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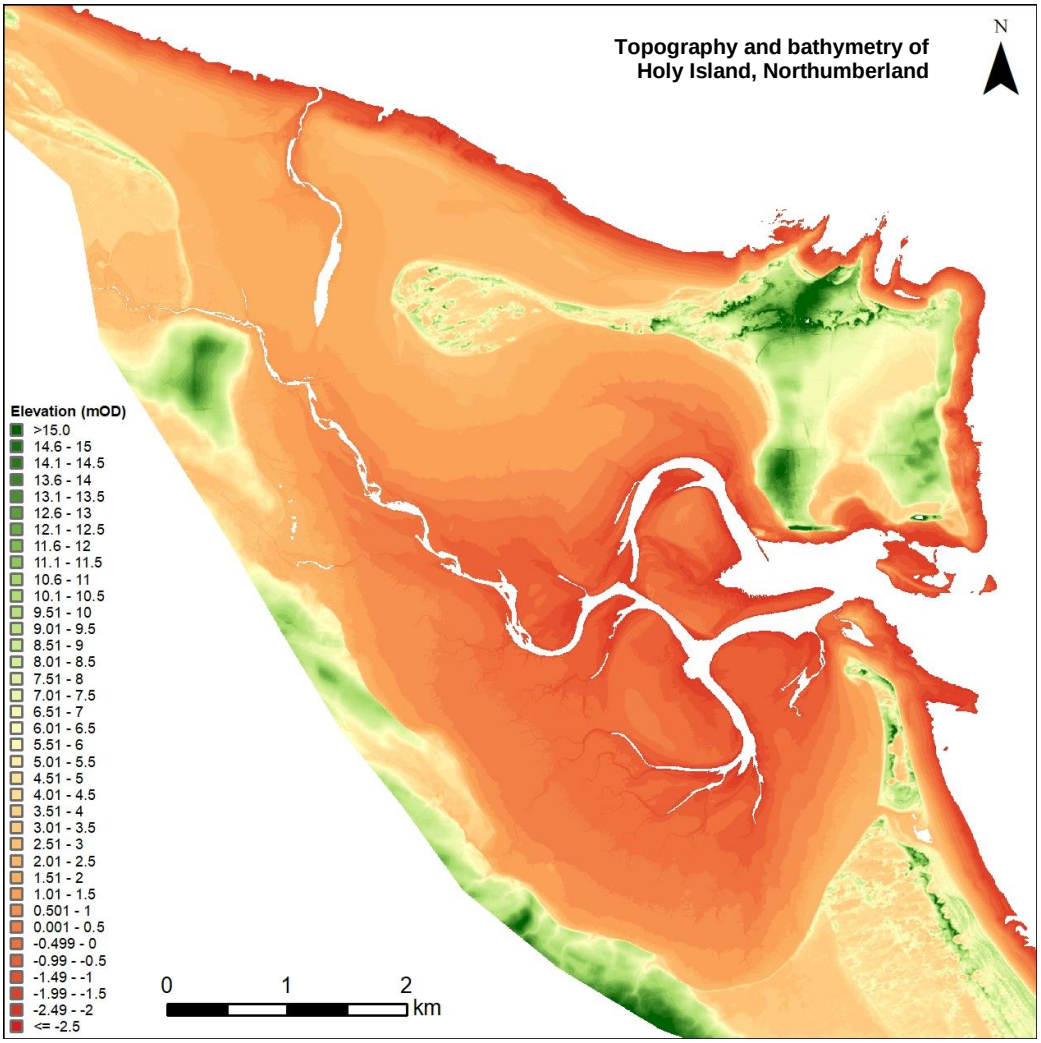

Cell 1 Regional Coastal Monitoring Programme Overview Report (2016 – 2021)

North East Coastal Observatory

August 2021

North East Coastal Observatory

Cell 1 Regional Coastal Monitoring Programme
Overview Report (2016 – 2021)

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Contents

Disclaimer iv
Abbreviations and Acronyms v
Glossary vi
Preamble vii

1. Introduction 1
1.1 Regional Coastal Monitoring 1
1.2 Aim and Objectives 1
1.3 Scope of Work 2
1.4 Wave and Tidal Analysis 2016 – 2021 5

2. Overview of Main Findings 2016 – 2021 9
2.1 Principal Observations 9
2.2 Northumberland 10
2.2.1 Monitoring Activities 10
2.2.2 Rationale 11
2.2.3 Key Findings 12
2.2.4 Discussion and Future Recommendations 13
2.3 North Tyneside 15
2.3.1 Monitoring Activities 15
2.3.2 Rationale 16
2.3.3 Key Findings 16
2.3.4 Discussion and Future Recommendations 17
2.4 South Tyneside 18
2.4.1 Monitoring Activities 18
2.4.2 Rationale 19
2.4.3 Key Findings 20
2.4.4 Discussion and Future Recommendations 20
2.5 Sunderland 21
2.5.1 Monitoring Activities 21
2.5.2 Rationale 22
2.5.3 Key Findings 22
2.5.4 Discussion and Future Recommendations 22
2.6 County Durham 23
2.6.1 Monitoring Activities 23
2.6.2 Rationale 24
2.6.3 Key Findings 24
2.6.4 Discussion and Future Recommendations 24
2.7 Hartlepool 25
2.7.1 Monitoring Activities 25
2.7.2 Rationale 25
2.7.3 Key Findings 26
2.7.4 Discussion and Future Recommendations 26
2.8 Redcar & Cleveland 27
2.8.1 Monitoring Activities 27
2.8.2 Rationale 28
2.8.3 Key Findings 29
2.8.4 Discussion and Future Recommendations 29
2.9 Scarborough 30
2.9.1 Monitoring Activities 30
2.9.2 Rationale 31
2.9.3 Key Findings 33

2.9.4 Discussion and Future Recommendations 34

3 Case Studies 35
3.1 Holy Island 35
3.2 Lynemouth Bay 41
3.3 Meggies Burn 48
3.4 Marsden Bay 53

4 Data Sharing 57

5 Knowledge Sharing 59

6 Conclusions and Recommendations 61

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[1] Scarborough Borough Council is acting as client on behalf of all Local Authorities within 'Coastal Cell 1'.

Abbreviations and Acronyms

Acronym / Abbreviation	Definition
AONB	Area of Outstanding Natural Beauty
DGM	Digital Ground Model
HAT	Highest Astronomical Tide
LAT	Lowest Astronomical Tide
MHWN	Mean High Water Neap
MHWS	Mean High Water Spring
MLWS	Mean Low Water Neap
MLWS	Mean Low Water Spring
m	metres
ODN	Ordnance Datum Newlyn

Glossary

Term	Definition
Beach nourishment	Artificial process of replenishing a beach with material from another source.
Berm crest	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.
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.
Offshore zone	Extends from the low water mark to a water depth of about 15 m and is permanently covered with water.
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.
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 refraction	Process by which the direction of approach of a wave changes as it moves into shallow water.

Preamble

The Cell 1 Regional Coastal Monitoring Programme covers approximately 300km of the northeast coastline, from the Scottish Border (just south of St. Abb's Head) to Flamborough Head in East Yorkshire. This coastline is often referred to as 'Coastal Sediment Cell 1' in England and Wales (Figure 0-1). Within this frontage the coastal landforms vary considerably, comprising low-lying tidal flats with fringing salt marshes, hard rock cliffs that are mantled with glacial till to varying thicknesses, softer rock cliffs, and extensive landslide complexes.

