claim (SMP). The mean high water mark has advanced 0.4 m/yr and the mean low water mark retreated 0.2 m/yr over the same period of time (SMP). The beach has therefore become steeper, although it should remain stable if the control points are maintained.

Control and Sensitive Points:
This short stretch of coast comprises a narrow sand beach located in a bay between South Groyne on the south side of the Tyne Estuary (to the north) and South Pier (to the south). The width of the beach increases in a southerly direction. The beach is backed by sand dunes partly defended by a sea wall and rock armour in front of a till hinterland. The supply of sediment to the beach is likely to be from the dunes and from sources offshore. Transport of sediment away from the beach is restricted by the controlling points. The underlying bedrock is Coal Measures.

Unit 2 – South Pier to Trow Point

Sediment Sources, Transport and Sinks:
This unit comprises a self-contained wide sand beach held in place by fixed control points of South Pier and Trow Point (the latter forming part of a larger headland to its south, unit 3). The beach is backed by sand dunes partly defended by a variety of defences in front of a till hinterland. The supply of sediment to the beach is likely to be from the dunes and from sources offshore. Transport of sediment away from the beach is restricted by the control points. The underlying bedrock is Coal Measures in the north and Magnesian Limestone in the south.

There is potential to move 810,500 m^3/yr of sediment longshore to the south (SMP). However, the actual input of sediment to this unit is restricted by South Pier which intercepts southerly sediment transport from north of the Tyne Estuary. Loss of sediment from the south end of the unit, around Trow Point, is considered to be relatively small, around 3,000 m^3/yr (High-Point Rendel). The build-up of sand adjacent to South Pier is probably due to the sheltering effect to north-easterly waves of the pier, possibly inducing a local reversal in transport direction in its lee.

This unit has been the subject of extensive land-claim of the beach for the amusement park and promenade. The coastline (dunes) has advanced between 0.5 and 1.3 m/yr over the last 100 years due to this land-claim, with higher rates of accretion towards the north of the unit (SMP). The historical evolution (last 100 years) of the fronting beach varies from north to south. In the northern part (500 m) the mean high water mark has remained static (0 m/yr) and the mean low water mark has advanced 0.1 m/yr indicating a relatively stable beach (SMP). The central part of the beach appears to have shallowed through deposition with retreat of the high water mark (0.2 m/yr) and advance of the low water mark (0.3 m/yr). The beach towards the southern end has eroded with retreat of both the mean high water and mean low water marks (0.45-0.5 m/yr and 0.25-1.05 m/yr, respectively) (SMP). Overall, the SMP suggests an erosion rate for undefended land in this unit of 0.2 m/yr.

Continued maintenance of South Pier would likely lead to stability of the beach in the north of the unit with gradually increasing erosion to the south (0.2 m/yr along the central section, up to 0.5 m/yr in the south).

Control and Sensitive Points:
The beach is held in place by the control points; South Pier and Trow Point. Trow Point is important as a barrier to sediment transport to the south and South Pier provides protection from dominant waves. Removal of South Pier may lead to loss of beach sediment through exposure to increased wave attack from the north and north-east. The main sensitive area is towards the Trow Point end of the unit where a revetment fronting the dunes pushes the coast seawards into a ‘un-natural’ alignment within the broader shape of the bay. The defences at the southern end of unit 2 are sensitive to overtopping.

Unit 3 – Trow Point to the north end of Marsden Bay

Sediment Sources, Transport and Sinks:
This is a jagged undefended coast of low Magnesian Limestone cliffs with a thin cap of Pelaw Clay (till) fronting a narrow shore platform with caves and occasional stack. The platform surface is covered with a veneer of pebbles and cobbles. The coast is indented by several small bays (including Frenchman's Bay) containing pocket beaches. The rock headlands act as partial barriers to longshore sediment transport, with transport largely confined to re-distribution within the pocket beaches.

The limestone cliffs contain little sand and gravel and are unlikely to be supplying much beach-building sediment to the nearshore system, although sand from the Pelaw Clay may supply locally. Net longshore sediment transport is to the south with a potential to move 670,400 m^3/yr (SMP). This stretch of coast is unlikely to fulfil this potential because the amount of mobile sediment is small (mainly rock platform). Much of the available sediment is trapped within the pocket beaches, with little potential for movement around longshore barriers such as headlands and outcropping rock platforms. The transport rate is more likely to be around 3,000 m^3/yr (High-Point Rendel).

This section of coast is a headland separating bays to the north (unit 2) and south (unit 4, Marsden Bay). This geomorphology produces an unequal distribution of wave energy along the coast caused by bathymetry variations. Low wave energies occur in the sheltered water of the bays and higher energy environments at this headland. This causes potential erosion of the headland and filling in of the bays. Because all the units have a similar resistance to wave erosion, this process should lead in time to a straightening of the coastline.

The coastline (cliffs) and mean high water mark have generally remained stable (0 m/yr) in this unit over the last 100 years whereas the mean low water mark (shore platform) has been stable or retreating (0-0.85 m/yr) (SMP). Even though the cliffs have been relatively stable in the long-term, the SMP suggests an erosion rate for undefended land in this unit of 0.6 m/yr. This appears to be high and a more likely rate of retreat is 0.1-0.2 m/yr.

Control and Sensitive Points:
This section of coast forms a broad headland (it is itself a control point) separating the beaches of unit 2 to the north and unit 4 to the south. Sub-headlands within this unit act as local control points effectively trapping sediments within the pocket beaches. From a coastal defence perspective, the continued erosion of the cliffs does not pose too many problems because there is a wide undeveloped hinterland of Magnesian Limestone behind them. However, immediately south of Trow Point extending to a small headland north of Frenchman's Bay is Trow Quarry, which used to extract Magnesian Limestone. The quarry was filled in with demolition waste after cessation of quarrying activities. Coastal erosion has resulted in the formation of low cliffs of the waste being exposed to wave action causing

wash-out of the infill material, including small quantities of asbestos contaminants.

Unit 4 – Marsden Bay

Sediment Sources, Transport and Sinks:
This stretch of coast is composed of Magnesian Limestone cliffs (25-30 m high) with a thin capping of Pelaw Clay. A number of stacks (including Marsden Rock) occur with caves present along the cliff base. The cliff line is relatively straight and fronted by a wide sand beach. The cliffs are only locally defended. The limestone cliffs (both within the bay and to the north) contain little sand and gravel and are unlikely to be supplying much beach-building sediment to the nearshore system, although sand from the Pelaw Clay may supply locally. The main source of sand may be offshore and 'funnelled' into the bay by waves. The net longshore sediment transport is to the south with a potential to move 460,300 m^3/yr (SMP).

Over the last 100 years, the coastline (cliffs) in Marsden Bay has been stable (0 m/yr) whereas the beach has generally steepened (SMP). The mean high water mark has advanced by 0.1 m/yr and the mean low water mark retreated by 0.1 m/yr. Towards the northern extreme of the bay both the mean high water and mean low water marks have retreated (both 0.3 m/yr). Even though the cliffs have been relatively stable in the long-term, the SMP suggests an erosion rate for undefended land in this unit of 0.2 m/yr. This is probably near the upper limit of erosion rate; the more likely rate being 0.1-0.2 m/yr.

Control and Sensitive Points:
This section of coast is a broad bay partially infilled with sand forming a beach. The main control points are headlands to the north (unit 3) and south (unit 5). Sensitive points are the locally defended infrastructure at the base of the cliffs. Removal of these may caused increased local erosion of the cliffs.

Unit 5 – South end of Marsden Bay to the north of Souter Point

Sediment Sources, Transport and Sinks:
This is a jagged undefended coast comprising low Magnesian Limestone cliffs with a thin capping of Pelaw Clay. The cliffs are fronted by a narrow shore platform, with a veneer of pebbles and cobbles, with caves and an occasional stack. The cliffs reduce in height to the south and the capping of Pelaw Clay becomes thicker (both absolutely and comparatively) and closer to sea level. The cliff line is indented by several small bays which are filled with pocket beaches. The rock headlands that bound the bays act as barriers to longshore sediment transport, with transport largely confined to re-distribution within the pocket beaches.

The limestone cliffs contain little sand and gravel and are unlikely to be supplying much beach-building sediment to the nearshore system, although sand from the Pelaw Clay may supply locally. The net longshore sediment transport is to the south with a potential to move 250,100 m^3/yr (SMP). This stretch of coast is unlikely to fulfil this potential because the amount of mobile sediment on coast is small (mainly rock platform) and much of the available sediment is trapped within the bays. The transport rate is more likely to be around 3,000 m^3/yr (High-Point Rendel).

The SMP indicates that the coastline (cliffs) and mean high water mark of this unit have been stable (0 m/yr) whereas the mean low water mark (platform) has retreated (0.2-0.4 m/yr) over the last 100 years. Even though the cliffs and mean high water mark have been relatively stable in the long-term, the SMP suggests an erosion rate for undefended land in this unit of 0.2 m/yr. This appears to be slightly high and a more likely rate of retreat is 0.1 m/yr. Indeed, High-Point Rendel estimated cliff retreat rates of 0.04-0.1 m/yr **[find]**.

Control and Sensitive Points:
Unit 5 forms the northern half of a major headland forming a control point to Marsden Bay (unit 4) to the north. Sub-headlands within this unit act as local control points effectively trapping sediments within the pocket beaches. From a coastal defence perspective, the continued erosion of the cliffs does not pose too many problems because there is a wide undeveloped hinterland of Magnesian Limestone behind them. However, unit 5 also contains disused limestone quarries (south of Lizard Point) which have been infilled with colliery waste. The waste is contained behind the Magnesian Limestone cliffs which form the seaward quarry walls. Cliff erosion may eventually breach the limestone barrier allowing the waste to be eroded and released into the coastal system.

Unit 6 – North of Souter Point to Souter Point

Sediment Sources, Transport and Sinks:
This short stretch of coast comprises an exposed raised beach immediately north of Souter Point backing a small shallow bay with a beach. The raised beach is backed by vegetated slopes of Magnesian Limestone. Erosion processes are operating on the raised beach and differentially eroding it between harder Magnesian Limestone cliffs to form a small bay. The backing Magnesian Limestone is remote from wave attack. The ancient beach is probably supplying some of the sediment to the modern beach. An erosion rate of 0.2 m/yr is estimated for this small bay.

Control and Sensitive Points:
The raised beach is sensitive to higher erosion rates compared to the surrounding bedrock, although the beach is backed by a wide undeveloped hinterland.

Unit 7 – Souter Point to South Bents

Sediment Sources, Transport and Sinks:
This is a coast of undefended low cliffs (5-10 m high) with Pelaw Clay relatively thick and close to sea level (with thinner Magnesian Limestone exposed at the base of the cliffs and in a shore platform). The cliffs appear to be more actively eroded by coastal processes than similar units to the north producing a relatively smooth longitudinal coastal profile. The shore platform is relatively wide, and covered in pebbles and cobbles. This may support the assertion that the Pelaw Clay does not supply much sand to the coastal system. There is the potential to move 250,100 m^3/yr (SMP) of sediment (net) longshore to the south.

According to the SMP, the coastline (cliffs) and mean high water mark of this unit have been stable (0 m/yr) whereas the mean low water mark (platform) has retreated over the last 100 years. Values of between 0.2 and 3.4 m/yr have been recorded for this retreat (SMP), although the higher value is likely to be localised. Even though the cliffs and mean high water mark have been relatively stable in the long-term, the SMP suggests an erosion rate for undefended land in this unit of 0.2 m/yr. This appears to be slightly high and a more likely rate of retreat is 0.1 m/yr. Indeed, High-Point Rendel estimated cliff retreat rates of 0.04-0.1 m/yr.

Control and Sensitive Points:
Unit 7 forms part of the headland that acts as a control point for Whitburn Bay (unit 8) to the south. The lithology of the cliffs (Pelaw Clay exposed in many places to wave action) suggests that they are more susceptible to erosion than the estimated cliff erosion rates suggest. In this case there is a coastal defence issue where the residential properties of Whitburn approach the cliff-top (south end of unit).

Unit 8 – South Bents to Roker Pier (Whitburn Bay)

Sediment Sources, Transport and Sinks:
Unit 8 comprises Whitburn Bay, composed of a sand beach with isolated platform exposures (Parson's Rocks). Apart from the northern extremity, where the dunes are exposed, the beach is backed by a sea wall (constructed *c*. 1950). Behind the sea wall is a narrow strip of dunes and a Magnesian Limestone/Pelaw Clay hinterland to the north of Parson's Rocks and Magnesian Limestone/till cliffs and slopes to the south. The main sources of sediment to the beach are likely to be the sand dunes and from offshore where sediment is 'funnelled' into Whitburn Bay by waves. An ancient submerged forest of peat is also present in the bay overlain by the beach deposits.

Net longshore sediment transport is to the south with a potential to move 620,200-762,500 m^3/yr (SMP) and 63,700 m^3/yr (Scott Wilson). Roker Pier extends across the littoral zone and restricts the southerly transport of sediment beyond the Wear Estuary. However, a receding mean low water mark immediately north of the pier between 1861 and 1984 suggests that little sediment is accreting in the lee of the pier.

Scott Wilson approximated that over the period 1861-1984 the cliffs and dunes of Whitburn Bay yielded around 483,300 m^3 (3930 m^3/yr) of sediment (all types) to the coastal zone. The corresponding gain of beach volume (sand) was 25,000 m^3 (200 m^3/yr) indicating an overall loss of sediment from the system of 458,300 m^3 (3730 m^3/yr). These data suggest that the beach is losing sediment very slowly and that the rate of longshore sediment transport is low.

According to the SMP, the coastline (dunes and cliffs) and mean high water mark of this unit have been stable (0 m/yr) whereas the mean low water mark has retreated over the last 100 years. The mean low water mark of the main beach in Whitburn Bay has retreated at 0.75 m/yr, whereas Parson's Rocks (platform) has retreated at 0.1 m/yr (SMP). Higher rates of mean low water mark retreat are recorded immediately north of Roker Pier (0.75-1.9 m/yr). Even though the cliffs and mean high water mark have been relatively stable in the long-term, the SMP suggests an erosion rate for undefended land in this unit of 0.4-0.6 m/yr. By comparison, Scott Wilson indicate that between Parson's Rocks and Roker Rocks the cliff line remained relatively stable between 1861 and 1984 whereas the low water mark retreated between 0.79 and 1.49 m/yr. Mean low water mark retreat rates of 0.85-1.17 m/yr and mean high water mark retreat rates of 0.26-0.4 m/yr have been recorded in Whitburn Bay north of Parson's Rocks with dune erosion rates between 0.26 and 0.44 m/yr (Scott Wilson).

Control and Sensitive Points:
Whitburn Bay and its beach are controlled by a headland (South Bents) to the north and Parson's Rocks and Roker Pier to the south. Roker Pier may act as a longshore sediment transport control point, although transport through unit 8 is likely to be low. Historically, the beach has been sensitive to coastal processes and is currently likely to be losing sediment, hence causing potential problems for the sea walls and dunes that back the bay.

Unit 9 – Roker Pier to north Hendon Sea Wall (Sunderland Docks)

Sediment Sources, Transport and Sinks:
This unit is a heavily defended (sea walls and revetments) built-up area with no intertidal zone. Net longshore sediment transport is to the south with a potential to move 434,700 m^3/yr (SMP). To maintain Sunderland Docks and its channels, around 100,000 m^3 of sediment is removed every two years (SMP), although Scott Wilson suggest that more recent dredging removes double this.

Control and Sensitive Points:
The whole of this unit is a fixed hard point controlling processes to its north and south. The area is sensitive to removal of any of the sea walls as this would lead to increased erosion of the soft materials (Wear delta and floodplain deposits) that lie behind the defences and loss of major infrastructure. The SMP suggests a retreat rate of around 0.2 m/yr for undefended land in this unit. Removal of any of the barriers to longshore transport may also lead to sediment bypassing the estuary mouth from the north with subsequent loss of beach material from Whitburn Bay. Hendon sea wall is sensitive to overtopping and flooding of the low-lying land behind.

Unit 10 – South Hendon Sea Wall to Grangetown

Sediment Sources, Transport and Sinks:
The coast comprises a sea wall and rock revetment fronted by a sand beach. Behind the sea wall are slopes of Magnesian Limestone. Net longshore sediment transport is to the south with the potential to move 348,700 m^3/yr (SMP) and 59,100 m^3/yr (Scott Wilson). Scott Wilson report that beach levels have fallen in front of the sea wall since its construction. This is exemplified by the landward movement of the mean low water mark by between 0.97 m/yr and 1.21 m/yr and the mean high water mark by 0.16 m/yr and 0.32 m/yr between 1861 and 1984. The cliffs have eroded 0.14-0.34 m/yr over the same period of time, although the SMP suggests a potential to erode of 0.6 m/yr.

Control and Sensitive Points:
The beach is held in place by a series of groynes and artificial headlands at the south (rock revetment) and north (sea wall) ends of the beach. Removal of these structures would probably release this sediment to longshore transport to the south, with eventual loss of the beach and potential for undermining the sea wall.

Unit 11 – Grangetown to Seaham Harbour North Pier

Sediment Sources, Transport and Sinks:
This is a relatively smooth coast of undefended Magnesian Limestone cliffs capped by glacial sand and gravel, with wide sweeping bays and sand beaches between headlands and shore platforms. There are softer areas of cliff where glacial sediment approaches sea level. The cliffs are protected by a sea wall and a short revetment between Seaham Hall Hotel and Seaham Harbour.

The sediment on the beaches is likely to be derived from the till topping the limestone cliffs and from offshore which then becomes trapped in the wide bays between the headland control points. Scott Wilson approximated that over the period 1861-1984 the cliffs between Hendon and Ryhope (northern part of unit 11) yielded around 6,217,300 m^3 (50,550 m^3/yr) of sediment (all types) to the coastal zone. The corresponding loss of beach volume was 12,600 m^3 (100 m^3/yr) indicating an overall loss of sediment from the system of 6,229,900 m^3 (50,650 m^3/yr). Net longshore sediment transport is to the south with a potential to move 151,500 m^3/yr (SMP) and 195,000 m^3/yr (Posford Haskoning). A more realistic transport rate is probably around 10,000 m^3/yr (Motyka and Bevan). The lack of large-scale beach accretion north of Seaham suggests that the longshore rate must be modest. Posford Haskoning indicated that there are two principal areas for transport, in the nearshore area around 1000 m from the intertidal zone and over the intertidal beach.

The northern part of this coastline (cliffs between Salterfen Rocks and Pincushion) has eroded at a rate of 0.3-0.75 m/yr (SMP) whereas south of Pincushion the cliffs have been stable (0 m/yr) over the last 100 years. For the whole unit, the mean high water mark (beach) has generally retreated (0-0.75 m/yr), as has the mean low water mark (beach) (0.4-1.4 m/yr) (SMP). The mean high water mark and mean low water mark at Featherbed Rocks (platform) have retreated at 0.2 m/yr and 1.0 m/yr, respectively. Overall, the SMP suggests an erosion rate for undefended land in this unit of 0.4-0.6 m/yr, even though the cliffs south of Pincushion have been stable. Posford Haskoning estimated rates of 0.4 m/yr. By comparison, Scott Wilson reported cliff retreat rates of between 0.2 and 0.58 m/yr (1861-1984) for the northern half of this unit. Correspondingly, the mean low water mark moved landwards 0.46-2.3 m/yr (Scott Wilson). From the northern end of the unit to Salterfen Dene, Bullen reported recession rates of 0.8-1.1 m/yr between 1974 and 2001. At Ryhope, Bullen recorded a retreat rate 0.77 m/yr (1974-1988). For the entire unit, the softer stretches of cliff may erode at up to 2 m/yr (Scott Wilson).

Posford Duvivier indicated a gradual reduction in cliff erosion rates (between 1897 and 1939) from north to south in this unit. Values of 1-1.3 m/yr at Salterfen Rocks, 0-0.6 m/yr between Salterfen Rocks and Pincushion and 0-0.15 m/yr between Pincushion and Seaham Harbour were estimated.

Correspondingly the mean high water mark retreated 1-1.3 m/yr and 0-0.6 m/yr in the northern part of the unit and accreted (0-0.45 m/yr) in the south.

Overall, there appears to be a gradual reduction in cliff erosion rates from north to south. Rates are relatively high at Salterfen Rocks (*c*. 0.8 m/yr) and relatively low at Pincushion (0.3-0.4 m/yr) and Featherbed Rocks (0.2 m/yr).

Control and Sensitive Points:
The wide bays and associated beaches are controlled by three headlands (Salterfen Rocks, Pincushion and Featherbed Rocks/Seaham Harbour). Seaham Harbour North Pier acts as a major longshore sediment transport control point. From a coastal defence perspective, the continued erosion of the cliffs does not pose too many problems because there is a wide undeveloped hinterland of Magnesian Limestone behind them. The presence of sub-headlands with shallow bays in-between produces an unequal distribution of wave energy along the coast caused by bathymetry variations. Low wave energies occur in the sheltered water of the bays and higher energy environments at the headlands. This causes potential erosion of the headlands and filling in of the bays. Because this stretch of coast has a similar resistance to wave erosion, this process should lead in time to a straightening of the coastline. This is particularly the case at Salterfen Rocks which are eroding relatively rapidly compared to the exposed coast to the south and the defended coast to the north.

Unit 12 – Seaham Harbour

Sediment Sources, Transport and Sinks:
This is a heavily defended built-up area with harbour walls and rock revetment to its south, all acting as a strong point. Net longshore sediment transport is to the south (with possible reversals during southerly storms), with a potential to move 151,500-333,400 m^3/yr (SMP) and 800,000 m^3/yr (Posford Haskoning). Posford Haskoning suggest that the transport takes place in a narrow corridor around 1050 m offshore (across the head of the harbour piers). Around 48,000 tonnes of silt, sand and gravel is dredged annually from the harbour. This has reduced steadily from over 60,000 tonnes prior to the cessation of colliery waste tipping on the beaches to the north (around 1999) **.**

Control and Sensitive Points:
The whole of this unit is a fixed hard point controlling processes to its north and south. Although only a partial barrier (some sediment does bypass the entrance), removal of the breakwaters would lead to sediment bypassing the harbour from the north with potential loss of beach material from the Pincushion to Featherbed Rocks beach. However, the continued presence of Featherbed Rocks may continue to provide a barrier to southerly longshore sediment transport.

Unit 13 – South end of Seaham Harbour to Blackhall Rocks

Sediment Sources, Transport and Sinks:
This long stretch of coast comprises undefended Magnesian Limestone cliffs capped with till eroded into a series of broad bays controlled by a series of headlands. This unit contains several steep sided, heavily wooded valleys or denes, dissecting the cliff line. They are incised into the till and sometimes into the underlying limestone. The valleys are partially filled and they are likely to extend for some distance offshore. Denes include Hawthorn Dene, Foxholes Dene and Castle Eden Dene. Till thickness and height varies, sometimes being present at sea level, particularly in the Denes, other areas it is perched on the bedrock. The thickest till deposits are preserved in channels cut by glacial melt water through the Magnesian Limestone (e.g. Hawthorn Hive). The bays contain beaches composed of sand, backed by colliery waste in terraces derived from coal mining activities. The waste raised beach levels and extended the high water mark seaward, leaving the original cliffs isolated from the sea. Although landslipping of these cliffs still takes place, the slumped material is not transported away, allowing many of the backing cliffs to become vegetated (e.g. Hawthorn Hive and Horden Beach).

Now the tipping of waste on to the beaches has ceased, coastal processes are eroding the waste. Morphologically, the waste comprises two components; a wide consolidated terrace of chemically altered waste extending out from the foot of the limestone cliffs to the wave run-up limit, and a lower unconsolidated active beach in the intertidal zone. The terraces appear to be of two types. The first type are formed by erosion of the waste at the tipping point (e.g. Blast Beach and Easington Beach) and are characterised by an eroding low cliff (2-3 m high) along their seaward edge. Erosion, forming these terraces, has resulted, to date, in a drop in their surface levels of 7-8 m in places (SMP), from the cliff top to their present level.

The second are formed by redeposition of the eroded waste onto beaches further down the longshore transport system (e.g. Hawthorn Hive and Horden Beach). These terraces lack a sharp seaward boundary merging more gradually with the fronting beach. Both types of terrace are typically at elevations of +5-6 m OD and are up to 150 m wide.

In some areas the waste has been removed artificially as part of a regeneration programme along the coast (Turning the Tide). The colliery land-claim sites at Easington and Horden had large cliff edge spoil heaps. As part of the regeneration, these heaps were removed and the waste spread over the sites, capped and covered with soil to create public open space at Easington and for habitat recreation at Horden. In total 1.3 million tonnes of waste was removed and 80 ha of land reclaimed by this process.

Beach profile data captured between 1994 and 2001 describe lateral erosion of the waste terrace cliff and beach at Blast Beach (waste from Dawdon colliery which stopped in 1991) of around 17-18 m per year. Comparison of the 1989 and 1993 OS maps showed an erosion rate of 20 m per year. The Easington Beach (waste from Easington Colliery) data is more difficult to interpret, but suggests an erosion rate of around 12 m per year (25 m/yr for the first 2 years followed by 8 m/yr). These data suggest that in these areas, where the terrace is formed by erosion, a high rate of erosion has continued after waste tipping ceased. If these erosion rates continue into the future (and there is no reason to suspect it will not), then a terrace of waste 150 m wide will be completely eroded in 8 to 13 years.

