NORTHWEST REGIONAL MONITORING

Wirral Coastal Processes Report, 2017

Prepared for

Wirral Metropolitan Borough Council

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Contents

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Glossary

Beach nourishment	Artificial process of replenishing a beach with material from another source.
Beach profile	A cross-section of a coast, determined by measuring elevation along a transect perpendicular to the shoreline.
Berm	Ridge of sand or gravel deposited by wave action on the shore just above the normal high water mark.
Breaker zone	Area in the sea where the waves break.
Coastal squeeze	The reduction in habitat area which can arise if the natural landward migration of a habitat under sea level rise is prevented by the fixing of the high water mark, e.g. a sea wall.
Downdrift	Direction of alongshore movement of beach materials.
Ebb-tide	The falling tide, part of the tidal cycle between high water and the next low water.
Fetch	Length of water over which a given wind has blown that determines the size of the waves produced.
Flood-tide	Rising tide, part of the tidal cycle between low water and the next high water.
Foreshore	Zone between the high water and low water marks, also known as the intertidal zone.
Geomorphology	The branch of physical geography/geology which deals with the form of the Earth, the general configuration of its surface, the distribution of the land, water, etc.
Groyne	Shore protection structure built perpendicular to the shore; designed to trap sediment.
Gravel	Coarse-grained beach material of 2 to 64mm size. Sediment transport by waves preferentially moves gravel towards the back of the beach, where it may form a steep storm beach.
LiDAR	Light Detection And Ranging. A remote sensing tool that uses an aircraft or helicopter-mounted laser scanner to accurately record ground elevation and produce a digital elevation model.
Mean High Water (MHW)	The average of all high waters observed over a sufficiently long period.
Mean Low Water (MLW)	The average of all low waters observed over a sufficiently long period.
Mean Sea Level (MSL)	Average height of the sea surface over a 19-year period.
Nearshore zone	Area of shore profile that extends from mean low water to the typical offshore limit of wave-induced sediment transport.
Offshore zone	Extends from the low water mark to a water depth of about 15 m and is permanently covered with water.

Shoreline Management Plan (SMP)	A Shoreline Management Plan (SMP) provides a large-scale assessment of the risks associated with erosion and flooding at the coast. It also presents policies to help manage these risks to people and to the developed, historic and natural environment in a sustainable manner. Coastal monitoring is undertaken to support of SMP policies for management units that may be 'hold the line', 'no active intervention' or 'managed realignment'.
Storm surge	A rise in the sea surface on an open coast, resulting from a storm.
Swell	Waves that have travelled out of the area in which they were generated.
Tidal prism	The volume of water within the estuary between the level of high and low tide, typically taken for mean spring tides.
Tide	Periodic rising and falling of large bodies of water resulting from the gravitational attraction of the moon and sun acting on the rotating earth.
Tombolo	A narrow piece of land which connects an island to the mainland.
Topography	Configuration of a surface including its relief and the position of its natural and man-made features.
Transgression	The landward movement of the shoreline in response to a rise in relative sea level.
Updrift	Direction opposite to the predominant movement of longshore transport.
Wave direction	Direction from which a wave approaches.
Wave height	Distance (m) between wave trough and wave peak. The statistical measure of height is known as the Significant Wave Height, which is calculated as the mean of the highest third of waves over a given time period.
Wave refraction	Process by which the direction of approach of a wave is distorted by shallowing water or structures. Depending on the bathymetry or location of structures this can cause wave energy to focussed or dissipated on a specific coastal frontage.

1 Introduction

1.1 Governance

Wirral Metropolitan Borough Council is a Maritime Authority and is a partner in the development and delivery of the Shoreline Management Plan. This report will help inform any decisions they may need to take to manage risk to their communities, which extend from Heswall on the southwestern side of the Wirral peninsula, up around the North Wirral coast, then down to the Seacombe Ferry on the northeast side of the peninsula. The Council will manage risk to their communities through four key activities:

1. Understanding risk to our communities
2. Avoiding increase of risk to our communities
3. Reducing risk to our communities
4. Reducing consequences to our communities

This report supports the delivery of the Strategy and will be linked back to the strategy. The Shoreline Management Plan is reflected in this strategy.

The **Environment Agency** has a role both in terms of tidal flooding and an overview in relation to the delivery of the Shoreline Management Plan. This report will provide evidence to them in relation to the delivery of the Shoreline Management Plan and provide supporting evidence for any management decisions they may take within the area.

The **Shoreline Management Plan** covers the area from the Solway Firth to the Great Orme (North West England and North Wales) and sets out the long-term policy for the management of the coast in relation to tidal flood risk and coastal erosion. It sets the policies out over three future time periods (0-20, 20-50 and 50-100 years) but these are indicative only. In many cases the shoreline management policy is expected to change over time. Analysis of monitoring data presented in this report supports decision-making required to at the end of first policy time-period. The SMP policies are not fixed, and a change over other time periods might be triggered by unforeseen events such as storms, failure of defences or climate change impacts. The polices are summarised Table 1.

Table 1: SMP2 policies

Policy Option	Description
Hold the line (HTL)	Maintaining or improving the current standard of protection. This policy includes those situations where work is carried out in front of the existing defences (such as beach recharge, rebuilding the toe of a structure, building offshore breakwaters) to improve or maintain the standard of protection provided by the existing defence line. It also includes work behind existing defences (such as building secondary flood defences) where this work would form an essential part of maintaining the current coastal defence system.
Advance the Line (ATL)	By building new defences on the seaward side of the original defences. Use of this policy is limited to those policy units where significant land reclamation is considered.
Managed Realignment (MR)	By allowing the shoreline to erode or accrete, with management to control or limit this change (such as controlling erosion or building new defences on the landward side of the original defences).
No active Intervention (NAI)	Where there is no investment in coastal defences or operations and the coast functions naturally .

The Maritime Authorities responsible for the Shoreline Management Plan aim to keep it relevant by regularly reviewing and updating the evidence upon which the policies are based and where necessary reviewing the policies. They will co-ordinate this through the North West and North Wales Coastal Group, the Northern Coastal sub-group and Liverpool Bay Coastal sub-group. This report will contribute to that process.

SMPs divide the UK coastline into a series of **Cells,** bounded by major littoral drift divides (where sediment transport pathways diverge) or sediment sinks (where sediment transport pathways converge). The coast of North Wales and North West England between Great Orme's Head and the Solway Firth is known as Cell 11. Cells are then subdivided into **Sub-Cells,** delineated by smaller, less well-defined littoral drift divides or sediment sinks. Cell 11 is sub-divided into the following **Sub-cells**:

- Sub-cell 11a: Great Orme's Head to Southport Pier (including the Clwyd, Dee and Mersey Estuaries);
- Sub-cell 11b: Southport Pier to Rossall Point (including the Douglas and Ribble Estuaries);
- Sub-cell 11c: Rossall Point to Hodbarrow Point (including the Wyre, Lune, Kent, Leven and Duddon Estuaries);
- Sub-cell 11d: Hodbarrow Point to St Bees Head (including the Ravenglass estuary complex); and,
- Sub-cell 11e: St Bees Head to the Scottish Border (including Morecambe Bay and the Eden estuary).
- The Wirral coastline covered by this report is in sub-cell 11a.

The Sub-cells have then been subdivided further into **Policy Areas**, each of which has a Policy Statement that present the SMP2 policies for that Policy Area. The Wirral coastline falls within these three Policy Areas:

- Policy Area 11a5: Dee Estuary
- Policy Area 11a6: North Wirral
- Policy Area 11a7: Mersey Estuary

Did you know? Definitions of the technical terms mentioned in this report can be found in the Glossary at the front of the

1.2 Purpose of this report

The purpose of this report is to review our policies and actions for coastal defence as set out in the Shoreline Management Plan (SMP) and supporting documents. To do this we will review, and where necessary update, our conceptual understanding of coastal processes against results of monitoring activities undertaken along the coast annually. This report therefore presents an update of CH2M (2016), making use of monitoring data collected during 2017. The conceptual model of how this coast works is presented in Section 3, the monitoring objectives and datasets are presented in Section 4.1 and the implications to the management of each section of coast are discussed in Sections 4.2 to 4.4.

The conceptual model forms a baseline understanding of coastal processes and evolutionary trends for the development of policies. We will also review progress against our action plan and compare this against what is happening on the coast (natural and human activity) to see if it needs updating in relation to the activities set out or their timing.

To achieve this purpose, this report will summarise our understanding of coastal processes, our policies and our action plans based on the following documents:

- North West England and North Wales Shoreline Management Plan (SMP; Halcrow, 2010a)
- Local Flood Risk Management Strategy (Wirral Metropolitan Borough Council, 2016)

- Cell 11 Regional Monitoring Strategy Monitoring Update Report (Halcrow, 2012)
- Cell Eleven Tide and Sediment Study (CETASS; Halcrow, 2010b)
- Estuary Reports for the Dee (Barber, 2006) and the Mersey (Blott et al., 2006)
- Past Coastal Process Reports, with data collected and analysed between the mid-1980s and 2013 (CEUK, 2005, 2006, 2013; CH2M, 2016).

Reference should be made to these documents if more details on coastal processes, shoreline management policies and action plans are required. It is not anticipated that understanding or policies will change significantly year to year, but the action plan is not fixed and will be updated as coastal processes understanding develops or if the coastal land-use changes. The monitoring of natural processes is based upon extensive data collection and analysis which is available in digital form but for the purposes of this report only the summary of the analysis is considered.

2 Key Summary Points from this Report

This section provides a summary of key points from this report that relate to the entire Wirral Metropolitan Borough Council coastline. Further details for each SMP Policy Area can be found in Sections 3 and 4 below.

2.1 Planned actions from the SMP

The action plan was developed as part of the North West England and North Wales SMP2 (Halcrow, 2010a) to address gaps in knowledge about the coast and help put the SMP policies into practice. Several different types of action were recommended, including studies, strategies, schemes, and monitoring. The action plan was updated in April 2017 for the North Wirral and Mersey Estuary Policy Areas, but not for the Dee Estuary so the original 2010 actions remain in place here. The actions related to coastal monitoring along the Wirral Metropolitan Borough Council coast are:

- Undertake estuary, beach and coastal defence asset monitoring in conjunction with Cell 11 Regional Monitoring Strategy to inform strategy and future SMP reviews
- Environmental monitoring of designated sites to provide baseline data for future Habitat Regulations Assessments
- Monitor morphological change in the Dee estuary to inform management at both the policy unit and estuarine level
- In potential areas of managed realignment on the North Wirral, investigate the hazard that the landfill site poses to people and the environment from leaching or the release of contaminated materials. Where necessary, consider protection in situ or excavation and removal of material.

The full list of actions for each Policy Area are detailed in Sections 4.2.2, 4.3.2, and 4.4.2.

2.2 Notable changes identified by recent monitoring

To inform coastal flood and erosion risk management, coastal monitoring is undertaken regularly on the Wirral as part of The North West Strategic Regional Coastal Monitoring Programme, an Environment Agency funded project (further details in Section 4.1). The data collected in 2017 have been compared to the data collected in 2016 (or the most recent surveys before that) to assess any recent changes in coastal processes and response. These changes have also been compared to long term trends evident in the monitoring records dating back to 1985, to determine whether recent changes are unusual, or are within the range of natural variation observed in the longer term. A summary of notable changes identified by the monitoring is provided below, and the full data analysis report is provided in Appendix A.

It was not possible to assess short term coastal change along the West Wirral (Dee Estuary) coast or most of the North Wirral Coast because 2017 beach survey data was not available from any part of Policy Area 11a 5 the western part of Policy Area 11a 6 (Red Rocks to the Leaseowe breakwater).

The comparison of 2016 and 2017 topographic survey data collected between Leaseowe and the Seacombe Ferry (Policy Area 11a7 and the eastern part of Policy Area 11a6) indicated that short term coastal changes here were generally of lower magnitude than those observed during the previous year (2015-2016), remaining well within the range of natural variation observed in the longer term datasets. This reflects the wave and water level conditions experienced along the frontage in 2016-2017, which were calmer than the average conditions observed in the longer term (Appendix A).

The main notable short term change on the East Wirral (Mersey Estuary) coast, was up to 0.5 m beach scour at the base of the seawall opposite Sandon Road / Wilson Road between 2016 and 2017 (between Egremont Groyne and Seacombe Ferry). This is a continuation of longer term erosion trends here, and previous beach profile data has indicated that the upper beach in this area was considerably lower in 2016 than historically recorded since 2009 (CH2M, 2016). Photos at this location taken in September 2017 (Figure 16) show exposure of the sheet piling at the base of the seawall. This may require closer monitoring if beach levels are approaching the toe of the wall, because there could be a risk of undermining of the seawall if erosion were to continue. Further investigation in the form of comparison of beach levels with known wall foundation elevations is recommended.