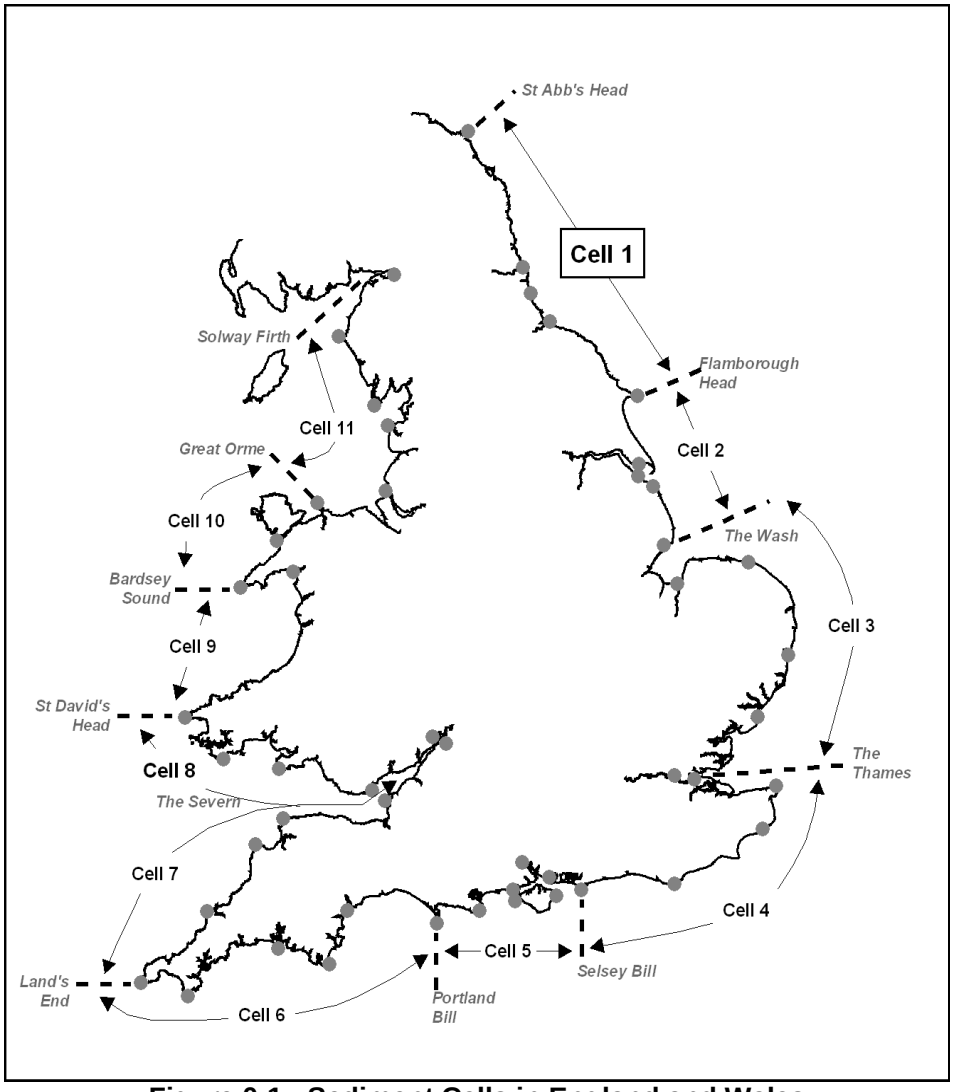


Figure 0-1 - Sediment Cells in England and Wales

The programme commenced in its present guise in September 2008[2] and is managed by Scarborough Borough Council on behalf of the North East Coastal Group. It is funded by the Environment Agency, working in partnership with the following organisations:

Royal HaskoningDHV has been appointed to provide Analytical Services in relation to the Cell 1 Regional Coastal Monitoring Programme 2016 - 2021. The present report provides an overview of the main findings from the programme over this phase. For purposes of analysis, the Cell 1 frontage has been split into the sub-sections listed in Table 0-1.

[2] Prior to 2008, coastal monitoring was undertaken on a consistent basis across Northumberland and North Tyneside as part of the (then) Northumbrian Coastal Authorities Group's monitoring programme which commenced in 2002, whilst several authorities between the River Tyne and Flamborough Head undertook their own local monitoring programmes.

Table 0-1 Sub-divisions of the Cell 1 Coastline

Authority	Zone
Northumberland County Council	Spittal A
	Spittal B
	Goswick Sands
	Holy Island
	Bamburgh
	Beadnell Village
	Beadnell Bay
	Embelton Bay
	Boulmer
	Alnmouth Bay
	High Hauxley and Druridge Bay
	Lynemouth Bay
	Newbiggin Bay
	Cambois Bay
	Blyth South Beach
North Tyneside Council	Whitley Sands
	Cullercoats Bay
	Tynemouth Long Sands
	King Edward's Bay
South Tyneside Council	Littehaven Beach
	Herd Sands
	Trow Quarry (incl. Frenchman's Bay)
	Marsden Bay
Sunderland Council	Whitburn Bay
	Harbour and Docks
	Hendon to Ryhope (incl. Halliwell Banks)
Durham County Council	Featherbed Rocks
	Seaham
	Blast Beach
	Hawthorn Hive
	Blackhall Colliery
Hartlepool Borough Council	North Sands and Headland
	Middleton
	Hartlepool Bay
	North Gare
Redcar & Cleveland Borough Council	Coatham Sands
	Redcar Sands
	Marske Sands
	Saltburn Sands
	Cattersty Sands (Skinningrove)
Scarborough Borough Council	Staithes
	Runswick Bay
	Sandsend Beach, Upgang Beach and Whitby Sands
	Robin Hood's Bay
	Scarborough North Bay
	Scarborough South Bay
	Cayton Bay
	Filey Bay

1. Introduction

1.1 Regional Coastal Monitoring

Coasts can be highly dynamic environments. In order to assess and appropriately manage the risks from coastal erosion and sea flooding, maritime Local Authorities and the Environment Agency, together with other organisations with related responsibilities, have recognised the need for regional-scale coastal monitoring programmes to improve the long-term and broad-scale understanding of coastal processes and shoreline change across coastal cells. This provides the necessary core data to inform coastal management decisions, including future coastal adaptation in response to sea level rise owing to global climate change.

These data are also used to reduce uncertainty in design assessments for capital coastal defence schemes, fine-tune existing operational and maintenance regimes, and enable post-project evaluation of specific schemes to be interpreted within a broader context. These data can also support the set-up, calibration and verification of numerical models that are used in initiatives such as Tidal Flood Forecasting Systems and physical coastal processes assessment, thereby improving confidence in their outputs.

The particular advantages of a region-wide understanding are:

- Delivery of continuous improvement in shoreline management – By continually building the knowledge and understanding of how the coast behaves and evolves, the philosophy of Defra's Shoreline Management Plan (SMP) Guidance (i.e. not just to repeat 'business as usual', but to enhance the coastal processes understanding and its role in SMP production) will be delivered.

- Selection of the most suitable SMP policies or Coastal Strategy options – By providing improved coastal data more quantitative information on mechanisms and rates of coastal change will mean that uncertainties are reduced and consequently policies or options will be selected that have greater sustainability in the longer-term.

- Improved phasing of schemes – Improved understanding of the behaviour of the coastal systems will mean that schemes can be constructed at more appropriate time, avoiding implementation earlier than they need be, under an overly precautionary approach, or later than they should have been, under an otherwise purely reactive approach that often involves interim emergency works.

- Improved scheme design – Reduced uncertainties and improved measured data from the nearshore zone will mean that defences will be better designed to particular marine parameters, such as more appropriate crest levels to reduce overtopping risk, or foundation levels to reduce undermining risk from beach level fluctuations.

- Enhanced operational management and maintenance regimes – The context provided by the regional coastal monitoring data to local activities will provide opportunities in terms of operational management and maintenance regimes that are more tailored to local issues, such as seasonal beach level changes, and also the implications of wider scale changes, such as longer term trends of erosion or accretion.

1.2 Aim and Objectives

The aim of the Cell 1 monitoring is to provide better understanding on the coastal processes and the locations, rates and mechanisms of shoreline morphological change at key locations between St. Abb's Head and Flamborough Head. Recognising that 'one size does not fit all', rather than simply mirroring programmes from some other coastal regions of the UK, the Cell 1 programme has specifically been designed to gain further insight into areas of risk and uncertainty that were identified in the two SMPs which between them cover the entire Cell 1 frontage; the Northumberland & North Tyneside SMP2 (Royal Haskoning, 2009) and the River Tyne to Flamborough Head SMP2 (Royal Haskoning, 2007).