The beach profiles from Hawthorn Hive and Horden Beach, where the terrace is formed of redeposited waste, suggest a more stable beach regime. Over the period 1996-2001 (Hawthorn Hive) and 1994-2001 (Horden Beach) the terrace has eroded little. This may suggest that these beaches and terraces are still being fed with an adequate supply of sediment from further up the longshore transport system. Hawthorne Hive receives sediment eroded from Blast Beach and Horden Beach receives sediment from erosion of Easington Beach. However, in 8 to 13 years this supply is likely to be exhausted, and the terraces will then begin to erode. The erosion rate may be similar to that incurred by the tipped waste (i.e. 12-18 m per year).

Shippersea Bay and Blackhall Beach appear to be intermediate between the two regimes described above. Both beaches have laterally eroded over a 5 year period (1996-2001) by 2.5-3 m per year.

The end result is likely to be complete removal of all the mine waste leading to re-exposure of the backing cliffs in those particular bays. Exposure will take place first at Blast Beach and Easington Beach (after 8-13 years) followed by later exposure at Hawthorn Hive and Horden Beach (up to 30 years). This supports the conclusion of Posford Duvivier that upon cessation of waste tipping the coast would recede to its original position of 1896, after 15-50 years.

Based on these data, it is possible to divide the Durham coast into two ‘erosion cells’, which appear to be controlled by the location of the waste tipping points along the coast (Blast Beach and Easington Beach), and the subsequent erosion and redeposition of this waste. Considering the northern ‘cell’, after cessation of tipping at Blast Beach, the waste has eroded rapidly (17-20 m per year) through natural processes. Much of the fines in this waste will have been transported offshore. However, longshore transport to the south has led to redeposition of some of the waste and formation of terraces in bays to the south such as Hawthorn Hive and Shippersea Bay. Although diminished through time, the Blast Beach source continues to supply Hawthorn Hive (the first bay south of Blast Beach) and hence the terrace of waste is presently stable and not eroding. In Shippersea Bay (the second bay south of Blast Beach and separated from Hawthorn Hive by a wide headland), the initial pulse of eroded material was deposited on the beach to form the terrace. However, because the bay is further down the longshore transport system from Blast Beach, the diminished supply through time means the beach is now eroding. South of Shippersea Bay to the next tipping point at Easington Beach the beaches appear to be relatively clean with respect to redeposited mine waste indicating that bypass of this material beyond Shippersea Bay is limited.

The same logic can be applied to the southern 'cell' involving tipping of waste on Easington Beach, redeposition and continued supply to Horden Beach, and redeposition followed by erosion of Blackhall Beach. South of Blackhall Rocks the beaches are relatively clean. The effect on Blackhall Beach of tipping at Horden has been negated because of its artificial removal. The tipping of waste at Blackhall occurred to the south of the Blackhall Beach profile.

The potential cliff retreat rate is between 0.3 m/yr (Posford Duvivier) and 0.5 m/yr (Posford Haskoning), but is probably not being realised in the bays where the waste provides protection to the cliffs from wave attack. At the headlands Posford Duvivier estimate an erosion rate of 0.1-0.2 m/yr. Along Easington Beach the backing cliffs (Magnesian Limestone with till near sea level) have become heavily vegetated and relatively stable. The erosion rate of the colliery waste is estimated at 1 m/yr (Posford

Haskoning). Net longshore sediment transport is to the south, with the potential to move 333,400-1,376,800 m^3/yr (SMP) and 130,000-800,000 m^3/yr (Posford Haskoning). However, a more realistic transport rate is around 10,000 m^3/yr (Motyka and Bevan). Posford Haskoning suggested transport around 800 m offshore between Nose's Point and Chourdon Point, and 900-1200 m and 1350-1500 m offshore around Horden Point.

The SMP indicates that between 1858 and 1990 the coastline has generally been stable in this unit whereas the mean high water and mean low water marks have accreted (0.39 m/yr and 0.05-0.14 m/yr, respectively). However, the SMP indicates that overall, the rate of undefended cliff erosion is between 0.1-0.4 m/yr.

Posford Duvivier indicated fairly stable cliffs in the north of unit (0-0.08 m/yr) with some erosion (0-0.3 m/yr) in the south (Fox Holes to Blackhall Rocks) between 1897 and 1939. This provides an indication of cliff behaviour before intensive dumping of colliery waste took place. Over the same time period, the movement of the mean high water mark has been variable in the north (erosion of 0.45 m/yr to accretion of 1 m/yr) and consistently accretionary in the south (0-2.1 m/yr).

Control and Sensitive Points:
The broad bays and associated beaches are controlled by a series of headlands (Nose's Point, Chourdon Point, Hive Point/Beacon Point, Fox Hole, Horden Point, Blackhall Rocks). Blackhall Rocks forms the southernmost control point to transport of sediment (including colliery waste). The whole of unit 13 is sensitive to coastal processes because the artificial infilling of the bays with colliery waste has led to 'disequilibrium' and the coast is now actively trying to adjust to a state of equilibrium. The colliery waste is particularly sensitive to erosion and will eventually be completely

eroded to re-expose the backing cliffs to wave attack. Overall, it is estimated that the waste in each bay will be completely eroded in 10-30 years time, after which the backing cliffs will begin to erode at *c*. 0.3 m/yr.

Unit 14 – Blackhall Rocks to Crimdon Park

Sediment Sources, Transport and Sinks:
Unit 14 is composed of undefended cliffs of Magnesian Limestone (at base) with a thick till cap exposed to wave attack (colliery waste is absent). The till approaches sea level further south in the unit. A wide (but probably thin) sandy beach is present with intermittent exposure of shore platform in the north. The beach is supplied with sediment from erosion of till from the cliffs. The estimated net longshore sediment transport is to the south, with a potential to move 1,376,800 m^3/yr (SMP).

The SMP indicates that between 1858 and 1990 the coastline (cliffs) has generally been stable in this unit whereas the mean high water and mean low water marks have accreted (0.39 m/yr and 0.14 m/yr, respectively). However, the SMP indicates that overall, the rate of undefended cliff erosion is between 0.2-0.4 m/yr. This appears to be high and a more likely rate of retreat is 0.2 m/yr. Posford Duvivier indicated stable cliffs (0 m/yr) between 1897 and 1939, and a variable movement of the mean high water mark (erosion of 0.35 m/yr to accretion of 0.3 m/yr).

Control and Sensitive Points:
Blackhall Rocks forms a northern control point restricting longshore sediment to the south from beaches to its north. There is no control point to the south where the beach of unit 14 grades south into a (probably thicker) sand beach backed by dunes (unit 15). Southerly longshore sediment transport is uninterrupted between units 14 and 15.

Unit 15 – Crimdon Park to north end of Hartlepool Headland (North Sands)

Sediment Sources, Transport and Sinks:
Unit 15 comprises a wide sandy beach (North Sands) backed mainly by sand dunes forming links. The supply of sediment to these features is likely to be from erosion of the till in unit 14 to the north. Atkins suggested that this stretch of coast has been stable for some time and there is no progressive erosion or accretion trend. Potential net longshore transport rates of 86,000-176,000 m^3/yr to the south are estimated for North Sands (Atkins) and between 27,000 m^3/yr to the north near Hartlepool Headland. The SMP estimates rates of between 94,400 and 195,600 m^3/yr to the north. However, it is likely that the net longshore transport is small compared to the cross-shore movement.

The SMP indicates that between 1858 and 1990 the coastline has receded in the north (0.08 m/yr) and accreted in the south (0.15 m/yr). The mean high water mark has on average retreated in the north (0.09 m/yr) and accreted in the south (0.17 m/yr), whereas the mean low water mark has accreted along the entire unit (0.23-0.27 m/yr). Although it appears fairly stable in the long-term, the SMP indicates that overall, the rate of undefended coastline erosion is between 0.2-0.4 m/yr. This appears to be slightly high and a more likely rate of retreat is 0-0.1 m/yr. Posford Duvivier indicated a stable coastline (0 m/yr) between 1897 and 1939, and advancement of the mean high water mark (0-1.1 m/yr).

Control and Sensitive Points:
The northern end of the unit is not controlled and processes continue into unit 14. North Sands beach is held in place by Hartlepool Headland to its south. A pier and series of groynes are also present towards the southern end of the unit where the area behind the coast becomes more built-up (Hartlepool). Here the dunes appear to be in poorer condition and subject to further deterioration, suggesting the structures do not function properly. There is also a small cliff of landfill at the southern end of unit, which is now releasing waste to the beach, and is sensitive to further erosion.

Unit 16 – Hartlepool Headland (to Pilot Pier)

Sediment Sources, Transport and Sinks:
The coast is a heavily defended built-up area with a sea wall backing a bedrock shore platform with little mobile sediment. A vertical drop in shore platform level of 0.01-0.03 m/yr (Atkins) has been estimated over the last 100 years and the mean low water has retreated landwards as the platform has eroded. These values appear to be very high for platform downcutting. Mid-way along this unit is Heugh Breakwater protecting Hartlepool Docks from north-easterly waves. The Heugh Breakwater may act as a sediment drift divide with longshore sediment to the north (most of unit 15) and south of it. Potential net longshore transport rates to the north of 317,000 m^3/yr (SMP) have been estimated. This stretch of coast is unlikely to fulfil this potential because the amount of mobile sediment on coast is small (mainly rock platform). The net longshore transport of sediment south around the headland is small and very little passes the Heugh Breakwater, hence the absence of beaches around the breakwater.

Control and Sensitive Points:
The whole of this unit is a fixed hard point (both with structures and bedrock control) controlling processes to its north and south. Removal of Heugh Breakwater would increase wave heights in the outer harbour and dock entrance and impact on Block Sands and Middleton Beach.

Unit 17 – Pilot Pier to South Pier

Sediment Sources, Transport and Sinks:
This coast is a heavily defended built-up area with sea walls and rock revetments. It is generally subtidal apart from Middleton Beach confined by the North Pier and Middleton Pier forming a pocket beach. The low water mark of Middleton Beach has historically retreated. The main sediment sink is the dredged channel into Hartlepool Dock. Sediment is dredged from this location and dumped at sea. In terms of sediment budget, the coarser dredgings are lost from the system, reducing the supply to the beaches to the south.

Control and Sensitive Points:
The whole of this unit is a fixed hard point controlling processes to its north and south. The area is sensitive to removal of any of the defences and breakwaters as this would lead to increased erosion of the soft materials (floodplain deposits) that lie behind the defences and loss of major infrastructure.

Unit 18 – South Pier to Seaton Carew

Sediment Sources, Transport and Sinks:
This stretch of coast comprises a sand beach backed by hard structures (rock revetment) behind which are ancient sand dunes. The northern end (between South Pier and Newburn Bridge) has historically shown no discernible erosion/accretion trend. At Newburn Bridge, net potential longshore sediment transport rates have been estimated between 145,000 and 419,000 m^3/yr to the south (Atkins) and 385,800 and 1,695,100 m^3/yr to the south (SMP). Onshore-offshore sediment transport in Hartlepool Bay is significant with offshore bars formed during winter. Atkins suggested that sediment exchange with the sea bed in Hartlepool Bay below 10-20 m CD is insignificant. Beach material in the bay is derived from nearshore/offshore sediment transport from the north. Motyka suggested that it is likely that very little beach sediment moves south out of Hartlepool Bay. Indeed, it tends to act as a sediment trap, and there has been much infilling throughout the Holocene in both bays, enhanced by land-claim.

The SMP indicates that the coastline along this unit has been stable (0 m/yr) or accreting (0.26 m/yr) between 1858 and 1990. The mean high water mark has accreted (0.05-0.19 m/yr) over the same period of time, whereas the low water mark has retreated (0.47-0.5 m/yr). Overall, the SMP suggests an erosion rate for undefended land of 0.2-0.4 m/yr. The higher rate is likely to be towards the north whereas the lower rate is towards the south.

Control and Sensitive Points:
Removal of the rock revetments would lead to rapid erosion of the ancient dunes behind. This would release more sediment to the fronting beaches.

Unit 19 – Seaton Carew to North Gare Breakwater

Sediment Sources, Transport and Sinks:
This stretch of coast is undefended and comprises a sand beach backed by a wide area of sand dune forming links. The North Gare Breakwater holds the beach in place preventing longshore sediment transport across the mouth of the Tees Estuary. Sediment is supplied to the beach from the dunes (and probably from offshore). Potential net longshore sediment transport is to south and estimated around 1,695,100 m^3/yr (SMP). Motyka suggested that it is likely that very little beach sediment moves south out of Tees Bay. Indeed, it tends to act as a sediment trap, and there has been much infilling throughout the Holocene in the bay, enhanced by land-claim.

The dunes have accreted by an average of 1.75 m/yr between 1858 and 1990, whereas the mean high water and mean low water marks have retreated (0.06 m/yr and 1.08 m/yr, respectively) (SMP). The accretion of the dunes is enhanced by the presence of North Gare Breakwater. Overall, and although the dunes have long-term accretion, the SMP indicates that the typical erosion rate for undefended land is 0.1 m/yr. The long-term evidence suggests that this stretch of dune is stable.

Control and Sensitive Points:
The North Gare Breakwater is a fixed control point preventing longshore transport of sediment into the channel of the Tees Estuary. Removal of the breakwater would lead to sediment bypass to the south with potential infilling of the Tees Estuary mouth. This would also lead to loss of sediment from the beaches south of Hartlepool, with potential for erosion of the dunes and undermining of the defences fronting Seaton Carew.

Unit 20 – Mouth of Tees Estuary

Sediment Sources, Transport and Sinks:
The mouth of the estuary is a sink for sediments.

Refer Estuary Assessment (Appendix I)

Control and Sensitive Points:

Unit 21 – South Gare Breakwater to west end of Coatham Rocks (Coatham Sands)

Sediment Sources, Transport and Sinks:
This stretch of coast is undefended and comprises a 300 m wide sand beach (Coatham Sands) backed by low sand dunes forming links (British Geological Survey, 1998a). The hinterland comprises a low-lying land-claimed coastal plain (Coatham Marsh) in the mouth of the Tees Estuary and till further south-east towards Redcar. The South Gare Breakwater in the north-west and Coatham Rocks in the south-east hold the beach in place. In addition, three nearshore slag banks at low water east of South Gare Breakwater, known as the German Charlies, provide further shelter to the coast. The crenulated nature of the bay indicates that the beach plan shape is likely to be tending towards an equilibrium form. Sediment is likely to be supplied to the beach from the dunes and from sources offshore in Tees Bay. Indeed, Motyka (1986) suggested that very little beach sediment moves south out of Hartlepool Bay and Tees Bay, tending to act as sediment traps.

The coastline in this area has been altered considerably by the construction of the North and South Gare Breakwaters. Motyka and Beven (1986) determined from map data accretion of 130,000 m^3/yr north of the Tees Estuary mouth (Seaton Sands) and 107,000 m^3/yr to the south (Coatham Sands) between 1891 and 1930. This major accretion occurred as a result of accumulation of sediment against the northern breakwater due to dominant southerly sediment transport, and accumulation to the south-east due to the sheltering effect of the southern breakwater which induces a local reversal of transport in its lee (Babtie, 1997). Motyka and Beven (1986) estimated that the breakwaters have resulted in a reduction of southerly longshore transport by as much as an order of magnitude, to around 50,000 m^3/yr. Although South Gare Breakwater restricts passage of sediment across the mouth of the Tees Estuary into Coatham Sands, Coatham Rocks appear to be ‘leaky’ and allow sediment to bypass further to the south.

The long-term (1858-1990) historical development of the dunes has been stability (0 m/yr), whereas the mean high water and mean low water marks have accreted (1.55 m/yr and 0.11 m/yr, respectively) (Babtie, 1999). Despite the long-term stability of the dunes, Babtie (1999) concluded that the typical erosion rate for undefended land is 0.1 m/yr. The morphology of the dunes suggests that erosion is taking place towards Coatham, whereas the dunes become gradually more stable towards the north.

There are several anthropogenic activities that are influencing sediment budgets along Coatham Sands. Motyka and Beven (1986) suggested that dredging in the mouth of the Tees Estuary is intercepting much of the southerly moving sediment. The role of the River Tees in supplying fine sediment to the coastal zone has been reduced considerably by the construction of the Tees Barrage. The Barrage was designed to allow bypassing of sediment, but observed accumulations upstream, and a 24%

reduction in the dredging requirement of the harbour indicates that much of the river sediment is trapped.

Control and Sensitive Points:
The beach is held in place by control points South Gare Breakwater and 'leaky' Coatham Rocks. The crenulate nature of the bay between South Gare Breakwater and Coatham Rocks indicates that the beach plan shape is likely to be tending towards an equilibrium form.

Unit 22 – Redcar Sands

Sediment Sources, Transport and Sinks:
The coastline fronting Redcar headland comprises a sand beach (Redcar Sands) backed by a sea wall and revetments. Behind the sea wall is a variable width land-claimed sand dune fronting till. Seaward of the beach is a well-defined rock shore platform (Coatham and Redcar Rocks) composed of Redcar Mudstone Formation (British Geological Survey, 1998a) which controls the position of the headland.

The beach appears to be fairly volatile and sensitive to wave conditions with loss over short periods followed by recovery over periods of a few years (Babtie, 1997). For example, substantial amounts of sand were lost from this beach during storms in 1995/1996 followed by recovery in 1997. Longshore sediment transport around the headland is to the south (Babtie, 1997, 1999). However, large volumes of sediment could potentially be moved north under easterly storm conditions such as those in winter 1995/96. The mean high water and mean low water marks have suffered long-term (1858-1990) erosion of 0.3 m/yr and 0.17 m/yr, respectively (Babtie, 1999). It is possible that the long-term lowering of Redcar Sands is related to sediment trapping in Tees Bay by North and South Gare Breakwaters.

Redcar headland is a fixed hard point containing a sea wall and a wide rock shore platform. The presence of a sandy beach fronting the shoreline here indicates that this headland is not a longshore sediment transport barrier and there is connectivity between the beaches to its west (Coatham Sands) and east (Marske Sands).

Beach elevation data for the central part of Redcar Sands for December 2004 has been provided by SBC. The data shows the upper 130 m of the beach at the western side slopes gradually seaward from an elevation of 3.4 m OD at the base of the sea wall to around 0.9 m OD at a distance of 130 m. The eastern side closer to Redcar Rocks slopes from 1.8 m OD to -0.7 m OD. The data shows a lowering (and likely thinning) of the beach in an easterly direction towards the exposure of shore platform, which is at an average elevation of around 0.7 m OD.

Control and Sensitive Points:
This headland is a fixed hard point containing a sea wall and a wide rock shore platform. Although the unit is a headland it contains a wide sand beach indicating that it is not a longshore sediment transport barrier and there is connectivity between unit 21 to its west and unit 23 to its east. From a coastal defence perspective, the sea wall at Coatham Rocks is sensitive, because it is at risk of overtopping with the potential to flood parts of Redcar immediately behind it.

The headland is sensitive to coastal processes because of the unequal distribution of wave energy along this stretch of coast caused by bathymetry variations between units 21 (Coatham Sands), 22 (this unit) and 23

(Marske/Saltburn Sands). The changes in water depth result in a low wave energy environment providing sheltered water in the bays (the Sands) and a higher energy environment at the headland (Coatham Rocks and sea wall). This causes increased pressure on the headland relative to the bays to either side.

Unit 23 – East end of Coatham Rocks to Saltburn-by-the-Sea (Marske/Saltburn Sands)

Sediment Sources, Transport and Sinks:

This stretch of coast comprises a wide (300-400 m) sand beach (Marske/Saltburn Sands) held in place by Saltburn Scar (Redcar Mudstone Formation headland) to the east. Along the western end the beach is backed by a rock revetment built on to the face of a narrow strip of sand dune fronting a till hinterland (British Geological Survey, 1998a). Here the beach is controlled by groynes, which were nourished with 70 m^3 of sand and shingle per metre of frontage between 1973 and 1983. The eastern half is mainly undefended and the beach is backed by a narrow strip of dunes in front of till slopes, apart from a stretch of sea wall in front of Saltburn-by-the-Sea at the eastern extremity. Prior to defences, the dunes and till cliffs appear to have been eroding at a fairly constant rate to form a gently curving bay between Redcar Rocks and Saltburn Scar.

The dunes are in poor health and are actively eroding, forming a 'veneer' in front of the till hinterland. In places the dunes are absent and till is exposed at the coast. In front of the till, the beach is composite with pebbles forming an upper storm beach with a wide sandy lower beach, indicate that the pebbles are supplied locally through erosion of the till. In front of the dunes, the upper pebble beach breaks down and there are patches of shingle sometimes shaped into cusps on the beach surface, which is mainly sand.

Net longshore sediment transport is to the east (Babtie, 1997, 1999). Numerical modelling suggests that the potential to transport sediment increases gradually from Coatham Sands, across Coatham/Redcar Rocks to Marske Sands. This is probably due to a subtle change in orientation of the coast relative to the predominant wave direction. These values suggest that more sediment is being lost from Marske/Saltburn Sands than is being delivered from the west, around Redcar headland. Only small sediment build-up on the west side of the Redcar groynes indicates that actual longshore sediment transport is low in this area. In addition, the presence of Saltburn Scar does not allow much loss of sediment to the east.

Babtie (1999) showed that over the long-term (1858-1990), the mean high water mark has consistently retreated (0.04-0.74 m/yr, with the highest values in the west). The mean low water mark has also retreated in most areas (0.15-0.8 m/yr) but with local accretion at Marske-by-the-Sea (0.01 m/yr). Overall, Babtie (1999) estimated the erosion rate for undefended land to be around 0.4 m/yr with localised rates of 0.6-0.7 m/yr closer to Redcar.

Control and Sensitive Points:

Marske/Saltburn Sands is held in place by a control point at Saltburn-by-the-Sea (Saltburn Scar). Prior to defences, the dunes and till cliffs appear to have been eroding at a fairly constant rate to form a gently curving bay between Coatham Rocks and Saltburn Scar. However, the crenulate nature of the bay is now interrupted by the presence of the revetment and the groynes in its western half. The revetment forms a hard stretch which has caused the bay to slightly protrude seaward of its ‘natural’ shape, and the wall is therefore a pressure point. The sea wall at Saltburn-by-the-Sea is sensitive to overtopping.

Unit 24 – Saltburn-by-the-Sea to Skinningrove Jetty

Sediment Sources, Transport and Sinks:
This stretch of coast comprises undefended high vertical cliffs composed of Redcar Mudstone, Staithes Sandstone and Cleveland Ironstone Formations backing a wide shore platform of Redcar Mudstone Formation covered with a veneer of pebbles and cobbles (British Geological Survey, 1998a). The height of the cliffs reduces at Skinningrove and till becomes more predominant in the overall cliff height. To the west of Skinningrove jetty the till reaches sea level, and a sand beach has accumulated both to the west and east of the jetty (Cattersty Sands). Accumulation has been such that sand dunes occur at the back of the beach indicating the beach is relatively stable. Erosion of the till cliffs supplies sand to the beach, which is self-contained in a small bay between Hunt Cliff and Hummersea Scar. The top and base of the rock cliffs at Hunt Cliff are retreating at rates around 0.1 m/yr (Agar, 1960), with increased rates at Cattersty Sands (0.3 m/yr) where the cliffs are till. The yield of beach-building sediment from the rock cliffs is low.

Longshore sediment transport is likely to be to the east, although the actual sediment transport volumes are very low considering the nature of the foreshore (shore platform with little mobile sediment). Longshore transport in Skinningrove Bay is to the south-east for waves from the north, and north-west for waves from the east. This subtle change in transport is critical to the stability of the beach and its ability to protect the cliffs. There is likely to be significant cross-shore transport. Winter storms cause erosion of the upper beach with deposition at lower levels and summer conditions tend to build the upper beach by moving sediment onshore. Sediment build-up at lower levels is vulnerable to longshore movement around the tip of the jetty from its west to east side. In addition, the build up of sand and shingle to the east of the jetty may be enhanced by a local reversal in the direction of longshore transport, due to the sheltering effect of the jetty.

Skinningrove jetty provides a control point causing Cattersty Sands to build up on its western side (although some bypasses during storm conditions). This has allowed the beach to accrete and become wider than would have been possible without the jetty. If the jetty were to be removed sediment would be transported more rapidly east from Cattersty Sands to potentially bypass Skinningrove.

Control and Sensitive Points:
Skinningrove jetty provides a control point at the southern end of the unit causing Cattersty Sands to build up on its western side (although some may bypass during storm conditions). This has allowed the beach to accrete and become wider than would have been possible without the jetty. The presence of Cattersty Sands is critical to the stability of the till cliffs upon which Skinningrove sits. If the jetty were to be removed sediment would be transported more rapidly south from Cattersty Sands and the cliffs would be more vulnerable to wave attack. The presence of the jetty is therefore essential for the long-term stability of the beach and the dunes.

Unit 25 – Skinningrove

Sediment Sources, Transport and Sinks:
This short stretch of coast is dominated by Skinningrove harbour at the mouth of Skinningrove Beck. Skinningrove is a small mining village set in the bottom of a steep river valley and situated a short distance upstream of the beck mouth. The harbour is protected by a western jetty that prevents most sediment moving around it from the north. The beach to the east of the jetty is stabilised by a fish-tail groyne and this beach has shown little change since construction of the groyne (1991). The evolution of the beach is controlled by waves, the beck and supply of sediment around the jetty. Winter storms cause erosion of the upper beach with deposition at lower levels and summer conditions tend to build the upper beach by moving sediment onshore. Under conditions of low flow, sand and gravel blocks the mouth of the beck although the source is not the beck itself. High flow beck events wash much of the upper beach to lower levels between the fish-tail groyne and the jetty. The sand and shingle accumulation at the beck mouth provides protection against waves from the north-east. The build up of sand and shingle to the east of the jetty may indicate a local reversal in the direction of longshore transport, due to the sheltering effect of the jetty.