2.3 Potential influences on SMP2 Policies

Due to the lack of 2017 beach survey data for the whole of Policy Area 11a5 and the most of Policy Area 11a6, it was not possible to assess any new potential influences on SMP policies in these areas in 2017. However, the potential influences identified in the 2016 Coastal Processes Report (CH2M, 2016) may still be relevant in these locations.

The notable recent coastal change on the Wirral's Mersey Estuary coast (identified via analysis of the 2017 3D topographic surveys) was localised beach erosion at the seawall opposite Sandon Road/Wilson Road. This was an isolated issue related to the stability of an individual coastal structure, which does not affect or conflict with the wider SMP2 policies in place for each Policy Unit along this frontage.

Figure 1: Eroding cliffs at Wirral Country Park, Dee Estuary Coast. (Photo Source: CH2M Site Visit 3rd October 2017)

2.4 Uncertainties and issues

The lack of 2017 beach profile/topographic data along the West Wirral (Dee Estuary) coast, and most of the North Wirral coast between Red Rocks to the Leaseowe breakwater, meant it was not possible to assess short term beach change here between 2016 and 2017.

However, the uncertainties and issues identified by the 2016 Wirral Coastal Processes Report (CH2M, 2016) and the SMP2 are likely to still be relevant; these are repeated below:

11a 5 Dee Estuary:

1. Actual rates of cliff erosion along the undefended coast at Thurstaston are unknown. A limited number of beach profile surveys cover the cliff here, and these records only began in 2012. This leads to uncertainty over when properties and paths at the clifftop/cliff base will be at risk from erosion/damage.
2. The future of the Wirral's Dee Estuary shoreline is heavily dependent upon any changes in the tidal channels and banks, but the exact position of the channels is difficult to predict.
3. There is uncertainty whether the ongoing foreshore zone erosion at Caldy is being caused by the restriction of sediment supply by the cliff toe defences, or whether it is more driven by the effect

that West Kirkby Marine Lake has on tidal currents and sediment supply to the frontage downdrift. If the former is dominant, this may have implications for the SMP2 policy which presently permits maintenance of existing localised private defences in Policy Unit 5.6 further south as long as there are no adverse effects on sediment movement and coastal processes.

4. There are uncertainties in land ownership/defence responsibilities between Gayton and Heswall (CEUK, 2013).

North Wirral:

1. It is uncertain whether the recent accretions of sand against the seawall at Hoylake could increase the risk of overtopping during certain wave and water level conditions.
2. There is uncertainty surrounding the rates of accretion on this frontage and whether increasing sea levels may overtake the rate of accretion, hence reducing the area of intertidal zone and resulting in coastal squeeze against the hard defences (Halcrow, 2010a).

Did you know? Global sea level rise is occurring due to climate change, but local impacts are moderated by settlement or uplift of the land surface. Rising sea-level will result in tides reaching a higher level, putting increased pressure on our defences as deeper water allows larger waves to reach the shoreline during storms. Higher water levels may also cause more frequent overtopping of coastal defences, which will lead to coastal flooding unless defence levels are increased. However, the effect is offset if sediment supply is sufficient to maintain healthy beaches. Predictions suggest that the sea level may increase by about a metre by the end of the century.

Mersey Estuary:

1. Beach levels are at historically low elevations at Wilson Road, Riverside School field and Lowry Bank, which may pose a hazard to the stability of the saeawalls. These locations should be assessed by the Council to determine the level of risk and to determine if interventions are required.
2. There is limited data available on residual life of the defences (Halcrow, 2010a).
3. The overall response of the Mersey Estuary to sea level rise is uncertain. The supply of sediment to the estuary is expected to continue and will allow the estuary to accrete vertically in line with sea level rise. However, if sediment supply does **not** keep pace with sea level rise in the long term then erosion of the estuary margins may then occur (Halcrow, 2010a).

2.5 Recommendations for additional activities

Several activities are recommended in addition to the existing monitoring and analysis programme and SMP2 actions to address some of the issues and uncertainties described in Section 2.4.

Recommendations have either been informed by recent monitoring data analysis in 2016 and 2017 (CH2M, 2016) or have been carried forward from past monitoring reports by CEUK (2013) where relevant. These recommendations do not include any coastal defence structure maintenance/repair activities because no asset condition surveys have been undertaken on the Wirral coast recently.

11a 5 Dee Estuary:

1. Between Gayton and Thurstatson, analysis of historical aerial imagery and LiDAR data could be undertaken to understand cliff recession rates and determine when there may be a risk to clifftop properties and access paths, and Shore Cottage at the cliff base (CH2M, 2016).

2. Use remote sensing data (e.g. LiDAR, aerial photography) to monitor the migration of tidal channels at Thurstaston, as the landward movement of channels could increase the erosion along the toe of the cliffs here, which could have implications for properties and paths at the clifftop/cliff base (CEUK, 2013).
3. Determine the role that cliff toe defences play in foreshore erosion at Caldy via further investigation into defence construction and erosion timeframes and possibly sediment sample analysis (CH2M, 2016).
4. Confirm land ownership/defence responsibilities between Gayton and Heswall (CEUK, 2013).

11a 6 North Wirral:

1. Investigate whether the high steep next to the wall at Hoylake increases the risk of overtopping of the seawall in certain wave and water level conditions (CH2M, 2016).
2. Undertake analysis of accretion rates and compare with sea level rise predictions to inform the required level of investment required to defend the frontage in the future (CH2M, 2016).
3. Monitor the accumulation of mud on the sandy foreshore near the RNLI station and assess whether it poses a public safety hazard (CEUK, 2013).
4. Monitor the algal growth on lower sections of the Wallasey Embankment, particularly between Bennets Lane and the Lingham Lane access, and assess whether it poses a public safety hazard (CEUK, 2013).

11a 7 Mersey Estuary:

1. Opposite Wilson Road and between Riverside School field and Lowry Bank, compare recent beach levels at the seawall with known wall foundation elevations to assess whether low beach levels pose a hazard to the stability of the structure.
2. Monitor the algal growth on stepped beach access points and assess whether it poses a public safety hazard (CEUK, 2013).

Did you know? Coastal sediments vary in size, and are described as one of the following grain size classes (from small to large): clay, silt, sand, gravel, cobbles and boulders. Clays and silts are collectively referred to as 'mud'.

3 Conceptual Model

3.1 How this coast works

3.1.1 Coastal geomorphology

The Wirral is a rectangular peninsula in Liverpool Bay which is bounded to the west by the River Dee, to the north by the Irish Sea, and to the east by the River Mersey.

The coastline on the southwestern side of the Wirral peninsula is typically dominated by saltmarsh in the inner Dee Estuary., backed by a narrow sand upper beach, with low dunes formed in places. Moving northwards along the western shoreline to the middle and outer reaches of the Dee Estuary, the coastline becomes more dominated by sand, gravel and cobbles which are backed by cliffs up to 18 m high (Halcrow, 2010a). These cliffs are formed of glacial sediment, which comprises sediment of mixed sizes deposited beneath a glacier or by glacial meltwater channels around 15,000 to 20,000 years ago. Between West Kirkby and Hilbre Point there are also backshore dunes fronted by a wide intertidal sandflat. The underlying sandstone bedrock is exposed at Hilbre Point and Red Rocks, to the east of which the coastline changes orientation onto the North Wirral coastline.

Figure 2: Undefended cliffs at Wirral Country Park (Photo Source: CH2M Site Visit 3rd October 2017)

The North Wirral coastline is characterised by wide sandy beaches and large intertidal sandbanks, the largest of which is called East Hoyle Bank which extends along the eastern end of the frontage from the mouth of the Dee Estuary around to Leasowe Lighthouse (Halcrow, 2010a). At low tide, the Meols Channel flows at across the western half of the frontage and drains out to sea through East Hoyle Bank and North Bank. At the far eastern end of the North Wirral frontage, the coastline changes orientation again at Fort Perch, around to the eastern side of the Wirral Peninsula which forms the western bank of the Mersey Estuary.

The eastern side of the Wirral peninsula is characterised by sandy beaches and mixed sand/gravel beaches in the outer Mersey Estuary, interspersed with rocky outcrops. The beaches tend to get narrower moving southwards down the coastline from towards Fort Perch to Seacombe Ferry.

3.1.2 Wind, waves, tides and surges

3.1.2.1 Wind

The strength and direction of the wind affects the local generation of waves and can sometimes affect water levels and currents near the coastline. The wind can also drive transport of sand and fine sediment (known as 'aeolian sediment transport').

The prevailing wind direction across the eastern Irish Sea and north-west English coast is southwesterly (Pye and Blott, 2009). During the summer months, the wind is more evenly distributed throughout the compass but the dominant winter storms blow in from the Atlantic predominantly from the southwest (Halcrow, 2012).

It has been reported that southwesterly and northwesterly winds act to funnel water into the Mersey Estuary (EA, 2008).

3.1.2.2 Waves

Liverpool Bay is a semi-enclosed sea which is sheltered from ocean wave conditions by the surrounding land, so wave action is limited by the relatively small fetch lengths (the length of water over which the wind has blown that determines the size of the waves produced).

Waves in Liverpool Bay are measured by Liverpool Wavenet Buoy, located off Formby Point around 13 km north of the Wirral (see Appendix A). Wave measurements collected here over the past 15 years, displayed as a wave rose below, suggest that larger waves up to around 4 m in height mainly approach from the west, with some smaller waves up to around 2.5 m in height approaching less frequently from the northwest. There are sometimes smaller waves up to 1.5 m in height that come from the southeast, generated across the fetch of the River Mersey Estuary.

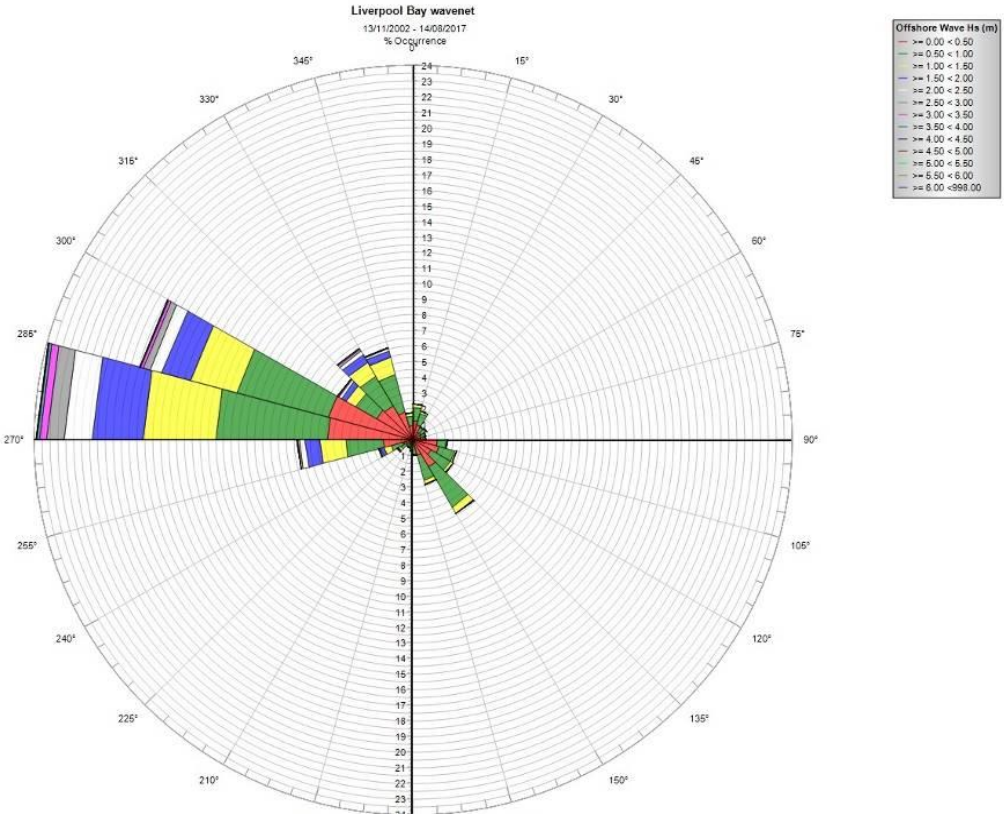

Figure 3 Wave rose for Liverpool Bay Wavenet wave data (13/11/2002 to 14/08/2017)

Various sandbanks and spits at the mouth of the Dee Estuary shelter the western Wirral coastline from wave action, and the rocky outcrop at Hilbre Island also acts as a natural breakwater protecting the northwestern Wirral coastline (Halcrow, 2012). Wave energy to the North Wirral shoreline is also considerably reduced by the breaking of waves on East Hoyle Bank in the intertidal zone and Great Burbo bank further offshore (Halcrow, 2012). The shallow seabed and narrow mouth of the Mersey Estuary limits wave energy reaching the eastern Wirral shoreline (Gifford and Partners, 2004), and coastal processes here tend to be dominated by the strong tidal currents in the Estuary.