The design of the Cell 1 monitoring therefore reflects the nature and magnitude of the uncertainties in the coastal erosion and sea flooding risks in the northeast region. The selection of appropriate monitoring techniques and suitable data collection frequencies during its design took into consideration the following:

- anticipated extent and mechanisms of change in cliff top position, based on understanding of underlying solid geology and overlying drift geology;
- behaviour of dunes and beaches, based on seasonal and longer-term historic observations;
- magnitude and variation in coastal forcing conditions, such as waves, tides and surges, and exposure of the shore to those;
- composition of shoreline and nearshore sediments and their dynamism;
- extent of development in areas of coastal change, recognising that much of the northeast coast is rural but that there are some key urban and industrial areas;
- the anticipated behaviour of the coastal cell under future sea level rise owing to global climate change; and
- the availability of complementary data from other sources (e.g. Environment Agency, Port Authorities, CEFAS Wavenet).

The programme also provides a framework within which region-wide bespoke studies can be procured and undertaken to investigate emerging issues.

1.3 Scope of Work

The main elements of the Cell 1 Regional Coastal Monitoring Programme involve:

- beach profile surveys
- topographic surveys
- cliff top recession surveys
- real-time wave data collection
- bathymetric and sea bed characterisation surveys
- aerial photography
- Light Detection and Radar (LiDAR) surveys
- walk-over cliff and coastal defence asset inspection surveys

The beach profile surveys, topographic surveys and cliff top recession surveys are undertaken as a Full Measures survey in autumn/early winter every year with some surveys being repeated the following spring as part of a Partial Measures survey.

Each year, an **Analytical Report** is produced for each individual authority, providing a detailed analysis and interpretation of the Full Measures surveys. This is followed by an **Update Report** providing ongoing findings from the Partial Measures surveys. In addition to these, separate reports are produced for other elements of the programme when different types of survey or data collection are undertaken.

- **Wave and Tide Analysis Reports** are produced annually, with each report superseding earlier versions.

- **Bathymetric and Sea Bed Sediment Characterisation Reports** are produced when data from such surveys are available.

- **Aerial Photography and LiDAR Survey Reports** are produced to analyse changes in cliff top position or morphological changes in beach features.

- **Walkover Inspection Reports**, covering the condition of structures and activity in cliffs, beaches and dunes along the coast are produced every two years.

All data and routine interpretative reports for the Cell 1 Regional Coastal Monitoring programme are available on the project website:

http://www.northeastcoastalobservatory.org.uk

The purpose of this **Overview Report** is to provide a general synthesis of the main findings from the Cell 1 Regional Coastal Monitoring programme over the period 2016 – 2021.

Note that in addition to the routine reports (summarised in Table 1-1), occasional bespoke reports are also produced and during the period 2016 to 2021 these have been the Cell 1 Coastal Landfills Study (2019) and the Cell 1 Microplastics Study (2018-19).

Table 1-1 Routine Cell 1 Regional Coastal Monitoring Programme Reports Produced to Date

Year		Beach Profile, Beach Topographic and Cliff Top Surveys		Waves & Tides	Bathymetry & Sea Bed Sediments	Aerial Photography & LiDAR	Walkover Inspections	Overview
		Analytical Report	Update Report					
1	2008/09	♦	♦	-	-	-	♦	-
2	2009/10	♦	♦	-	-	-	-	-
3	2010/11	♦	♦	♦	♦	♦	-	♦
4	2011/12	♦	♦	-	-	-	♦	-
5	2012/13	♦	♦	-	-	♦	-	-
6	2013/14	♦	♦	♦	-	-	-	-
7	2014/15	♦	♦	♦	-	-	♦	-
8	2015/16	♦	♦	♦	♦	♦		♦
9	2016/17	♦	♦	♦	-	-		-
10	2017/18	♦	♦	♦	-	♦	♦	-
11	2018/19	♦	♦	♦	-	-	-	-
12	2019/20	♦	♦	♦	-	-	♦	-
13	2020/21	♦	♦	♦	♦[1]	♦	-	♦

Notes:

[1] Interim Report (awaiting survey data for St Abb's Head to Farne Islands and Blyth to Sunderland to enable finalisation and uploading to website).

1.4 Wave and Tidal Analysis 2016 – 2021

When interpreting the morphological changes that have been observed by the surveys and reports that are listed in Section 1.1, it is useful to have understanding of the physical forcing factors, primarily the wave climate and tidal regime, that have prevailed over this period because it is these factors which govern the observed morphological changes.

Throughout the current phase of the Cell 1 Regional Coastal Monitoring Programme, wave rider buoys (Plate 1-1) have been deployed off the coast of Newbiggin (Northumberland) and Whitby and Scarborough (both North Yorkshire). In addition, wave data have been derived from Cefas' WaveNet buoy further offshore at Tyne-Tees and water level data have been collected from tide gauges at North Shields (North Tyneside), Whitby and Scarborough (both North Yorkshire). Whilst each of the three Cell 1 waverider buoys has been out of action for some periods of time, the overall data record is of excellent quality.

Plate 1-1 - Wave rider buoy (image courtesey FugroEMU)

The longest running dataset is from the Cefas Tyne-Tees waverider buoy that forms part of WaveNet. Analysis of the December 2006 to March 2021 data from the Tyne-Tees buoy (Figure 1-1) against a storm threshold of 4m significant wave height (H_s) indicates that the stormiest year over this period was 2010 (thirteen storms above the threshold) whilst the years with the fewest number of storms were 2011 and 2014 (three storms in each year above the threshold). The average number of storms over the fourteen full years between 2007 and 2020 is 6.9 storms per year above the 4m H_s threshold. The average over the five year period 2016 – 2021 was 7.2 storms per year, with 2017 and 2019 being particularly notable for the number of storms recorded above the threshold.

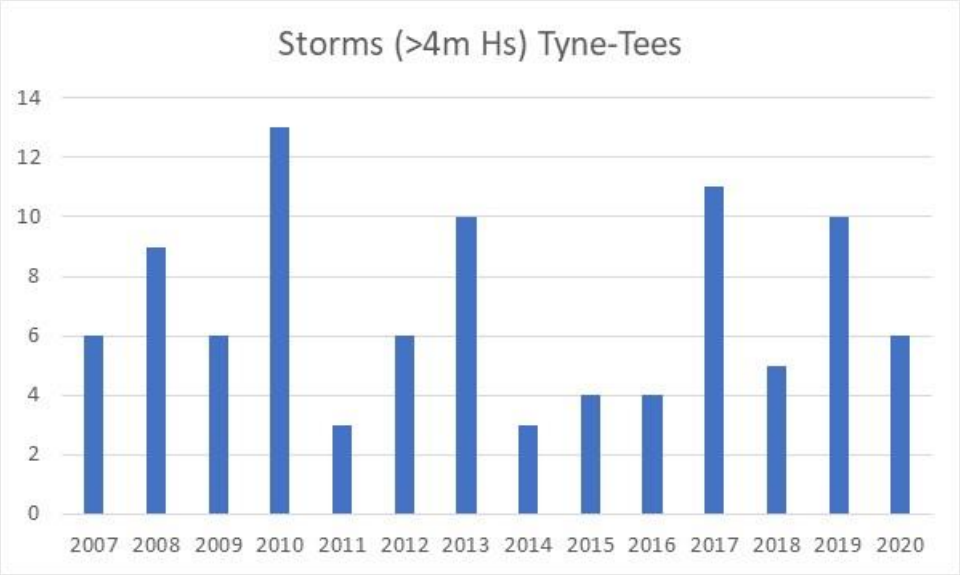


Figure 1-1 – Storms (>4m H_s) at Tyne-Tees Wave Buoy

Similar analysis of data from the Newbiggin, Whitby and Scarborough wave buoys against a storm threshold of 3m significant wave height (H_s) is shown below. Considering full years of data records, over the eight years from 2013 to 2020, on average Newbiggin experiences 6 storms per year above the 3m H_s threshold, with Whitby experiencing 5.1 storms per year and Scarborough 3.8 storms per year. For the most recent five full years, between 2016 and 2020, Newbiggin experienced average conditions, whilst Whitby and Scarborough experienced slightly more storms than average. The years 2017, 2018 and 2019 were noted to be particularly stormy, with 2020 lower than average in terms of number of storms.