Control and Sensitive Points:
Skinningrove jetty provides a control point at the eastern end of this unit. If the jetty was removed, sediment would be transported more rapidly into the mouth of the beck from Cattersty Sands. The till slope to the south-east of the jetty is unstable with movement of the slope leading to continual shifting of the jetty path. The slope is particularly active through winters. Continued slipping may destabilise the overlying made ground on the upper part of the slope and place some industrial developments at risk.

Unit 26 – Skinningrove to Staithes

Sediment Sources, Transport and Sinks:
The coast comprises undefended high vertical cliffs composed of Lower Lias shales and sandstones backing a rock shore platform covered with a veneer of pebbles and cobbles. The cliffs rise towards the centre of the unit reducing in height at the western and eastern ends. The central high section of cliff is topped by Middle Lias sandstones with ironstone bands which have been extensively mined in the past. The lower western and eastern sections are capped with till. Patchy areas of sand occur on the foreshore towards Staithes. Longshore sediment transport is to the east, although the potential to move sediment is very low considering the nature of the foreshore (shore platform with little mobile sediment). The Skinningrove jetty is an effective barrier to longshore transport to the east.

The cliffs are exposed to wave attack at the foot and subaerial weathering of the cliff face and cliff top, and are retreating by means of regular cliff falls and slope failures. Sea caves have been eroded into the base of the Lias rocks where they are locally weaker. The cliff top is subject to infrequent scallop-like failures in the till, promoted by retreat of the rock face (undercutting the base of the till) and high groundwater levels in the till (heavy rainfall, poor drainage).

Cliff retreat rates are variable in the short-term but at the extreme eastern end near Staithes they are 0.05 m/yr at both the top and base between 1892 and 1960 (Agar). Cliff-top retreat rates at Boulby vary between 0 and 0.1 m/yr between 1850 and 1998 (High-Point Rendel). However, short-term cliff-top recession rates appear to be more variable than the cliff face rates, i.e. long periods of no recession separated by short periods of relatively large losses. Rates at Cowbar were assessed as potential of the order of 0.25m/yr (High-Point Rendel). Subsequent work (M. Lim, 2006) has demonstrated that over a 36 month period erosion rates measured at 0.025m/yr. This more recnt work based on detailed monitoring by Durham University has also indicated different mechanisms for cliff erosion. Overall, an erosion rate of *c*. 0.1 m/yr is consideredx possible for the Lias cliffs in this unit, although the measure ments at Cowbar Cottages give far lower rates. . The very slow lowering of the shore platform is integral to the overall erosion process (Robinson).

Control and Sensitive Points:
From a coastal defence perspective, the continued erosion of the cliffs does not pose too many problems because there is a wide undeveloped hinterland of Lower Lias behind the cliffs.

Unit 27 – Staithes

Sediment Sources, Transport and Sinks:
Staithes Harbour is sheltered by closely spaced north and south breakwaters (built 1920s) and the village is protected by a sea wall with two small groynes. The amount of sediment in the harbour has since reduced. Much of the sediment that could potentially enter Staithes is trapped west of Skinningrove jetty.

Control and Sensitive Points:
The breakwaters and sea wall are at risk from overtopping.

Unit 28 – Staithes to west end of Runswick Bay

Sediment Sources, Transport and Sinks:
The coast comprises undefended vertical cliffs (and along some stretches slopes) composed of Upper Lias Whitby Mudstone Formation backing a shore platform covered with a veneer of pebbles and cobbles. Longshore sediment transport is to the east, although the potential to move sediment is very low considering the nature of the foreshore (shore platform with little mobile sediment). The Skinningrove jetty (unit 25) is an effective barrier to longshore transport to the east. There is the potential for reversal across Penny Steel (immediately east of Staithes) because of the protection afforded by Cowbar Nab. The yield of beach-building sediment from these cliffs is low.

Agar reported cliff foot erosion rates of 0.1-0.11 m/yr in this unit between 1862 and 1960. High-Point Rendel estimated cliff foot recession rates between 0 and 0.17 m/yr and cliff top rates of 0-0.12 m/yr for this unit over the last 100 years. Overall, an erosion rate of *c.* 0.1 m/yr is likely for the Lias cliffs in this unit. The very slow lowering of the shore platform is integral to the overall erosion process. Robinson measured downcutting rates of 0.00008-0.00328 m/yr (average 0.0011 m/yr) for the plane and 0.00716-0.01931 m/yr (average 0.01466 m/yr) for the ramp at Lingrow Knock.

Control and Sensitive Points:
From a coastal defence perspective, the continued erosion of the cliffs does not pose too many problems because, apart from isolated properties, there is a wide undeveloped hinterland of Upper Lias behind the cliffs.

Unit 29 – Runswick Bay

Sediment Sources, Transport and Sinks:
Runswick Bay is a deep, wide bay located between Whitby Mudstone Formation headlands to the west (Cobble Dump) and east (Kettle Ness) (British Geological Survey, 1998a). The bay has a sand beach in its western quarter (Figure B.1) (generally coarsening from west to east) where the backing cliffs are composed of till at sea level. Sediment is supplied to the beach from erosion of the till. Further to the east the beach gives way to a shore platform (with pebble veneer) where the backing cliffs are Whitby Mudstone Formation.

A long-term (100 years) erosion rate of *c*. 0.1 m/yr is likely for the rock cliffs, with greater rates (*c*. 0.2 m/yr) for the till cliffs (High-Point Rendel, 2002a). Although the long-term erosion of the till cliffs is relatively low, they are prone to larger short-term landslip events. The bay has a long history of instability with recorded major landslips occurring in 1689 (Runswick Bay), 1829 (Kettleness), 1975-1977 (Runswick Bay, Rozier and Reeves, 1979) and 1999 (Kettleness). In the 1999 event, a 70,000 tonnes slip occurred below Kettleness village. This affected the sediment transport pattern for a few months until the landslip debris was removed by coastal processes.

Sediment transport in Runswick Bay is likely to be dominated by onshore-offshore movements, while littoral transport serves to redistribute sediment within the bay. Although the foreshore in Runswick Bay has remained relatively stable over the long term, there is seasonal variation in the beach elevation. Large waves in winter draw sediments down and create a flatter beach profile and lower beach levels. In the summer the sediment lying on the nearshore sea bed is transported landward by more constructive wave action resulting in the formation of a steeper beach profile and higher beach levels.

High-Point Rendel (2003) suggested that the sand beach of Runswick Bay is connected to an extensive spread of sand lying offshore in water depths of 5-15 m, *via* sand filled channels that run normal to the shoreline, between the rock platforms. However, they provided no evidence to support this assertion.

Control and Sensitive Points:
The beach at Runswick Bay is controlled by headlands to the west and east. The village of Runswick Bay is protected by a concrete wall built between 1950 and 1970. The till cliffs to its south are weak and this end of the wall is at risk as are a number of houses along the unprotected part of the bay. The long-term erosion of the till cliffs is relatively low, but they are prone to larger short-term episodic landslides. The village of Kettleness is situated close to the cliff top towards the eastern end of the bay where an erosion rate of 0.1 m/yr is estimated.

Unit 30 – East end of Runswick Bay to west end of Sandsend Wyke

Sediment Sources, Transport and Sinks:
This coast comprises undefended vertical cliffs composed of Whitby Mudstone Formation backing a shore platform covered with a veneer of pebbles and cobbles. Till is perched high up on the cliff towards the southern extreme where the cliffs are lower. The whole of this stretch of coast forms a broad headland between Runswick Bay to the north and Sandsend Wyke to the south. Occasional patches of sand occur on the foreshore although the supply of beach-building sediment from these cliffs is low. Longshore sediment transport is likely to be to the south-east, although the actual volume of sediment movement is very low considering the lack of mobile sediment on the shore platform. The cliffs have eroded at long-term rates up to 0.11 m/yr (average *c*. 0.1 m/yr) (High-Point Rendel, 2002a).

Control and Sensitive Points:
From a coastal defence perspective, the continued erosion of the cliffs does not pose too many problems because, apart from isolated properties, there is a wide undeveloped hinterland of Upper Lias behind the cliffs.

Unit 31 – Sandsend Wyke

Sediment Sources, Transport and Sinks:
This stretch of coast comprises a sand beach infilling the western half of a bay between a headland (Sandsend Ness) to the west and the start of Whitby coastal defences to the east. The bay has been formed by the presence of till at sea level (in 20-30 m high cliffs) eroding at a greater rate than Sandsend Ness (Whitby Mudstone Formation) to the north and the Saltwick Formation at Whitby. The coast is undefended apart from a sea wall at its western end to protect the village of Sandsend and a revetment along the stretch immediately west of Raithwaite Gill. The exposed till slopes (around 1 km length west of Raithwaite Gill) are subject to erosion and significant slope instability and landslips (Figure B.2). A long-term retreat rate of up to 0.26 m/yr (*c*. 0.2 m/yr) is likely for the till cliffs (Agar, 1960; High-Point Rendel, 2002a).

The till comprises lower and upper units split by irregular beds of gravel, sand and silt (Harrison, 1895; Fox-Strangeways and Barrow, 1915). The lower till comprises clay with abundant pebbles and cobbles. The upper till (6-12 m) is similar to the lower till but contains less coarse sediment. The middle sands and gravels may be up to 15 m thick along this stretch of coast. They comprise two beds of sand containing many coal particles (especially the upper bed) split by a bed of gravel (Fox-Strangeways and Barrow, 1915). The coal particles in the glacial sediments may provide an alternative source for the coal particles found on the beaches at Scarborough (Section 3.4.14), and a far-field source (i.e. the dumped waste of Durham) may not need to be invoked.

The coast north-west of Sandsend Wyke contains no permanent deposits of sand that could feed the Sandsend Wyke frontage. Much of the sediment is retained much further west in Runswick Bay (west of Kettle Ness). Sediment is supplied to the beach from the backing cliffs, but, according to High-Point Rendel (2002b), the long term presence of a sand beach at Sandsend Wyke indicates a substantial offshore supply. Potential longshore transport calculations and volume changes indicate that without the offshore supply, the beach would have been removed completely many years ago. High-Point Rendel (2003) suggested that the sand beach of Sandsend Wyke/Whitby Sands is contiguous with an extensive spread of sand lying offshore in water depths of 5-15 m, *via* sand filled channels that run normal to the shoreline, between the rock platforms. However, they provided no evidence to support this assertion. Beach movement is therefore dominated by onshore-offshore movements while littoral transport serves to redistribute sediment within the bay. Net longshore sediment transport is to the east, with the magnitude of potential movement reducing progressively eastwards.

Over the long-term there has been a consistent landward retreat of the low water mark (0.82-1.44 m/yr) and a net decline in beach volume (Halcrow, 2002C), although in the short term, beach levels are highly variable (High-Point Rendel, 2002b). The loss of beach sediment between 1892 and 1967 has been estimated at 4620 m^3/yr for Sandsend Wyke. Under storm conditions the beach can be largely removed with a significant volume of sediment moved offshore, exposing a foreshore of till and localised areas of rock platform to leave a narrow strip of beach deposits in front of the defences. This sediment is returned during calm periods when the top of the beach can accumulate to a level of around 4.5-5.5 m OD (High-Point Rendel, 2002b). In low energy conditions the beaches also tend to be wider by up to several hundred metres.

Control and Sensitive Points:
The eastern end of this unit is open and continues in to unit 32 (Whitby Sands). The western end of the bay is bounded by an Upper Lias headland. The sea wall fronting Sandsend is also acting as a hard point at the western end of the bay and has produced an 'un-natural' bulge in the coastal profile. The sea wall at Sandsend is at risk from overtopping exacerbated by the continued recession of the low water mark.

Unit 32 – Whitby Sands

Sediment Sources, Transport and Sinks:
Whitby Sands forms a natural continuation of Sandsend Wyke ending in the east alongside Whitby West Pier (River Esk) and cliffs of Saltwick Formation. The beach is backed by a sea wall and rock revetment protecting the till cliffs (30 m high) from erosion. Cliff stabilisation and coast protection measures began in the 1920s with construction of a sea wall along part of the area. Further cliff stabilisation was carried out during the late 1960s and 1970s, with the latest phase completed in 1990 (Clark and Guest, 1991).

Longshore sediment transport is to the east with West Pier providing a partial barrier to transport across the mouth of the River Esk and further east along the coast (High-Point Rendel, 2002b). It has been estimated that over half of this potential transport takes place outside the intertidal zone. West Pier is therefore critical in controlling the loss of beach sediment to the east. Removal of this structure and East Pier would likely lead to loss of beach sediment through longshore transport to the east. This would put the backing revetments and sea wall at greater risk of wave attack. What little sand is transported around the breakwater tends to be swept into the harbour entrance by storm waves. Here it settles out to form a bar on the east side of the entrance downstream of the swing bridge. Finer sediments settle in the upper harbour, upstream of the swing bridge. Little sediment is found east of the harbour because sediment that does not settle in the harbour is forced offshore by the piers and continues to be transported into deeper water. Around 10,000 m^3/yr of sand from the bar and 90,000 m^3/yr of silt are removed from Whitby Harbour (Deputy Harbour Master, personal communication). The dredged sand is disposed offshore of Whitby Harbour in water depths of 35-40m (54° 30.8'N 00° 35.9'W). The disposal site is in water deeper that the estimated closure depth of 20m (see Section C.1.1.) and is unlikely to be transported back to the coast. Hence, once the sand has been removed from the harbour it is lost from the system.'

Between 1892 and 1967 there has been a small overall landward retreat of the low water mark (0.29-0.71 m/yr) and a net decline in beach volume, although in the short term, beach levels are highly variable (High-Point Rendel, 2002b) as a result of both storm events and seasonal changes. Adjacent to the existing sea wall, beach levels have been observed as high as 5 m OD and as low as 0.5 m OD (Clark and Guest, 1991). The loss of beach sediment between 1892 and 1967 has been estimated at 1740 m^3/yr along Whitby Sands. A similar pattern of onshore and offshore movements of sediment occur along Whitby Sands as do along Sandsend Wyke.

Construction of coast defences along Whitby Sands has led to curtailment of sediment inputs from cliff retreat. Prior to coast protection works, Clark and Guest (1991) indicated long-term cliff-top retreat rates of 0.5 m/yr and the estimated input of coarser, beach-building sediment from the Upgang Ravine-West Pier till slopes was estimated as 4967 m^3/yr. Between Sandsend and West Pier, current inputs of sediment from the cliffs are likely to be around 35% of that prior to construction of the defences. This may have contributed to the degradation of the beaches.

A budget for the whole Sandsend Wyke-Whitby Sands frontage is summarised below (High-Point Rendel, 2002b):

- Around 10,000 m^3/yr of sand is dredged from the mouth of the River Esk.
- Around 2,200 m^3/yr is lost from the beaches of Sandsend Wyke and Whitby Sands.
- Assuming an erosion rate of 0.3 m/yr for the 1 km of till cliffs west of Raithwaite Gill, a height of 35 m and beach-building sediment comprising 25% of the cliff, then the cliffs potentially supply 2,600 m^3/yr.

Even allowing for some movement of sand into the harbour from upstream in the River Esk, combined losses in beach volume and gains from the cliffs are lower than the deposition rates of sand in the harbour. This imbalance implies longshore or offshore input of sediment to the beach. The lack of beach-building sand west of Sandsend indicates that this source is most likely from offshore.

Control and Sensitive Points:
The east end of the beach is held in place by the control point West Pier. The sustainability of the beach is sensitive to the presence or absence of this pier. Removal of this structure and East Pier would likely lead to loss of beach sediment through longshore transport to the east. This would put the backing revetments and sea wall at greater risk of wave attack. The western end of this unit is not controlled and the beach forms a natural transition with the beach of unit 31 (Sandsend Wyke). The presence of the coastal defences has created an artificial hard point protruding further seaward than the till cliffs to the west (unit 32) that have been allowed to erode.

West and East Pier's provide coast protection and flood defence to properties along the lower reaches of the River Esk. West Pier is also important in controlling the build up of the beaches in front of West Cliff, contributing to the coast protection.

Unit 33 – West/East Pier to north end of Robin Hood's Bay

Sediment Sources, Transport and Sinks:
This coast comprises undefended vertical cliffs composed of Whitby Mudstone Formation (overlain by Ravenscar Group sandstones and mudstones) backing a shore platform covered with a veneer of pebbles and cobbles. Towards the north end of Robin Hood's Bay, the Staithes Sandstone Formation and Cleveland Ironstone Formation are exposed in the cliffs (British Geological Survey, 1998b). Till is perched on the cliff top towards the northern extreme where the cliffs are lower. Elsewhere, where the cliffs are higher, the till is absent. This stretch of coast forms a broad headland between Whitby Sands to the north and Robin Hood's Bay to the south. Small sand-filled bays occur occasionally where erosion has taken advantage of weaker sections of cliff.

A long-term (100 years) cliff erosion rate of up to 0.19 m/yr (average *c*. 0.1 m/yr) has been estimated for the rock cliffs (Agar, 1960; High-Point Rendel, 2002a). Longshore sediment transport is likely to be to the south, although it is negligible, because the beaches have only sparse superficial deposits and the amount of sand input from erosion of the cliffs is low.

Control and Sensitive Points:
From a coastal defence perspective, the continued erosion of the cliffs does not pose too many problems because, apart from isolated properties and occasional caravan park, there is a wide undeveloped hinterland of Upper Lias behind the cliffs.

Unit 34 – Robin Hood's Bay

Sediment Sources, Transport and Sinks:
This stretch of coast comprises a deep, wide bay located between a Staithes Sandstone, Cleveland Ironstone and Whitby Mudstone Formations headland to the north and Ravenscar Group sandstones and mudstones to the south. Although similar in shape to other bays, Robin Hood's Bay is not 'till controlled' but formed in an anticlinal structure where the less resistant Redcar Mudstone Formation has been eroded (British Geological Survey, 1998b). The bay contains an extensive shore platform of Redcar Mudstone Formation with only localised patches or narrow sand beaches. At points around the bay, till approaches sea level and forms the entire cliff (Figure B.3). The long-term (100 years) erosion rate for the rock cliffs has been estimated as up to 0.3 m/yr and for the till cliffs in the centre of the bay, 0.1-0.3 m/yr (Agar, 1960; High-Point Rendel, 2002a). Overall, an erosion rate of *c*. 0.3 m/yr is likely for the cliffs of Robin Hood's Bay.

At the southern end of the village of Robin Hood's Bay, progressive coast protection works have led to an increase in erosion of the till cliff immediately to their south. High-Point Rendel (1997) estimated retreat rates of 0.3 m/yr between 1892 and 1960, 0.5 m/yr between 1960 and 1973, and 0.6 m/yr between 1973 and 1996. This increased erosion may result from concentration of reflected wave energy at the end of the structure.

There appears to be little longshore sediment transport in the bay. The beaches are patchy and have only sparse superficial sand and gravel deposits, and the coast to the north of Robin Hood's Bay contains no permanent deposits of sand that could feed the frontage. The erosion of the till cliffs within the bay does not appear to be sufficient to maintain any permanent beaches. However, small beaches do occur near The Nab and at Stoupe Beck Sands. It would also appear that offshore supply is insufficient to maintain any substantial beaches. Much of the sediment liberated from the till cliffs is probably lost offshore.

Control and Sensitive Points:
The sea wall at Robin Hood's Bay village is sensitive to increased erosion due to its protrusion into the bay. The till cliffs immediately to its south are also prone to increased erosion due to wave focussing. However, throughout much of the bay, the continued erosion of the cliffs does not pose too many problems because there is a wide undeveloped hinterland behind the cliffs.

Unit 35 – South end of Robin Hood's Bay to Scalby Ness

Sediment Sources, Transport and Sinks:
This long stretch of coast comprises undefended variable height vertical cliffs composed of Ravenscar Group sandstones and mudstones (British Geological Survey, 1998b) backing a shore platform covered with a veneer of pebbles and cobbles. Towards the south end of Robin Hood's Bay, the Whitby Mudstone and Blea Wyke Sandstone Formations are exposed in the base of the cliff.

The cliffs can be divided into two parts. The northern part between Robin Hood's Bay and Cloughton Wyke are very high cliffs with no till cap (British Geological Survey, 1998b). Here all formations of the Ravenscar Group are present apart from the youngest Scalby Formation. South of Cloughton Wyke the cliffs are much reduced in height (approximately 30 m) and comprise a near vertical lower rock section (the dip of the rocks bringing the Scalby Formation to sea level) and a shallower angle upper section which is formed of till with larger exposures of gravel and sand. Fox-Strangeways and Barrow (1882) identified thick units of gravel and sand (up to 40 m) exposed in the cliffs south of Cloughton Wyke. This southern section comprises small shallow bays separated by headlands. The main supplier of sediment along this stretch of coast is the till. Although containing sandstone, the bedrock cliffs do not supply significant quantities of coarse material. There is limited southwards longshore transport because the beaches have only sparse superficial deposits and exchange between each shallow bay is limited by the headlands.

Long-term (100 years) cliff retreat rates of up to 0.13 m/yr (average *c*. 0.1 m/yr) have been estimated for the rock cliffs (High-Point Rendel, 2002a). The till in the cliffs south of Cloughton Wyke are estimated to deliver around 17,000 m^3 per metre of cliff recession of potential beach building material (i.e. sand, gravel, cobbles) assuming an average coarse sediment content of 25% (High-Point Rendel, 2003). At an erosion rate of 0.1 m/yr, this value equates to 1700 m^3/yr. The gravel and coarser components of this sediment are retained where they form narrow fringing and pocket beaches, whereas the sand may be moved offshore by wave action (Halcrow 2002C). Only in small sheltered areas (i.e. immediately north of Scalby Ness) are the waters calm enough for sand to remain on the foreshore.

Control and Sensitive Points:
From a coastal defence perspective, the continued erosion of the cliffs does not pose too many problems because there is a wide undeveloped hinterland behind the rock cliffs.

Unit 36 – Scalby Ness to north end Castle Cliff (North Bay)

Sediment Sources, Transport and Sinks:
North Bay comprises a wide fine sand beach backed by a sea wall which has protected the slope behind for around 100 years (Figure B.4). The beach is broad and sandy in the centre of the bay, becoming narrower and lower to the north and south. The northern half of the bay contains a shore platform fronting the beach around low tide level, providing some shelter and protection to the sea wall. The sea wall is backed by an undulating Middle Jurassic and till slope, which used to be sea cliffs. The protection afforded by the sea wall prevents input of sediment to the foreshore by cliff erosion. The beach is 'self-contained' constrained by control points to the north (Scalby Ness) and south (Castle Cliff).
Scalby Ness acts as a control point for sediment transport to the south, so the erosion of the till to the north of Scalby Ness supplies sediment but is unlikely to be critical in maintaining the integrity of the beaches at Scarborough (including South Bay). These beaches are more likely to be dependent on supply from offshore sand stores.

The beach along North Bay from the Sea Life Centre to the Corner Café (500 m) has been accreting since at least 1900. The net increase in volume has been 33,000 m^3 or 400 m^3/yr since 1912 (High-Point Rendel, 2001). The southern end of North Bay has been eroding since 1900 with a net loss of 26,000 m^3 between 1912 and 2000 (300 m^3/yr). Overall the net change has been negligible and it is likely that sediment eroded from the southern end has migrated into the northern end, i.e. longshore sediment transport is to the north. These long-term changes are likely to be small compared to losses that may occur during a single storm.

Beach elevation data collected in September 2001 and April 2004 was supplied by SBC. The latter data shows a variable beach slope, with a shallower slope in the north (2-3 m OD at the sea wall dropping to OD around 60-100 m seaward) and a steeper slope in the south (2.5 m OD at the sea wall dropping sharply to OD around 20 m seaward). These data have been compared to provide an indication of recent short-term change in beach morphology. The data indicate that large areas of the beach have gained sediment (up to 1 m) over the 2.5 year period with smaller areas of loss. Around 7350 m^3 was lost compared to 55550 m^3 gained, equating to a net gain of 48200 m^3 (19300 m^3/yr). These short-term data differ from the long-term 'balance' interpretation of High-Point Rendel (2001).

Control and Sensitive Points:
North Bay beach is constrained by control points to the north (Scalby Ness) and south (Castle Cliff). Scalby Ness acts as a longshore transport barrier, although the amount of sediment being moved from north to south, to the north of Scalby Ness, is very low. In the absence of a sea wall the cliffs would erode by several different mechanisms such as multiple rotational landslides (with shear surfaces in the Jurassic mudstones) and shallow transitional

slides in the mud rocks and till. The average rate of erosion would be *c*. 0.3 m/yr. The sea wall is at risk from overtopping.

Unit 37 – Castle Cliff

Sediment Sources, Transport and Sinks:
This is a heavily protected stretch of coast where faulting has brought the Middle and Upper Jurassic rocks on to the cliff line, including the Osgodby Formation sandstones and the Oxford Clay Formation. Most of the erosion that takes place is by mass movements such as rock falls, rock slides and topples forming near vertical cliffs. Net longshore sediment transport is small. The foreshore is narrow with little mobile sediment on the surface.

Control and Sensitive Points:
The pronounced nature of the headland means that it is under threat of increased wave attack relative to more sheltered bays to either side. Castle Cliff acts as a major barrier to sediment transport between the North and South Bays, with little exchange around the headland.