3.1.2.3 Tides

The tides in Liverpool Bay are semi-diurnal which means there are usually two high tides and two low tides each day. The tidal range around the Wirral coastline is large, and is classed as 'macro-tidal' because it is greater than 4 m.

At the mouth of the Dee Estuary at Hilbre Island (northwest Wirral), the mean spring and neap tidal ranges are 7.6 m and 4.1 m respectively. The incoming tide (known as the flood tide) in the Dee estuary is of shorter duration than the outgoing tide (known as the ebb tide) and the average flood tidal current velocities are higher than the average ebb velocities (Pye, 1996). The highest predicted astronomical tides (i.e. not including changes in water level generated by atmospheric pressure or wind) exceed 4.5 m above Ordnance Datum Newlyn and occur around the time of the spring and autumn equinoxes.

In the Mersey Estuary, the spring and neap tidal ranges are ~4 m and ~ 10 m respectively (eastern Wirral), although the shape of the estuary between 'the Narrows' and Eastham acts to increase the tidal range along this stretch (Gifford and Partners, 2004), meaning that the largest spring tidal range is 10.5 m and the smallest neap tidal range is 3.5 m at Gladstone Dock (EA, 2008). The narrowing of the estuary mouth here also acts to increase maximum spring tidal current velocities from 1 m/s (flood tide) at the entrance to Queen's Channel, to 2.2 m/s (ebb and flood tides) in the Narrows (Blott et al., 2006).

Did you know? Tides are the regular rise and fall of sea level caused by interaction of the Sun and Moon's gravity and rotation of the Earth on the seas. The timing and elevation of tides around the world is affected by landmasses. The typical pattern is for high and low tides to occur every 6 hours or so. The tidal range between high and low tide levels is larger during 'spring' tides when the Sun, Moon and Earth are in a line, and smaller during 'neap' tides when the sun and moon are at right angles to each other. The average tidal range in Liverpool Bay is very large, over 4m, and is classed as 'macro-tidal'.

The Mersey Estuary, like the Dee, has a flood tide of slightly shorter duration than the ebb tide (ABPmer, 2005). The estuary is classified as being flood dominant, although there is evidence that this dominance is reducing over time (Gifford and Partners, 2004).

3.1.2.4 Storm surges

A storm surge is a rise in the sea surface above the predicted tidal levels, and is caused by low atmospheric pressures and high winds during a storm. Liverpool Bay experiences some of the highest surge conditions in the UK (Halcrow, 2002). The shape of the Irish Sea means that storm surges are often of short duration but intense, with the highest current velocities concentrating in Liverpool Bay. During the winter months, storm surges can raise predicted high water levels by up to 2 m and the major storm surges in recent decades occurred in 1976, 1977, 1983, 1990 and 1997 (Pye 1996).

3.1.3 Sediment sources, transport and sinks

On a regional scale, the main source of sediment to Liverpool Bay is the onshore movement of marine clay, silts and sands from the Irish Sea, and there is evidence to suggest that Liverpool Bay is a regional sand sink. Inputs of river sediments into Liverpool Bay from the Dee and Mersey are very small compared to offshore marine sources. The net longshore drift is generally west to east within the Bay (Halcrow, 2012).

On a local scale within the Dee Estuary, the main sediment sources are sediments transported eastwards alongshore from the North Wales coast, as well as offshore sediments from the Irish Sea. Erosion of the undefended cliffs on the western Wirral coastline between Heswall and Thurstaston Causeway also provides minor sources of sediment, but this cliff sediment is not likely to be transported very far due to low longshore transport rates in the estuary, so it only inputs sediment to beaches directly below the cliffs (Halcrow, 2002). Across the mouth of the Dee Estuary there is eastwards wave-driven sand transport via West Hoyle Bank and East Hoyle Spit (Halcrow, 2012). Along the northwest Wirral at West Kirkby, the wind is also a major mode of sand transport, shaping sand dunes and blowing sand into gardens or promenades where it can be lost from the system. Sediment transport within the Dee Estuary is predominantly driven by tidal currents, with the net direction being upstream (southwestwards; Pye and Blott, 2009), and the Estuary acts as a large sink for muds and silts (Halcrow, 2012).

On a local scale along the North Wirral frontage, the major source of sediment is longshore drift from the North Wales coastline and the net longshore sediment transport direction is from west to east (Halcrow, 2012). Longshore sediment transport along the North Wirral coastline occurs primarily on the lower beach as contemporary coastal defence measures have reduced transport along the upper beach.

Did you know? Different sizes of sediment are transported by different coastal processes. Cobbles and boulders are only moved when the largest waves break on beaches. Coarse sand and gravel move along a beach by longshore drift. Fine sand, silt and clay may be transported along the seabed or in estuaries by weaker tidal or wave-generated currents. Deposits of coarse material seen in deep water are immobile and likely to be relicts from times of lower sea-level.

The volume of longshore sediment transport is reduced by the presence of East Hoyle Bank, and the bank acts as a major local sediment sink/temporary store (Halcrow, 2012). However, strong tidal currents swirling around Hilbre Point transport some sediment from East Hoyle Bank to the upper beaches at Hoylake and West Kirby (Metropolitan Borough of Wirral, 2000). Ultimately, the sediment moving along the North Wirral shoreline is transported into the Mersey Estuary, which is a sediment sink (Halcrow, 2012). The wind is also a key driver of sand transport on the North Wirral frontage, and there are frequent accumulations of wind-blown sand on promenades and roads (Thomas and Wardle, 2003).

On a local scale in the Mersey Estuary, a small contemporary source of sediment is the erosion of the Ince Bank and soft cliffs at the Speke Garston Coastal Reserve on the western bank of the Mersey, (not part of the Wirral Borough) (HR Wallingford, 1999; Pye and Blott, 2004). However, the main sediment inputs to the Mersey are offshore sources and the North Wirral Frontage, with only very small river sediment inputs because the Manchester Ship Canal traps most sediment further upstream (Halcrow, 2012). Within the estuary, the dominant sediment transport direction is generally upstream, likely driven by strong flood-dominant tidal currents. However locally-generated waves from the west and southwest within the estuary may also influence sediment transport in intertidal areas (Halcrow, 2012). Eastwards longshore drift does not continue across the mouth of the Mersey Estuary

due to the complicated interaction of waves and strong tidal currents. Instead, the Mersey Estuary acts a sink for material lost from the North Wirral frontage, with sediment likely moved into the Crosby channel and either transported into the inner estuary, or dredged and deposited offshore within Liverpool Bay (Halcrow, 2012).

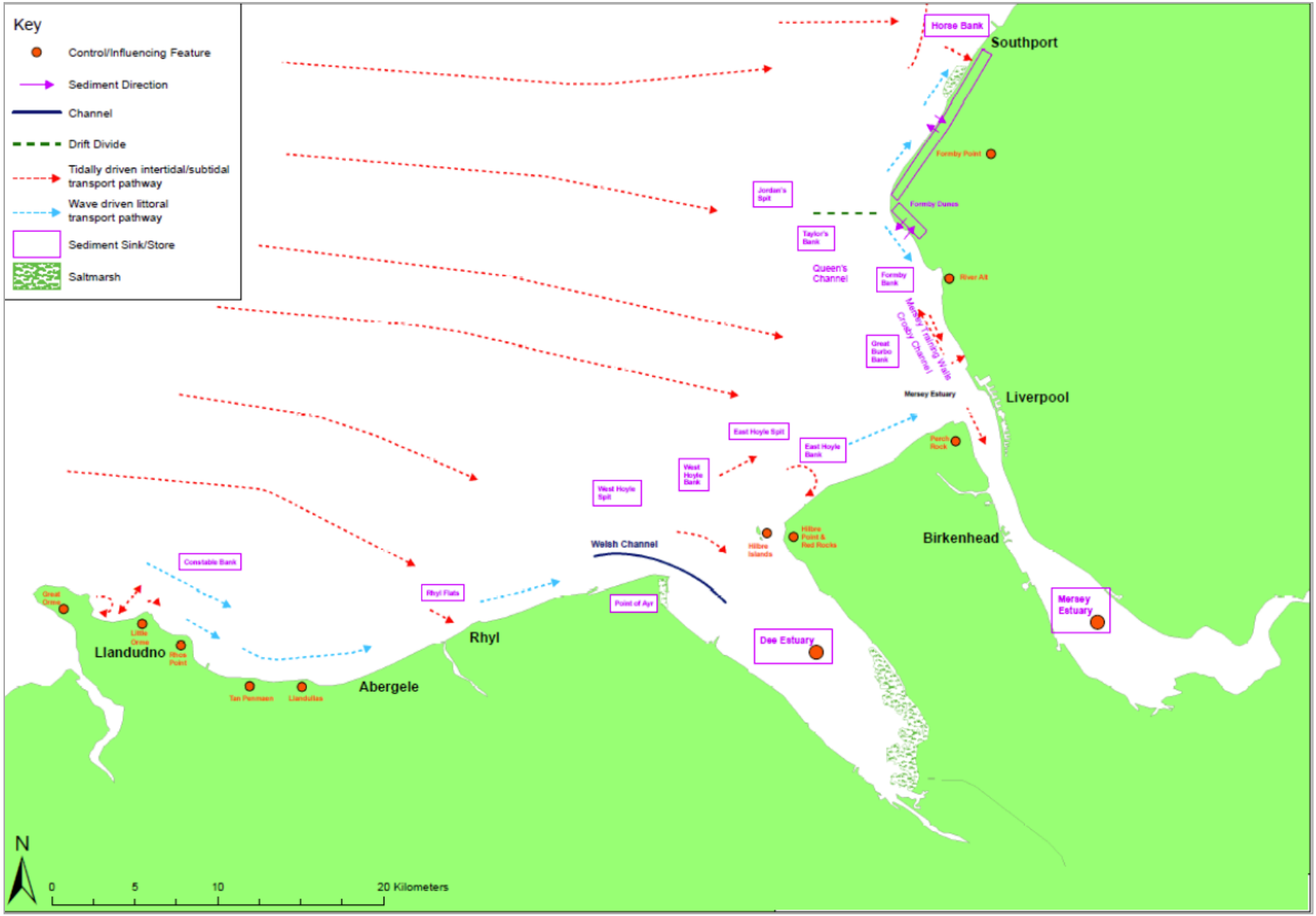

Figure 4: Conceptual model of the coastal processes in the Liverpool Bay area

3.2 What we expect to see happen in any one year

West Wirral (Dee Estuary) — the saltmarsh between Gayton and Heswall tends to either be stable or accreting slowly each year. The sand/gravel upper beach and lower mudflats further north between Heswall and Thurstaston tend to fluctuate slightly more, increasing or decreasing in elevation by around 20 cm in a year. The undefended cliffs between Gayton and Thurstaston are eroding in response to coastal processes (e.g. waves and tidal currents attacking the cliff base during storms) and/or geotechnical processes (rainwater and groundwater reducing the stability of the upper cliff.) This cliff erosion is likely to be episodic (happening in bursts rather than at a steady rate), so some years the cliffs may not change considerably whereas other years there may be large landslides or slumps. For example, in the 1 year between 2015 and 2016 there was up to 2 m movement in the cliff toe position as it either slumped seawards or receded landwards.

We can expect less cliff erosion north of Thurstatson as there are coastal defences protecting the base of these cliffs from waves and tidal currents; but some erosion of the upper cliff may still occur via rainwater/groundwater processes. In the ~2 km stretch of coast south of West Kirkby Marine Lake, the sand/gravel upper beach and lower mudflats are lowering slowly, at a rate of around 5-10 cm per year. In contrast, the sandy beach to the north between the Marine Lake and Red Rocks is accreting quickly and saltmarsh may continue growing on the foreshore each year (depending on the extent of management actions to remove this vegetation to retain this as a sandy beach for amenity purposes). We can expect the sand dunes behind the beach to remain relatively stable as they seem to be well protected from storm erosion by the high intertidal zone, but there may be localised erosion caused by people walking through the dunes, as this acts to destabilise the dune vegetation and makes the dunes more susceptible to wind erosion.