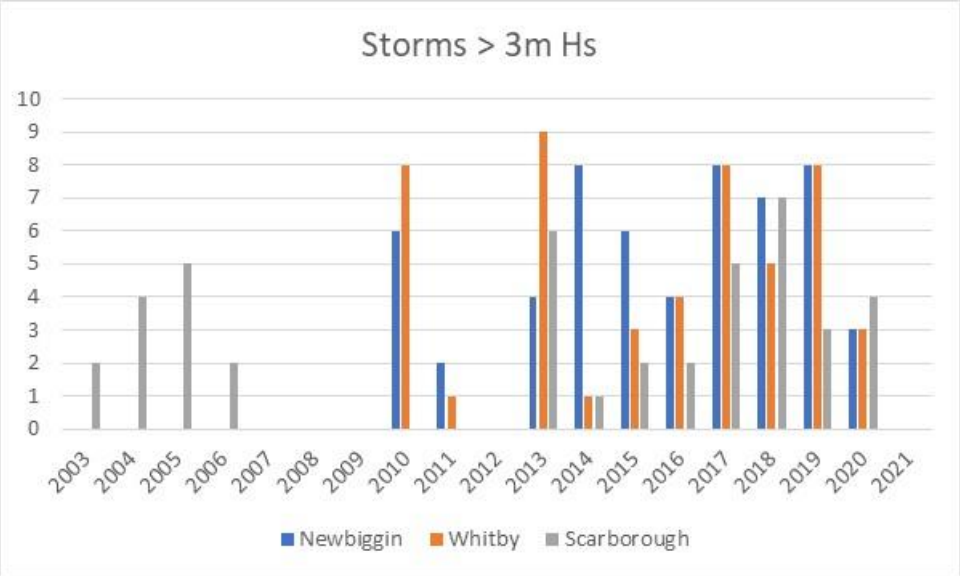


Figure 1-2 – Storms (>3m H_s) at Newbiggin, Whitby and Scarborough Wave Buoys

The largest significant wave heights (H_s) in the records to March 2021 occurred on the following dates:

- Newbiggin 27th February 2018 (6.4m);
- Tyne Tees 27th January 2019 (8.3m);
- Whitby 21st November 2015 (6.7m);
- Scarborough 13th January 2017 (6.7m).

At three sites (Newbiggin, Tyne-Tees and Scarborough) the largest H_s values were recorded during the current five year phase of the programme, whilst at Whitby it was just before the current phase. Also, in September 2020, a Hs value of 6.6m (just 0.1m lower than the recorded highest value) was recorded at Whitby.

Wave roses for the full datasets available for Newbiggin Ness, Whitby, and Scarborough are shown in Figure 1-3. Offshore wave directions incident on the Cell 1 coast are predominantly between 0 and 30 degrees (north to northeast), with a secondary wave approach direction from the northeast to southeast also observed although some parts of the coast are more sheltered from certain fetches than others.

The largest high water levels in the records to March 2021 occurred during the storm surge on the 5th December 2013 when the following levels were reached:

- North Shields 3.98m OD
- Whitby Not recording
- Scarborough 4.39m OD

During the current five-year phase of the programme (2016-2021) the largest high water levels recorded were:

- Whitby 13th January 2017 (3.48m OD)
- Scarborough 10th February 2020 (3.44m OD)

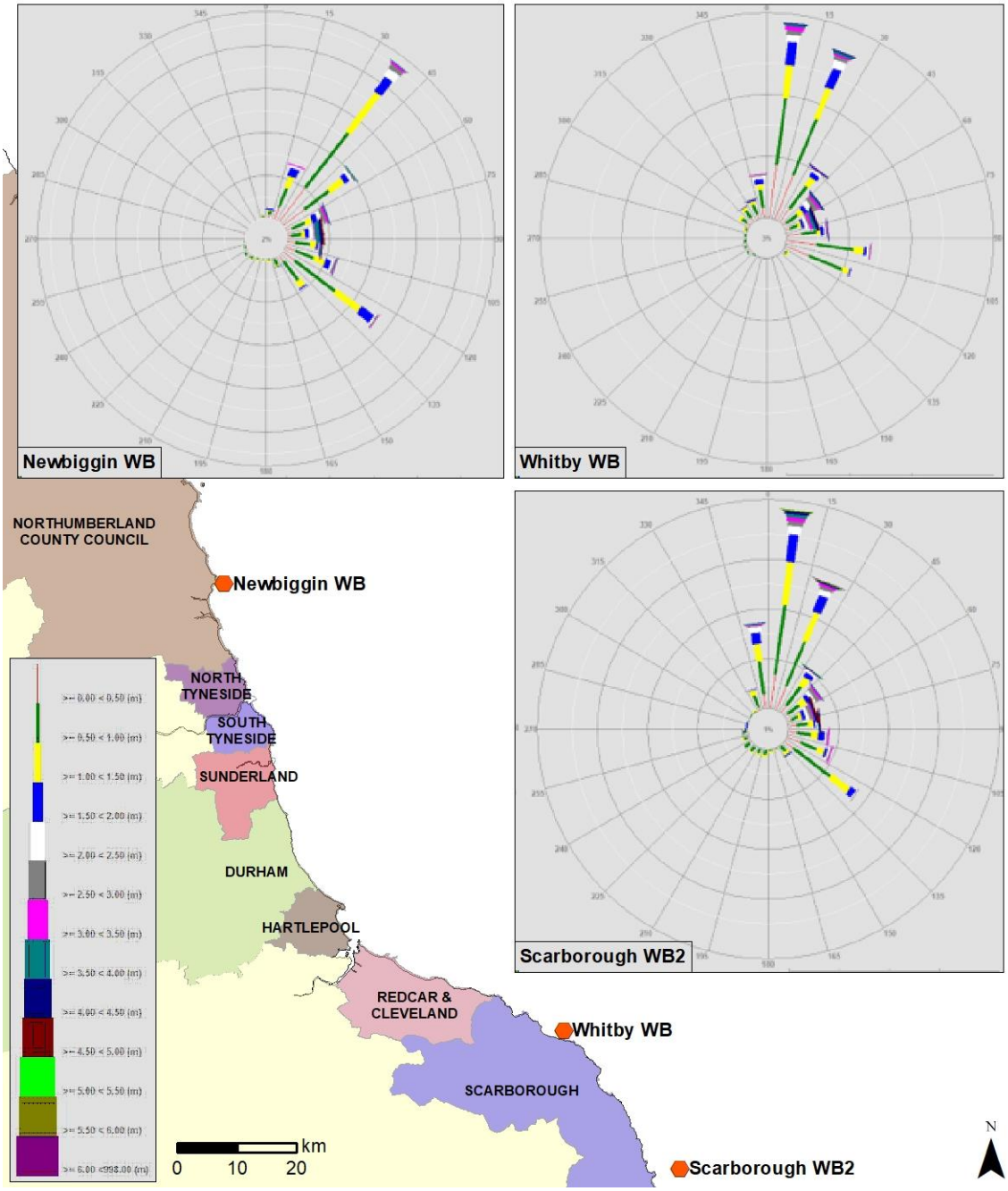


Figure 1-3 – Wave Roses (1st April 2016 to 31st March 2021) from Newbiggin Ness, Whitby and Scarborough

2. Overview of Main Findings 2016 – 2021

2.1 Principal Observations

The monitoring outputs have generally revealed that most of the beaches within the region experience seasonal changes in morphology, with lower, flatter beach profiles in winter compared to summer. Typically this is triggered by winter storms, which remove sediment form the upper beach, causing lowering at the toe of structures or erosion at the toe of dunes, and deposit it on the lower beach or in the shallow nearshore zone. Although there is generally not a strong longshore transport of beach sediment, once drawn down to the lower beach profile fine sediment can become transported in suspension in the water column by the prevailing net southerly tidal currents or, for slightly coarser sediment, along nearshore bars such as at Whitby in North Yorkshire, before being moved back onshore during calmer periods. During summer months, the beaches typically rebuild naturally. This understanding of seasonal changes has been useful in some in areas in avoiding unnecessary and potentially damaging 'knee-jerk' reactions of intervention, sometimes driven by political expediency, upon observations of winter lowering or erosion.