Unit 38 – South end Castle Cliff to Holbeck (South Bay)

Sediment Sources, Transport and Sinks:
South Bay comprises a wide sand beach (in the north) and a shore platform (in the south) backed by a sea wall which protects the backing slopes (Figure B.5). The strata behind the sea wall are till towards the centre of the bay with Scarborough and Scalby Formation sandstones and mudstones towards its southern end (British Geological Survey, 1998c). The protection of the cliff toe by the sea wall limits input of sediment to the foreshore by cliff erosion. However, the absence of marine erosion at the foot of the cliffs does not mean the slopes are stable. All slopes show some signs of degradation with failure in the form of small to large-scale slumping and landslipping. Large-scale failures are exemplified by the major Holbeck Hall landslide that took place in 1993. Here, the final dimensions of the slip when it came to rest were 270 m from back-scarp to toe, 120 m in width and involved 1 million tonnes of sediment.

The beach of South Bay is 'self-contained' between Castle Cliff to the north and White Nab to the south. The beach is widest at its northern end, where the sand is nearly at the top of the sea wall (around 3.5 m OD) at road level. There is a considerable amount of sand over the road. Halcrow (2002c) suggested increased accumulation of sand along the northern part of the bay because of the shelter afforded by Castle Cliff and the harbour. The beach is approximately 0.5-1.0 m lower at its southern end. The beach slopes seaward going below OD around 100 m from the sea wall. Sediment is not actively 'lost' out of South Bay suggesting that the volume transported southwards beyond Black Rocks is negligible. Coal particles are believed to have been recorded on the beach of South Bay. Two potential sources are identified here; a far-field source from coal waste on the Durham beaches and a nearer-field source in cliff-exposed glacial sands and gravels.

The beach between the harbour West Pier and the Spa (600 m) has accreted between 1953 and 2000 by around 55,000 m^3 (1170 m^3/yr) (High-Point Rendel, 2001). However, the low water mark has been receding causing the beach to steepen. Over the same time period the beaches between the Spa and South Cliff Gardens eroded by 21,800 m^3 (460 m^3/yr). The northern end of the site is occupied by Scarborough Harbour, from which around 18,000 m^3 of sand and 2,000 m^3 of silt are removed annually (Deputy Harbour Master, personal communication). The sand enters the harbour as bedload from South Beach and is removed to be disposed of in water depths of around 11 m directly off shore from South Beach (56º 16.6'N, 00º 22.1'W). The disposal site is within the 20 m bathymetric contour (estimated closure depth, see Section C.1.1.) so there is potential for this sand to be transported in an onshore direction, to return to the coast, to feed the beach of South Bay. The combined accretion in the north (beach plus harbour) is around two orders of magnitude greater than the erosion in the south indicating a relatively large supply of sediment from offshore. The local longshore transport of sand may be to the north. SBC is currently removing sand from the northern end of the South Bay and depositing it at the Spa.

Beach elevation data collected in September 2001 and April 2004 was supplied by SBC. These data have been compared to provide an indication of recent short-term change in beach morphology. The data indicate that the beach was consistently at its lowest in September 2001 with accretion (generally up to 0.5 m, but over 0.5 m in places) across the whole beach up to April 2004. A net gain of 75200 m^3 (30100 m^3/yr) is recorded by the data.

Control and Sensitive Points:
In the absence of a sea wall the cliffs would erode by several different mechanisms such as multiple rotational landslides (with shear surfaces in the Jurassic mudstones) and shallow transitional slides in mud rocks and till. The average rate of erosion would be *c*. 0.3 m/yr. Castle Cliff acts as a major barrier to sediment transport between the North and South Bays, with little exchange around the headland. Also, little sediment appears to leave the bay to the south. The sea wall is at risk from overtopping.

Unit 39 – Holbeck to Osgodby Point

Sediment Sources, Transport and Sinks:
This stretch of coast comprises an undefended headland separating South Bay to the north and Cayton Bay to the south. The coast is composed of Scarborough and Scalby Formations sandstone and mudstone cliffs fronted by a rock shore platform. Erosion of the cliffs occurs but the fronting beaches are narrow and fragmented, with small amounts of sand accumulating at the cliff toes. Beach-forming sediment that is released from these cliffs is transported south towards Cayton Bay or offshore. Some of this sand accumulates in the lee of Osgodby Point. Overall, an erosion rate of *c*. 0.2-0.3 m/yr is likely for the cliffs along this stretch of coast.

Control and Sensitive Points:
This section of coast forms a short headland (it is itself a control point) separating the beaches South Bay (unit 38) to the north and Cayton Bay (unit 40) to the south. In terms of coastal processes, unit 39 is sensitive. This is because the unequal distribution of wave energy along the coast caused by bathymetry variations between units 38, 39 and 40 results in a low wave energy environment providing sheltered water in the bays (South Bay and Cayton) and a higher energy environment at the headland (this unit). This causes erosion of the headland and filling in of the bays. All of these units have a similar resistance to wave erosion, and this process should lead in time to a straightening of the coastline. In the long-term, this may lead to the joining of South Bay and Cayton Bay.

Unit 40 – Cayton Bay

Sediment Sources, Transport and Sinks:
Cayton Bay contains a wide sand beach bounded to the north and south by rock headlands. A series of faults run through the bay (British Geological Survey, 1998c) resulting in a range of lithologies being exposed in the unprotected cliffs, controlling its spatial and temporal development and the scale of landslipping. The northern part of the bay comprises Oxford Clay Formation overlain by 5-30 m of till (Figure B.6); the central part of the bay is dominated by till cliffs (20-30 m high, divided into an upper sandier unit and a lower muddier unit) whereas the southern end is Ravenscar Group sandstones and mudstones. The northern part of the bay has been subject to numerous historical landslips, primarily developed in the till but with a basal shear in the underlying Oxford Clay Formation. The cliffs are generally unprotected throughout the bay and its crenulate shape indicates that the beach plan is tending towards an equilibrium form. Overall, an erosion rate of *c*. 0.3-0.4 m/yr is likely for the cliffs in the bay.

The key input of sediment to the bay is from erosion of its backing cliffs (Halcrow, 2002C). Only coarser sediment is retained as the beach, with finer material transported offshore. Longshore sediment transport is weakly to the south within the bay with accretion of sand in the centre of the bay. This may be enhanced by protection afforded by a rock outcrop at low tide (Calf Allen Rocks). A limited amount of sediment may find its way into the bay from the north around Osgodby Point. Halcrow (2002a) estimated that the average annual sediment supply to Cayton Bay is between 7,100 and 40,700 m^3, of which 3,700 to 20,200 m^3 is derived from the ongoing erosion of the cliffs. The remainder is contributed from larger scale episodic failures.

Beach elevation data collected in March 2002 and April 2004 was supplied by SBC. The back of the beach is at elevations between 2 m and 2.5 m OD sloping seaward to OD around 50-100 m from the cliff. These data have been compared to provide an indication of recent short-term change in beach morphology. The data indicate that large areas of the beach have lost sediment (up to 1 m, but can be up to 2 m towards the low water mark) over the 2 year period with smaller areas of gain. Around 8350 m^3 was gained compared to 131000 m^3 lost, equating to a net loss of 122650 m^3 (61350 m^3/yr).

Control and Sensitive Points:
The beach at Cayton Bay is controlled by headlands to the north and south. The cliffs are generally unprotected throughout the bay and its crenulate shape indicates that the beach plan is tending towards an equilibrium form. Sensitive points are the locally defended infrastructure at the base of the cliffs. Removal of these may caused increased local erosion of the cliffs.

Unit 41 – South end of Cayton Bay to Filey Brigg

Sediment Sources, Transport and Sinks:
This stretch of coast consists of vertical cliffs of Middle (Ravenscar Group) to Upper Jurassic (Corallian Group) rocks capped by 'bevelled' till and fronted by a shore platform. The platform is sand-free apart from small accumulations immediately south of Cayton Bay. The cliffs lower gradually towards Filey Brigg, where thin Corallian Group sandstones and limestones are overlain by a thick till mantle. The Jurassic cliffs are exposed to wave attack at the foot and subaerial weathering of the cliff face, and are retreating by means of cliff falls. There is little information on historic cliff erosion rates. However, based on the geology and geomorphology, estimates of 0.1-0.2 m/yr (Yons Nab to Gristhorpe Cliff) and 0.2 m/yr (Gristhorpe Cliff to Filey Brigg) are made.

Control and Sensitive Points:
From a coastal defence perspective, the continued erosion of the cliffs does not pose too many problems because, apart from a caravan park south of Cayton Bay, there is a wide undeveloped hinterland behind the cliffs.

Unit 42 – Filey Brigg to Speeton (Filey Bay)

Sediment Sources, Transport and Sinks:
This stretch of coast comprises the wide sand beach of Filey Bay backed by till cliffs of varying heights (Figure B.7). The northern limit is marked by Filey Brigg. The southern end of Filey Bay occurs where the beach stops and the chalk cliffs and associated shore platform of the Flamborough headland begins. The coast is undefended apart from a stretch of sea wall in front of Filey Town. The top of the beach varies in elevation from 3 m OD near Filey Town to 2 m OD near Reighton, and slopes seaward to go below OD around 100 m from the cliff.

The till sequence in the cliffs of Filey Bay (30-50 m high) has been divided into an Upper Till Series and a Lower Till Series split by up to 3 m of sand and gravel (Edwards, 1981). The Upper Till Series is clay-rich and the Lower Till Series has a fine sand/silt matrix. Cliffs cut into this till are subject to erosion rates up to 0.3 m/yr (average *c*. 0.25 m/yr) (Institute of Estuarine and Coastal Studies, 1991; Mouchel, 1997; Halcrow, 2002b). These values are a long-term trend masking any short-term episodic failures. The till has eroded to form a gently curving sandy bay between the harder rocks of Filey Brigg and Flamborough Head. This crenulate-shaped bay indicates that the beach plan shape is tending towards an equilibrium form. Halcrow (2002c) suggested that continued erosion of the Filey Bay coast would lead to the focus of erosion potentially migrating north-west along the bay, as the shoreline seeks to maintain its natural position.

Longshore sediment transport is to the south between Filey and Reighton. At Speeton the net direction of transport reverses towards Filey Brigg, with convergence just south of Reighton, coinciding with a change in orientation of the coastline. There is therefore potential for erosion at the northern end of the bay and accretion around Reighton. Indeed, at Reighton the low water mark is not retreating at the same rate as the cliffs suggesting an accumulation of sediment. Moving east, along Buckton Cliffs, the transport direction reverses again towards Flamborough Head, resulting in a longshore sediment transport divide, though the transport rate has significantly reduced.

Sand within the bay is fed by erosion of the till cliffs in Filey Bay itself. However, not all the sediment is suitable for retention within the bay. Halcrow (2002b) estimated that the average annual sediment supply to Filey Bay is between 4,179 and 23,176 m^3, of which 1,354 to 5,597 m^3 is derived from the ongoing erosion of the cliffs. The remainder is contributed from larger scale episodic failures. Institute of Estuarine and Coastal Studies (1991) estimated that around 10,000 m^3/yr of beach-building sediment is input from the cliffs. Accumulation of sand in Filey Bay is aided by Filey Brigg, which provides shelter from northerly waves. South-easterly wave conditions result in local reversals of the transport direction. There do not appear to be long-term problems due to offshore loss of beach sediment because the losses are balanced by supply from the cliffs. However, in some cases during storms sand may be stripped from the beach, exposing the underlying cohesive layer, which cannot be replaced once eroded, resulting in permanent lowering of the beach levels.

For the whole of the coast between Filey Brigg and Flamborough Head, the inputs from the cliffs are 4,000-23,000 m^3/yr. The loss of sediment from the bay is offshore during storms, estimated as 40,000 m^3/yr (Institute of Estuarine and Coastal Studies, 1991). This sediment is likely to move south around Flamborough Head. Inputs of 45,000 m^3/yr are estimated from sources south of Flamborough Head transported into the bay by tidal currents. So the budget suggests a surplus of sediment in the bay of between 9,000 and 28,000 m^3/yr.

Beach elevation data collected in March 2002 and April 2004 was supplied by SBC. These data have been compared to provide an indication of recent short-term change in beach morphology. The data indicate that large areas of the beach have lost sediment (up to 0.5 m, but can be up to 1 m in places) over the 2 year period with smaller areas of gain. Around 64600 m^3 was gained compared to 329900 m^3 lost, equating to a net loss of 265300 m^3 (132650 m^3/yr).

Control and Sensitive Points:
The sea wall at Filey Town protrudes seaward from the 'natural' shape of Filey Bay through erosion of the till to either side of the wall. This sea wall is at risk from overtopping and wave attack at its base. Elsewhere the erosion of the till cliffs could have impacts on several built-up areas close to the cliff top. Removal of the gabions would lead to enhanced erosion of the backing till cliff.

Unit 43 – Speeton to Flamborough Head

Sediment Sources, Transport and Sinks:
The coast between Speeton and Flamborough Head is dominated by the Cretaceous Chalk Group (British Geological Survey, 1986) creating characteristically tall steep cliffs (up to 50 m high) with very slow rates of retreat fronted by a narrow chalk shore platform. The cliffs are overlain by a thin cap of till which increases in thickness from Speeton towards Flamborough Head. Processes are limited to occasional rock falls and landslip activity in the till cap, the latter having only minor importance to overall morphology. Pebble and cobble beaches formed of chalk are found at the foot of the cliffs as a product of cliff erosion. There is little evidence for mobile sediment on the foreshore. There is little information on historic cliff erosion rates. However, based on the geology an estimate of 0.1 m/yr is made.

An important aspect of sediment transport along this stretch of coastline is the small but important exchange around Flamborough Head. The Flamborough Head foreshore is free of mobile sediment and its existing integrity and stability is not dependent on a longshore source of sediment. Along the northern side of Flamborough Head, longshore transport by waves is low and tidal currents in the nearshore zone are thought to dominate the southerly transport of sediment. However, it is believed that north-easterly wave activity during extreme storm events (1 in 50 return period) can cause a southerly movement of sediment from an extensive sand deposit located offshore in Filey Bay. During such an event, it is estimated that 40,000 m^3 of sand is transported south around Flamborough Head. This sediment is gradually returned to Filey Bay by transport on tidal residual current flowing north around Flamborough Head. According to Mouchel (1997), there is a residual tidal current to the north during spring tides of 0.11 m/s, and a residual current to the south during neap tides of 0.09 m/s. Hence, sediment is able to move around the headland into Filey Bay and is sufficient to balance the losses.

Control and Sensitive Points:
Apart from some of the small bays (which are controlled by headlands and contain sand beaches), the continued erosion of the cliffs does not pose too many problems because there is a wide undeveloped hinterland behind the chalk cliffs.

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C2 Defence Assessment

This section details the condition of the hard defences along the SMP coast between the River Tyne and Flamborough Head.

This data is also mapped and stored within the GIS/database system where the defence locations and extents can be visualised. The data has been sourced from, the 1994 and 1997 MAFF coastal protection surveys, the previous SMP's and updated where possible using more recent data from Strategy Studies.

Table c2.1 Defence Assessment

Information from MAFF survey 1994 (and updates from 1997)							**Updated Information from other sources**					
Location	**MAFF Defence no.**	**Classific-ation**	**Type**	**Condit-ion (Class)**	**Residual Life**	**Year Construct-ed**	**Other Ref no.**	**Defence Name**	**Source Title**	**Source Author**	**Source Date**	**Residual Life (yrs)**
South Shields	220/7001	mm hard	Splash wall & revetment	3	5-10	1930						
South Shields	220/7002	mm hard	Breakwater	2	>10	1990						
South Shields	220/7003	mm hard	Shore & Splash wall	1	>10	1930						
South Shields	220/7004	mm hard	Seawall & rock armour	2	>10 yrs	1987						
South Shields	220/7005	mm hard	Seawall & rock armour	2	>10 yrs	1987						
South Shields	220/7006	mm hard	Breakwater	2	>10	1960						
South Shields	220/7007	mm hard	Stone embankment	2	>10	1970						
South Shields	220/7008	mm hard	Splash wall & apron	2	>10	1990						
South Shields	220/7009	mm hard	Revetment	2	>10	1990						
South Shields	220/7010	mm hard	Revetment	2	>10	1990						

Information from MAFF survey 1994 (and updates from 1997)							Updated Information from other sources					
Location	**MAFF Defence no.**	**Classific-ation**	**Type**	**Condit-ion (Class)**	**Residual Life**	**Year Construct-ed**	**Other Ref no.**	**Defence Name**	**Source Title**	**Source Author**	**Source Date**	**Residual Life (yrs)**
Marsden	220/7011	nat hard	Cliff with small sections of wall at each end	2	>10	1950						
Whitburn	220/7012	nat hard	Cliff	2		na						
South Bents	220/6901	mm hard	Seawall	2	>10	1950	6901	South Bents Sea wall	Whitburn to Ryhope Coast Protection Strategy Study (Draft)	Scott Wilson	Feb-01	20
Seaburn	220/6902	mm hard	Seawall	4	<5	1950	6902	South Bents Sea wall	Whitburn to Ryhope Coast Protection Strategy Study (Draft)	Scott Wilson	Feb-01	10
Seaburn	220/6903	mm hard	Seawall	4	<5	1950	6903	Seaburn Seawall	Whitburn to Ryhope Coast Protection Strategy Study (Draft)	Scott Wilson	Feb-01	5
Seaburn	220/6904	mm hard	Seawall	1	>10	1950	6904	Seaburn Seawall	Whitburn to Ryhope Coast Protection Strategy Study (Draft)	Scott Wilson	Feb-01	20
Seaburn	220/6905	mm hard	Seawall revetment splash wall	3	>10	1950	6905	Seaburn Seawall	Whitburn to Ryhope Coast Protection Strategy Study (Draft)	Scott Wilson	Feb-01	5

Information from MAFF survey 1994 (and updates from 1997)							Updated Information from other sources					
Location	**MAFF Defence no.**	**Classific-ation**	**Type**	**Condit-ion (Class)**	**Residual Life**	**Year Construct-ed**	**Other Ref no.**	**Defence Name**	**Source Title**	**Source Author**	**Source Date**	**Residual Life (yrs)**
Seaburn	220/6906	mm hard	Seawall	2	>10	1960	6906	Seaburn Seawall	Whitburn to Ryhope Coast Protection Strategy Study (Draft)	Scott Wilson	Feb-01	50
Roker, Sunderland	220/6907	mm hard	Seawall	4	<5	1950	6907	Roker Seawall	Whitburn to Ryhope Coast Protection Strategy Study (Draft)	Scott Wilson	Feb-01	5
Roker, Sunderland	220/6908	mm hard	Seawall	2	>10	1980	6908	Roker Seawall	Whitburn to Ryhope Coast Protection Strategy Study (Draft)	Scott Wilson	Feb-01	10
Roker, Sunderland	220/6909	mm hard	Pier	2	>10	1930	6909	Roker Pier	Whitburn to Ryhope Coast Protection Strategy Study (Draft)	Scott Wilson	Feb-01	10
Sunderland Harbour	220/6910	mm hard	Seawall	2	>10	1950	6910	North Harbour North	Whitburn to Ryhope Coast Protection Strategy Study (Draft)	Scott Wilson	Feb-01	20
Sunderland Harbour	220/6911	mm hard	Seawall revetment	1	>10	1980	6911	North Harbour South	Whitburn to Ryhope Coast Protection Strategy Study (Draft)	Scott Wilson	Feb-01	50

Information from MAFF survey 1994 (and updates from 1997)							Updated Information from other sources					
Location	**MAFF Defence no.**	**Classific-ation**	**Type**	**Condit-ion (Class)**	**Residual Life**	**Year Construct-ed**	**Other Ref no.**	**Defence Name**	**Source Title**	**Source Author**	**Source Date**	**Residual Life (yrs)**
Port of Sunderland	220/6912	mm hard	Revetment	1	>10	1980	6912	South Harbour	Whitburn to Ryhope Coast Protection Strategy Study (Draft)	Scott Wilson	Feb-01	20
Port of Sunderland	220/6913	mm hard	Seawall	2	>10	1930	6913	South Harbour	Whitburn to Ryhope Coast Protection Strategy Study (Draft)	Scott Wilson	Feb-01	5
Port of Sunderland	220/6914	mm hard	Breakwater	2	>10	150	6914	New South Pier	Whitburn to Ryhope Coast Protection Strategy Study (Draft)	Scott Wilson	Feb-01	10
Port of Sunderland	220/6915	mm hard	Seawall	3	<5	1960	6915	Stone Hill Wall	Whitburn to Ryhope Coast Protection Strategy Study (Draft)	Scott Wilson	Feb-01	5
Port of Sunderland	220/6916	mm hard	Revetment	2	>10	1950	6916	Rock revetment	Whitburn to Ryhope Coast Protection Strategy Study (Draft)	Scott Wilson	Feb-01	50
Port of Sunderland	220/6917	mm hard	Revetment & groyne	4	<5	1950	6917	Rock revetment	Whitburn to Ryhope Coast Protection Strategy Study (Draft)	Scott Wilson	Feb-01	50
Port of Sunderlan	220/6918	mm hard	Seawall	3	5-10	1930	6918	North East Pier (outer)	Whitburn to Ryhope Coast Protection	Scott Wilson	Feb-01	0

Information from MAFF survey 1994 (and updates from 1997)							Updated Information from other sources					
Location	**MAFF Defence no.**	**Classific-ation**	**Type**	**Condit-ion (Class)**	**Residual Life**	**Year Construct-ed**	**Other Ref no.**	**Defence Name**	**Source Title**	**Source Author**	**Source Date**	**Residual Life (yrs)**
d									Strategy Study (Draft)			
Port of Sunderland	220/6919	mm hard	Seawall	1	>10	1970	6919	South West Breakwater	Whitburn to Ryhope Coast Protection Strategy Study (Draft)	Scott Wilson	Feb-01	50
Port of Sunderland	220/6920	mm hard	Seawall	4	5-10	1930	6920	Hendon Foreshore Barrier	Whitburn to Ryhope Coast Protection Strategy Study (Draft)	Scott Wilson	Feb-01	5
Port of Sunderland	220/6921	mm hard	Seawall revetment	2	>10	1950	6921	Hendon Tip Wall	Whitburn to Ryhope Coast Protection Strategy Study (Draft)	Scott Wilson	Feb-01	20
Port of Sunderland	220/6922	mm hard	Seawall	2	>10	1930	6922	Hendon Banks Barrier	Whitburn to Ryhope Coast Protection Strategy Study (Draft)	Scott Wilson	Feb-01	10
Hendon	220/6923	mm hard	Seawall, revetment & groynes	4	>10	1950-1990	6923	Hendon Seawall	Whitburn to Ryhope Coast Protection Strategy Study (Draft)	Scott Wilson	Feb-01	10
Hendon Ryhope	220/6924	nat hard	Cliff	4	5-10	na	6924					
Sunderland Dock	220/6925	mm hard	Breakwater	3	5-10	1970	6925	North East Pier (inner)	Whitburn to Ryhope Coast Protection	Scott Wilson	Feb-01	10

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									Strategy Study (Draft)			
Sunderland Dock	220/6926	mm hard	Revetment	3	>10	1990	6926	Rubble revetment (north inside)	Whitburn to Ryhope Coast Protection Strategy Study (Draft)	Scott Wilson	Feb-01	10
Sunderland Dock	220/6927	mm hard	Seawall revetment	3	>10	1970-1990	6927	South Outlet Sheetpile Wall	Whitburn to Ryhope Coast Protection Strategy Study (Draft)	Scott Wilson	Feb-01	5
Sunderland Dock	220/6928	mm hard	Revetment	3	5-10	1980	6928	Rubble revetment (south inside)	Whitburn to Ryhope Coast Protection Strategy Study (Draft)	Scott Wilson	Feb-01	10
Sunderland Dock	220/6929	mm hard	Breakwater	3	>10	1910-1970	6929	South West Breakwater (outside)	Whitburn to Ryhope Coast Protection Strategy Study (Draft)	Scott Wilson	Feb-01	10
Seaham North	220/6801	nat hard	Cliff	4	5-10	1980	C1/01/01	Seaham Hall Car Park	Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	
Seaham North	220/6802	mm hard	Seawall & groynes	2	>10	1950	C1/02/01	North Seaham Promenade	Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	15-20
Seaham Featherbed	220/6803	nat hard	Cliff & revetment	3	>10	na	C1/03/01	Feather bed Rocks	Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	50
Seaham	220/6804	mm hard	cliff &	4	<5	1930	C1/04/01	Feather bed	Seaham Coastal	Posford	Jul-04	50

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Bessies Hole			revetment					Rocks	Strategy Study	Haskoning		
Seaham Bessies Hole	220/6805	mm hard	Seawall & rock toe	4	<5	1930-1970	C1/05/01	SE of Bessies Hole	Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	>10
Seaham North Terrace	220/6806	mm hard	Seawall & rock toe	4	>10	1950	C1/06/01	SE of Bessies Hole	Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	>10
Seaham North Terrace	220/6807	nat hard	Cliff & revetment	4	5-10	na	C1/07/01	North Seaham Beach	Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	>10
Seaham North Terrace	220/6808	nat hard	Cliff	4	5-10	1960	C1/08/01	Beach north of Seaham Port	Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	>10
Seaham Harbour	220/6809	mm hard	Revetment	1	>10	1980	C1/09/01	Rear of north pier of Seaham	Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	>10
Seaham North Pier	220/6810	mm hard	Breakwater	2	>10	1910	C1/10/01	Outer North Pier	Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	>10
							C1/11/01	Revetment btwn Inner and Outer Piers	Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	>10
							C1/12/01	Inner North Pier	Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	>10
							C1/13/01	Inner South	Seaham Coastal	Posford	Jul-04	>10