Figure 5 Cliff toe defences north of Thurstaston (Photo Source: CH2M Site Visit 3rd October 2017)

North Wirral — we can expect beach levels along most of this coast to become higher, with a general trend of up to ~ 20 cm a year in some locations. The most noticeable changes tend to occur close to the seawall/embankment, particularly at Hoylake, where the beach level can vary by up to ~1.5 m in any one year due to scour by high energy waves or wind and subsequent infilling of the scour trough during calmer conditions. Between Meols and Leasowe, rapid accretion is occurring on East Hoyle Bank (a large intertidal sand bank) which is growing eastwards, perhaps at an accelerating rate according to monitoring in recent years. However, the growth of the bank is also causing localised erosion further landward southwest of Dove Point as it pushes the Meols channel landwards, causing the upper beach to lose volume as it is squeezed against the Wallasey Embankment. East of Leasowe, we can expect most change in beach levels to occur near to the groyne and breakwater structures,

Did you know? Longshore drift describes the movement of sand and gravel along a beach by the action of waves. When waves approach the shore at an angle, sediment is driven up the beach at the same angle. The sediment is then drawn back down the beach at right angles to the shoreline. Over time, this 'zig-zag' action moves sediment alongshore until it is interrupted by obstructions like groynes or headlands.

with lowering of the beach on the east side of structures and vertical accretion on their west side in any one year. However, this pattern may reverse temporarily if there are sustained winds blowing from the east which cause a longshore drift reversal.

East Wirral (Mersey Estuary) — the longer term trend over the past ~30 years has been steady beach accretion along this frontage, although more recent monitoring suggests that this trend may be slowing, with more beach level fluctuations and areas of erosion. Nowadays, we can expect most change in beach levels to occur near to the groynes, with typically lowering of the beach on the south side of structures and vertical accretion on their north side each year.

Figure 6: The intertidal area along the Mersey Estuary coast, looking landwards towards Fort Perch (Photo source: CH2M site visit, 1st September 2017)

Localised change in beach levels may also occur away from the structures via the movement of ridges and runnels (elongated beach undulations formed due to the interaction of tides, currents and beach topography).

To the south between Egremont Groyne and Seacombe Ferry the beach levels tend to generally be more stable than further north, apart from ongoing lowering of upper beach levels at isolated locations opposite Wilson Road and between Riverside School and Lowry Bank, where the beach next to the seawall is lowering by ~10 cm each year on average.

4 Coastal Monitoring and Implications to Coastal Management

4.1 Regional monitoring programme

The North West Strategic Regional Coastal Monitoring Programme is an Environment Agency funded project to collect coastal process and response data to inform coastal flood and erosion risk management. Datasets have been collected to establish baselines against which change can be measured by repeated surveys. Data collected through the programme is available through an Open Government Licence; for further information please visit www.channelcoast.org or contact the project team at coastaldefence@sefton.gov.uk.

4.1.1 Datasets

Along the Wirral Metropolitan Borough Council frontage, the following datasets are collected:

Beach profiles: These are cross-sections of the coast, determined by taking measurements of the ground surface elevation along a transect that runs perpendicular to the shoreline. Measurements usually extend from the backshore out to the level of Mean Low Water Springs (if conditions allow). The frequency of beach profile measurements collected along the Wirral coastline depends on the perceived level of risk: the higher the risk the more frequent the beach profile surveys, and some profiles are surveyed up to twice a year. The start date of monitoring for these profile lines is variable, with the earliest surveys dating to 1985. The locations of the profile lines are shown in Figure 7. **No beach profile data was available from 2017.**

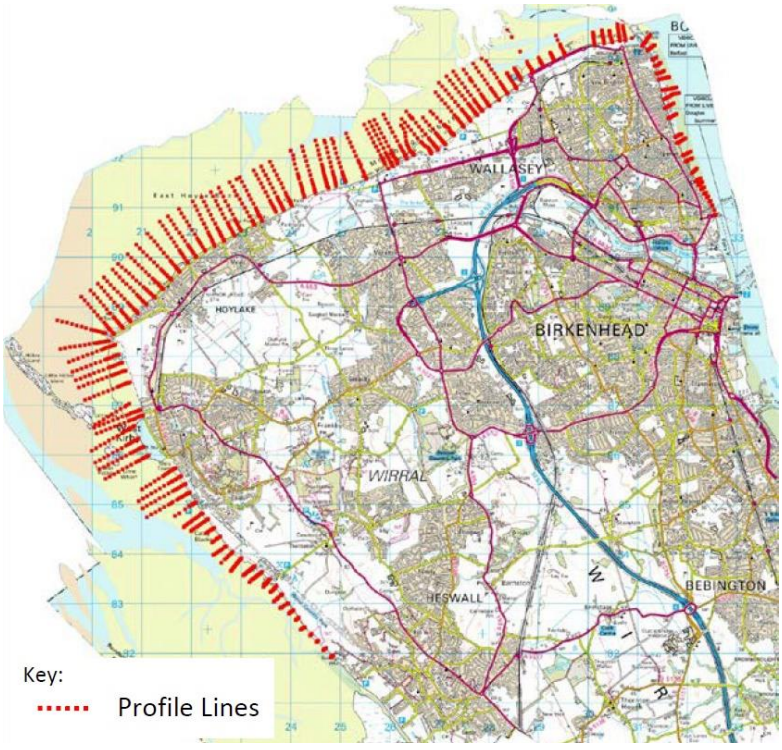

Figure 7: The location of the 133 beach profile lines along the Wirral coast. Image source: Sefton Council (2016) Background mapping provided by Ordnance Survey © Crown Copyright and database rights 2014 Ordnance Survey 100018192.

Three-dimensional (3D) topographic surveys: These surveys record spot elevations across the beach, starting on a parallel line close to the land and then continuing along parallel lines spaced every 20-50 m, out to the level of Mean Low Water Springs (where possible). 3D topographic surveys have been undertaken in three areas in 2012, 2015, 2016, and 2017:

- In the Western part of the Wallasey Embankment to Harrison Drive subdivision
- In the Western part of the Kings Parade, Wallasey (Coast Guard to Fort Perch) subdivision
- Along the Mersey Estuary frontage from Fort Perch to Seacombe Ferry

The extent of the topographic surveys is shown in in Figure 8.

Figure 8: The locations of 3D topographic surveys (black areas) undertaken on the Wirral coast. Image source: Sefton Council (2016) with background mapping provided by Ordnance Survey © Crown Copyright and database rights 2014 Ordnance Survey 100018192.

Hydrographic extensions: These are continuations of the beach profile lines out into the sea via bathymetric survey to establish the level of the sea bed below the low water mark. Bathymetric surveys were last carried out off the north Wirral coast in 2010 and 2015 (Sefton Council, 2016).

Fixed-point photography: Photographs of the foreshore and structures were captured in September/October 2017 at a series of fixed waypoints at strategic locations around the Wirral coastline (maps in Appendix A). Photographs were captured with a digital SLR camera with a minimum of 8 megapixels. These photos are used alongside analysis of the other dataset to validate the changes observed, and support understanding of local costal processes.

Laser scanning: A laser scan survey was carried out of the cliffs at Caldy in 2013 (Sefton Council, 2016). Future laser scans can be compared to this initial scan to assess any cliff erosion occurring at this location.

LiDAR data: Light Detection and Ranging (LiDAR) surveys provide an alternative method of recording the elevations of the beach and land behind from an aeroplane. LiDAR surveys have been undertaken over various parts of the Wirral since 2001, with the most recent survey in June 2013 (Sefton Council, 2016).

Aerial photography: Aerial photography captures images of the land from the air and can be collected vertically (map view) or at an angle (oblique). Oblique aerial photography was captured of the Wirral coastline in 2008, 2009, 2012, 2013 and September 2015. Vertical aerial photography was captured of the Wirral coastline in 2010 and 2012/13 (Sefton Council 2016).

Wave and current measurements: Instruments to measure waves and currents were deployed off Formby Point in 2012 (after a 1 year trial in 2010) in the Mersey from 2014-2016 (Sefton Council, 2016).

Sediment Analysis: The Autumn 2014 survey included sediment sampling for the entire North West Coast. The Regional Sediment Analysis Intertidal Report has been completed (Sefton 2016).

Ecological Mapping: Ecological mapping surveys were undertaken in coastal areas and estuaries around the Wirral between September 2014 and January 2015. This data set is now available to view and download from the Channel Coast Observatories Web portal (Sefton Council, 2016).

4.1.1.1 Limitations of the survey data

While uncertainty due to survey accuracy or systematic error is likely to be present in all datasets, the work is carefully managed to ensure data are as accurate as possible and results are not misleading. Error may arise from the limits of precision of survey techniques used, from low accuracy measurements being taken or from systematic failings of equipment.

For 2D beach profiles and 3D topographic surveys, all incoming data are checked allowing systematic errors to be identified, and removed from plots and subsequent analysis. The accuracy of these surveys is not known, but it is likely that all measurements are correct to ±0.1m. Therefore, changes less than ±0.1m are ignored and greyed out in the diagrams showing topographic change.

While considering the uncertainty in comparing and analysing change between monitoring datasets, it is also relevant to caution against drawing conclusions about short or longer term trends. Clearly the longer the dataset the more confidence that can be given to likely ranges of beach changes and trends in change. Potential for seasonal, annual and longer term cycles need to be considered. Studies of long term monitoring data sets for other coastal and estuarial data have established that there are long period cyclical trends related to the 18.6 years lunar nodal cycle which need to be accounted for. Simply put this means that although the Cell 11 monitoring programme now has data in some locations up to 11 years, another 8 to 10 years of consistent data is needed before confidence can be given in trends from the analysis. In the context of this report “Longer Term Trends” are mentioned in each section and it should be noted that this is based on simple visual interpretation of the available data since the current programme began, and is generally based on only 5 to 10 years of data.

4.2 11a 5: Dee Estuary (part)

4.2.1 Site overview

The part of the Wirral Metropolitan Borough Council coastline that coincides with part of the 11a5 ‘Dee Estuary’ Policy Area extends along the western side of the Wirral between Gayton and Hilbre Point, and is orientated in an approximately northwest-southeast direction.

Most of this coastline is defended by various types of coastal structure, with the main exception being the undefended cliffs between Heswall and

Did you know? Saltmarsh usually forms in areas of low energy, such as estuaries or sheltered coasts. Mud accumulates between low and high tides levels and vegetation grows near the high water mark. Once established, saltmarsh plants trap more mud leading a gradual increase in the elevation of the marsh of up to 3 cm per year. Saltmarsh reduces wave energy and is a natural coastal defence.

the Thurstaston Causeway.

At the southeastern end of the coast between Gayton and Heswall, the shoreline is defended by a series of privately owned seawalls, which were built in the late 19th to early 20th century and only have a function during high wave and/or water level events. Saltmarsh growth along this area has occurred since the 1940s, encouraged by the introduction of *Spartina* grass in the 1920s. Prior to this, the cliffs along this southeastern part of the frontage were actively eroding, providing sand to the foreshore and likely creating a more extensive sand beach then than exists today (Halcrow, 2010a).

Further north, the stretch of cliffs between Heswall and Thurstaston Causeway remains undefended; whereas various modifications have been made to try and slow the rate of cliff erosion to the north of Thurstatson Causeway, including cliff drainage, re-profiling and cliff toe protection. Since the 1980s, a rock toe revetment has protected most of the frontage between Thurstaston and West Kirby, with a short section of sloping concrete revetment at the northern end (Halcrow, 2010a).

At West Kirkby, a Marine Lake was constructed in 1899 and extended seaward in 1986. A seawall extends behind the Marine Lake and there is an embankment with sheet piles and rock armour facing on the seaward side of the lake. To the north of the lake, there are various private defences comprising vertical or sloping concrete walls and post/plank fences. A natural dune belt with localised rock armour toe then extends in front of the Royal Liverpool Golf Links up to Red Rocks, where private sea walls are present (Halcrow, 2010a).

4.2.2 Current (SMP2) policy and approach (adopted 2010)

The SMP2 policy for each timeframe within each Policy Unit (Halcrow, 2010a) is provided in Table 2 below.