It is also noticeable that in areas of Northumberland and County Durham where colliery spoil tipping has historically occurred, the backing sea cliffs, coastal slopes or sand dunes have become relict features, disconnected from marine processes by the prograding shore. However, after cessation of tipping when the regional coal mines closed (the most recent closure being in 2005) the spoil beaches and spoil cliffs have eroded, by up to 5m per year in places. Although marine erosion of the natural features landward of the spoil has not yet commenced, it will occur once the legacy of the fronting spoil has fully eroded.

In general, cliff-top recession occurs at relatively low rates along many frontages, but where apparent changes have occurred they generally are triggered by periods of prolonged and/or intense rainfall coincident with high tides or stormy seas, or from freeze-thaw cycles in the groundwater within fissures of the cliff. These mechanisms can lead to local rock falls in the harder cliffs and fairly large-scale landslips in the softer cliffs (or small headscarp slippages in areas where layers of till overlay more resistant bedrock). For example, ongoing coastal slippages along the cliffs leading to Cowbar within Redcar & Cleveland, has resulted in abandonment of the original access road and its relocation inland.

The captured aerial photography is also useful in understanding ongoing morphological changes. Whilst the larger estuaries of the Rivers Tweed, Tyne, Wear, Tees and Esk have breakwater and pier control structures at their mouths, many of the small river channels and becks which drain into the North Sea within Cell 1 are unconstrained at their mouths and can adopt differing courses dependent upon preceding physical conditions such as rainfall (affecting river spate) or sea storms (affecting beach changes). In some locations the changing course of these channels across the foreshore can increase, or conversely reduce, exposure to erosion processes along the toe of adjacent dunes or lead to undermining of nearby coastal structures.

In some areas, the cliffs are experiencing cave formation at their bases and when these caves penetrate deep into the rock structure, it can lead to wash-out of softer material behind and the formation of 'sink holes' in the cliff top land. This is most notably occurring along South Tyneside's frontage.

2.2 Northumberland

2.2.1 Monitoring Activities

Northumberland County Council's frontage extends from the Scottish border in the north to Hartley in the south. For the purposes of data analysis, it has been sub-divided into fifteen areas, namely:

- Spittal A (Sandstell Point)
- Spittal B
- Goswick Sands
- Holy Island
- Bamburgh
- Beadnell Village / Beadnell Bay
- Embleton Bay
- Boulmer
- Alnmouth Bay
- Hauxley & Druridge Bay
- Lynemouth Bay
- Newbiggin-by-the-Sea
- Cambois
- Blyth South Beach

Along Northumberland County Council's frontage, coastal monitoring has been undertaken since 2002, initially under a programme for the coast north of the Tyne set up by the predecessor District Councils and amalgamated with the wider Cell 1 programme in 2008. The following data are now available:

Full Measures survey annually each autumn comprising:

- Beach profile surveys along 78 transect lines (commenced 2002[3])
- Beach profile surveys along additional transect lines (commenced 2007)
- Beach profile surveys along additional transect lines (commenced 2010)
- Topographic survey along Holy Island Causeway (commenced 2004)
- Topographic survey along Alnmouth Bay (commenced 2005)
- Topographic survey along Sandstell Point (commenced 2009)
- Topographic survey along Lynemouth Bay (commenced 2020)
- Topographic survey along Newbiggin Bay (commenced 2010)

Partial Measures survey annually each spring comprising:

- Beach profile surveys along 29 transect lines (commenced 2002)
- Beach profile surveys along additional transect lines (commenced 2007)
- Beach profile surveys along additional transect lines (commenced 2010)
- Beach profile surveys along additional transect lines (commenced 2011)
- Topographic survey along Alnmouth Bay (commenced 2005)
- Topographic survey along Sandstell Point (commenced 2009)
- Topographic survey along Lynemouth Bay (commenced 2021)
- Topographic survey along Newbiggin Bay (commenced 2010)

Cliff top survey (bi-annually) at:

[3] Profile BTBC29 has historically been observed from the same GPS base station. As phone signal reception has improved in the area, the opportunity arose to survey the section using VRS (i.e. direct measurement without the need for a base station). This uncovered a height error on the base station of 1.048m, meaning all historical data on this section was 1.048m too low. All profile data has now been corrected and is the correct datum value.

- Colliery spoil edge survey at Lynemouth Bay (commenced 2020)
- Cliff top survey at Newbiggin Point (commenced 2008)
- Cliff top survey at Cambois Bay (Sandy Bay) (commenced 2008)
- Cliff top survey at Cambois Bay (Cambois) (commenced 2009)

Sand extent survey (bi-annually) at:

- Edge of sand survey at Newbiggin Bay, Spital Carrs, (commenced 2011 to determine potential adverse impact on foreshore SSSI of the Newbiggin beach recharge scheme)

Other surveys, comprising:

- Aerial photography and LiDAR survey along the whole frontage in 2010, 2012-13, 2015, 2017 and 2019-20
- Wave data collection with offshore wave-riders deployed at Newbiggin Ness from May 2010 to June 2011 and from June 2013 to present
- Walk-over inspections of coastal defences and natural assets in summer / autumn every two years since 2002.

2.2.2 Rationale

The monitoring programme along the Northumberland coast was initially designed in 2001 to incorporate beach profiles along seventy-eight transect lines, aerial photography and walk-over inspections in order to better understand changes in key areas highlighted by the St. Abb's Head to River Tyne Shoreline Management Plan, which was published in September 1998.

The design of the programme adopted a risk-based approach, meaning that large sections of stable coastline (typically hard rock geology) or areas with few assets at risk of erosion were not surveyed using 2D beach profiles, but instead changes were recorded by the aerial photography and walk-over inspections. Beach profiling then focused on areas where change was anticipated to be more dynamic or where assets were perceived to have been at some potential risk from erosion or overtopping.

The beach profiles were first surveyed in April 2002 along seventy-eight transect lines. These were repeated in autumn 2002 and annually thereafter each autumn during Full Measures surveys. From spring 2003, repeat beach profile surveys were undertaken each spring along twenty-nine representative transect lines in a Partial Measures survey to monitor seasonal cycles of behaviour. In 2007, a further ten profile lines were added to better understand changes along some bays. Over subsequent years small numbers of additional profile lines have also been added. These have been repeated in each Full and Partial Measures survey since then.

Topographic surveys were added to the monitoring programme at Holy Island (2004) to investigate the impacts of raising the road causeway upon the adjacent sand flats. Similar surveys have since been added at Alnmouth (2005) and Sandstell Point (2009) to capture the three-dimensional nature of changes along the foreshore associated with complex behaviour patterns between the foreshore and the adjacent river channels. A topographic survey was also introduced at Newbiggin Bay (2010) to continue the post-project monitoring that was being undertaken to evaluate the performance of a large capital recharge and offshore breakwater scheme constructed in 2007. A topographic survey was introduced in Lynemouth Bay in 2000 to better inform the high rates of erosion of the colliery spoil beaches and cliffs.