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								Pier	Strategy Study	Haskoning		
Seaham South Pier	220/6811	mm hard	Breakwater	2	>10	1910	C1/14/01	Outer south pier	Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	>10
Seaham Harbour Wall	220/6812	mm hard	Seawall & rock revetment	3	5-10	1930-1980	C1/14/02		Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	50
Seaham South	220/6813	mm hard	Seawall & cliffs	4	>10	1930	C1/15/01 -02		Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	>10
Seaham Dawdon	220/6814		Recharge	4	5-10	1900	C1/16/01 & C1/17/01		Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	
Seaham Dock	220/6815	mm hard	Revetment & wall	2	>10	1950-1970			Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	
Seaham Dock	220/6816	mm hard	Breakwater	2	>10	1900			Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	
Seaham Dock	220/6817	mm hard	Breakwater	2	>10	1900			Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	
Seaham Dock	220/6818	mm hard	Seawall & cliff	3	>10	1900-1930			Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	
Seaham Dock	220/6819	mm hard	Breakwater	3	>10	1900			Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	
Seaham Dock	220/6820	mm hard	Seawall	3	>10	1930			Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	
Seaham Dock	220/6821	mm hard	Breakwater	3	>10	1960			Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	

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Seaham Dock	220/6822	mm hard	Breakwater	3	>10	1930			Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	
							C2/01/01	Noses Pt to Chourdon Pt	Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	>10
							C2/02/01		Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	
							C2/03/01		Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	5-10
							C2/04/01		Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	>10
							C2/05/01		Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	>10
							C2/06/01		Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	>10
							C2/07/01		Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	>10
							C2/08/01		Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	5-10
							C3/01/01		Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	5-10
							C3/01/02		Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	5
							C3/02/01		Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	>10
							C3/03/01		Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	>10

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							C3/03/02		Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	>10
							C3/04/01		Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	5-10
							C3/05/01		Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	>5
							C3/06/01		Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	>5
							C3/07/01		Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	>5
							C3/08/01		Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	>10
							C3/09/01		Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	>10
							C3/10/01		Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	>10
							C3/11/01		Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	>10
							C3/12/01		Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	>10
							C3/13/01	Blackhall rocks to Crimdon Park	Seaham Coastal Strategy Study	Posford Haskoning	Jul-04	5-10
Hartlepool	220/6701	mm hard	Gabions	4	<5	1980	6701	Britmag/Old cemetery	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	0

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Hartlepool	220/6702	mm hard	Embankment revetment	4	5-10	1970	6702	Spion Kop	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	0
Hartlepool	220/6703	mm hard	Seawall revetment	4	5-10	1900-1950	6703	Marine Drive	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	20-50
Hartlepool	220/6704	mm hard	Seawall	3	5-10	1930-1990	6704	Seaview Terrace to Lighthouse Ramp	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	5-10
Hartlepool	220/6705	mm hard	Seawall	2	>10	1938-1950	6705	Knuckle end	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	10-20
Hartlepool	220/6706	mm hard	Seawall	2	5-10	1938-1950	6706a and 6706 b	Knuckle End to Bath Terrace to Catherine St	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	10-20
Hartlepool	220/6707	mm hard	Seawall	2	>10	1938	6707	Root of Heugh Breakwater	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	10-50
Hartlepool	220/6708	mm hard	Breakwater	4	5-10	1930	6708	Heugh Breakwater	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	0-20
Hartlepool	220/6709	mm hard	Seawall	4	5-10	1970	6709	Block Sands (Rowell St Corner to Wood St)	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	5-10
Hartlepool	220/6710	mm hard	Seawall	2	>10	1990	6710	Block Sands (Wood St to St Hildas Chare)	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	5-10

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Hartlepool	220/6711	mm hard	Seawall	3	5-10	1940	6711	Block Sands (Albion Terrace to York Place)	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	10-20
Hartlepool	220/6712	mm hard	Breakwater	2	>10	1950-1991	6712	Old Pier (Pilot Pier)	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	10-50
Hartlepool	220/6713	mm hard	Seawall	2	>10	1950	6713	Croft Terrace	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	>10
Hartlepool	220/6714	mm hard	Seawall & groynes	3	>10	1850-1950	6714 CH 0 to 120m	Town Wall	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	<5
							6714 CH 120 to 230m	Town Wall	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	5-10
							6714 CH 230 to 417	Town Wall	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	25-50
Hartlepool	220/6715	mm hard	Breakwater	1	>10	1990	6715	Middleton Pier (Banjo)	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	>50
Hartlepool	220/6716	mm hard	Gabions	4	<5	1990	6716	Banjo Pier to Ferry Rd	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	10-50
Hartlepool	220/6717	mm hard	Seawall	4	<5	1960	6717	Heerema new length	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	10-50
Hartlepool	220/6718	mm hard	Seawall	2	>10	1930	6718	Heerema old length	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	5-10

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Hartlepool	220/6719	mm hard	Breakwater & Groynes	3	5-10	1930-1990	6719	North Pier	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	5-10
Hartlepool	220/6720	mm hard	Breakwater	1	>10	1990	6720	South Pier	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	>50
Hartlepool	220/6721	mm hard	Seawall revetment	1	>10	1990	6721	Root of South Pier to Hilda Walk	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	>50
Hartlepool	220/6722	mm hard	Seawall revetment	4	5-10	1980	6722	Hilda Walk to Burbank Street	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	>50
Hartlepool	220/6723	mm hard	Revetment	2	>10	1960	6723 Ch 0 to 50	Newburn Bridge North	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	<2
							6723 Ch 50 to 120	Newburn Bridge North	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	<2
							6723 Ch 120 to 220	Newburn Bridge North	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	<5
Hartlepool	220/6724	mm hard	Revetment	3	>10	1970	6724	Newburn Bridge South	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	<2
Hartlepool	220/6725	mm hard	Seawall revetment	1	>10	1990						
Hartlepool	220/6726	mm hard	Wall, concrete & revetment	1	>10	1996						

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Seaton Carew	220/6727	mm hard	Wall, concrete & revetment	1	>10	1996						
Seaton Carew	220/6728	mm hard	Revetment	3	>10	1960						
Seaton Carew	220/6729	mm hard	Wall, concrete & revetment	1	>10	1996						
Seaton Carew	220/6730	mm hard	Seawall & revetment	1	>10	1995						
Seaton Carew	220/6731	mm hard	Seawall	3	5-10	1950						
Seaton Carew	220/6732	mm hard	Seawall	3	5-10	1930						
Seaton Carew	220/6733	mm hard	Revetment	3	5-10	1970						
Seaton Carew	220/6734	mm hard	Seawall	4	<5	1980						
Tees Mouth North Breakwat er	220/6735	mm hard	Breakwater	3	5-10	1991						
Hartlepool Fish Quay	220/6736	mm hard	Seawall	3	>10	1930						
Hartlepool	220/6737	mm hard	Seawall and	3	>10	1930-1960						

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Victoria Harbour			deck									
Hartlepool Victoria Harbour	220/6738	mm hard	Wall	3	>10	1930						
Hartlepool Victoria Harbour	220/6739	mm hard	Revetment	3	>10	1960						
Hartlepool Victoria Harbour	220/6740	mm hard	Sheetpiles and deck	2	>10	1980-1990						
Hartlepool Victoria Harbour	220/6741	mm hard	Breastwork	2	>10	1980						
Hartlepool Victoria Harbour	220/6742	mm hard	Seawall	3	>10	1930						
Hartlepool Victoria Harbour	220/6743	mm hard	Revetment	2	>10	1980						
Hartlepool Victoria Harbour	220/6744	mm hard	Seawall	1	>10	1990						
Hartlepool West Harbour	220/6745	mm hard	Breakwater	2	>10	1930-1970	6745	Inner pier north	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	10-50

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Hartlepool West Harbour	220/6746	mm hard	Revetement	4	5-10	1960	6746	Boat yard revetment	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	>50
Hartlepool West Harbour	220/6747	mm hard	Wall	2	>10	1930	6747	Harbour Quay Wall A	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	10-50
Hartlepool West Harbour	220/6748	mm hard	Wall	1	>10	1990	6748	Harbour Quay Wall B	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	>50
Hartlepool West Harbour	220/6749	mm hard	Revetment	1	>10	1990	6749	Harbour Quay Wall C	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	>50
Hartlepool West Harbour	220/6750	mm hard	Wall	1	>10	1990	6750	Sailing Club Wall	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	>50
Hartlepool West Harbour	220/6751	mm hard	Breakwater	3	>10	1930-1980	6751	Inner Pier South	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	10-50
Hartlepool West Harbour	220/6752	mm hard	Wall	3	>10	1930-1990	6752	Harbour Quay Wall D	Hartlepool Coastal Strategy (Draft)	Ws Atkins	Ongoing	>50
Hartlepool West Harbour	220/6753	mm hard	Breakwater	3	>10	1930						

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Teesmouth South Breakwater	220/6601		Revetment	3	>10	1950-1975						
Redcar	220/6602	mm hard	Seawall revetment	2	>10	1940	The Redcar Beach Study, Stage 2 Strategy Report, Dec 2000, by Babtie does not provide any further update of defence condition beyond the data that was used for SMP1.					
Redcar	220/6603	mm hard	Revetment	3	>10	1940						
Redcar	220/6604	mm hard	Seawall	2	>10	1940						
Redcar	220/6605	mm hard	Seawall	2	>10	1960						
Redcar	220/6606	mm hard	Seawall revetment	3	5-10	1960						
Redcar	220/6607	mm hard	Revetment	4	5-10	1940						
Redcar	220/6608	mm hard	Revetment	3	5-10	1955						
Redcar	220/6609	mm hard	Seawall, revetment & groynes	3	5-10	1955						
Marske by the Sea	220/6610	mm hard	Seawall	2	5-10	1900						
Marske by the Sea	220/6611	mm hard	Revetment	2	5-10	1900						

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Marske by the Sea	220/6612	mm hard	Seawall	2	>10	1950						
Saltburn	220/6613	mm hard	Seawall	2	>10	1900-1950						
Saltburn	220/6614	mm hard	Seawall	2	>10	1900						
Saltburn	220/6615	mm hard	Revetment	2	>10	1900						
Saltburn	220/6616	mm hard	Seawall	2	>10	1960						
Saltburn	220/6617	mm hard	Seawall	3	>10	1960						
Saltburn	220/6618	mm hard	Seawall	4	5-10	1960						
Skinningrove	220/6619	mm hard	Breakwater	1	>10, < 5 (at head)	1900						
Skinningrove	220/6620	mm hard	Revetment	1	>10	1987						
Skinningrove	220/6621	mm hard	Seawall revetment	3	>10	1970-1987						
Skinningrove	220/6622	mm hard	Breakwater	1	>10	1987						
Skinningrove	220/6623	mm hard	Seawall	3	5-10	1900						
Cowbar Cliffs	220/6624	nat hard	Cliff	2	5-10	na						
Staithes	220/6625	mm hard	Seawall	2	>10	1930						
Redcar	220/6626	mm hard	Seawall	3	>10	1930						
Staithes	240/6501	mm hard	Breakwater revetment	2	>10	1900-1985						

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Staithes	240/6502	mm hard	Seawall	2	>10	1910-1930						
Staithes	240/6503	mm hard	Seawall	2	>10	1930						
Staithes	240/6504	mm hard	Seawall groynes	3	>10, 5-10 (for groynes)	1970-1978						
Staithes	240/6505	mm hard	Revetment	2	>10	1980						
Staithes	240/6506	mm hard	Breakwater revetment	2	>10	1900-1987						
Runswick	240/6507	mm hard	Seawall	2	>10	1950						
Runswick	240/6508	mm hard	Seawall	3	5-10	1930-1960						
Runswick	240/6509	mm hard	Revetment	2	>10	1970						
Runswick	240/6510	mm hard	Revetment	4	>50	1999						
Runswick	240/6511		Shore	2	5-10	na						
Sandsend	240/6512		Shore	2	>10	na	1	Sandsend Cliffs	Whitby Coastal Strategy Sandsend to Abbey Cliff	High Point Rendel	Jul-02	na
Sandsend	240/6513	mm hard	Seawall	2	5-10	1970-1978	2A	Sandsend car park - sloping concrete wall	Whitby Coastal Strategy Sandsend to Abbey Cliff	High Point Rendel	Jul-02	10-20
Sandsend	240/6514	mm hard	Seawall groynes	3	5-10	1970	3A	Sandsend frontage - concrete wall	Whitby Coastal Strategy Sandsend to Abbey Cliff	High Point Rendel	Jul-02	30-40

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Sandsend	240/6515	mm hard	Seawall	2	>10	1950-1970	3B	Sandsend frontage - cantilevered footpath	Whitby Coastal Strategy Sandsend to Abbey Cliff	High Point Rendel	Jul-02	20-30
Sandsend	240/6516	mm hard	Seawall	2	>10	1950	4A	East row Beck	Whitby Coastal Strategy Sandsend to Abbey Cliff	High Point Rendel	Jul-02	30-40
Sandsend	240/6517	mm hard	Revetment	3	5-10	1950	4D, 5A	Sloping wall	Whitby Coastal Strategy Sandsend to Abbey Cliff	High Point Rendel	Jul-02	10-20
Whitby	240/6518	mm hard	Seawall revetment	1	>10	1990	9	West cliff	Whitby Coastal Strategy Sandsend to Abbey Cliff	High Point Rendel	Jul-02	40-50
Whitby	240/6519	mm hard	Seawall	2	>10	1930	10	West cliff seawall	Whitby Coastal Strategy Sandsend to Abbey Cliff	High Point Rendel	Jul-02	0-10
Whitby	240/6520	mm hard	Seawall	2	>10	1950			Whitby Coastal Strategy Sandsend to Abbey Cliff	High Point Rendel	Jul-02	
Whitby	240/6521	mm hard	Seawall	3	5-10	1950			Whitby Coastal Strategy Sandsend to Abbey Cliff	High Point Rendel	Jul-02	
Whitby	240/6522	mm hard	Seawall	2	>10	1930	13	West cliff Spa	Whitby Coastal Strategy Sandsend to Abbey Cliff	High Point Rendel	Jul-02	0-10

Information from MAFF survey 1994 (and updates from 1997)							Updated Information from other sources					
Location	**MAFF Defence no.**	**Classific-ation**	**Type**	**Condit-ion (Class)**	**Residual Life**	**Year Construct-ed**	**Other Ref no.**	**Defence Name**	**Source Title**	**Source Author**	**Source Date**	**Residual Life (yrs)**
Whitby	240/6523	mm hard	Seawall revetment	2	5-10	1950-1960	12B	West cliff Metropole (east) seawall	Whitby Coastal Strategy Sandsend to Abbey Cliff	High Point Rendel	Jul-02	10-20
Whitby	240/6524	mm hard	Seawall	2	>10	1930	14	est cliff blockwork wall	Whitby Coastal Strategy Sandsend to Abbey Cliff	High Point Rendel	Jul-02	10-20
Whitby	240/6525	mm hard	Seawall	2	>10	1960			Whitby Coastal Strategy Sandsend to Abbey Cliff	High Point Rendel	Jul-02	
Whitby	240/6526	mm hard	Seawall	2	>10	1930			Whitby Coastal Strategy Sandsend to Abbey Cliff	High Point Rendel	Jul-02	
Whitby	240/6527	mm hard	Breakwater	2	>10	1930	17A	Harbour west pier - main arm	Whitby Coastal Strategy Sandsend to Abbey Cliff	High Point Rendel	Jul-02	0-10
Whitby	240/6528	mm hard	Breakwater	2	>10	1950	17B	Harbour west pier - outer arm	Whitby Coastal Strategy Sandsend to Abbey Cliff	High Point Rendel	Jul-02	20-30
Whitby	240/6529	mm hard	Breakwater	2	>10	1950	18B	Harbour east pier - outer arm	Whitby Coastal Strategy Sandsend to Abbey Cliff	High Point Rendel	Jul-02	20-30
Whitby	240/6530	mm hard	Breakwater	2	>10	1930	18A	Harbour east pier - main arm	Whitby Coastal Strategy Sandsend to Abbey Cliff	High Point Rendel	Jul-02	0-10

Information from MAFF survey 1994 (and updates from 1997)							Updated Information from other sources					
Location	**MAFF Defence no.**	**Classific-ation**	**Type**	**Condit-ion (Class)**	**Residual Life**	**Year Construct-ed**	**Other Ref no.**	**Defence Name**	**Source Title**	**Source Author**	**Source Date**	**Residual Life (yrs)**
Whitby	240/6531	nat hard	Shore & rock revetment	3	>10	2001	20	Abbey cliff	Whitby Coastal Strategy Sandsend to Abbey Cliff	High Point Rendel	Jul-02	na
Robin Hood's Bay	240/6532	nat hard	Shore & rock revetment	2	>10	2000??			Robin Hoods Bay Coast Protection and Cliff Stabilisation - Engineers Report in support of an application for grant aid to MAFF - Volume 1	High Point Rendel	Mar-99	
Robin Hood's Bay	240/6533	mm hard	Seawall	3	>10	1970			Robin Hoods Bay Coast Protection and Cliff Stabilisation - Engineers Report in support of an application for grant aid to MAFF - Volume 1	High Point Rendel	Mar-99	
Robin Hood's Bay	240/6534	mm hard	Seawall	2	>10	1930						
Robin Hood's Bay	240/6535	mm hard	Revetment	2	>10	1950						

Information from MAFF survey 1994 (and updates from 1997)							Updated Information from other sources					
Location	**MAFF Defence no.**	**Classific-ation**	**Type**	**Condit-ion (Class)**	**Residual Life**	**Year Construct-ed**	**Other Ref no.**	**Defence Name**	**Source Title**	**Source Author**	**Source Date**	**Residual Life (yrs)**
Robin Hood's Bay	240/6536	mm hard	Seawall	2	>10	1930-1970						
Robin Hood's Bay	240/6537	mm hard	Seawall	2	>10	1950-1960						
Scarborough North	240/6538	mm hard	Seawall	2	>10	1970						
Scarborough North	240/6539	mm hard	Seawall	2	5-10	1950						
Scarborough North	240/6540	mm hard	Seawall	2	>10	1960						
Scarborough North	240/6541	mm hard	Seawall	2	>10	1960						
Scarborough North	240/6542	mm hard	Seawall revetment	2	>10	1970						
Scarborough North	240/6543	mm hard	Seawall	2	>10	1960						
Scarborough North	240/6544	mm hard	Seawall	2	>10	1930						
Scarborough North	240/6545	mm hard	Seawall	3	5-10	1950						
Scarborough North	240/6546	mm hard	Seawall	4	<5	1930		Marine Drive Revetment			2005	>50 yrs
Scarborough North	240/6547	mm hard	Seawall	4	<5	1930						

Information from MAFF survey 1994 (and updates from 1997)							Updated Information from other sources					
Location	MAFF Defence no.	Classific-ation	Type	Condit-ion (Class)	Residual Life	Year Construct-ed	Other Ref no.	Defence Name	Source Title	Source Author	Source Date	Residual Life (yrs)
Scarborough East Pier	240/6548	mm hard	Pier	2	>10	1860						
Scarborough West Pier	240/6549	mm hard	Pier	2	>10	1950						
Scarborough	240/6550	mm hard	Seawall	1	>10	1930						
Scarborough	240/6551	mm hard	Seawall	2	>10	1930						
Scarborough	240/6552	mm hard	Seawall	2	>10	1960						
Scarborough	240/6553	mm hard	Seawall	2	>10	1950-1970						
Scarborough	240/6554	mm hard	Seawall	2	>10	1950						
Scarborough	240/6555	mm hard	Seawall	3	5-10	1940						
Scarborough	240/6556	mm hard	Seawall	2	>10	1950						
Scarborough	240/6557	mm hard	Seawall	4	50	1994		Holbeck Cliff	Holbeck-Scalby Mills, Scarborough Coastal Defence Strategy	High Point Rendel	May-03	
Cayton Sands	240/6558	mm hard	Seawall	2	>10	1980						

Information from MAFF survey 1994 (and updates from 1997)							Updated Information from other sources					
Location	**MAFF Defence no.**	**Classific-ation**	**Type**	**Condit-ion (Class)**	**Residual Life**	**Year Construct-ed**	**Other Ref no.**	**Defence Name**	**Source Title**	**Source Author**	**Source Date**	**Residual Life (yrs)**
Cayton Bay	240/6559	mm hard	Seawall	2	5-10	1950-1970						
Cayton Bay	240/6560	mm hard	Seawall	3	5-10	1930						
Cayton Bay	240/6561	nat soft	Shore	4	>10	na						
Filey	240/6562	nat soft	Shore	3	>10	na						
Filey	240/6563	mm hard	Seawall	1	>10	1993						
Filey	240/6564	mm hard	Seawall	3	5-10	1970						
Filey	240/6565	nat soft	Shore	2	>10	na						
Filey	240/6566	mm hard	Seawall	3	>10	1930						
Filey	240/6567	mm hard	Seawall	3	>10 (<5 for headland wall)	1930-1950						
Hunmanby Sands	240/6568	mm hard	Gabions	3	5-10	1990						
Upgang Beach	240/6569	nat soft	Shore	2	>10	na						
Whitby	240/6570	mm hard	Seawall revetment	1	>10	1990	11	West cliff east	Whitby Coastal Strategy Sandsend to Abbey Cliff	High Point Rendel	Jul-02	40-50
Whitby	240/6571	mm hard	Seawall	4	5-10	1930	12A	West cliff Metropole (west) seawall	Whitby Coastal Strategy Sandsend to Abbey Cliff	High Point Rendel	Jul-02	10-20

Information from MAFF survey 1994 (and updates from 1997)							Updated Information from other sources					
Location	**MAFF Defence no.**	**Classific-ation**	**Type**	**Condit-ion (Class)**	**Residual Life**	**Year Construct-ed**	**Other Ref no.**	**Defence Name**	**Source Title**	**Source Author**	**Source Date**	**Residual Life (yrs)**
Scarborough Old Harbour	240/6572	mm hard	Seawall	2	>10	1860-1970						
Scarborough Old Harbour	240/6573	mm hard	Revetment	2	>10	1860						
Scarborough Old Harbour	240/6574	mm hard	Wall	2	>10	1860						
Scarborough Old Harbour	240/6575	mm hard	Seawall	2	>10	1920						
Scarborough Old Harbour	240/6576	mm hard	Seawall	3	>10	1950						
Scarborough Old Harbour	240/6577	mm hard	Seawall	3	>10	1970						
Scarborough Old Harbour	240/6578	mm hard	Seawall	2	>10	1930						
Scarborough Old Harbour	240/6579	mm hard	Revetment	2	>10	1920						
Scarborough Old	240/6580	mm hard	Seawall	2	>10	1970						

Information from MAFF survey 1994 (and updates from 1997)							Updated Information from other sources					
Location	**MAFF Defence no.**	**Classific-ation**	**Type**	**Condit-ion (Class)**	**Residual Life**	**Year Construct-ed**	**Other Ref no.**	**Defence Name**	**Source Title**	**Source Author**	**Source Date**	**Residual Life (yrs)**
Harbour												
Flamboro ugh	240/6401	mm hard	Revetment	2	>10	1960						

C3 Climate Change and Sea Level Rise

C3.1 Introduction

The global climate is constantly changing, but it is generally recognised that we are entering a period of change, particularly with respect to rising sea levels and the anticipated implications of climate change and sea level rise present a significant challenge to future coastal management. Over the last few decades, there have been numerous studies into the impact of potential changes in the future, however, there remains considerable uncertainty both within the science of future climate modelling and associated with future global development patterns.

C3.2 Sea level rise

The north-east coast is believed to be still reposnding to changes during the last 10,000 years when sea levels rose rapidly, flooding the North Sea Basin, but there is now conceren over human-induced acceleration in sea level rise due to climate change. Relative sea level change depends upon changes in global sea level (eustatic change) and in land-level (isostatic change).

Isotstatic change is the change in land level as the crust slowly readjusts to unloading of the weight of the ice since the last Ice Age. Therefore, areas which were covered by ice, i.e. northern England and Scotland, have been experiencing a rise in land levels over the last few thousand years, whereas the southern areas of England has been subsiding. The north-east coast is approximately at the fulcrum of the see-saw and therefore remains relatively stable (Source: Ian Shennan, 1989).

Eustatic change can be influenced by climatic changes. Evidence suggests that global average sea level rose by about 1.5mm/year during the twentieth century; this is believed to be due to a number of factors including thermal expansion of warming ocean waters and the melting of land glaciers, but after adjustment for natural land movements, it has been calculated that the average rate of sea level rise during the last century around the UK coastline was approximately 1mm/year.

Predictions of sea level change have been developed by the UK Climate Impacts Programme (UKCIP) for four possible future climate scenarios: Low, Medium-Low, Medium-High and High; these span a range of emissions scenarios and different climate sensitivities. The table below presents the current UKCIP (2002) estimates of future sea level change for the north east of England for the two extreme scenarios, low emissions scenario and high emissions scenario. The Table also includes the Defra 2003 recommendation for sconsideration of sea level rise.

	Regional Isostatic Subsidence (mm/yr)	UKCIP Net Sea level Change 2080s (relative to 1961-90) (mm)		Defra recommendation for NE England (mm/yr)
		Low Emissions	High Emissions	
NE England	+0.3	60	660	4
Yorkshire	-0.5	150	750	4

Note: Data from Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report. UKCIP do advise that these could vary by +-50% because of regional variations in global sea level rise.

Due to this uncertainty a rate of 5mm/year has been adopted for use in the SMP assessments.

C3.3 Storminess

It has been postulated that climate change may increase storminess around the UK, but although the UKCIP02 studies indicate some increase in storminess, there is a high degree of uncertainty and little agreement between models, regarding changes in mid-latitude variability. Therefore, although this is recognised as an uncertainty within the predictions, no detailed analysis of potential impacts has been undertaken.