Table 2: SMP2 Policy and approach for the Wirral Metropolitan Borough Council's western coastline (Halcrow, 2010a)

Location (SMP2 Policy Unit)	2010-2030	2030-2060	2060-2110
5.5 Burston Point to Thurstaston Cliffs	***No Active Intervention*** Allow natural erosion or accretion where undefended, however, allow for continued limited intervention to maintain existing defences where economically justified and environmentally acceptable. Reassess justification for intervention if erosion becomes re-established.	***No Active Intervention*** Allow natural erosion or accretion where undefended, however, allow for continued limited intervention to maintain existing defences where economically justified and environmentally acceptable. Reassess justification for intervention if erosion becomes re-established.	***No Active Intervention*** Allow natural erosion or accretion where undefended, however, allow for continued limited intervention to maintain existing defences where economically justified and environmentally acceptable. Reassess justification for intervention if erosion becomes re-established.
5.6 Thurstaston Cliffs	***No Active Intervention*** Allow natural erosion of cliffs, however, permit maintenance of existing localised private defences as long as no adverse affects on sediment movement, coastal processes, the SSSI.	***No Active Intervention*** Allow natural erosion of cliffs, however, permit maintenance of existing localised private defences as long as no adverse affects on sediment movement, coastal processes, the SSSI.	***No Active Intervention*** Allow natural erosion of cliffs, however, permit maintenance of existing localised private defences as long as no adverse affects on sediment movement, coastal processes, the SSSI.
5.7 Thurstaton Slipway to Croft Drive, Caldy	***Hold the Line*** *(private funding agreement)* – Manage erosion risk by maintaining existing defences to an adequate standard.	***Hold the Line*** *(private funding agreement)* – Manage erosion risk by maintaining existing defences to an adequate standard.	***Hold the Line*** *(private funding agreement)* – Manage erosion risk by maintaining existing defences to an adequate standard.
5.8 Croft	***Hold the Line***	***Hold the Line***	***Hold the Line –***

Drive Caldy to West Kirby Marine Lake	Manage erosion risk by maintaining existing defences to an adequate standard.	Manage erosion risk by maintaining existing defences to an adequate standard. Work towards private / public funding agreement with frontages to allow for private maintenance of defences.	*(private / public funding agreement)* Manage erosion risk by maintaining existing defences to an adequate standard.
5.9 West Kirby Marine Lake to Royal Liverpool Golf Club	***Hold the Line*** Manage flood and erosion risk by beach management and maintaining existing defences to an adequate standard.	***Hold the Line*** Manage flood and erosion risk by beach management and maintaining existing defences to an adequate standard.	***Hold the Line*** Manage flood and erosion risk by beach management and maintaining existing defences to an adequate standard.
5.10 Royal Liverpool Golf Club to Hilbre Point (Stanley Road)	***No Active Intervention –*** Area is presently accreting and defences are covered with dunes. Allow natural processes to continue with monitoring and maintenance work to encourage dune growth. Reassess justification for intervention if erosion becomes re-established.	***No Active Intervention –*** Area is presently accreting and defences are covered with dunes. Allow natural processes to continue with monitoring and maintenance work to encourage dune growth. Reassess justification for intervention if erosion becomes re-established.	***No Active Intervention –*** Area is presently accreting and defences are covered with dunes. Allow natural processes to continue with monitoring and maintenance work to encourage dune growth. Reassess justification for intervention if erosion becomes re-established.
5.11 Hilbre Island	***Hold the Line –*** Through limited intervention to maintain the integrity of the island.	***Hold the Line –*** Through limited intervention to maintain the integrity of the island.	***Hold the Line –*** Through limited intervention to maintain the integrity of the island.

The **key assumptions** made during the development of these policies were:

Did you know? Saltmarsh can adapt to rising sea-levels to provide a natural defence against climate change. If the supply of mud is sufficient, saltmarsh accretion can keep in step with rising sea-levels, and marsh may increase in height or extend landwards or seawards. 'Coastal squeeze' describes the loss of saltmarsh that may occur where fixed coastal defence structures stop the natural landward movement of saltmarsh. This may ultimately lead to increased flood and erosion risks.

- Changes to the low water channels have a major control on the estuary processes and defence management in the estuary. It has been assumed that the position of these channels will continue to influence patterns of accretion and erosion in the future.
- The exact position of the channels is difficult to predict but can be influenced by training works within the estuary. The future maintenance strategies for these training works are therefore critical in determining the overall response of the estuary.
- Predicted changes in rainfall patterns with future climate change may increase river flows which may in turn affect river channel meandering and siltation rates.
- The supply of sediment to the estuary will continue and will allow the estuary to accrete vertically in line with sea level rise. This assumption is consistent with the past history of the estuary which has shown accretion. In the long term there is uncertainty over the balance between sediment supply and sea level rise. It has been assumed that supply will continue to allow vertical accretion within the estuary although the horizontal expansion of marsh habitats may have decreased or even ceased. If sediment supply were not to keep pace with sea level rise in the long term then roll back of the estuary could occur, which would be expected to lead to coastal squeeze in locations where the high water mark abuts the defences.
- Actual erosion rates for eroding estuary cliffs are uncertain; therefore rates stated in the accompanying map are estimates.

- Management of this section will be closely linked with the management of the adjacent Welsh open coast frontage due to shared flood risk issues.
- The long term flood risk management policy for this estuary, as with others in the North West may change if proposals for tidal power barrages are progressed.
- There are a number of uncertainties associated with the economic benefits for tangible and intangible assets that could influence the economic viability of some policies and the timing of a move towards no active intervention along the east shore of the Dee Estuary. These will be addressed when developing a flood and erosion risk management strategy and supporting investigations as recommended in the Action Plan.
- Works to maintain defences, both private and publicly funded, would be subject to obtaining necessary consents.
- The SMP2 policies will be subject to review if sea level rise predictions are changed.

The **issues** related to coastal flood and erosion risk management identified in SMP2 for this frontage were:

- Heswall contains significant numbers of residential properties together with associated infrastructure and facilities. Although these settlements are generally set on higher ground, there are significant numbers of properties within the coastal / tidal flood risk zone. There are also key community infrastructure facilities such as Neston and Heswall Sewage Treatments Works and Neston School.
- Several small coastal settlements and isolated properties are located along the banks of the Dee Estuary and therefore may be prone to coastal erosion and flooding.
- West Kirby contains a significant number of residential and commercial properties as well as recreational / amenity / tourist facilities. There are flooding and wind-blown sand issues along this frontage. Tidal flooding of the highway and gardens along South Parade occurs approximately 4 times/year.
- West Kirby Railway Station and the Wirral Railway Line are located within 500 m of the coast. Significant flooding of this rail infrastructure would compromise their safe operation.
- Issues exist around the management of the foreshore as an amenity area at West Kirby (it was previously granted ENCAMS Rural Beach Status).
- Within the Hilbre Island archipelago concerns exist around the erosion of Little Eye and the loss of heritage and amenity features. Elsewhere on Middle Eye and Hilbre similar concerns relate to the erosion of the sandstone cliffs and the impact this erosion has on amenity use (loss of asset and safety issues) and also loss of heritage, in particular the Listed Lifeboat Station and slipway on Hilbre Island. It is noted however that the eroding nature of the island is a key feature within the SSSI and SAC. With regard to coastal processes Hilbre Island acts as an anchor for East Hoyle Bank which affords protection to much of North Wirral. The position of the channel to the east of West Hoyle is also determined by the presence of the archipelago.
- Any changes to coastal evolution could affect the Dee Estuary Ramsar, SAC SSSI site. Currently, there are issues with regards to coastal defence works and their impact on coastal processes. The SAC includes reference to Annex 1 habitat of drift line vegetation and sand dunes which are reliant upon continuation of natural sediment transport processes.
- Coastal erosion could reduce the net area of the Red Rocks SSSI and the Dee Cliffs SSSI.
- Coastal processes are the key to the conservation of geological SSSIs and therefore a “threat” to the Dee Cliffs SSSI (geological) is the construction of coastal defences.

4.2.3 Summary of behaviour

Short term and long term coastal behaviour is assessed via the analysis of coastal monitoring data collected in this Policy Area (more details on the datasets are in Section 4.1).

It was not possible to assess short term coastal change between 2016 and 2017 because there were no beach profile or other topographic survey data collected in this Policy Area in 2017. The only data collected in this Policy Area in 2017 were fixed-point photographs of the foreshore (usually used to support the analysis of topographic data), captured in September/October 2017 and presented in Appendix A.

With respect to longer term behaviour, most of the Wirral's Dee Estuary coast has shown relatively modest change since monitoring began in the 1980s, with the most notable changes being erosion of the undefended cliffs south of Thurstaston and considerable accretion of the sandy beach between West Kirkby Marine Lake and Red Rocks.

In the southeast of the frontage, between Gayton and Heswall (Figure 9), there has been steady accretion of the saltmarsh over the past ~30 years. This accretion may be continuation of the effects of extensive land reclamation in the upper Dee Estuary over the past three centuries, which has reduced the estuarine area by 27%, hence reducing the tidal prism (the volume of water within the estuary between the level of high and low tide), and causing sediment accretion within the estuary (Halcrow, 2012).

Figure 9: Saltmarsh at Riverbank Road, between Gayton and Heswall (Photo source: CH2M Site Visit on 3rd October 2017)

The undefended cliffs between Gayton and Thurstaston (Figure 10) have been eroding for the last 80 years (Halcrow, 2002) and recent beach profile monitoring since 2012 suggests continued sliding/slumping of the lower cliff. Cliff erosion directly south of Thurstaston has been reported to have been exacerbated due to the landward movement of a tidal channel that runs parallel to the shoreline and possibly also the interruption of longshore drift by Thurstatson Causeway, which restricts the supply of beach sediment to protect the cliff toe (Halcrow, 2010a).

Figure 10: The undefended cliffs between Gayton and Thurstaston (Photo source: CH2M Site Visit on 3rd October 2017)

In the ~2 km stretch of coast south of the West Kirkby Marine Lake, modest beach erosion has been occurring since monitoring began in the mid-1980s and was still occurring in 2016 (CH2M, 2016). This may be linked to extension of the Marine Lake in 1986, which effectively holds the shoreline further seaward than its natural position, potentially modifying tidal flows and blocking some longshore sediment transport from reaching the Caldy coast further downdrift. The slow lowering of beach levels here may also be linked to the coastal defences built to prevent cliff erosion along this frontage, which restricts the supply of sediment to the beach (Halcrow, 2002).

The coast between the Marine Lake and Red Rocks has shown a considerable increase in beach levels across the intertidal zone over the past ~10 years, which may be linked to the changes in offshore sandbanks which have resulted from the artificial training of the main Dee Estuary channel (Halcrow, 2010a). In particular, the growth of East Hoyle Bank to the north (CEUK, 2013) is likely to be reducing the wave energy reaching the shoreline here, allowing sediment transported by tidal currents to accumulate in the intertidal zone. Saltmarsh is colonising the upper beach here, perhaps initiated by this reduction in wave energy and continuing via natural estuarine processes that enhance further trapping of finer sediment once saltmarsh plants become established.

Figure 11: Saltmarsh colonising the foreshore between West Kirkby Marine Lake and Red Rocks (Photo Source: CH2M Site Visit 3rd October 2017)

Monitoring in the past ~10 years up to 2016 showed little change to the sand dunes at the back of the beach along this frontage, suggesting that they are protected from storm erosion by the high intertidal zone and/or the rocky outcrop of Hilbre Island which acts as a natural breakwater.

4.2.4 Recommendations for actions and triggers

It is recommended that that bi-annual beach profile measurements are resumed along the Wirral coast following the gap in data collection during 2017. Due to the lack of 2017 beach profile/topographic data for this Policy Area, it was not possible to make any other recommendations this year. However, the recommendations from the 2016 Coastal Processes Report (CH2M, 2016) and a previous CEUK (2013) monitoring report may still be relevant to address some of the issues and uncertainties identified by previous monitoring; these are repeated below:

1. Between Gayton and Thurstatson, cliff recession rates should be monitored using the periodically-collected aerial photography ad LiDAR surveys (CH2M, 2016).
2. Use remote remote sensing techniques (e.g. LiDAR, aerial photography) to monitor the migration of tidal channels at Thurstaston as the landward movement of channels could increase the erosion along the toe of the cliffs here, which could have implications particularly for the cliff top caravan park and Shore Cottage, as well as cliff top access paths (CEUK, 2013).
3. Determine the effect of cliff toe defences at Caldy on coastal processes via further investigation into defence construction and erosion timeframes and possibly sediment sample analysis (CH2M, 2016).

4. Confirm land ownership/defence responsibilities between Gayton and Heswall (CEUK, 2013).

The wider SMP2 actions and triggers for this Policy Area are shown in Table 3 below (Halcrow, 2010a). Although the action plan was updated in April 2017 for the North Wirral and Mersey Estuary Policy Areas, it was not updated for the Dee Estuary so the original SMP2 actions from 2010 remain in place.