Having identified active cliff retreat from aerial photography analysis and the 2-yearly walk-over inspections, cliff top surveys were introduced at Newbiggin Bay caravan park (2007), Sandy Bay caravan park (2007) and Cambois Bay (2009) to capture better data on the location and rates of cliff erosion. A colliery spoil edge survey was introduced in 2020 at Lynemouth Bay to record the high rates of retreat.

Walk-over inspections of the coastal defences and natural assets, such as beaches, dunes and cliffs, commenced in 2002 and have been repeated at 2-yearly intervals since. These

have informed the development of maintenance strategies and applications for funding for capital improvement works under the annual Medium Term Plan process. Data was originally input to both a bespoke MS Access database and the Environment Agency's National Flood and Coastal Defence Database. During the 2011 to 2016 programme the data from the MS Access databases, which had become obsolete, was ported into a SANDS database alongside similar data for the rest of Cell 1.

Aerial photography was undertaken in 1999 (prior to the formal monitoring programme, but intended to help inform the original SMP development) and 2003. In 2010, 2012-13, 2015, 2017 and 2019-20 more accurate orthorectified imagery was captured along with synchronous LiDAR survey. Oblique imagery was also collected.

A wave-rider buoy was deployed off Newbiggin Ness in May 2010 for a period of 1 year to capture data relating to the wave climate and help inform post-project evaluation and future management of the Newbiggin Bay capital recharge and offshore breakwater scheme. After a short gap, a wave rider buoy was re-deployed off Newbiggin Ness in June 2013 and has remained largely operational to the present day.

2.2.3 Key Findings

- On the River Tweed, Sandstell Point spit undergoes notable variations in form due to prevailing marine and river conditions and at times a secondary channel opens across the feature, changing the energy exposure in the inner estuary. The spit is often characterised by a redistribution of sediment between successive surveys with a berm on its crest varying in form from a wide, flat feature centrally located on the spit to a narrow, high feature towards the river side of the spit. The dunes at the mouth of the estuary have experience periods of erosion and landward retreat and periods of stability.
- Along the Spittal coastal frontage, upper beach level changes can be quite large between successive surveys, but there is no clear and consistent trend in behaviour, suggesting the frontage is responsive to its high marine exposure conditions.
- Goswick Sands, Holy Island, Bamburgh, Beadnell village, Beadnell Bay, Embleton Bay and Druridge Bay all tend to be relatively stable and healthy, except for during particularly severe winters or individual storms when cut-back can particularly occurs. However, recovery of beach and dune levels typically occurs within a period of 6 to 12 months.
- The dunes in Alnmouth Bay show significant change in the vicinity of the River Aln dependent upon the position of the unconstrained channel from the river.
- Ongoing erosion of the colliery spoil cliffs and beaches at Lynemouth Bay has occurred, particularly to the immediate north of the defended power station frontage.
- The replenished beach within Newbiggin Bay has exhibited significant redistribution of imported sediment following recharge and offshore breakwater construction in 2007 and a natural general net influx of material due to the quiescent conditions in the lee of the offshore breakwater. The beaches have generally been at a medium to high level and there have been several beach management campaigns to redistribute sand accumulation in the northern part of the bay. Monitoring of the SSSI-notified shore platform in the south of the bay shows the extent of sand on the upper beach fluctuates a small amount, but there is no evidence of the platform being obscured by sand.
- South of Newbiggin, the cliffs at Hawks Cliff have experienced a large rock fall, which has necessitated inland relocation of the England Coast Path. Also, further south along these cliffs towards the River Wansbeck, cliff erosion has been observed ongoing at Sandy Bay Caravan Park.
- Cliff erosion monitoring at Cambois shows locally high rates of erosion, particularly south of the River Wansbeck and walkover inspections in 2020 identified a failed section of gabion baskets at North Blyth. In 2018 there were problems with damage to the dunes along North Blyth caused by the (then ongoing) works to protect the cooling water outfall of the former Blyth Power Station and install the electrical transmission cables for the Blyth Offshore Demonstrator Windfarm, although this now appears to have been repaired by the Contractor for those works.
- Blyth South Beach has experienced a 'sink hole' opening underneath the most southern groyne due to undercutting by the channel of Meggies Burn. Generally, there has been an ongoing overall improvement in the condition of coastal defence assets within the

Northumberland County Council frontage. This is evidenced by the decrease in the number of assets in 'very poor' or 'poor' condition between 2014 (58), 2016 (58), 2018 (55) and the 2020 walkover inspections (51). The number of assets in 'very good' condition is also currently at the highest it has been (8) in recent records.

- The majority of the improvements in the condition of assets can be attributed to the implementation of capital schemes. Since 2014 there have been capital schemes at Seahouses Main Pier, Little Shore Wave Basin, Beadnell, Amble, Boulmer, Alnmouth, Blyth South Beach and Holy Island.
- Scheme development is ongoing at Lynemouth Bay to address the legacy issue of refuse being released into the wider environment from within the historically tipped colliery spoil, due to high rates of ongoing coastal erosion.
- Some frontages have assets which remain in need of maintenance, repair or demolition, including Green's Haven (breakwater), Beadnell (seawall and gabions), Church Hill Alnmouth (retaining wall), Cresswell (cliff landslip), Newbiggin Point (upper coastal slope and piecemeal walls), North Blyth (gabions), Blyth South Beach (groynes and sink hole) and Seaton Sluice harbour (sink hole).

2.2.4 Discussion and Future Recommendations

Long term beach profile data is available from 2002, together with good records from beach topographic surveys, aerial photography, LiDAR, walk-over inspections, and cliff top surveys.

In most areas, beach changes are dominated by seasonal variation with no clear net trend, but cliffs and dunes show erosional responses to storms (and in the case of dunes, post-storm recovery is also demonstrated).

However, in some areas longer term trends of erosion are observed that clearly are distinguishable from shorter-term or seasonal change. Examples include cliff erosion at Sandy Bay or colliery spoil erosion at Lynemouth Bay.

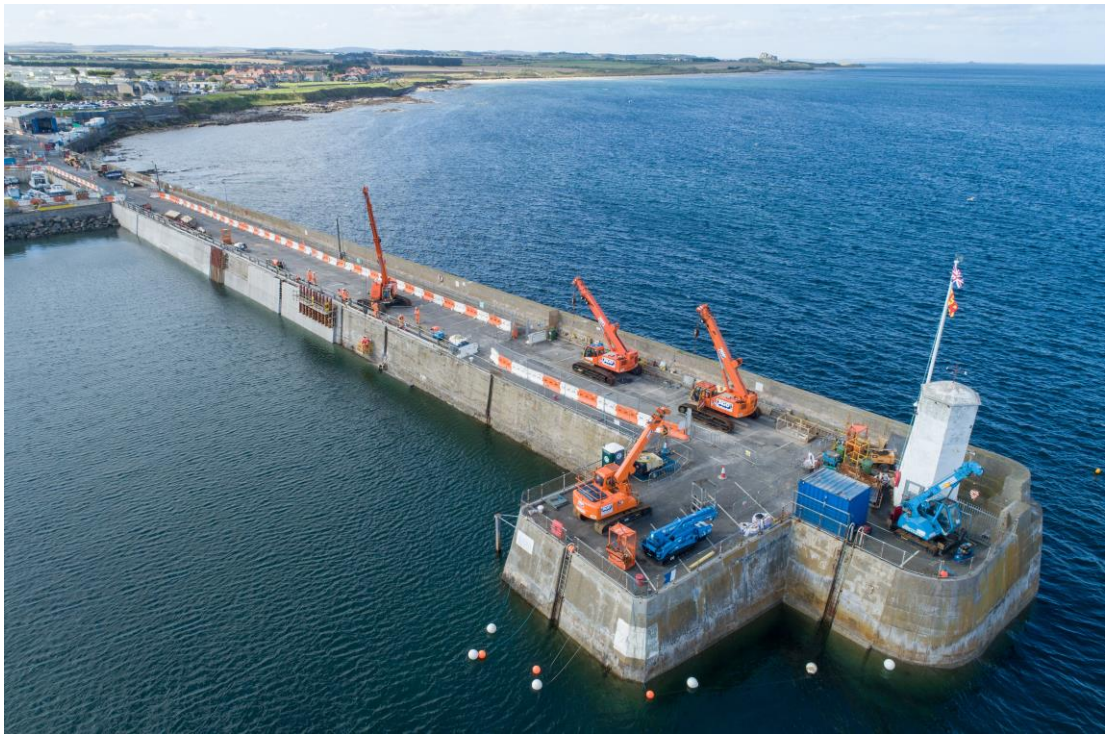
In addition, in more morphologically dynamic areas, such as barrier beaches or unconstrained river channels, progressive (usually accretional) or cyclical (accretion-erosion) patterns in behaviour have been observed.