C3.4 Precipitation

In addition to sea level rise and storminess, the other climate change factor that is important to coastal evolution is precipitation. UKCIP predictions suggest that winters will become wetter but summers may become drier throughout the UK. However, there is potential for heavy winter rain to become more frequent. This may have an impact on the softer cliffs along this coastline and could increase the likelihood of large-scale slope failures, but although this is recognised as an uncertainty this has not been directly taken into account in the shoreline evolution predictions, as e=ffects are likely to be localised, but where large scale failure is a potential hazard this has been recosgnised in the scenario assessments.

C3.5 Affect of climate change on shoreline change predictions made in the SMP

Due to the uncertainty in estimates a sea level rise rate of 5mm/year has been adopted for use in the SMP assessments.

Erosion rates relating to individual frontages are discussed in section C1. Where there have been specific studies examining potential increase in erosion due to climate change this information has been used in assessing different scenarios. Where there is little direct evidence a factor has been applied to predicted erosion rates to account for sea level rise and increased storminess. This factor has been determined from a simple historical projection mdel (National Research Council 1987; Leatherman 1990) as follows:

$$\text{Future recession rate} = \frac{\text{Historical recession rate}}{\text{Historical sea level rise}} \times \text{future sea level rise}$$

The model is very simple and assumes that sea level rise is the dominant influence on recession. Recent analysis of tidal gauge data (Woodworth et al, 1999) has demionstrated that over the last century sea-level has risen on the north east coast by up to 2mm/year (based on North Sheild data, 1901-1996), together with accelaeration in this trend of 0.8mm/year/century. If the sea level rises over the next 100 years at an average rate of 5mm/year, the above historical projection method suggests a factor of 2.5 increase in average annual recession rate. This figure probably represents an upper bound rate, with the current recession rate providing a lower bound figure.

The shoreline change predictions have therefore included a factor of 2 for the 2055 prediction and 2.5 for the 2105 prediction where there are cliff frontages. Where there are sloped beach frontages, a generic estimate of an additional shoreline recession of

10m at 2055 and 20m at 2105 has been applied, based on sea level rise of 5mm/year and an average beach slope of 1 in 40.

C4 Baseline Case 1 – No Active Intervention (NAI)

The following tables are provided in the GIS/database system.

Table C4.1 Assessment of Shoreline Response – No Active Intervention

SCENARIO REF: BASELINE SCENARIO 1 - NO ACTIVE INTERVENTION						
Location	**Predicted Change for**					
	Years 0-20 (2025)		**Years 20-50 (2055)**		**Years 50-100 (2105)**	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Littlehaven Beach, South Shields	South Pier and the back beach defences will remain in place for this period.	The defences will continue to hold the beach in place.	South Groyne, South Pier and the back beach defences will remain in place for this period.	The defences will continue to hold the beach in place.	Complete failure of South Groyne and the northern back beach defences at the start of this period. South Pier will remain in place for this period.	After the failure of the South Groyne which was the northern control structure for the beach, there will be rapid erosion of the northern end of the beach.
Herd Sand, South Pier to Trow Point, South Shield	South Groyne, South Pier and the back beach defences will remain in place for this period.	The defences will continue to hold the beach in place.	South Pier and the back beach defences will remain in place for this period.	The defences will continue to hold the beach in place.	Complete failure of back beach defences at the start of this period. South Pier will remain in place for this period.	Beach will generally retreat at 0.2m/yr with some slightly more accelerated retreat in the south to relieve pressure and allow beach shape to form natural curve ie. follow MHW profile. A further 20m retreat due to sea level rise.
Trow Point to Marsden Lea	No defences	Cliffline will retreat at approximately 0.2m/year. Net cliffline retreat will be approximately 4m by 2025.	No defences	Cliffline will retreat at approximately 0.2m/year with adjustment for sea level rise (x 2). Net cliffline retreat will be approximately 20m by 2055.	No defences	Cliffline will retreat at approximately 0.2m/year with adjustment for sea level rise (x 2.5). Net cliffline retreat will be approximately 50m by 2105.

SCENARIO REF: BASELINE SCENARIO 1 - NO ACTIVE INTERVENTION						
Location	**Predicted Change for**					
	Years 0-20 (2025)		**Years 20-50 (2055)**		**Years 50-100 (2105)**	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Marsden Lea to Lizard Point	Short sections of defence at base of cliff at Lifeguard Station and Public House will remain in place for this period.	Undefended cliffline will erode at approximately 0.2m/year with a net retreat of approximately 4m.	Short sections of defence at at base of cliff at Lifeguard Station and Public House fail at the start of this period.	Undefended cliffline will continue to erode at approximately 0.2m/year, with adjustment for sea level rise (x 2). Net retreat of cliffline is generally 20m, with some areas assessed locally. A more curved embayment will form as control structures at each end erode. Marsden Rock and other smaller nearshore rocks will be eroding, leaving the sections of cliff behind them more exposed than they have been historically.	No defences	Undefended cliffline will continue to erode at approximately 0.2m/year, with adjustment for sea level rise (x 2.5). Marsden Rock and other smaller nearshore rocks will have eroded completely. A more curved embayment will continue to form as control structures at each end erode and nearshore rocks no longer afford protection to the coastline. Net retreat of 50m generally with some areas assessed locally.
Lizard Point to southern end of Whitburn Point Nature Reserve	No defences	Undefended cliffline will erode at approximately 0.1m/year with a net retreat of approximately 2m.	No defences	Undefended cliffline will erode at approximately 0.1m/year with adjustment for sea level rise (x 2). Net cliffline retreat will be approximately 10m by 2055.	No defences	Undefended cliffline will erode at approximately 0.1m/year with adjustment for sea level rise (x 2.5). Net cliffline retreat will be approximately 25m by 2055.

SCENARIO REF: BASELINE SCENARIO 1 - NO ACTIVE INTERVENTION						
Location	**Predicted Change for**					
	Years 0-20 (2025)		**Years 20-50 (2055)**		**Years 50-100 (2105)**	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Southern end of Whitburn Point Nature Reserve to Souter Point	No defences	Undefended cliffline will erode at approximately 0.2m/year with a net retreat of approximately 4m. Souter Point remains the southern control structure.	No defences	Undefended cliffline will erode at approximately 0.2m/year with adjustment for sea level rise (x 2). Net cliffline retreat will be approximately 20m by 2055. Souter Point remains the southern control structure.	No defences	Undefended cliffline will erode at approximately 0.1m/year with adjustment for sea level rise (x 2.5). Net cliffline retreat will be approximately 50m by 2055. Souter Point remains the southern control structure.
Souter Point to The Bents, Whitburn	No defences	Undefended cliffline will erode at approximately 0.1m/year with a net retreat of approximately 2m.	No defences	Undefended cliffline will erode at approximately 0.1m/year with adjustment for sea level rise (x 2). Net cliffline retreat would be 10m by 2055.	No defences	Undefended cliffline will erode at approximately 0.1m/year with adjustment for sea level rise (x 2.5). Net cliffline retreat will be approximately 25m by 2055.
Whitburn Bay (The Bents to Parsons Rocks)	Back beach defences will remain in place for this period.	The defences will continue to hold the beach in place.	Complete failure of back beach defences at the start of this period.	An immediate retreat of 10m will occur when defences fail. Readjustment of the bay will then occur at 0.4m/year with some local variation. A further 10m retreat due to sea level rise. Net retreat will be approximately 32m by 2055.	No defences	Beach retreat at 0.4m/yr will continue. As the northern control feature (The Bents) and the southern control feature (Parsons Rocks) retreat, the bay will readjust to a deeper curvature. A further 20m retreat due to sea level rise will occur. Net retreat will be approximately 62m by 2055.

SCENARIO REF: BASELINE SCENARIO 1 - NO ACTIVE INTERVENTION						
Location	**Predicted Change for**					
	Years 0-20 (2025)		**Years 20-50 (2055)**		**Years 50-100 (2105)**	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Parsons Rocks	Defence fails in 5 years.	The undefended coastline, forward of the adjacent coastlines, will erode at approximately 0.4m/year with a net retreat of approximately 2m. Parsons Rocks is a control feature for the beaches to the north and south. Any retreat at this location will therefore cuase associated retreat of the adjacent beaches.	No defences	Erosion will continue at 0.4m/year with an adjustment for sea level rise (x 2). Net retreat is 36m by 2055.	No defences	Erosion will continue at 0.4m/year with a an adjustment for sea level rise (x 2.5). Net retreat is 95m by 2105.
Parson Rocks to Coastguard Lookout, Roker	Cliff defences will remain in place for this period.	The defences will continue to hold the beach and cliffline in place. Defences to the south have failed and some outflanking of defences in this area will commence.	Cliff defences will remain in place for this period.	The defences will continue to hold the beach and cliffline in place. Erosion of northern control feature (Parsons Rocks) will start to put additional pressure on back beach defences. Outflanking of defences due to failure of defences to the south will continue.	Cliff defences fail completely at the start of this period.	The cliffline will retreat at 0.2m/year with a an adjustment for sea level rise (x 2.5). Net retreat is 25m by 2105.

SCENARIO REF: BASELINE SCENARIO 1 - NO ACTIVE INTERVENTION						
Location	**Predicted Change for**					
	Years 0-20 (2025)		**Years 20-50 (2055)**		**Years 50-100 (2105)**	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Coastguard Lookout to Roker Pier	Cliff defences fail completely after 10 years.	The cliffline will retreat at 0.2m/year. Net retreat is 2m by 2025.	No defences	The cliffline will retreat at 0.2m/year with an adjustment for sea level rise (x 2). Net retreat is 16m by 2055.	No defences	The cliffline will retreat at 0.2m/year with a an adjustment for sea level rise (x 2.5). Net retreat is 45m by 2105.
Sunderland Harbour, Roker Pier to New South Pier	Defences will remain in place for this period with the exception of North Pier which fails after 10 years.	The remaining defences will continue to generally maintain the harbour in its existing condition. The failure of North Pier will result in some loss of width on the northern beach as sand is transported in to the harbour entrance.	Roker Pier and New South Pier fail completely at the start of this period. Other harbour defences will remain in place for this period.	Readjustment of the harbour will occur with significant losses of the northern beach and a spit beginning to form at the harbour entrance.	No defences	Readjustment of the harbour will continue, with complete erosion of the northern end of the reclaimed docks area and further loss and spit formation on the northern side of the entrance. The harbour entrance is likely to realign south of its existing location as the spit increases in the north and the dock area erodes to the south.
New South Pier to southern end of Sunderland Docks	Most of the Dock defences will remain in place for this period. Defences at southern end of Dock area (at Sewage Works) will fail completely in 10 years.	The defences will continue to hold the current Dock arrangement in place, though completely disconnected from the mainland due to the failure of the southern defences.	Most of the Dock defences will remain in place for this period. No defences at southern end of Dock area (at Sewage Works).	The defences will continue to hold the current Dock arrangement in place though it will be completely disconnected from the mainland due to the failure of the southern defences.	Only defences on the mainland will remain.	The coastline will retreat back to the existing mainland coastline as the reclimed area of the Docks wil have eroded completely by the end of this period.

SCENARIO REF: BASELINE SCENARIO 1 - NO ACTIVE INTERVENTION						
Location	**Predicted Change for**					
	Years 0-20 (2025)		**Years 20-50 (2055)**		**Years 50-100 (2105)**	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Hendon frontage	Defences will remain in place for this period.	The defences will continue to hold the cliffline and beaches in place.	Defences will fail completely at the start of this period.	Cliffline will retreat at approximately 0.4m/year with adjustment for sea level rise (x 2). Net cliffline retreat will be approximately 24m by 2055.	No defences	Cliffline will retreat at approximately 0.4m/year with adjustment for sea level rise (x 2.5). Net cliffline retreat will be approximately 80m by 2105.
Grangetown/Ryhope frontage to Ryhope Dene	No defences	Cliffline will retreat at approximately 1.0m/year. Net cliffline retreat will be approximately 20m by 2025. Pincushion headland will erode more slowly and remain a control structure.	No defences	Cliffline will retreat at approximately 1.0m/year with adjustment for sea level rise (x 2). Net cliffline retreat will be approximately 100m by 2055. Pincushion headland will erode more slowly and remain a control structure.	No defences	Cliffline will retreat at approximately 1.0m/year with adjustment for sea level rise (x 2.5). Net cliffline retreat will be approximately 250m by 2105. Pincushion headland will erode more slowly and remain a control structure.
Ryhope Dene to Featherbed Rocks, Seaham	Defence fail completely at the end of this period.	The defences will maintain the frontage in its existing condition for most of this period. Immediate retreat of 12m as the defences fail. Net cliffline retreat will be approximately 12m by 2025.	No defences	The beach will readjust retreating on average 0.4m/year with adjustment for sea level rise (x 2). Net cliffline retreat will be approximately 36m by 2055.	No defences	The beach will continue to retreat on average 0.4m/year with adjustment for sea level rise (x 2.5). Net cliffline retreat will be approximately 92m by 2105.

SCENARIO REF: BASELINE SCENARIO 1 - NO ACTIVE INTERVENTION						
Location	**Predicted Change for**					
	Years 0-20 (2025)		**Years 20-50 (2055)**		**Years 50-100 (2105)**	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Featherbed Rocks to Red Acre, Seaham	Cliff base defences will remain in place for most of this period. Defences will fail completely at the end of this period.	The defences will continue to maintain the frontage in its existing condition for most of this period. Immediate retreat of 12m as the defences fail. Net cliffline retreat will be approximately 13m by 2025.	Defences will fail completely at the start of this period.	Cliffline will retreat at 0.3m/ year following an immediate retreat of 10m with adjustment for sea level rise (+10m). Net cliffline retreat will be approximately 32m by 2055.	No defences	Cliffline will retreat at approximately 0.3m/year with adjustment for sea level rise (+20m). Net cliffline retreat will be approximately 57m by 2105.
Beach to north of Seaham Harbour	No defences	Cliffline will retreat at 0.3m/ year. Net cliffline retreat will be approximately 6m by 2025.	No defences	Cliffline will retreat at 0.3m/ year with adjustment for sea level rise (+10m). Net cliffline retreat will be approximately 25m by 2055.	No defences	Cliffline will retreat at 0.3m/ year with adjustment for sea level rise (+20m). Net cliffline retreat will be approximately 50m by 2105.
Seaham Harbour	Piers and harbour defences remain in place for this period.	Harbour is maintained in curent form for this period.	Piers and harbour defences fail completely at the start of this period.	General readjustment of coastline back towards its natural state. Refer mapping.	No defences	General readjustment of coastline back towards its natural state. Refer mapping.

SCENARIO REF: BASELINE SCENARIO 1 - NO ACTIVE INTERVENTION						
Location	**Predicted Change for**					
	Years 0-20 (2025)		**Years 20-50 (2055)**		**Years 50-100 (2105)**	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Chemical Beach, Dawdon	Defences remain in place for this period.	The defences will continue to hold the beach in place. Colliery waste on the beach is progressively eroded throughout this period.	Defences fail at the start of this period.	Colliery waste is completely eroded by the start of this period. Cliffline erosion proceeds at 0.5m/year with some local variation and adjustment for sea level rise (+10m).	No defences	
Liddle Stack to Nose's Point, Dawdon	No defences	Colliery waste on the beach is completely eroded within 10 years. Cliffline erosion proceeds at 0.5m/year with some local variation	No defences	Cliffline erosion continues at 0.5m/year with some local variation and adjustment for sea level rise (x2).	No defences	Cliffline erosion continues at 0.5m/year with some local variation and adjustment for sea level rise (x2.5).
Nose's Pont to Chourdon Point	No defences	Colliery waste on the beach is completely eroded within 10 years. Cliffline erosion proceeds at 0.3m/year with some local variation	No defences	Cliffline erosion continues at 0.3m/year with some local variation and adjustment for sea level rise (+10m).	No defences	Cliffline erosion continues at 0.3m/year with some local variation and adjustment for sea level rise (+20m).

SCENARIO REF: BASELINE SCENARIO 1 - NO ACTIVE INTERVENTION						
Location	**Predicted Change for**					
	Years 0-20 (2025)		**Years 20-50 (2055)**		**Years 50-100 (2105)**	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Chourdon Point to Hawthorn Burn	No defences	Colliery waste on the beach is progressively eroded throughout this period.	No defences	Colliery waste on the beach is completely eroded within 30 years. Cliffline erosion then proceeds at 0.3m/year with some local variation and adjustment for sea level rise (+10m). Net cliffline retreat will be approximately 16m by 2055.	No defences	Cliffline erosion continues at 0.3m/year with some local variation and adjustment for sea level rise (+20m). Net cliffline retreat will be approximately 41m by 2105.
Hawthorn Burn to Beacon Point	No defences	Cliffline will retreat at 0.3m/ year. Net cliffline retreat will be approximately 6m by 2025.	No defences	Cliffline will retreat at 0.3m/ year with adjustment for sea level rise (+10m). Net cliffline retreat will be approximately 25m by 2055.	No defences	Cliffline erosion continues at 0.3m/year with adjustment for sea level rise (+20m). Net cliffline retreat will be approximately 50m by 2105.

SCENARIO REF: BASELINE SCENARIO 1 - NO ACTIVE INTERVENTION						
Location	**Predicted Change for**					
	Years 0-20 (2025)		**Years 20-50 (2055)**		**Years 50-100 (2105)**	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Shippersea Bay	No defences	Colliery waste on the beach is progressively eroded throughout this period.	No defences	Colliery waste on the beach is completely eroded within 30 years. Cliffline erosion then proceeds at 0.3m/year with some local variation and adjustment for sea level rise (+10m). Net cliffline retreat will be approximately 16m by 2055.	No defences	Cliffline erosion continues at 0.3m/year with adjustment for sea level rise (+20m). Net cliffline retreat will be approximately 41m by 2105.
Shippersea Point to Blackhalls Rocks	No defences	Colliery waste is completely eroded within 10 years. Cliffline erosion proceeds at 0.3m/year with some local variation. Net cliffline retreat will be approximately 3m by 2025.	No defences	Cliffline erosion continues at 0.3m/year with some local variation and adjustment for sea level rise (+10m). Net cliffline retreat will be approximately 22m by 2055.	No defences	Cliffline erosion continues at 0.3m/year with some local variation and adjustment for sea level rise (+20m). Net cliffline retreat will be approximately 47m by 2105.
Blackhalls Rocks to Parton Rocks	No defences	No further supply of colliery material south of Blackhall Rocks. The cliffline will retreat at 0.3m/year. Net retreat is 6m by 2025.	No defences	The cliffline will retreat at 0.3m/year with an adjustment for sea level rise (+10m). Net retreat is 25m by 2055.	No defences	The cliffline will retreat at 0.3m/year with a an adjustment for sea level rise (+20m). Net retreat is 50m by 2105.

SCENARIO REF: BASELINE SCENARIO 1 - NO ACTIVE INTERVENTION						
Location	**Predicted Change for**					
	Years 0-20 (2025)		**Years 20-50 (2055)**		**Years 50-100 (2105)**	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Frontage at Parton Rocks	No defences	The cliffline will retreat at 0.3m/year. Net retreat is 6m by 2025.	No defences	The cliffline will retreat at 0.3m/year with an adjustment for sea level rise (+10m). Net retreat is 25m by 2055.	No defences	The cliffline will retreat at 0.3m/year with a an adjustment for sea level rise (+20m). Net retreat is 50m by 2105.
Hartlepool Headland to Heugh Breakwater	Headland defences including Huegh Breakwater will remain in place for this period.	The defences will continue to hold the headland cliffline in place.	Headland defences fail completely at the start of this period.	Cliffline will retreat at 0.3m/ year with adjustment for sea level rise (x1.2) following an immediate retreat of 10m when defences fail. Net cliffline retreat will be approximately 30m by 2055.	No defences	The cliffline will retreat at 0.3m/year with an adjustment for sea level rise (x1.8). Net retreat is 90m by 2105.
Hartlepool Headland - Heugh Breakwater to Old Pier	Headland defences fail completely at 10 years.	Following failure of defences, there will be an immediate retreat of 10m then the cliffline will retreat at 0.5m/year. Net retreat is 15m by 2025.	No defences	The cliffline will retreat at 0.5m/year with an adjustment for sea level rise (x1.2). Net retreat is 36m by 2055.	No defences	The cliffline will retreat at 0.3m/year with a an adjustment for sea level rise (x1.8). Net retreat is 99m by 2105.
Old Pier and Croft Terrace	Defences including Old Pier will remain in place for this period.	The defences will continue to hold the headland cliffline in place.	Defences including Old Pier fail completely at the start of this period.	The cliffline will retreat immediately 10m when defences fail then at 0.5m/year. Net retreat is 36m by 2055.		

SCENARIO REF: BASELINE SCENARIO 1 - NO ACTIVE INTERVENTION						
Location	**Predicted Change for**					
	Years 0-20 (2025)		**Years 20-50 (2055)**		**Years 50-100 (2105)**	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Town Wall	Town wall defences fail completely at 10 years.	Following failure of defences, there will be an immediate retreat of 10m then the cliffline will retreat as mapped.	No defences	The shoreline will retreat as mapped.	No defences	The shoreline will retreat as mapped.
Victoria Harbour	Defences will remain in place for this period.	The defences will continue to hold the harbour in place.	Harbour defences fail completely at the start of this period.	Shoreline will retreat as mapped.	No defences	Shoreline will retreat as mapped.
Middleton Beach	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Back beach defences fail completely at the start of this period.	Shoreline retreats at approximately 1m/year with some local variation.	No defences	Shoreline retreats at approximately 1m/year with some local variation.
West harbour and marina	Defences including north and south piers will remain in place for this period.	The defences will continue to hold the harbour in place.	Defences including north and south piers will remain in place for this period.	The defences will continue to hold the harbour in place.	Harbour defences fail completely at the start of this period.	Shoreline will retreat back to the natural curvature of Hartlepool Bay as mapped.
Old Town beach (to south of South Pier)	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Defences will remain in place for this period.	The defences will continue to hold the beach in place.
Carr House Sands to Long Scar	Back beach defences fail after 5 years north of Newburn Bridge and 10 years in the south.	Following failure of defences, the cliffline will retreat at 0.4m/year on average though erosion in the south will be greater. Net average retreat is 5m by 2025.	No defences	The cliffline will retreat at 0.4m/year with adjustment for sea level rise (+10m) and local variation. Net average retreat is 27m by 2055.	No defences	The cliffline will retreat at 0.4m/year with adjustment for sea level rise (+20m) and local variation. Net average retreat is 57m by 2105.

SCENARIO REF: BASELINE SCENARIO 1 - NO ACTIVE INTERVENTION						
Location	**Predicted Change for**					
	Years 0-20 (2025)		**Years 20-50 (2055)**		**Years 50-100 (2105)**	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Long Scar to Little Scar	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Back beach defences fail completely at the start of this period.	The cliffline will retreat at 0.4m/year with an adjustment for sea level rise (+10m). Net retreat is 22m by 2055.	No defences	The cliffline will retreat at 0.4m/year with adjustment for sea level rise (+20m). Net average retreat is 52m by 2105.
Seaton Sands	Short sections of defence at the centre of the beach fail after 10 years. North Gare breakwater also fails after 10 years.	The cliffline will retreat at 0.4m/year except where defences are still viable. Net average retreat is 8m by 2025 where there are no defences. Beach sand will be transported south into the mouth of the Tees following the failure of the North Gare breakwater.	No defences	The cliffline will retreat at 0.4m/year with an adjustment for sea level rise (+10m). Net retreat is 30m by 2055.		The cliffline will retreat at 0.4m/year with adjustment for sea level rise (+20m). Net average retreat is 60m by 2105.
Coatham Sands	South Gare breakwater to the north will remain in place for this period. There are no back beach defences.	Cliffline will retreat at 0.2m/ year. Net cliffline retreat will be approximately 4m by 2025.	South Gare breakwater to the north will remain in place for this period. There are no back beach defences.	Cliffline will retreat at 0.2m/ year with adjustment for sea level rise (+10m). Net cliffline retreat will be approximately 20m by 2055.	South Gare breakwater to the north will fail at the start of this period. There are no back beach defences.	Cliffline erosion continues at 0.2m/year with adjustment for sea level rise (+20m) and local variation. Net cliffline retreat will be 40m by 2105 with additional attack in the north..

SCENARIO REF: BASELINE SCENARIO 1 - NO ACTIVE INTERVENTION						
Location	**Predicted Change for**					
	Years 0-20 (2025)		**Years 20-50 (2055)**		**Years 50-100 (2105)**	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Coatham Rocks and Recar Rocks frontage	Defences fail in 10 years.	Following failure of defences, cliffline will retreat at 0.4m/ year. Net cliffline retreat will be approximately 4m by 2025.	No defences	Cliffline will retreat at 0.4m/ year with adjustment for sea level rise (+10m). Net cliffline retreat will be approximately 26m by 2055.	No defences	Cliffline erosion continues at 0.4m/year with adjustment for sea level rise (+20m). Net cliffline retreat will be approximately 56m by 2105.
Marske Sands to Rat Howle	Short section of defence in north at Rat Howle, will fail in 10 years.	Cliffline will retreat at 0.4m/ year. Net cliffline retreat will be approximately 8m by 2025.	No defences	Cliffline will retreat at 0.4m/ year with adjustment for sea level rise (+10m). Net cliffline retreat will be approximately 30m by 2055.	No defences	Cliffline erosion continues at 0.4m/year with adjustment for sea level rise (+20m). Net cliffline retreat will be approximately 60m by 2105.
Marske Sands to Saltburn	No defences	Cliffline will retreat at 0.4m/ year. Net cliffline retreat will be approximately 8m by 2025.	No defences	Cliffline will retreat at 0.4m/ year with adjustment for sea level rise (+10m). Net cliffline retreat will be approximately 30m by 2055.	No defences	Cliffline erosion continues at 0.4m/year with adjustment for sea level rise (+20m). Net cliffline retreat will be approximately 60m by 2105.
Saltburn Sands	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Back beach defences fail completely at the start of this period.	The cliffline will retreat at 0.4m/year with an adjustment for sea level rise (+10m). Net retreat is 22m by 2055.	No defences	The cliffline will retreat at 0.4m/year with adjustment for sea level rise (+20m). Net average retreat is 52m by 2105.