Table 3: SMP2 actions for the part of Policy Area 11a 5 North Wirral that covers the Wirral Metropolitan Borough Council coast (Halcrow, 2010a)

Action Reference	Policy Area/Unit ID	Action Type	Action Description
1.1	11a 5	Study for policy area	Develop a strategic approach to beach management and beach recharge for the whole north Wales frontage from Little Orme through to the Dee estuary. Strategy development should include a sediment transport study to assess monitoring data, review potential sediment sources, use numerical modelling and environmental for assessment of options and appraisal of costs and benefits.
1.2	11a 5.1 to 5.5	Study for policy area	Complete the ongoing strategy studies for the Dee estuary and adjoining coastal flood cells to develop a consistent approach to management of flood risk in the large flood cells and inform Dee estuary wide strategy .(see item 3.1).The strategy will include a range of actions to manage the likelihood and consequences of flooding.
1.4	PU 5.5 to 5.11	Study for policy area	Complete ongoing strategy studies in PU 5.5 to 5.11 and feed into the estuary wide strategy (item 3.1)
1.5	Estuary wide	Study for policy area	Undertake Dee estuary wide study to investigate links between land contamination and flood risk management options in order to inform long term strategy on the requirements for implementation of measures to address any problems arising from this study including consideration of removal of contamination so as not to constrain future management. This work will focus on areas outside of the Wirral.
1.6	Estuary wide	Study for policy area	Undertake Dee Estuary wide managed realignment, habitat creation and flood storage study to inform the estuary wide strategy and develop any necessary mitigation for impact on the internationally designated sites. This work will focus on areas outside of the Wirral
1.7	Estuary wide	Study for policy area	Development of strategic approach to implementation of the SMP2 policies for Dee Estuary, considering flood risks from fluvial, coastal and land drainage issues.
1.8	Estuary wide	Study for policy area	Undertake a qualitative risk assessment to identify particularly vulnerable communities along the frontage.
2.7	11a 5.5	Study for policy unit	Investigate the changing risks along the Burton Point to Thurstaston Cliffs frontage in the future with sea level rise, e.g. implications of saltmarsh erosion and associated risks to local communities.
2.8	11a 5.6	Study for policy unit	Monitor erosion of undefended cliffs and reassess risks or need for adaptation in relation to caravan park, isolated properties and disused landfill site at northern boundary
2.9	11a 5.7	Study for policy unit	Develop a more detailed economic case for the proposed policy, taking account of risks from contaminated land and to golf club land in order to inform future approaches at strategy level and confirm the viability of the policies at the next SMP review.
2.10	11a 5.8	Study for policy unit	Investigate erosion risks and justification and affordability of rebuilding defences at end of residual life. Confirm a funding source and or a viable adaptation strategy to inform SMP3 review.

			Also investigate legal issues around maintenance at Cubbins Green. Confirm arrangements for future maintenance.
2.11	PU5.10	Study for policy unit	Undertake more detailed assessment of flood risks in event of dune and defence breach to inform strategy appraisal.
3.1	Estuary wide	Strategy	Adopt tidal flood and erosion risk management strategies for the Tidal Dee and the Wirral that are compatible and work with estuary process to take a long term view towards sustainable and affordable management of flood and erosion risks in the whole Dee estuary.
4.1	Estuary wide	Scheme work	To be defined through above strategy and studies.
5.1	Estuary wide	Monitoring (Data Collection)	Undertake estuary and coastal defence asset monitoring in conjunction with Cell 11 Regional Monitoring Strategy to inform strategy and future SMP reviews.
5.2	Estuary wide	Monitoring (Data Collection)	Environmental monitoring of designated sites to provide baseline data for future Habitat regulations Assessments.
5.3	Estuary wide	Monitoring (Data Collection)	Monitor morphological change in the Dee estuary to inform management at both the policy unit and estuarine level.
6.1	Estuary wide	Asset management	Maintenance of defences and beach and dune management including management of public access.
7.1	Estuary wide	Communication	Undertake consultation with key stakeholders and general public during strategy development
7.2	Estuary wide	Communication	Monitoring and management of Action Plans by the North West and North Wales Coastal Group to ensure SMP policies are put into practice
8.1	Estuary wide	Interface with Planning and Land Management	Advise local Planning Authority about SMP policies and flood and erosion risks so they can be accounted for in the next revisions of land use plans in order to help manage residual risks from flooding and erosion, in accordance with WAG's "New Approaches" policy.
8.2	Estuary wide	Interface with Planning and Land Management	Advise local Planning Authority about SMP policies and flood and erosion risks so they can take due account in planning decisions and aim to reduce the need to manage flood risk in future.
9.1	Estuary wide	Emergency Response	Development, monitoring and review of emergency response plans to prepare for over design standard events.
10.1	Estuary wide	Adaptation/Resilience	Investigate recommendations for managed realignment,
10.2	Estuary wide	Adaptation/Resilience	Monitor proposals for tidal power embayments and barrages and build into next review of SMP
11.1	Estuary wide	Flood Forecasting and Warning	Continue with improvements to flood risk maps and inundation modelling to provide improved flood warning service.
12.1	Estuary wide	Habitat Creation and environmental mitigation	Undertake habitats regulations assessment for the Dee estuary strategy to provide more detailed assessment of potential impacts on the international site, including development of plans for any required environmental mitigation or compensation.

4.2.5 Potential influences on SMP policies

Due to the lack of 2017 data for this Policy Area, it was not possible to assess any new potential influences on SMP policies this year. However, the potential influences identified in the 2016 Coastal Processes Report (CH2M, 2016) may still be relevant.

4.3 11a 6: North Wirral

4.3.1 Site overview

The entire length of the North Wirral coastline from Hilbre Point to Fort Perch has been defended by artificial structures since the 1840s. The hard defences are a combination of seawall, revetment, offshore breakwaters and rock groynes (Halcrow, 2010a).

The seawalls that have been constructed along the coast of Hoylake are both Council and privately owned. Further to the east, across the Meols frontage, vertical masonry walls and a promenade were constructed at the turn of the 19th/20th centuries. Wind-blown sand can be a problem along this frontage and sand mesh is used in various locations to reduce the volume of sand deposited on North Parade. Clearance of material that builds up against the mesh fences is cleared at irregular intervals (Thomas and Wardle, 2003), and wind-blown sand at Hoylake is dumped on the beach seaward of the developing sand dune and saltmarsh (Metropolitan Borough of Wirral, 2000). Saltmarsh grass that has started to colonise the foreshore, approximately 150 m offshore of the Hoylake Promenade (North Parade), has been ploughed to slow down its colonisation and maintain amenity as a sandy beach (Metropolitan Borough of Wirral, 2000).

During the 1840s, the Wallasey Embankment was constructed between Meols and Leasowe. During the 1970s and 1980s, the embankment was reconstructed and a new embankment was built on top of the old one for most of its length. The embankment was originally constructed to prevent the River Mersey from cutting a new route through the Wirral. The eastern end of the embankment is protected with an offshore rock armour breakwater (constructed 1981) which is now linked to the shoreline. A short shore-connected groyne has also been constructed at Dove Point to keep the Meols channel away from the toe of the defences (Halcrow, 2010a).

Figure 12: The Wallasey Embankment (Photo Source: CH2M Site Visit 29th September 2017)

Original defences between Leasowe and Wallasey (Leasowe Revetment) were constructed in the 1920s comprising a sloping concrete revetment, which separated the sand dunes along the frontage from the foreshore. At Leasowe Bay a small section of sand dunes was left undefended between the Wallasey Embankment and the Leasowe Embankment, and the shoreline eroded by nearly 100 m from the mid-19th century to 1953 (Liverpool Bay Coastal Group, 1999). The embayment between remained undefended until the 1970s when a clay embankment was constructed and subsequently a rock revetment was built in front to prevent further erosion. A small fish tail rock groyne was also constructed to the west end of the Leasowe frontage to alleviate pressure at the interface with the hard defences (Halcrow, 2010a).

Did you know? Beaches are a natural buffer between the land and sea that absorb wave energy. They protect us from erosion and flooding hazards. They are composed of different sized sediments, from fine sands to boulders, that may be supplied from seabed erosion, cliff recession or transport from adjoining beaches. Understanding beaches through monitoring is critical to understanding levels of coastal erosion and flooding risk and to support their management decisions.

In the late 1970s/early 1980s the Leasowe Revetment was reconstructed with a similar design to the reconstructed Wallasey Embankment. A second breakwater (Sandhills Island) was also constructed at the western end of the revetment which works in tandem with the one at the eastern end of the Wallasey Embankment (Leasowe Breakwater). Both breakwaters are connected to the shore by links constructed in rock or precast units, although the Sandhills Breakwater link has been buried by sand accumulations (CEUK, 2013). Wind-blown sand from the Leasowe Breakwater tombolo (a narrow piece of land which connects an island to the mainland) frequently blocks the low-level access road. A high-level road was built in 2001 to mitigate against the increased cost of clearing sand from the low-level road (Thomas and Wardle, 2003).

Along the eastern end of the North Wirral coastline, high seawalls were constructed at Wallasey in the 1930s, as a means of reclaiming the foreshore and dunes behind. These vertical walls lead to beach erosion of the order of 1.0 m per decade over the next forty years. During the 1980s, a beach-stabilisation scheme was implemented between Harrison Drive and Fort Perch Rock comprising linear protection, shore-connected breakwaters and offshore rock breakwaters. The scheme had the effect of reducing wave energy at the vertical seawall, encouraging material to accrete at the toe of the wall and enhancing its structural stability (Thomas and Wardle, 2003). Wind-blown sand frequently accumulates on the promenade (Thomas and Wardle, 2003).

4.3.2 Current (SMP2) policy and approach (adopted 2010)

The SMP2 policy for each timeframe within each Policy Unit (Halcrow, 2010a) is provided in Table 4.

Table 4: SMP2 Policy and approach for the North Wirral coastline (Halcrow, 2010a)

Location (SMP2 Policy Unit)	2010-2030	2030-2060	2060-2110
6.1 Hilbre Point (Stanley Road) to Wallasey Embankment (Meols)	***Hold the Line*** Manage flood and erosion risk by maintaining existing defences and beach management. As part of wider strategy, undertake a more detailed study into risks and the viability of maintaining defences	***Hold the Line*** Manage flood and erosion risk by maintaining existing defences and beach management, depending on outcome of strategy study	***Hold the Line*** Manage flood and erosion risk by maintaining existing defences and beach management, depending on outcome of strategy study
6.2 Wallasey Embankment (Meols to Leasowe)	***Hold the Line*** Maintain existing defences. Investigate opportunities to establish secondary or set back defences in the medium term so less substantial defences are required on the front line.	***Hold the Line*** Depending on outcome of investigations, construct additional secondary defences to help manage flood risk.	***Hold the Line*** Maintain defences to manage flood risk.
6.3 Wallasey Embankment (Leasowe) to	***Hold the Line*** Maintain existing defences. Investigate the justification and	***Hold the Line*** Maintain existing defences. Update studies to confirm	***Managed Realignment*** Depending on previous studies, if practical, after defences reach the

Harrison Groyne (New Brighton)	affordability of the policy including assessing contamination risks from landfill and potential for long term creation of more natural dunes.	justification and affordability of the policy and potential for long term reestablishment of more natural dunes.	end of their effective life allow coast to take a more natural state. Construct set back defences if justified.
6.4 Harrison Groyne to Perch rock (New Brighton)	***Hold the Line*** Maintain existing defences. Undertake studies to confirm approach: re-assess coastal risks; detailed economic appraisal including social and environmental benefits of options; select the most appropriate, economical and affordable long term approach.	***Hold the Line*** Maintain existing defences. Undertake further studies to investigate the most appropriate form of defence and alignment in the long term and assess the economic viability of the defences.	***Hold the Line*** Maintain existing defences while economic to do so then, subject to further studies, construct a new defence system, taking account of potential outflanking from west.

The **key assumptions** made during the development of the policies were:

- East Hoyle Bank is likely to continue to accrete and move eastwards, resulting in increased foreshore levels in this location at least into the medium epoch. To the east of Meols, as East Hoyle Bank migrates to the east, the Meols Channel will be pushed further against the shoreline increasing pressure on the defences. Into the long term increasing sea levels may overtake the rate of accretion reducing the area of intertidal zone and resulting in coastal squeeze against the hard defences.
- Uncertainty surrounding the rates of accretion and consequence on the required level of investment to defend the frontage will need to be explored as part of the supporting investigations detailed in the Action Plan. The studies to be undertaken as part of a coastal risk management strategy will also help refine flooding extents and assessment of benefits.
- The SMP2 policies will be subject to review if sea level rise predictions are changed.

The **issues** related to coastal flood and erosion risk management identified in the SMP2 for this frontage were:

- At Hoylake there are local concerns about the increase in vegetation growing on the beach and the development of saltmarsh at this amenity frontage. Hoylake is one of the premier sites for Sand Yachting in Britain due to its wide intertidal sandflats and is the venue for the European Sand Yacht Championships. The amenity beach at Hoylake is maintained by removing this vegetation. Wind blown sand is also an issue at Hoylake from Kings Gap to Hoyle Road.
- There are concerns about the integrity of the seawall protecting large areas of Meols, Moreton and Leasowe from tidal flooding. Along the Meols frontage tidal flooding of the Meols promenade, gardens and open spaces occurs approximately twice per year.
- The sand dunes at Leasowe are the largest such system on the Wirral. Much of the area is at or below sea level and is protected by a coastal embankment. Spray overtopping causes flooding to the highway between New Brighton and Leasowe Revetment on most spring tide periods between October and April. Along the embankment are the remains of fortifications built during the Second World War. Coastal erosion and flooding would be detrimental to these features.
- Any changes to coastal evolution could affect the Mersey Narrows and North Wirral Foreshore potential SPA & Ramsar and the North Wirral Foreshore SSSIs.
- The Meols Meadows SSSI could be vulnerable to changes in water levels.