Confirming these seasonal changes and longer-term trends through ongoing monitoring is important to improve understanding for purposes of shoreline management planning along this frontage. It is therefore strongly recommended that data collection continues uninterrupted into the future with the following addition to the future programme:

- It is planned that bathymetric surveys are undertaken in 2023, extending existing beach profile surveys seaward to the 20m sea bed contour at the centre of Druridge Bay, Newbiggin Bay (seaward of the offshore breakwater), Lynemouth Bay and Blyth South Beach.

It is questioned whether the ongoing basis for the topographic survey along Holy Island causeway and the 'edge of sand' survey at Spital Carrs (Newbiggin Bay) is justified. Both surveys have clearly demonstrated that no adverse effects are being caused by the causeway raising at Holy Island or the coastal defence scheme at Newbiggin Bay in the context of the nearby natural habitat features that were of concern to Natural England. If agreement could be reached by Northumberland County Council with Natural England, these surveys could potentially be removed.

There is some value in collecting and analysing sediment samples from the beaches and sea bed along parts of the Northumberland coast, especially areas like Lindisfarne National Nature Reserve, to better inform understanding of observed changes in morphology and habitat over time.



Seahouses Main Pier, Northumberland

2.3 North Tyneside

2.3.1 Monitoring Activities

North Tyneside Council's frontage extends from Hartley in the north to the River Tyne in the south. For the purposes of data analysis, it has been sub-divided into four areas, namely:

- Whitley Sands
- Cullercoats Bay
- Tynemouth Longsands
- King Edward's Bay (sometimes known as Tynemouth Shortsands)

Along North Tyneside Council's frontage, the following coastal monitoring has been undertaken:

- Full Measures survey annually each autumn/early winter comprising:
  - Beach profile surveys along eight transect lines (commenced 2002)
  - Beach profile surveys along an additional two transects (commenced 2010)
  - Topographic survey along Whitley Sands (commenced 2010)
  - Topographic survey along Tynemouth Longsands (commenced 2011)
- Partial Measures survey annually each spring comprising:
  - Beach profile surveys along all ten transect lines (commenced 2010)
- Aerial photography and LiDAR survey along the whole frontage in 2010, 2012-13, 2015, 2017 and 2019-20
- Walk-over inspections of coastal defences and natural assets in summer/early autumn (commenced 2002 and repeated every two years since).

Cullercoats Bay, North Tyneside

2.3.2 Rationale

The monitoring programme along the North Tyneside coast was initially designed in 2001 to incorporate beach profiles along eight transect lines, aerial photography and walk-over inspections in order to better understand changes in key areas highlighted by the St. Abb's Head to River Tyne Shoreline Management Plan, which was published in September 1998.

As much of the North Tyneside coast is defended, with most cliff top and riverside areas being heavily developed, each of Whitley Sands, Cullercoats Bay, Tynemouth Longsands and King Edward's Bay had at least one profile transect line.

The beach profiles were first surveyed in April 2002 along the eight transects. These were repeated in autumn 2002 and annually thereafter during Full Measures surveys. In 2010 a further two profile lines were added to the surveys and from spring 2010 repeat beach profile surveys were also undertaken along all of the transect lines in Partial Measures surveys to record seasonal cycles of behaviour. Topographic surveys were added in 2010 (Whitley Sands) and 2011 (Longsands) to better capture the extent of seasonal changes.

Walk-over inspections of the coastal defences and natural assets, such as beaches, dunes and cliffs, commenced in 2002 and have been repeated at 2-yearly intervals since. These have informed the development of maintenance strategies and applications for funding for capital improvement works under the annual Medium Term Plan process.

Aerial photography has been undertaken in 1999 (prior to the formal monitoring programme, but intended to help inform the original SMP development), 2003 and 2010, 2012-13, 2015, 2017 and 2019-205. Surveys undertaken since 2010 comprised synchronous capture of LiDAR allowing map-accurate orthorectified imagery to be produced, allowing cliff recession to be measured precisely.

2.3.3 Key Findings

- Beaches along the whole North Tyneside frontage (and dunes where they are present along Tynemouth Longsands and King Edward's Bay) experience fluctuations in level and form due to seasonal variations in wave climate and individual storm events. Over the past 5 years, beach and dune profiles have recorded levels mostly within the range of previous observations. Where lowering beyond the range of previous observation has locally been recorded after storms, the beaches have subsequently recovered. This is classic beach and dune response to seasonal variations, typically with winter storms drawing material from the upper beach and dune toe, and depositing it lower down the beach profile and in the shallow nearshore zone. During calmer periods, typically over summer months, the material is more gradually pushed back up the beach by constructive wave action to restore profile levels.

- The March 2018 storms were the most notably 'damaging' events during the past 5-year period, causing localised erosion of the leading dune edge along Tynemouth Longsands. A combination of natural sediment recovery and management intervention (e.g. fencing) has since enabled the dunes to recover and embryo vegetation growth to occur.

- There have been ongoing localised shallow slumps in the cliff face along the undefended Whitley Bay Miniature Golf Course and the Council has erected warning signs along both the cliff top and the beach below the cliffs during the past 5-year period.

- The walkover inspections reveal that 96% of the assets in North Tyneside are currently in 'fair' or better condition. A major reason for the improvement in condition from the 2018 inspection onwards is completion of many phases of the capital works for the Whitley Bay Seafront Master Plan.

- Significant recent capital or maintenance works include schemes at Whitley Bay's Southern, Central and Northern Promenades (as part of the Seafront Master Plan), outflanking protection at Trinity Road Seawall, and Cullercoats North and South Piers.

- A number of ongoing concerns include the presence of a precarious rock stack near Tynemouth North Point, which has the potential to topple, and the structural condition of the southern tie-in of the Tynemouth Pool wall. The St. Mary's Island causeway also has numerous defects, although these are scheduled for attention as part of the final phase of the Whitely Bay Seafront Master Plan.

- A key observation from the inspections is that maintenance budgets in North Tyneside are being utilised effectively and pro-actively by prioritising the revenue spend on areas flagged up by the 2-yearly walkover inspections undertaken as part of the Cell 1 Regional Coastal Monitoring programme.

2.3.4 Discussion and Future Recommendations

With beach profile data available since 2002 and beach topographic survey records since 2010, together with good records from aerial photographs, LiDAR and walk-over surveys, an understanding of behaviour of the North Tyneside beaches has improved, particularly in relation to seasonal fluctuations and long-term patterns of sediment movement.

It is strongly recommended that data collection continues uninterrupted with no major amendments proposed for the future programme. The only minor addition is that bathymetric surveys are planned to be undertaken in 2023, extending an existing beach profile survey line seaward to the 20m sea bed contour at the centre of Tynemouth Longsands. The survey in 2023 will provide a baseline against which future surveys may be compared.