SCENARIO REF: BASELINE SCENARIO 1 - NO ACTIVE INTERVENTION						
Location	**Predicted Change for**					
	Years 0-20 (2025)		**Years 20-50 (2055)**		**Years 50-100 (2105)**	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Saltburn to Blue Nook	No defences	Cliffline will retreat at 0.1m/ year. Net cliffline retreat will be approximately 2m by 2025.	No defences	Cliffline will retreat at 0.4m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 10m by 2055.	No defences	Cliffline erosion continues at 0.4m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 25m by 2105.
Cattersty Sands	Jetty at southern end of beach remains in place for this period.	The defences will continue to hold the beach in place.	Jetty at southern end of beach fails at the start of this period.	Following jetty failure the beach will erode rapidly as sand is transported to the south. The cliffline will retreat at 0.3m/ year with adjustment for sea level rise (+10m). Net cliffline retreat will be approx-imately 19m by 2055.	No defences	Cliffline erosion continues at 0.3m/year with adjustment for sea level rise (+20m). Net cliffline retreat will be approximately 44m by 2105.
Skinningrove	Jetty to the north and other defences remain in place for this period.	The defences will continue to hold the bay in place.	Jetty to the north and other defences fails at the start of this period.	Potential landslips in cliffs are actiuvated during this period. Cliffline retreats as per mapping.	No defences	Potential landslips in cliffs are actiuvated during this period. Cliffline retreats as per mapping.
Loftus	No defences	Cliffline will retreat at 0.1m/ year. Net cliffline retreat will be approximately 2m by 2025.	No defences	Cliffline will retreat at 0.4m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 10m by	No defences	Cliffline erosion continues at 0.4m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 25m by 2105.

SCENARIO REF: BASELINE SCENARIO 1 - NO ACTIVE INTERVENTION						
Location	**Predicted Change for**					
	Years 0-20 (2025)		**Years 20-50 (2055)**		**Years 50-100 (2105)**	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
				2055.		
Loftus and Boulby Alum quarries	No defences	Cliffline will retreat at 0.2m/ year. Net cliffline retreat will be approximately 4m by 2025.	No defences	Cliffline will retreat at 0.2m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 20m by 2055.	No defences	Cliffline erosion continues at 0.2m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 50m by 2105.
Boulby to Cowbar	No defences	Cliffline will retreat at 0.2m/ year. Net cliffline retreat will be approximately 4m by 2025.	No defences	Cliffline will retreat at 0.2m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 20m by 2055.	No defences	Cliffline erosion continues at 0.2m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 50m by 2105.
Cowbar to Staithes	Local defences	Cliffline will retreat at 0.025m/ year. Net cliffline retreat will be approximately 0.5m by 2025.	Local defences	Cliffline will retreat at 0.025m/ year. Although there remains significant uncertainty, current eveidence indicates no increase. Erosin would be 1.25m by 2055.	No defences	Cliffline erosion continues at 0.025m/year Although there remains significant uncertainty, current eveidence indicates no increase. Erosin would be 2.5m. by 2105.

SCENARIO REF: BASELINE SCENARIO 1 - NO ACTIVE INTERVENTION						
Location	**Predicted Change for**					
	Years 0-20 (2025)		**Years 20-50 (2055)**		**Years 50-100 (2105)**	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Staithes	Defences will remain in place for this period	The defences will continue to hold the shoreline in place. The undefended cliffs to the north will retreat at 0.1m/year. Net cliffline retreat in the south will be approximately 2m by 2025.	Defences will remain in place for this period	The defences will continue to hold the shoreline in place. The undefended cliffs to the north continue to retreat at 0.1m/year. Net cliffline retreat in the south will be approximately 10m by 2025.	Breakwaters will remain in place for this period. Other defences fail at the start of this period.	The Staithes shoreline is still protected to some degree by the breakwaters and will erode as mapped. The undefended cliffs to the south continue to retreat at 0.1m/year. Net cliffline retreat in the south will be approximately 25m by 2105.
Staithes to Old Nab shaft	Defences will remain in place for this period.	The defences will continue to hold the Staithes shoreline in place. The undefended cliffs to the south retreat at 0.1m/year. Net cliffline retreat in the south will be approximately 2m by 2025.	Defences will remain in place for this period.	The defences will continue to hold the Staithes shoreline in place. The undefended cliffs to the south continue to retreat at 0.1m/year. Net cliffline retreat in the south will be approximately 10m by 2025.	Breakwaters will remain in place for this period. Other defences fail at the start of this period.	The Staithes shoreline is still protected to some degree by the breakwaters and will erode as mapped. The undefended cliffs to the south continue to retreat at 0.1m/year. Net cliffline retreat in the south will be approximately 25m by 2105.
Old Nab shaft to Runswick Bay	No defences	Cliffline will retreat at 0.1m/ year. Net cliffline retreat will be approximately 2m by 2025.	No defences	Cliffline will retreat at 0.1m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 10m by 2055.	No defences	Cliffline erosion continues at 0.1m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 25m by 2105.

SCENARIO REF: BASELINE SCENARIO 1 - NO ACTIVE INTERVENTION						
Location	**Predicted Change for**					
	Years 0-20 (2025)		**Years 20-50 (2055)**		**Years 50-100 (2105)**	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Runswick Bay settlement	Defences fail in 10 years.	Following failure of defences, cliffline is likely to experience landslip activity and will retreat as mapped.	No defences	Following landslip the cliffline will restabilise and retreat at 0.4m/ year with adjustment for sea level rise (+10m). Net cliffline retreat will be approximately 26m by 2055.	No defences	Cliffline erosion continues at 0.4m/year with adjustment for sea level rise (+20m). Net cliffline retreat will be approximately 56m by 2105.
Runswick Bay	No defences	Cliffline will retreat at 0.2m/ year. Net cliffline retreat will be approximately 4m by 2025.	No defences	Cliffline will retreat at 0.2m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 20m by 2055.	No defences	Cliffline erosion continues at 0.2m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 50m by 2105.
Kettleness to Sandsend	No defences	Cliffline will retreat at 0.1m/ year. Net cliffline retreat will be approximately 2m by 2025.	No defences	Cliffline will retreat at 0.1m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 10m by 2055.	No defences	Cliffline erosion continues at 0.1m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 25m by 2105.

SCENARIO REF: BASELINE SCENARIO 1 - NO ACTIVE INTERVENTION						
Location	**Predicted Change for**					
	Years 0-20 (2025)		**Years 20-50 (2055)**		**Years 50-100 (2105)**	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Sandsend	Defences fail in 10 years.	Cliffline will retreat at 0.25m/ year. Net cliffline retreat will be approximately 3m by 2025.	No defences	Cliffline will retreat at 0.25m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 20m by 2055.	No defences	Cliffline erosion continues at 0.25m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 56m by 2105.
Upgang Beach	No defences	Cliffline will retreat at 0.25m/ year. Net cliffline retreat will be approximately 3m by 2025.	No defences	Cliffline will retreat at 0.25m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 25m by 2055.	No defences	Cliffline erosion continues at 0.25m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 63m by 2105.
West Cliff	Defences will remain in place for this period.	The defences will continue to hold the shoreline in place.	Defences will remain in place for this period.	The defences will continue to hold the shoreline in place.	All defences fail at the start of this period.	The cliffs retreat at 0.25m/year with adjustment for sea level rise (x2.5). Net cliffline retreat in the south will be approximately 31m by 2105.
Whitby	Defences will remain in place for this period.	The defences will continue to hold the shoreline in place.	Defences will remain in place for this period.	The defences will continue to hold the shoreline in place.	All defences fail at the start of this period.	The cliffs retreat at 0.2m/year with adjustment for sea level rise (x2.5). Net cliffline retreat in the south will be approximately 25m by 2105.

SCENARIO REF: BASELINE SCENARIO 1 - NO ACTIVE INTERVENTION						
Location	**Predicted Change for**					
	Years 0-20 (2025)		**Years 20-50 (2055)**		**Years 50-100 (2105)**	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Whitby Harbour	Breakwaters and other defences will remain in place for this period.	The defences will continue to hold the shoreline in place.	Breakwaters and other defences will remain in place for this period.	The defences will continue to hold the shoreline in place.	All defences fail at the start of this period.	Abbey cliffs to the south of the harbour entrance retreat at 0.2m/year with adjustment for sea level rise (x2.5). Net cliffline retreat in the south will be approximately 25m by 2105. After the failure of the breakwaters at 50 years there will be southerly transport of the Whitby beach sands that would start to form a spit across the river mouth.
The Scar, Whitby	No defences	Cliffline will retreat at 0.1m/ year. Net cliffline retreat will be approximately 2m by 2025.	No defences	Cliffline will retreat at 0.1m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 10m by 2055.	No defences	Cliffline erosion continues at 0.1m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 25m by 2105.
Saltwick Nab	No defences	Cliffline will retreat at 0.7m/ year. Net cliffline retreat will be approximately 14m by 2025.	No defences	Cliffline will retreat at 0.7m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 70m by 2055.	No defences	Cliffline erosion continues at 0.7m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 175m by 2105.

SCENARIO REF: BASELINE SCENARIO 1 - NO ACTIVE INTERVENTION						
Location	**Predicted Change for**					
	Years 0-20 (2025)		**Years 20-50 (2055)**		**Years 50-100 (2105)**	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Saltwick Bay to Robin Hoods Bay	No defences	Cliffline will retreat at 0.1m/ year. Net cliffline retreat will be approximately 2m by 2025.	No defences	Cliffline will retreat at 0.1m/ year with adjustment for sea level rise (x2). Net retreat will be approximately 10m by 2055.	No defences	Cliffline erosion continues at 0.1m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 25m by 2105.
Robin Hoods Bay	Defences fail in 10 years.	Cliffline will retreat at 0.3m/ year. Net cliffline retreat will be approximately 3m by 2025.	No defences	Cliffline will retreat at 0.3m/ year with adjustment for sea level rise (x2). Net retreat will be approximately 24m by 2055.	No defences	Cliffline erosion continues at 0.3m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 68m by 2105.
Robin Hoods Bay to Low Nook	No defences	Cliffline will retreat at 0.3m/ year. Net cliffline retreat will be approximately 6m by 2025.	No defences	Cliffline will retreat at 0.3m/ year with adjustment for sea level rise (x2). Net retreat will be approximately 20m by 2055.	No defences	Cliffline erosion continues at 0.3m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 50m by 2105.
Low Nook to Rocky Point	No defences	Cliffline will retreat at 0.2m/ year. Net cliffline retreat will be approximately 4m by 2025.	No defences	Cliffline will retreat at 0.2m/ year with adjustment for sea level rise (x2). Net retreat will be approximately 20m by 2055.	No defences	Cliffline erosion continues at 0.2m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 50m by 2105.

SCENARIO REF: BASELINE SCENARIO 1 - NO ACTIVE INTERVENTION						
Location	**Predicted Change for**					
	Years 0-20 (2025)		**Years 20-50 (2055)**		**Years 50-100 (2105)**	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Rocky Point to Scalby Mills	No defences	Cliffline will retreat at 0.1m/ year. Net cliffline retreat will be approximately 2m by 2025.	No defences	Cliffline will retreat at 0.1m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 10m by 2055.	No defences	Cliffline erosion continues at 0.1m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 25m by 2105.
North Bay	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Back beach defences fail completely at the start of this period.	The cliffline will retreat at 0.2m/year with an adjustment for sea level rise (+10m). Net retreat is 16m by 2055.	No defences	The cliffline will retreat at 0.2m/year with adjustment for sea level rise (+20m). Net average retreat is 26m by 2105.
Scarborough Headland	Defences will remain in place for this period.	The defences will continue to hold the cliffline in place.	Defences will remain in place for this period.	The defences will continue to hold the cliffline in place.	Defences will remain in place for this period.	The defences will continue to hold the cliffline in place.
South Bay	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Back beach defences fail completely at the start of this period.	The cliffline will retreat at 0.3m/year with adjustment for sea level rise (+20m). Net average retreat is 35m by 2105.
South Bay to Osgodby Point	No defences	Cliffline will retreat at 0.2m/ year. Net cliffline retreat will be approximately 4m by 2025.	No defences	Cliffline will retreat at 0.2m/ year with adjustment for sea level rise (x2). Net retreat will be approximately 20m by 2055.	No defences	Cliffline erosion continues at 0.2m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 50m by 2105.

SCENARIO REF: BASELINE SCENARIO 1 - NO ACTIVE INTERVENTION						
Location	Predicted Change for					
	Years 0-20 (2025)		Years 20-50 (2055)		Years 50-100 (2105)	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Osgodby Point	No defences	Cliffline will retreat at 1m/ year. Net cliffline retreat will be approximately 20m by 2025.	No defences	Cliffline will retreat at 1m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 100m by 2055.	No defences	Cliffline erosion continues at 1m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 250m by 2105.
Cayton Bay	Short section of defence in centre of Bay will fail in 10 years.	Cliffline will retreat at 0.25m/ year. Net cliffline retreat will be approximately 5m by 2025 (2.5m where defended).	No defences	Cliffline will retreat at 0.25m/ year with adjustment for sea level rise (+10m). Net cliffline retreat will be approximately 23m by 2055 (20m where previously defended).	No defences	Cliffline erosion continues at 1m/year with adjustment for sea level rise (+20m). Net cliffline retreat will be approximately 45m by 2105 (43m where previously defended).
Cayton Bay to Filey Brigg	No defences	Cliffline will retreat at 0.25m/ year. Net cliffline retreat will be approximately 5m by 2025.	No defences	Cliffline will retreat at 0.25m/ year with adjustment for sea level rise (x2). Net retreat will be approximately 25m by 2055.	No defences	Cliffline erosion continues at 0.25m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 63m by 2105.
Filey Sands to Coble Landing	Short section of defence at sailing club.	Cliffline will retreat at 0.5m/ year. Net cliffline retreat will be approximately 10m by 2025.	No defences	Cliffline will retreat at 0.5m/ year with adjustment for sea level rise (+10m). Net retreat will be approximately 35m by 2055.	No defences	Cliffline erosion continues at 0.5m/year with adjustment for sea level rise (+20m). Net cliffline retreat will be approximately 70m by 2105.

SCENARIO REF: BASELINE SCENARIO 1 - NO ACTIVE INTERVENTION						
Location	**Predicted Change for**					
	Years 0-20 (2025)		**Years 20-50 (2055)**		**Years 50-100 (2105)**	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Filey town frontage	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Back beach defences fail completely at the start of this period.	The cliffline will retreat at 0.25m/year with an adjustment for sea level rise (+10m). Net retreat is 18m by 2055.	No defences	The cliffline will retreat at 0.25m/year with adjustment for sea level rise (+20m). Net average retreat is 40m by 2105.
Martins Gill to Flat Cliffs	No defences	Cliffline will retreat at 0.25m/ year. Net cliffline retreat will be approximately 5m by 2025.	No defences	Cliffline will retreat at 0.25m/ year with adjustment for sea level rise (+10m). Net retreat will be approximately 20m by 2055.	No defences	Cliffline erosion continues at 0.25m/year with adjustment for sea level rise (+20m). Net cliffline retreat will be approximately 43m by 2105.
Flat Cliffs	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 20m by 2025.	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 100m by 2025.	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 225m by 2025.
Hunmanby Gap	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 10m by 2025.	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 50m by 2025.	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 125m by 2025.
Reighton Sands	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 5m by 2025.	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 20m by 2025.	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 45m by 2025.

SCENARIO REF: BASELINE SCENARIO 1 - NO ACTIVE INTERVENTION						
Location	**Predicted Change for**					
	Years 0-20 (2025)		**Years 20-50 (2055)**		**Years 50-100 (2105)**	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Speeton Sands	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 20m by 2025.	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 100m by 2025.	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 225m by 2025.
Black Cliff, Speeton Sands	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 10m by 2025.	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 50m by 2025.	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 125m by 2025.
Queen Rocks	No defences	Cliffline will retreat at 1.5m/ year. Net cliffline retreat will be approximately 30m by 2025.	No defences	Cliffline will retreat at 1.5m/ year with adjustment for sea level rise. Net cliffline retreat will be approximately 75m by 2055.	No defences	Cliffline erosion continues at 1.5m/year with adjustment for sea level rise. Net cliffline retreat will be approximately 150m by 2105.
Dulcey Dock	No defences	Cliffline will retreat at 1m/ year. Net cliffline retreat will be approximately 20m by 2025.	No defences	Cliffline will retreat at 1m/ year with adjustment for sea level rise. Net cliffline retreat will be approximately 50m by 2055.	No defences	Cliffline erosion continues at 1m/year with adjustment for sea level rise. Net cliffline retreat will be approximately 100m by 2105.

SCENARIO REF: BASELINE SCENARIO 1 - NO ACTIVE INTERVENTION						
Location	**Predicted Change for**					
	Years 0-20 (2025)		**Years 20-50 (2055)**		**Years 50-100 (2105)**	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Speeton Moor to Flamborough Head	No defences	Cliffline will retreat at 0.1m/ year. Net cliffline retreat will be approximately 2m by 2025.	No defences	Cliffline will retreat at 0.1m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 10m by 2055.	No defences	Cliffline erosion continues at 0.1m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 25m by 2105.

C5 Baseline Case 2 – With Present Management (WPM)

With present management assumes management based on SMP1 policy; modified by subsequent strategies. The following tables are provided in the GIS/database system.

Table C5.1 Assessment of Shoreline Response – With Present Management

	SCENARIO REF: BASELINE SCENARIO 2 - WITH PRESENT MANAGEMENT					
Location	**Predicted Change for**					
	Years 0-20 (2025)		**Years 20-50 (2055)**		**Years 50-100 (2105)**	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Littlehaven Beach, South Shields	South Pier and the back beach defences will remain in place for this period.	The defences will continue to hold the beach in place.	South Groyne, South Pier and the back beach defences will remain in place for this period.	The defences will continue to hold the beach in place.	South Groyne, South Pier and the back beach defences will remain in place for this period.	The defences will continue to hold the beach in place.
Herd Sand, South Pier to Trow Point, South Shield	South Groyne, South Pier and the back beach defences will remain in place for this period.	The defences will continue to hold the beach in place.	South Groyne, South Pier and the back beach defences will remain in place for this period.	The defences will continue to hold the beach in place.	South Groyne, South Pier and the back beach defences will remain in place for this period.	The defences will continue to hold the beach in place.
Trow Point to Marsden Lea	No defences	Cliffline will retreat at approximately 0.2m/year. Net cliffline retreat will be approximately 4m by 2025.	No defences	Cliffline will retreat at approximately 0.2m/year with adjustment for sea level rise (x 2). Net cliffline retreat will be approximately 20m by 2055.	No defences	Cliffline will retreat at approximately 0.2m/year with adjustment for sea level rise (x 2.5). Net cliffline retreat will be approximately 50m by 2105.

Location	SCENARIO REF: BASELINE SCENARIO 2 - WITH PRESENT MANAGEMENT					
	Predicted Change for					
	Years 0-20 (2025)		Years 20-50 (2055)		Years 50-100 (2105)	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Marsden Lea to Lizard Point	Short sections of defence at base of cliff at Lifeguard Station and Public House will remain in place for this period.	Undefended cliffline will erode at approximately 0.2m/year with a net retreat of approximately 4m.	Short sections of defence at base of cliff at Lifeguard Station and Public House will remain in place for this period.	Undefended cliffline will continue to erode at approximately 0.2m/year, with adjustment for sea level rise (x 2). Net retreat of cliffline is generally 20m, with some areas assessed locally. A more curved embayment will form as control structures at each end erode. Marsden Rock and other smaller nearshore rocks will be eroding, leaving the sections of cliff behind them more exposed than they have been historically.	Short sections of defence at base of cliff at Lifeguard Station and Public House will remain in place for this period.	Undefended cliffline will continue to erode at approximately 0.2m/year, with adjustment for sea level rise (x 2.5). Marsden Rock and other smaller nearshore rocks will have eroded completely. A more curved embayment will continue to form as control structures at each end erode and nearshore rocks no longer afford protection to the coastline. Net retreat of 50m generally with some areas assessed locally.
Lizard Point to southern end of Whitburn Point Nature Reserve	No defences	Undefended cliffline will erode at approximately 0.1m/year with a net retreat of approximately 2m.	No defences	Undefended cliffline will erode at approximately 0.1m/year with adjustment for sea level rise (x 2). Net cliffline retreat will be approximately 10m by 2055.	No defences	Undefended cliffline will erode at approximately 0.1m/year with adjustment for sea level rise (x 2.5). Net cliffline retreat will be approximately 25m by 2055.

Location	SCENARIO REF: BASELINE SCENARIO 2 - WITH PRESENT MANAGEMENT					
	Predicted Change for					
	Years 0-20 (2025)		Years 20-50 (2055)		Years 50-100 (2105)	
	Defences	Natural coast	Defences	Natural coast	Defences	Natural coast
Southern end of Whitburn Point Nature Reserve to Souter Point	No defences	Undefended cliffline will erode at approximately 0.2m/year with a net retreat of approximately 4m. Souter Point remains the southern control structure.	No defences	Undefended cliffline will erode at approximately 0.2m/year with adjustment for sea level rise (x 2). Net cliffline retreat will be approximately 20m by 2055. Souter Point remains the southern control structure.	No defences	Undefended cliffline will erode at approximately 0.1m/year with adjustment for sea level rise (x 2.5). Net cliffline retreat will be approximately 50m by 2055. Souter Point remains the southern control structure.
Souter Point to The Bents, Whitburn	No defences	Undefended cliffline will erode at approximately 0.1m/year with a net retreat of approximately 2m.	No defences	Undefended cliffline will erode at approximately 0.1m/year with adjustment for sea level rise (x 2). Net cliffline retreat will be approximately 10m by 2055.	No defences	Undefended cliffline will erode at approximately 0.1m/year with adjustment for sea level rise (x 2.5). Net cliffline retreat will be approximately 25m by 2055.
Whitburn Bay (The Bents to Parsons Rocks)	Back beach defences will remain in place for this period.	The defences will continue to hold the beach in place.	Back beach defences will remain in place for this period.	The defences will continue to hold the beach in place.	Back beach defences will remain in place for this period.	The defences will continue to hold the beach in place.
Parsons Rocks	Defences will remain in place for this period.	The defences will continue to hold the headland in place.	Defences will remain in place for this period.	The defences will continue to hold the headland in place.	Defences will remain in place for this period.	The defences will continue to hold the headland in place.
Parson Rocks to Coastguard Lookout, Roker	Cliff defences will remain in place for this period.	The defences will continue to hold the beach and cliffline in place.	Cliff defences will remain in place for this period.	The defences will continue to hold the beach and cliffline in place.	Cliff defences will remain in place for this period.	The defences will continue to hold the beach and cliffline in place.
Coastguard Lookout to Roker Pier	Cliff defences will remain in place for this period.	The defences will continue to hold the beach and cliffline in place.	Cliff defences will remain in place for this period.	The defences will continue to hold the beach and cliffline in place.	Cliff defences will remain in place for this period.	The defences will continue to hold the beach and cliffline in place.

Location	SCENARIO REF: BASELINE SCENARIO 2 - WITH PRESENT MANAGEMENT					
	Predicted Change for					
	Years 0-20 (2025)		Years 20-50 (2055)		Years 50-100 (2105)	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Sunderland Harbour, Roker Pier to New South Pier	Defences will remain in place for this period.	The defences will continue to maintain the harbour in its existing condition.	Defences will remain in place for this period.	The defences will continue to maintain the harbour in its existing condition.	Defences will remain in place for this period.	The defences will continue to maintain the harbour in its existing condition.
New South Pier to southern end of Sunderland Docks	Dock defences will remain in place for this period.	The defences will continue to hold the current Dock arrangement in place.	Dock defences will remain in place for this period.	The defences will continue to hold the current Dock arrangement in place.	Dock defences will remain in place for this period.	The defences will continue to hold the current Dock arrangement in place.
Hendon frontage	Defences will remain in place for this period.	The defences will continue to hold the cliffline and beaches in place.	Defences will remain in place for this period.	The defences will continue to hold the cliffline and beaches in place.	Defences will remain in place for this period.	The defences will continue to hold the cliffline and beaches in place.
Grangetown/Ryhope frontage to Ryhope Dene	No defences	Cliffline will retreat at approximately 1.0m/year. Net cliffline retreat will be approximately 20m by 2025. Pincushion headland will erode more slowly and remain a control structure.	No defences	Cliffline will retreat at approximately 1.0m/year with adjustment for sea level rise (x 2). Net cliffline retreat will be approximately 100m by 2055. Pincushion headland will erode more slowly and remain a control structure.	No defences	Cliffline will retreat at approximately 1.0m/year with adjustment for sea level rise (x 2.5). Net cliffline retreat will be approximately 250m by 2105. Pincushion headland will erode more slowly and remain a control structure.
Ryhope Dene to Featherbed Rocks, Seaham	Defences will remain in place for this period.	The defences will continue to hold the cliffline and beaches in place.	Defences will remain in place for this period.	The defences will continue to hold the cliffline and beaches in place.	Defences will remain in place for this period.	The defences will continue to hold the cliffline and beaches in place.
Featherbed Rocks to Red Acre, Seaham	Cliff base defences will remain in place for this period.	The defences will continue to maintain the frontage in its existing condition for this period.	Cliff base defences will remain in place for this period.	The defences will continue to maintain the frontage in its existing condition for this period.	Cliff base defences will remain in place for this period.	The defences will continue to maintain the frontage in its existing condition for this period.