Figure 13: Sand dunes at Leasowe (Photo Source: CH2M Site Visit 29th September 2017)

- Several small coastal settlements and isolated properties are located along the North Wirral and may be prone to coastal erosion and flooding.
- Wallasey Golf Club, Warren Golf Club and Leasowe Golf Club are all located along the coastline and are at greatest risk from coastal erosion and flooding.
- The North Wirral Coastal Park runs for four miles along the coast, and includes public open space, common land, natural foreshore and sand-dunes. The park provides for a wide variety of recreational activities ranging from sailing to horse riding. These features and activities are at risk from coastal erosion and flooding.
- There are several key routes within this section and in particular the M53, which not only forms part of the Strategic Road Network but also the TEN-T. These networks are the primary routes which link the Wirral area to the rest of the north west and therefore any flooding can have a detrimental impact on the safe and efficient operation of these infrastructure networks.
- Wallasey is a predominantly residential area, which includes the seaside resort of New Brighton There are a number of redevelopment projects proposed for the New Brighton frontage.

4.3.3 Summary of behaviour

Short term and long term coastal behaviour is assessed via the analysis of coastal monitoring data collected in this Policy Area (more details on the datasets are in Section 4.1).

It was not possible to assess short term coastal change between 2016 and 2017 in the western part of this Policy Area (Red Rocks to the Leaseowe breakwater) because there were no beach profile or other topographic survey data collected here in 2017. In the eastern part of the Policy Area, 3D topographic beach surveys were undertaken in 2017 in two locations: (1) Leaseowe Bay; and (2) between Harrison Groyne and the Portland Breakwater. Comparison of 2016 and 2017 topographic surveys here showed that short term beach changes were generally of lower magnitude than those observed during the previous year (2015-2016), remaining well within the range of natural variation observed in the longer term datasets. This reflects the wave and water level conditions experienced along the frontage in 2016-2017, which were calmer than average conditions observed in the longer term (further details in Appendix A).

With respect to longer term behaviour, the wide sandy beaches of the North Wirral coast have generally been stable or accreting over the last 20 years, with only small isolated areas of erosion. This widespread accretion is largely linked to the construction of several groynes and breakwaters since the 1980s, and possibly modifications to the Mersey and Dee estuary channels prior to that (Halcrow, 2010a).

Much of the accretion in the past ~10 years has occurred on the lower intertidal zone off the Wallasey Embankment and Meols coast, which represents the eastwards growth of East Hoyle Bank (a large intertidal sandbank). Growth of the bank has been linked to the construction of training walls in both the Mersey and Dee Estuaries in the 1900s and ongoing dredging of navigation channels, which has changed the tidal flow patterns and resulted in large changes to erosion and accretion patterns in the intertidal zone (Halcrow, 2010a).

Figure 14: High beach levels next to the seawall at Hoylake (Photo Source: CH2M site visit 29th September 2017)

Accretion of the upper beaches has also occurred in recent years, particularly around Hoylake, where the 2016 beach levels next to the seawall were often the highest since records began, in some locations only leaving ~0.6 m vertical distance between the beach surface and the top of the seawall. This accumulation of sand against the seawall along this frontage may result from the increased sheltering of the upper beach from wave action provided by the growth of East Hoyle Bank, and/or increased aeolian (wind-blown) sand supply from the bank when it dries at low tide. This accretion may need to be monitored more closely in future years to determine if there is any risk that a high steep beach next to this wall may enhance wave run-up and increase the likelihood of waves overtopping the wall.

Directly southwest of Dove Point, the growth of East Hoyle bank appears to be having a different effect on the upper beach, as the landward accretion of the bank has pushed the Meols Channel landward in the past ~10 years, causing the upper beach to lose volume as it squeezed against the Wallasey Embankment. Further northeast, the monitoring data show that the position of the Meols Channel fluctuates more, appearing to move both landward and seaward over the past 10 years.

Beach behaviour in Leasehowe Bay and along Kings Parade appears to be driven mainly by the influence of the groynes and breakwater structures, with interruption of the predominantly eastwards longshore sediment transport causing localised erosion on the east side of structures (downdrift) and accretion on the west side of structures (updrift).

4.3.4 Recommendations for actions and triggers

It is recommended that that bi-annual beach profile measurements are resumed along the Wirral coast following the gap in data collection during 2017. Due to the lack of 2017 beach profile/topographic data in the western part of this Policy Area, it was not possible to make any other recommendations for this part of the coast this year. Analysis of topographic data collected in the eastern part of this subdivision in 2017 did not identify any areas of concern or recommendations. However, the recommendations from the 2016 Coastal Processes Report (CH2M, 2016) and a previous CEUK (2013) monitoring report may still be relevant to address some of the issues and uncertainties identified by previous monitoring; these are repeated below:

1. Investigate whether the high steep next to the wall at Hoylake increases the risk of overtopping of the seawall (CH2M, 2016).
2. Monitor the acumulation of mud on the sandy foreshore near RNLI station and assess whether it poses a public safety hazard (action brought forward from the monitoring report by CEUK, 2013).
3. Monitor the algal growth on lower sections of the Wallasey Embankment, particularly between Bennets Lane and the Lingham Lane access, and assess whether it poses a public safety hazard (CEUK, 2013).

The wider SMP2 actions and triggers for this Policy Area (updated in April 2017) are shown in Table 5.

Table 5: SMP2 actions for Policy Area 11a 6 North Wirral (updated April 2017)

Action Reference	Policy Area/Unit ID	Action Type	Action Description
1.1	11a 6	Studies for policy area	Undertake a more detailed assessment of flood and erosion risks including investigating contaminated land, costs of options and socio-economic and environmental benefits and dis-benefits for the whole frontage to inform the strategy development.
2.1	11a 6.1	Study for policy unit	Prepare a more detailed estimate of costs for maintaining defences and socio-economic assessment, to inform strategy
2.2	11a 6.2	Study for policy unit	Investigate opportunities to create secondary defence line in future to inform strategy
2.3	11a 6.3	Study for policy unit	Investigate opportunities to re-establish a more naturally functioning dune system to inform long term strategy.
2.4	11a 6.4	Study for policy unit	Update the assessment of flood risk in this area following the completion of the Wirral Coastal Strategy.
3.1	11a 6	Strategy	Develop coastal flood and erosion risk management strategy for the north Wirral frontage taking into account coastal and estuary processes and flood risk linkages between open coast and Mersey and Dee estuaries.
4.1	11a 6	Scheme Work	To be defined by strategy
5.1	11a 6	Monitoring (Data Collection)	Undertake beach coastal defence asset monitoring in conjunction with Cell 11 Regional Monitoring Strategy to inform strategy and future SMP reviews
5.2	11a 6	Monitoring (Data Collection)	Environmental monitoring of designated sites to provide baseline data for future Habitat Regulations Assessments
5.3	11a 6	Monitoring (Data Collection)	In areas of managed realignment, investigate the hazard that the landfill site poses to people and the environment from leaching or the release of contaminated materials. Where necessary, consider protection in situ or excavation and removal of material.

6.1	11a 6	Asset Management	Maintenance of defences and beach and dune management including management of public access
7.1	11a 6	Communication	Undertake consultation with key stakeholders and general public during strategy development
7.2	11a 6	Communication	Monitoring and management of Action Plans to ensure SMP policies are put into practice
8.1	11a 6	Interface with Planning and Land Management	Advise local Planning Authority about SMP policies and flood and erosion risks so they can be accounted for in the next revisions of land use plans in order to help manage residual risks from flooding and erosion.
8.2	11a 6	Interface with Planning and Land Management	Advise local Planning Authority about SMP policies and flood and erosion risks so they can take due account in planning decisions and aim to reduce the need to manage flood risk in future.
9.1	11a 6	Emergency Response	Development, monitoring and review of emergency response plans to prepare for over design standard events.
10.1	11a 6	Adaptation/Resilience	Investigations recommended for establishing a secondary line of defences, see items 2.2
10.2	11a 6	Adaptation/Resilience	Develop adaptation approaches to allow for long term coastal change at Leasowe and Wallasey
11.1	11a 6	Flood Forecasting and Warning	Continue with improvements to flood risk maps and inundation modelling to provide improved flood warning service.
12.1	11a 6	Habitat Creation and environmental mitigation	Consider potential for options for beach and foreshore control structures to manage foreshore levels to inform strategy development. Undertake a Habitats Regulation Assessment for the strategy.
12.2	11a 6	Habitat Creation and environmental mitigation	Seek opportunities for habitat enhancement during strategy development e.g. to incorporate scrub control and improvements to the grazing regime as part of flood/erosion risk management works, as appropriate and where possible, such as at Meols Meadows SSSI.

4.3.5 Potential influences on SMP policies

Due to the lack of 2017 data for the western part of this Policy Area (between Red Rocks and Leaseowe), it was not possible to assess any new potential influences on SMP policies along this part of the coast this year; although the potential influences identified in the 2016 Coastal Processes Report (CH2M, 2016) may still be relevant. There were no potential influences on SMP policies identified from coastal changes observed in the eastern part of the Policy Area (Leaseowe to Lighthouse Groyne).

4.4 11a 7 Mersey Estuary (part)

4.4.1 Site overview

This part of the 11a7 'Mersey Estuary' Policy Area extends along the eastern side of the Wirral between Fort Perch and Seacombe Ferry, and is orientated in an approximately north-south direction.

The entire length of this frontage is defended by the Mersey River Wall which comprises a vertical sandstone block seawall constructed in the second half of the 19th century, with localised rock armour protection added in places in the 1990s, and a stepped concrete revetment further south near Seacombe Ferry (Halcrow, 2010a). A vertical precast concrete seawall was constructed in late 1980s around the New Brighton Pumping station.

In addition to the linear defences, there are several shore-perpendicular structures that were constructed in the 1980s and 90s. In the north near Fort Perch, a shore-connected 'reef-block' breakwater with a rock stem was and an offshore reef-block breakwater (Victoria Island) were constructed between 1983-85 (Halcrow, 2010a).

Three rock groynes were then constructed along the frontage in the late 1990s, one at the Tower Grounds north of Dalmorton Road (Tower Groyne), one at Manor Lane (Manor Groyne) and one at Tobin Street (Egremont Groyne).

Dredging of the navigation channels in the Mersey Estuary began in 1883 and continues today, with ~400,000 m3 of sediment removed from the estuary each year and deposited in Liverpool Bay (Van der Wal and Pye, 2000).

Figure 15: The shore-connected 'reef-block' breakwater with a rock stem at Fort Perch. (Photo Source: CH2M site visit 1st September 2017)

4.4.2 Current (SMP2) policy and approach (adopted 2010)

The SMP2 policy for each timeframe within the one Policy Unit that covers this area (Halcrow, 2010a) is provided in Table 6.

Table 6: SMP2 Policy and approach for the Wirral Metropolitan Borough Council's eastern coastline (Halcrow, 2010a)

Location (SMP2 Policy Unit)	2010-2030	2030-2060	2060-2110
7.1 Perch Rock to Riverwood Road	***Hold the Line*** Manage flood and erosion risk by maintaining existing defences to an adequate standard.	***Hold the Line*** Manage flood and erosion risk by maintaining / upgrading defences.	***Hold the Line*** Manage flood and erosion risk by maintaining / upgrading defences.

The **key assumptions** made during the development of the policies in the table were:

- Changes to the low water channels have a control on the estuary processes and defence management in the estuary. It has been assumed that the position of these channels will continue to influence patterns of accretion and erosion in the future. The position of the channels is difficult to predict but can be influenced by training works within the estuary and in the Outer estuary. The future maintenance strategies for these training works and channel dredging are critical in determining the overall response of the estuary.

- Predicted changes in rainfall patterns with future climate change may increase river flows which may in turn affect river channel meandering and siltation rates.
- The supply of sediment to the estuary will continue and will allow the estuary to accrete vertically in line with sea level rise. In the long term there is uncertainty over the balance between sediment supply from Liverpool Bay and sea level rise.
- It has been assumed that supply will continue to allow vertical accretion within the estuary. If sediment supply were not to keep pace with sea level rise in the long term then this would be expected to lead to coastal squeeze in locations where the high water mark abuts the defences.
- The risks from contamination related to potential flooding or erosion of historical landfills and industrial sites are uncertain; therefore future studies will be required to address these uncertainties.
- The long term flood risk management policy for this estuary, as with others in the North West may change if proposals for tidal power barrages are progressed.
- Economic justification needs to be examined in more detail at strategy or scheme level and opportunities for co-funding need to be investigated.
- The SMP2 policies will be subject to review if sea level rise predictions are changed.