Location	SCENARIO REF: BASELINE SCENARIO 2 - WITH PRESENT MANAGEMENT					
	Predicted Change for					
	Years 0-20 (2025)		Years 20-50 (2055)		Years 50-100 (2105)	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Beach to north of Seaham Harbour	No defences	Cliffline will retreat at 0.3m/ year. Net cliffline retreat will be approximately 6m by 2025.	No defences	Cliffline will retreat at 0.3m/ year with adjustment for sea level rise (+10m). Net cliffline retreat will be approximately 25m by 2055.	No defences	Cliffline will retreat at 0.3m/ year with adjustment for sea level rise (+20m). Net cliffline retreat will be approximately 50m by 2105.
Seaham Harbour	Piers and harbour defences remain in place for this period.	Harbour is maintained in curent form for this period.	Piers and harbour defences fail completely at the start of this period.	General readjustment of coastline back towards its natural state. Refer mapping.	No defences	General readjustment of coastline back towards its natural state. Refer mapping.
Chemical Beach, Dawdon	Defences remain in place for this period.	The defences will continue to hold the beach in place. Colliery waste on the beach is progressively eroded throughout this period.	Defences remain in place for this period.	The defences will continue to hold the beach in place. Colliery waste is completely eroded by the start of this period.	Defences remain in place for this period.	The defences will continue to hold the beach in place.
Liddle Stack to Nose's Point, Dawdon	No defences	Colliery waste on the beach is completely eroded within 10 years. Cliffline erosion proceeds at 0.5m/year with some local variation	No defences	Cliffline erosion continues at 0.5m/year with some local variation and adjustment for sea level rise (x2).	No defences	Cliffline erosion continues at 0.5m/year with some local variation and adjustment for sea level rise (x2.5).
Nose's Pont to Chourdon Point	No defences	Colliery waste on the beach is completely eroded within 10 years. Cliffline erosion proceeds at 0.3m/year with some local variation	No defences	Cliffline erosion continues at 0.3m/year with some local variation and adjustment for sea level rise (+10m).	No defences	Cliffline erosion continues at 0.3m/year with some local variation and adjustment for sea level rise (+20m).

Location	SCENARIO REF: BASELINE SCENARIO 2 - WITH PRESENT MANAGEMENT					
	Predicted Change for					
	Years 0-20 (2025)		Years 20-50 (2055)		Years 50-100 (2105)	
	Defences	Natural coast	Defences	Natural coast	Defences	Natural coast
Chourdon Point to Hawthorn Burn	No defences	Colliery waste on the beach is progressively eroded throughout this period.	No defences	Colliery waste on the beach is completely eroded within 30 years. Cliffline erosion then proceeds at 0.3m/year with some local variation and adjustment for sea level rise (+10m). Net cliffline retreat will be approximately 16m by 2055.	No defences	Cliffline erosion continues at 0.3m/year with some local variation and adjustment for sea level rise (+20m). Net cliffline retreat will be approximately 41m by 2105.
Hawthorn Burn to Beacon Point	No defences	Cliffline will retreat at 0.3m/ year. Net cliffline retreat will be approximately 6m by 2025.	No defences	Cliffline will retreat at 0.3m/ year with adjustment for sea level rise (+10m). Net cliffline retreat will be approximately 25m by 2055.	No defences	Cliffline erosion continues at 0.3m/year with adjustment for sea level rise (+20m). Net cliffline retreat will be approximately 50m by 2105.
Shippersea Bay	No defences	Colliery waste on the beach is progressively eroded throughout this period.	No defences	Colliery waste on the beach is completely eroded within 30 years. Cliffline erosion then proceeds at 0.3m/year with some local variation and adjustment for sea level rise (+10m). Net cliffline retreat will be approximately 16m by 2055.	No defences	Cliffline erosion continues at 0.3m/year with adjustment for sea level rise (+20m). Net cliffline retreat will be approximately 41m by 2105.

Location	SCENARIO REF: BASELINE SCENARIO 2 - WITH PRESENT MANAGEMENT					
	Predicted Change for					
	Years 0-20 (2025)		Years 20-50 (2055)		Years 50-100 (2105)	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Shippersea Point to Blackhalls Rocks	No defences	Colliery waste on the beach is completely eroded within 10 years. Cliffline erosion proceeds at 0.3m/year with some local variation. Net cliffline retreat will be approximately 3m by 2025.	No defences	Cliffline erosion continues at 0.3m/year with some local variation and adjustment for sea level rise (+10m). Net cliffline retreat will be approximately 22m by 2055.	No defences	Cliffline erosion continues at 0.3m/year with some local variation and adjustment for sea level rise (+20m). Net cliffline retreat will be approximately 47m by 2105.
Blackhalls Rocks to Parton Rocks	No defences	No further supply of colliery material south of Blackhall Rocks. The cliffline will retreat at 0.3m/year. Net retreat is 6m by 2025.	No defences	The cliffline will retreat at 0.3m/year with an adjustment for sea level rise (+10m). Net retreat is 25m by 2055.	No defences	The cliffline will retreat at 0.3m/year with a an adjustment for sea level rise (+20m). Net retreat is 50m by 2105.
Frontage at Parton Rocks	No defences	The cliffline will retreat at 0.3m/year. Net retreat is 6m by 2025.	No defences	The cliffline will retreat at 0.3m/year with an adjustment for sea level rise (+10m). Net retreat is 25m by 2055.	No defences	The cliffline will retreat at 0.3m/year with a an adjustment for sea level rise (+20m). Net retreat is 50m by 2105.
Hartlepool Headland to Heugh Breakwater	Headland defences including Huegh Breakwater will remain in place for this period.	The defences will continue to hold the headland cliffline in place.	Headland defences including Huegh Breakwater will remain in place for this period.	The defences will continue to hold the headland cliffline in place.	Headland defences including Huegh Breakwater will remain in place for this period.	The defences will continue to hold the headland cliffline in place.
Hartlepool Headland - Heugh Breakwater to Old Pier	Headland defences will remain in place for this period.	The defences will continue to hold the headland cliffline in place.	Headland defences will remain in place for this period.	The defences will continue to hold the headland cliffline in place.	Headland defences will remain in place for this period.	The defences will continue to hold the headland cliffline in place.

Location	SCENARIO REF: BASELINE SCENARIO 2 - WITH PRESENT MANAGEMENT					
	Predicted Change for					
	Years 0-20 (2025)		Years 20-50 (2055)		Years 50-100 (2105)	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Old Pier and Croft Terrace	Defences including Old Pier will remain in place for this period.	The defences will continue to hold the headland cliffline in place.	Defences including Old Pier will remain in place for this period.	The defences will continue to hold the headland cliffline in place.	Defences including Old Pier will remain in place for this period.	The defences will continue to hold the headland cliffline in place.
Town Wall	Town wall defences will remain in place for this period.	The defences will continue to hold the headland cliffline in place.	Town wall defences will remain in place for this period.	The defences will continue to hold the headland cliffline in place.	Town wall defences will remain in place for this period.	The defences will continue to hold the headland cliffline in place.
Victoria Harbour	Defences will remain in place for this period.	The defences will continue to hold the harbour in place.	Defences will remain in place for this period.	The defences will continue to hold the harbour in place.	Defences will remain in place for this period.	The defences will continue to hold the harbour in place.
Middleton Beach	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Defences will remain in place for this period.	The defences will continue to hold the beach in place.
West harbour and marina	Defences including north and south piers will remain in place for this period.	The defences will continue to hold the harbour in place.	Defences including north and south piers will remain in place for this period.	The defences will continue to hold the harbour in place.	Defences including north and south piers will remain in place for this period.	The defences will continue to hold the harbour in place.
Old Town beach (to south of South Pier)	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Defences will remain in place for this period.	The defences will continue to hold the beach in place.
Carr House Sands to Long Scar	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Defences will remain in place for this period.	The defences will continue to hold the beach in place.
Long Scar to Little Scar	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Defences will remain in place for this period.	The defences will continue to hold the beach in place.

Location	SCENARIO REF: BASELINE SCENARIO 2 - WITH PRESENT MANAGEMENT					
	Predicted Change for					
	Years 0-20 (2025)		Years 20-50 (2055)		Years 50-100 (2105)	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Seaton Sands	Short sections of defence at the centre of the beach will remain in place for this period. North Gare breakwater also will remain in place for this period.	The defences will continue to hold the beach in place.	Short sections of defence at the centre of the beach will remain in place for this period. North Gare breakwater also will remain in place for this period.	The defences will continue to hold the beach in place.	Short sections of defence at the centre of the beach will remain in place for this period. North Gare breakwater also will remain in place for this period.	The defences will continue to hold the beach in place.
Coatham Sands	South Gare breakwater to the north will remain in place for this period. There are no back beach defences.	Cliffline will retreat at 0.2m/ year. Net cliffline retreat will be approximately 4m by 2025.	South Gare breakwater to the north will remain in place for this period. There are no back beach defences.	Cliffline will retreat at 0.2m/ year with adjustment for sea level rise (+10m). Net cliffline retreat will be approximately 20m by 2055.	South Gare breakwater to the north will fail at the start of this period. There are no back beach defences.	Cliffline erosion continues at 0.2m/year with adjustment for sea level rise (+20m) and local variation. Net cliffline retreat will be 40m by 2105 with additional attack in the north..
Coatham Rocks and Recar Rocks frontage	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Defences will remain in place for this period.	The defences will continue to hold the beach in place.
Marske Sands to Rat Howle	Short section of defence in north at Rat Howle, will remain in place for this period.	Undefended cliffline will retreat at 0.4m/ year. Net cliffline retreat will be approximately 8m by 2025.	Short section of defence in north at Rat Howle, will remain in place for this period.	Undefended cliffline will retreat at 0.4m/ year with adjustment for sea level rise (+10m). Net cliffline retreat will be approximately 30m by 2055.	Short section of defence in north at Rat Howle, will remain in place for this period.	Undefended cliffline erosion continues at 0.4m/year with adjustment for sea level rise (+20m). Net cliffline retreat will be approximately 60m by 2105.

Location	SCENARIO REF: BASELINE SCENARIO 2 - WITH PRESENT MANAGEMENT					
	Predicted Change for					
	Years 0-20 (2025)		Years 20-50 (2055)		Years 50-100 (2105)	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Marske Sands to Saltburn	No defences	Cliffline will retreat at 0.4m/ year. Net cliffline retreat will be approximately 8m by 2025.	No defences	Cliffline will retreat at 0.4m/ year with adjustment for sea level rise (+10m). Net cliffline retreat will be approximately 30m by 2055.	No defences	Cliffline erosion continues at 0.4m/year with adjustment for sea level rise (+20m). Net cliffline retreat will be approximately 60m by 2105.
Saltburn Sands	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Defences will remain in place for this period.	The defences will continue to hold the beach in place.
Saltburn to Blue Nook	No defences	Cliffline will retreat at 0.1m/ year. Net cliffline retreat will be approximately 2m by 2025.	No defences	Cliffline will retreat at 0.4m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 10m by 2055.	No defences	Cliffline erosion continues at 0.4m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 25m by 2105.
Cattersty Sands	Jetty at southern end of beach remains in place for this period.	The defences will continue to hold the beach in place.	Jetty at southern end of beach remains in place for this period.	The defences will continue to hold the beach in place.	Jetty at southern end of beach remains in place for this period.	The defences will continue to hold the beach in place.
Skinningrove	Jetty to the north and other defences remain in place for this period.	The defences will continue to hold the bay in place.	Jetty to the north and other defences remain in place for this period.	The defences will continue to hold the bay in place.	Jetty to the north and other defences remain in place for this period.	The defences will continue to hold the bay in place.

Location	SCENARIO REF: BASELINE SCENARIO 2 - WITH PRESENT MANAGEMENT					
	Predicted Change for					
	Years 0-20 (2025)		Years 20-50 (2055)		Years 50-100 (2105)	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Loftus	No defences	Cliffline will retreat at 0.1m/ year. Net cliffline retreat will be approximately 2m by 2025.	No defences	Cliffline will retreat at 0.4m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 10m by 2055.	No defences	Cliffline erosion continues at 0.4m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 25m by 2105.
Loftus and Boulby Alum quarries	No defences	Cliffline will retreat at 0.2m/ year. Net cliffline retreat will be approximately 4m by 2025.	No defences	Cliffline will retreat at 0.2m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 20m by 2055.	No defences	Cliffline erosion continues at 0.2m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 50m by 2105.
Boulby to Cowbar	No defences	Cliffline will retreat at 0.2m/ year. Net cliffline retreat will be approximately 4m by 2025.	No defences	Cliffline will retreat at 0.2m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 20m by 2055.	No defences	Cliffline erosion continues at 0.2m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 50m by 2105.
Cowbar to Staithes	Local defences	Cliffline will retreat at 0.025m/ year. The undefended net cliffline retreat will be approximately0.5m by 2025.	Local defences	Cliffline will retreat at 0.025m/ year. The undefended net cliffline retreat will be approximately 1.25m by 2055.	No defences	Cliffline erosion continues at 0.25m/year. The undefended net cliffline retreat will be approximately 2.5m by 2105.

Location	SCENARIO REF: BASELINE SCENARIO 2 - WITH PRESENT MANAGEMENT					
	Predicted Change for					
	Years 0-20 (2025)		Years 20-50 (2055)		Years 50-100 (2105)	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Staithes	Defences will remain in place for this period.	The defences will continue to hold the Staithes shoreline in place. The undefended cliffs to the north will retreat at 0.1m/year. Net cliffline retreat in the south will be approximately 2m by 2025.	Defences will remain in place for this period.	The defences will continue to hold the Staithes shoreline in place. The undefended cliffs to the north will continue to retreat at 0.1m/year. Net cliffline retreat in the south will be approximately 10m by 2025.	The defences will be extended behind the North breakwater.	Defences will provide additional protection to the natural cliff.
Staithes to Old Nab shaft	Defences will remain in place for this period.	The defences will continue to hold the Staithes shoreline in place. The undefended cliffs to the south retreat at 0.1m/year. Net cliffline retreat in the south will be approximately 2m by 2025.	Defences will remain in place for this period.	The defences will continue to hold the Staithes shoreline in place. The undefended cliffs to the south continue to retreat at 0.1m/year. Net cliffline retreat in the south will be approximately 10m by 2025.	Defences will remain in place for this period.	The defences will continue to hold the Staithes shoreline in place. The undefended cliffs to the south continue to retreat at 0.1m/year. Net cliffline retreat in the south will be approximately 25m by 2105.
Old Nab shaft to Runswick Bay	No defences	Cliffline will retreat at 0.1m/ year. Net cliffline retreat will be approximately 2m by 2025.	No defences	Cliffline will retreat at 0.1m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 10m by 2055.	No defences	Cliffline erosion continues at 0.1m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 25m by 2105.

Location	SCENARIO REF: BASELINE SCENARIO 2 - WITH PRESENT MANAGEMENT					
	Predicted Change for					
	Years 0-20 (2025)		Years 20-50 (2055)		Years 50-100 (2105)	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Runswick Bay settlement	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Defences will remain in place for this period.	The defences will continue to hold the beach in place.
Runswick Bay	No defences	Cliffline will retreat at 0.2m/ year. Net cliffline retreat will be approximately 4m by 2025.	No defences	Cliffline will retreat at 0.2m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 20m by 2055.	No defences	Cliffline erosion continues at 0.2m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 50m by 2105.
Kettleness to Sandsend	No defences	Cliffline will retreat at 0.1m/ year. Net cliffline retreat will be approximately 2m by 2025.	No defences	Cliffline will retreat at 0.1m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 10m by 2055.	No defences	Cliffline erosion continues at 0.1m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 25m by 2105.
Sandsend	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Defences will remain in place for this period.	The defences will continue to hold the beach in place.
Upgang Beach	No defences	Cliffline will retreat at 0.25m/ year. Net cliffline retreat will be approximately 3m by 2025.	No defences	Cliffline will retreat at 0.25m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 25m by 2055.	No defences	Cliffline erosion continues at 0.25m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 63m by 2105.
West Cliff	Defences will remain in place for this period.	The defences will continue to hold the shoreline in place.	Defences will remain in place for this period.	The defences will continue to hold the shoreline in place.	Defences will remain in place for this period.	The defences will continue to hold the shoreline in place.

Location	SCENARIO REF: BASELINE SCENARIO 2 - WITH PRESENT MANAGEMENT					
	Predicted Change for					
	Years 0-20 (2025)		Years 20-50 (2055)		Years 50-100 (2105)	
	Defences	Natural coast	Defences	Natural coast	Defences	Natural coast
Whitby	Defences will remain in place for this period.	The defences will continue to hold the shoreline in place.	Defences will remain in place for this period.	The defences will continue to hold the shoreline in place.	Defences will remain in place for this period.	The defences will continue to hold the shoreline in place.
Whitby Harbour	Breakwaters and other defences will remain in place for this period.	The defences will continue to hold the shoreline in place.	Breakwaters and other defences will remain in place for this period.	The defences will continue to hold the shoreline in place.	Breakwaters and other defences will remain in place for this period.	The defences will continue to hold the shoreline in place.
The Scar, Whitby	No defences	Cliffline will retreat at 0.1m/ year. Net cliffline retreat will be approximately 2m by 2025.	No defences	Cliffline will retreat at 0.1m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 10m by 2055.	No defences	Cliffline erosion continues at 0.1m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 25m by 2105.
Saltwick Nab	No defences	Cliffline will retreat at 0.7m/ year. Net cliffline retreat will be approximately 14m by 2025.	No defences	Cliffline will retreat at 0.7m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 70m by 2055.	No defences	Cliffline erosion continues at 0.7m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 175m by 2105.
Saltwick Bay to Robin Hoods Bay	No defences	Cliffline will retreat at 0.1m/ year. Net cliffline retreat will be approximately 2m by 2025.	No defences	Cliffline will retreat at 0.1m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 10m by 2055.	No defences	Cliffline erosion continues at 0.1m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 25m by 2105.

Location	SCENARIO REF: BASELINE SCENARIO 2 - WITH PRESENT MANAGEMENT					
	Predicted Change for					
	Years 0-20 (2025)		Years 20-50 (2055)		Years 50-100 (2105)	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Robin Hoods Bay	Defences will remain in place for this period.	The defences will continue to hold the shoreline in place.	Defences will remain in place for this period.	The defences will continue to hold the shoreline in place.	Defences will remain in place for this period.	The defences will continue to hold the shoreline in place.
Robin Hoods Bay to Low Nook	No defences	Cliffline will retreat at 0.3m/ year. Net cliffline retreat will be approximately 6m by 2025.	No defences	Cliffline will retreat at 0.3m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 20m by 2055.	No defences	Cliffline erosion continues at 0.3m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 50m by 2105.
Low Nook to Rocky Point	No defences	Cliffline will retreat at 0.2m/ year. Net cliffline retreat will be approximately 4m by 2025.	No defences	Cliffline will retreat at 0.2m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 20m by 2055.	No defences	Cliffline erosion continues at 0.2m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 50m by 2105.
Rocky Point to Scalby Mills	No defences	Cliffline will retreat at 0.1m/ year. Net cliffline retreat will be approximately 2m by 2025.	No defences	Cliffline will retreat at 0.1m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 10m by 2055.	No defences	Cliffline erosion continues at 0.1m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 25m by 2105.
North Bay	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Defences will remain in place for this period.	The defences will continue to hold the beach in place.
Scarborough Headland	Defences will remain in place for this period.	The defences will continue to hold the cliffline in place.	Defences will remain in place for this period.	The defences will continue to hold the cliffline in place.	Defences will remain in place for this period.	The defences will continue to hold the cliffline in place.

Location	SCENARIO REF: BASELINE SCENARIO 2 - WITH PRESENT MANAGEMENT					
	Predicted Change for					
	Years 0-20 (2025)		Years 20-50 (2055)		Years 50-100 (2105)	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
South Bay	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Defences will remain in place for this period.	The defences will continue to hold the beach in place.
South Bay to Osgodby Point	No defences	Cliffline will retreat at 0.2m/ year. Net cliffline retreat will be approximately 4m by 2025.	No defences	Cliffline will retreat at 0.2m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 20m by 2055.	No defences	Cliffline erosion continues at 0.2m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 50m by 2105.
Osgodby Point	No defences	Cliffline will retreat at 1m/ year. Net cliffline retreat will be approximately 20m by 2025.	No defences	Cliffline will retreat at 1m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 100m by 2055.	No defences	Cliffline erosion continues at 1m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 250m by 2105.
Cayton Bay	Short section of defence in centre of Bay will remain in place for this period.	Undefended cliffline will retreat at 0.25m/ year. Net cliffline retreat will be approximately 5m by 2025 (2.5m where defended).	Short section of defence in centre of Bay will remain in place for this period.	Undefended cliffline will retreat at 0.25m/ year with adjustment for sea level rise (+10m). Net cliffline retreat will be approximately 23m by 2055 (20m where previously defended).	Short section of defence in centre of Bay will remain in place for this period.	Undefended cliffline erosion continues at 1m/year with adjustment for sea level rise (+20m). Net cliffline retreat will be approximately 45m by 2105 (43m where previously defended).

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	Predicted Change for					
	Years 0-20 (2025)		Years 20-50 (2055)		Years 50-100 (2105)	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Cayton Bay to Filey Brigg	No defences	Cliffline will retreat at 0.25m/ year. Net cliffline retreat will be approximately 5m by 2025.	No defences	Cliffline will retreat at 0.25m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 25m by 2055.	No defences	Cliffline erosion continues at 0.25m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 63m by 2105.
Filey Sands to Coble Landing	Short section of defence at sailing club will remain in place for this period.	Undefended cliffline will retreat at 0.5m/ year. Net cliffline retreat will be approximately 10m by 2025.	Short section of defence at sailing club will remain in place for this period.	Undefended cliffline will retreat at 0.5m/ year with adjustment for sea level rise (+10m). Net cliffline retreat will be approximately 35m by 2055.	Short section of defence at sailing club will remain in place for this period.	Undefended cliffline erosion continues at 0.5m/year with adjustment for sea level rise (+20m). Net cliffline retreat will be approximately 70m by 2105.
Filey town frontage	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Defences will remain in place for this period.	The defences will continue to hold the beach in place.	Defences will remain in place for this period.	The defences will continue to hold the beach in place.
Martins Gill to Flat Cliffs	No defences	Cliffline will retreat at 0.25m/ year. Net cliffline retreat will be approximately 5m by 2025.	No defences	Cliffline will retreat at 0.25m/ year with adjustment for sea level rise (+10m). Net cliffline retreat will be approximately 20m by 2055.	No defences	Cliffline erosion continues at 0.25m/year with adjustment for sea level rise (+20m). Net cliffline retreat will be approximately 43m by 2105.
Flat Cliffs	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 20m by 2025.	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 100m by 2025.	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 225m by 2025.

Location	SCENARIO REF: BASELINE SCENARIO 2 - WITH PRESENT MANAGEMENT					
	Predicted Change for					
	Years 0-20 (2025)		Years 20-50 (2055)		Years 50-100 (2105)	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Hunmanby Gap	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 10m by 2025.	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 50m by 2025.	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 125m by 2025.
Reighton Sands	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 5m by 2025.	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 20m by 2025.	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 45m by 2025.
Speeton Sands	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 20m by 2025.	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 100m by 2025.	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 225m by 2025.
Black Cliff, Speeton Sands	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 10m by 2025.	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 50m by 2025.	No defences	There is landslip potential in this area and net cliffline retreat will be approximately 125m by 2025.
Queen Rocks	No defences	Cliffline will retreat at 1.5m/ year. Net cliffline retreat will be approximately 30m by 2025.	No defences	Cliffline will retreat at 1.5m/ year with adjustment for sea level rise. Net cliffline retreat will be approximately 75m by 2055.	No defences	Cliffline erosion continues at 1.5m/year with adjustment for sea level rise. Net cliffline retreat will be approximately 150m by 2105.

Location	SCENARIO REF: BASELINE SCENARIO 2 - WITH PRESENT MANAGEMENT					
	Predicted Change for					
	Years 0-20 (2025)		Years 20-50 (2055)		Years 50-100 (2105)	
	Defences	**Natural coast**	**Defences**	**Natural coast**	**Defences**	**Natural coast**
Dulcey Dock	No defences	Cliffline will retreat at 1m/ year. Net cliffline retreat will be approximately 20m by 2025.	No defences	Cliffline will retreat at 1m/ year with adjustment for sea level rise. Net cliffline retreat will be approximately 50m by 2055.	No defences	Cliffline erosion continues at 1m/year with adjustment for sea level rise. Net cliffline retreat will be approximately 100m by 2105.
Speeton Moor to Flamborough Head	No defences	Cliffline will retreat at 0.1m/ year. Net cliffline retreat will be approximately 2m by 2025.	No defences	Cliffline will retreat at 0.1m/ year with adjustment for sea level rise (x2). Net cliffline retreat will be approximately 10m by 2055.	No defences	Cliffline erosion continues at 0.1m/year with adjustment for sea level rise (x2.5). Net cliffline retreat will be approximately 25m by 2105.