The **issues** related to coastal flood and erosion risk management identified in the SMP2 for this frontage were:

- Wallasey is a predominantly residential area, which includes the seaside resort of New Brighton, which has the longest promenade in the UK and is a popular recreational facility for walking and cycling. 'Wirral Waters' is a regeneration scheme has been proposed by Peel Holdings for Wirral Docks (between Wallasey and Birkenhead).
- The ventilation tower for the Wallasey road tunnel is situated within 10 m of the existing river walls.
- New Brighton Station is within 800 m of the Mersey. Significant flooding of this rail infrastructure would compromise safe operation.
- Any changes to coastal evolution could affect the Mersey Narrows and North Wirral Foreshore potential SPA & Ramsar and the Mersey Narrows SSSI.

4.4.3 Summary of behaviour

Short term and long term coastal behaviour is assessed via the analysis of coastal monitoring data collected in this Policy Area (more details on the datasets are in Section 4.1).

There were no beach profile data collected in this Policy Area in 2017, but 3D topographic surveys and fixed point photographs were captured across the whole Policy Area in July 2017 and September 2017 respectively (presented in Appendix A).

The short term coastal changes, identified via comparison of 2016 and 2017 topographic surveys, were generally of lower magnitude than those observed during the previous year (2015-2016), remaining well within the range of natural variation observed in the longer term datasets. This reflects the wave and water level conditions experienced along the frontage in 2016-2017, which were calmer than average conditions observed in the longer term (further details in Appendix A).

The main notable short term change was up to 0.5 m beach scour at the base of the seawall opposite Sandon Road / Wilson Road between 2016 and 2017, which is a continuation of longer term trends observed in this area since 2009 (discussed further at the end of this Section). Photos at this location taken in September 2017 (Figure 16) show exposure of the sheet piling at the base of the seawall, which may require closer monitoring if beach levels continue to drop here in future.

Similar beach scour previously identified further south at Riverside School field and Lowry Bank between 2015 and 2016 could not be assessed between 2016 and 2017 due to the lack of both beach profile data in 2017 and 3D topographic survey coverage of this area in 2016.

Figure 16: Low beach levels exposing sheet piling at the base of the seawall opposite Wilson Road, between Egremont Groyne and Seacombe Ferry (Photo Source: CH2M site visit 1st September 2017).

With respect to longer term behaviour, the trend over the past 30 years along the Wirral's Mersey Estuary coastline has been steady beach accretion (CEUK, 2013), likely due to the construction of groynes and breakwaters in the 1980s and late-1990s that have acted to trap sediment on the beach.

More recent coastal monitoring suggests however, that this accretion may be slowing as the beach comes into equilibrium (balance) with the waves and currents ~15 years after the groynes were built. Instead of widespread accretion, there was modest fluctuation in beach levels between 2005-2015, with areas of erosion as well as accretion.

Recent patterns of erosion and accretion appear to be mainly controlled by the influence that the groyne structures have on tidal currents and/or longshore sediment transport, as the monitoring in the past ~10 years shows a strong pattern of localised erosion on the south side of the groynes and accretion on the north side of the groynes (see Figure 17). Tidal currents are likely to be the dominant driver of sediment transport along this frontage where the flow becomes constricted in the narrow estuary mouth, and the strongest flows tend to be southwards because the estuary is flood-dominant (ABPmer 2005). Considering this, the erosion on the south side of the groynes may be caused by turbulence that the groynes create which acts to scour the sediment down-current. Alternatively, the groynes may block the predominantly southwards sediment transport to the area immediately south (downdrift) of the groynes. The sediment removed from the south sides of the groynes is then transported southwards and accumulates on the north (updrift) sides of the groynes.

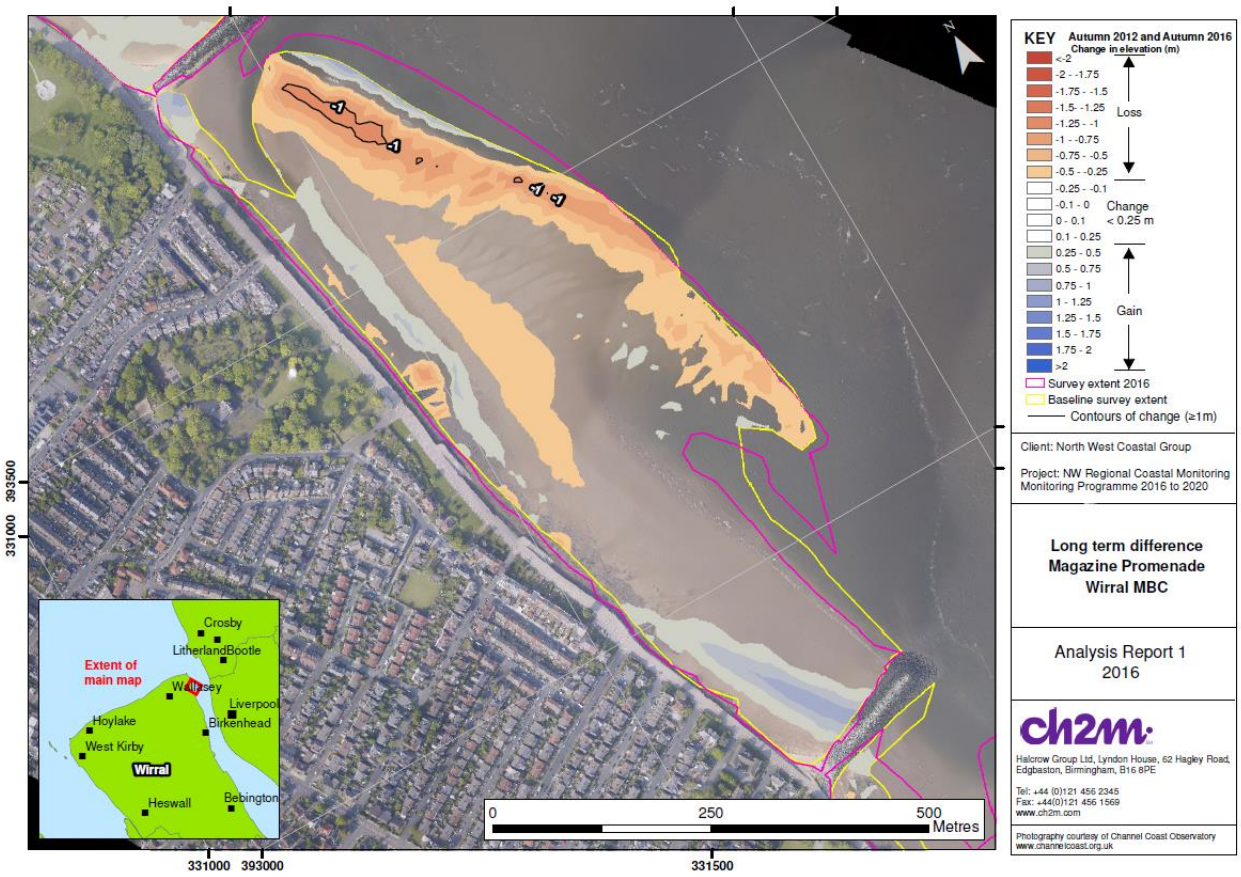

Figure 17: A topographic difference map for the frontage between Tower Groyne and Egremont Groyne which shows the difference in beach levels between Autumn 2012 and Autumn 2016. Red is erosion and blue is accretion.

Alternating strips of erosion and accretion were also evident in the topographic survey data, likely to be the movement of ridges and runnels in response to daily changes in wave and tide conditions (for more details see the 'Did you know?' explanation of ridges and runnels on this page).

Although the change in beach levels along this frontage are generally small due to the frontage being relatively sheltered from waves, there are some isolated locations where the beach has lowered considerably since monitoring began in the 1980s.

South of Egremont Groyne, there was evidence of long term beach erosion opposite Wilson Road, and also opposite Riverside School field and Lowry Bank, with 2016 beach levels at the wall ~1.5-2 m lower at these locations than ever recorded since 1985. These locations may require closer monitoring if beach levels are approaching the wall foundations, because this could pose a hazard to the stability of the wall. Erosion between Riverside School and Lowry Bank may potentially be due to the convex curve of the shoreline here which may increase its exposure to higher velocity tidal currents.

Did you know? Ridges and runnels are elongate beach undulations formed due to the interaction of tides, currents and beach topography. Ridges (high points) and runnels (low points) usually lie parallel or nearly parallel to the high water mark. The height difference between ridge and runnel may be up to 1m, but these features change in response to waves and tides. They are often higher in summer and can be flattened during storms: this means considerable changes in beach elevation change can occur.

4.4.4 Recommendations for actions and triggers

The present monitoring data type, frequency and accuracy is generally appropriate for informing coastal flood and erosion risk management across most of this Policy Area. However, some extra activities are recommended in addition to the existing monitoring and analysis programme, to address some of the issues and uncertainties identified by recent monitoring results. These recommendations have either been informed by recent monitoring data analysis in 2017 and 2016 by CH2M or have been carried forward from past monitoring reports by CEUK (2013) where relevant. These recommendations do not include any coastal defence structure maintenance/repair activities because no asset condition surveys have been undertaken on the Wirral coast recently.

1. Compare beach levels at the seawall with known wall foundation elevations at the following locations to assess whether lowering beach levels pose a hazard to the stability of the wall:
    a. opposite Sandon Road/Wilson Road,
    b. between Riverside School field and Lowry Bank.
2. Monitor the algal growth on stepped beach access points and assess whether it poses a public safety hazard (CEUK, 2013).

The wider SMP2 actions and triggers for this Policy Area (updated in April 2017) are shown *Table 7*.

Table 7: SMP2 actions for the Policy Area 11a 7 Mersey Estuary that covers the Wirral Metropolitan Borough Council coast (updated April 2017)

Action Reference	Policy Area/Unit ID	Action Type	Action Description
1.1	11a 7	Studies for policy area	Consider potential for changes to the Coast Protection Act coastal boundary (presently between Royal Seaforth Dock and Seacombe Ferry) and associated implications for managing erosion risks in the estuary, in order to inform next review of SMP.
1.2	11a 7	Studies for policy area	Undertake a more detailed assessment of coastal squeeze in the estuary to consider long term impacts of defences on internationally designated sites, This would include more detailed habitats regulations assessments and help to inform the regional habitats creation programme.
2.1	11a 7.1	Study for policy unit	Develop a more detailed assessment of the defences, including flood risks, defence condition and options for future.
3.1	11a 7	Strategy	In conjunction with areas managed by Wirral Council in 11a 6 and 11 a5 develop a coastal risk management strategy for the Wirral taking into account above studies.
4.1	11a 7	Scheme Work	To be defined by defence monitoring.
5.1	11a 7	Monitoring (Data Collection)	Undertake estuary and coastal defence asset monitoring in conjunction with Cell 11 Regional Monitoring Strategy to inform strategy and future SMP reviews
5.2	11a 7	Monitoring (Data Collection)	Environmental monitoring of designated sites to provide baseline data for future Habitat Regulations Assessments
6.1	11a 7	Asset Management	Maintenance of defences including management of public access
7.1	11a 7	Communication	Monitoring and management of Action Plans to ensure SMP policies are put into practice
8.1	11a 7	Interface with Planning and Land Management	Advise local Planning Authority about SMP policies and flood and erosion risks so they can be accounted for in the next revisions of land use plans in order to help manage residual risks from flooding and erosion.

8.2	11a 7	Interface with Planning and Land Management	Advise local Planning Authority about SMP policies and flood and erosion risks so they can take due account in planning decisions and aim to reduce the need to manage flood risk in future.
9.1	11a 7	Emergency Response	Development, monitoring and review of emergency response plans to prepare for over design standard events.
10.1	11a 7	Adaptation/Resilience	Monitor proposals for estuary tidal power barrages and build into next review of SMP -
11.1	11a 7	Flood Forecasting and Warning	Continue with improvements to flood risk maps and inundation modelling to provide improved flood warning service.
12.1	11a 7	Habitat Creation and environmental mitigation	See actions for Policy Units 7.4 and 7.6 (outside of the Wirral) which will inform future Habitats Regulations Assessments and feed into SMP3. Integrate these studies with the RHCP.

4.4.5 Potential influences on SMP2 policies

The notable recent coastal change on the Wirral's Mersey Estuary coast (identified via analysis of the 2017 3D topographic surveys) was localised beach erosion at the seawall opposite Wilson Road. This was an isolated issue related to the stability of an individual coastal structure, which does not affect or conflict with the wider SMP2 policies in place for each Policy Unit along this frontage.

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Appendix A
Analysis and Interpretation