2.4 South Tyneside

2.4.1 Monitoring Activities

South Tyneside Council's frontage extends from the mouth of the River Tyne estuary in the north, to the outfall south of Whitburn. For the purposes of data analysis, it has been sub-divided into four areas, namely:

- Littlehaven Beach
- Herd Sands
- Trow Quarry (including Frenchman's Bay)
- Marsden Bay

Along South Tyneside Council's frontage, the following coastal monitoring has been undertaken:

- Full Measures survey annually each autumn comprising:
    - Beach profile surveys along 17 transect lines (commenced 2008[4])
    - Topographic survey along Littlehaven Beach (commenced 2010)
    - Topographic survey along Herd Sands (commenced 2008
    - Topographic survey along Trow Quarry (commenced 2008*)
- Partial Measures survey annually each spring comprising:
    - Beach profile surveys along 11 transect lines (commenced 2008)
    - Topographic survey along Littlehaven Beach (commenced 2010)
- Cliff top survey bi-annually at:
    - Cliff top survey at Trow Quarry (incl. Frenchman's Bay) (commenced 2008)
- Bathymetric multibeam transect surveys and sea bed characterisation using grab samples in 2010 and 2015 at Herd Sands
- Aerial photography and LiDAR survey along the whole frontage in 2010, 2012-13, 2015, 2017 and 2019-20
- Walk-over inspections of coastal defences and natural assets in summer/early autumn (commenced 2008 and repeated every two years since).

The above elements of the Cell 1 Regional Coastal Monitoring Programme are complemented by a Local Monitoring Programme, which incorporates laserscan surveys of cliffs in Marsden Bay. This work was initially undertaken by the University of Northumbria (working directly for South Tyneside Council) between February 2015 and March 2017 with laserscan surveys at monthly intervals, but became subsumed within the Cell 1 programme in June/July 2019 and is repeated at 6-monthly intervals, with specific post-rockfall surveys as and when needed. The recent surveys have extended the survey to the Redwell Steps, which were demolished in 2020 and are planned to be replaced in 2021.

[4] Surveys at beach profiles 1bSS11, 1bSS12 and 1bSS13 were undertaken at a different location in 2008 to all subsequent surveys and therefore the 2008 data are excluded from time-series analyses.

Littlehaven Promeande and Seawall, South Tyneside

2.4.2 Rationale

The monitoring programme along the South Tyneside frontage was initially designed in 2008 to incorporate beach profiles, beach topographic surveys, cliff top monitoring, aerial photography, bathymetric and sea bed characterisation surveys, and walk-over inspections to better understand changes in key areas highlighted by the River Tyne to Flamborough Head Shoreline Management Plan 2 (Royal Haskoning, 2007). Some aspects of the programme were also intended to capture suitable data to enable the post-project evaluation of the capital scheme at Trow Quarry, which was completed in 2008.

The beach profiles along 17 transects and topographic surveys at Herd Sands and Trow Quarry were first surveyed in autumn 2008 and then were repeated annually thereafter during the Full Measures surveys. From spring 2009, repeat beach surveys were undertaken along a representative sample of 11 of the beach transects in the Partial Measures surveys to record seasonal cycles of behaviour.

From the Partial Measures survey in 2010 onwards, a topographic survey has also been undertaken at Littlehaven Beach to assist with the appraisal and design of a realigned sea wall. Construction of the new seawall commenced in 2013 and was completed early in 2014. Surveys have been continued since 2014 to monitor beach response to the new structure.

2.4.3 Key Findings

- Beaches throughout South Tyneside exhibit a degree of seasonal variation in form and level, but no significant erosional trends were observed over the latest 5-year period.
- In fact, at Herd Sands, the dunes and beach have experienced considerable accretion, causing sand covering of existing footpaths and fence lines through the dunes.
- Whilst Target Rock experiences ongoing rockfalls, there is no risk of compromising the rock revetment structures installed at Trow Quarry at the present time.
- In addition to existing caves and cliff top sink holes, which at Old Harbour Quarry in particular has enlarged over time, further sink holes have opened at Man Haven (around 2016) and Old Harbour Quarry (around 2019).
- The cliffs in areas such as Frenchman's Bay, Man Haven Bay, Old Harbour Quarry and Marsden Bay are susceptible to local rock falls, especially after periods of heavy rainfall combined with adverse cold weather. A rockfall in Marsden Bay in January 2021 was video-recorded by a member of the public and gained some social media attention.
- Recognising the risks from ongoing cliff erosion, South Tyneside Council initiated the *Marsden Bay Risk Management and Emergency Response Plan* in 2019. This drew from the aerial photography, walkover inspections and laserscan surveys to identify locations where caves are undercutting the cliff toe. In these areas, recommendations to set back the cliff-top path beyond the inland extent of cave penetration (with a suitable buffer added for safety) were implemented. Further considers are ongoing regarding local diversion to a section of the coast road at a vulnerable 'pinch point' where the road edge is close to the cliff top.
- At the time of the most recent (2020) walkover inspections, Redwell Steps/Lifeguard Station in Marsden Bay remained in very poor condition. However, these obsolete structures have since been demolished and replacement steps are planned to be installed in late 2021, allowing the winter period to naturalise the newly exposed section of cliff before access is reinstated. As a result, it is envisaged that the condition of this asset will have significantly improved by the time of the next inspections in 2022. With this asset condition improving, it will mean no defended assets within the South Tyneside frontage will be graded worse than in 'fair' condition, suggesting the maintenance budgets in South Tyneside are generally being utilised effectively.

2.4.4 Discussion and Future Recommendations

The data collected since 2008 provides an excellent basis for identifying patterns of change, but to fully understand the mechanisms governing the changes the monitoring should be continued. The complimentary approach of observing broad characteristics and trends through the Cell 1 Regional Monitoring Programme and then further investigating key concerns through more detailed Local Coastal Monitoring is suitable for this purpose. The on-going development of sinkholes near the clifftop should be carefully monitored through walkover inspections and aerial photography.

The monitoring in its present form is providing suitable information for the appraisal, design and post-project evaluation of capital schemes, and for ongoing operational decisions (e.g. relocation of cliff top footpaths) and therefore is of value and it is highly recommended to continue.

2.5 Sunderland

2.5.1 Monitoring Activities

Sunderland City Council's frontage extends from The Bents to Ryhope Dene. For the purposes of data analysis, it has been sub-divided into three areas, namely:

- Whitburn Bay (also referred to as Sunderland North)
- Sunderland Harbour and Docks (also referred to as Sunderland Central)
- Hendon to Ryhope (also referred to as Sunderland South)

Along Sunderland City Council's frontage, the coastal monitoring undertaken since 2008 comprises:

- Full Measures survey annually each autumn comprising:
    - Beach profile surveys along 52 transect lines (commenced 2009)
    - Topographic survey at Whitburn Bay (commenced 2009)
    - Topographic survey at Hendon to Ryhope (including Halliwell Banks) (commenced 2009)
- Partial Measures survey annually each spring comprising:
    - Beach profile surveys along 13 transect lines (commenced 2009)
- Cliff top survey bi-annually at:
    - Hendon to Ryhope (including Halliwell Banks) (commenced 2009)
- Bathymetric multibeam transect surveys and sea bed characterisation using grab samples at Whitburn Sands and Salterfen Rocks in 2010 and 2015.
- Bathymetric multibeam echo sounder and sub-bottom profiler survey (from Ryhope south to Redcar) undertaken between November 2017 and January 2018
- Aerial photography and LiDAR survey along the whole frontage in 2010, 2012-13, 2015, 2017 and 2019-20
- Walk-over inspections of coastal defences and natural assets in summer/early autumn (commenced 2008 and repeated every two years since).

Roker Pier, Sunderland

2.5.2 Rationale

The monitoring programme along the Sunderland frontage included beach profile surveys that were initially designed and undertaken prior to 2008 as part of a local monitoring programme, but became incorporated within the Cell 1 programme in Partial Measures 2009. Additionally, cliff top monitoring, aerial photography, bathymetric and sea bed characterisation surveys, and walk-over inspections were added as part of the Cell 1 programme from 2008 to better understand changes in key areas highlighted by the River Tyne to Flamborough Head Shoreline Management Plan 2 (Royal Haskoning, 2007).

The monitoring contains a relatively dense network of beach profiles, including along the cliffs at Halliwell Banks to investigate the cliff erosion rates in front of the historical landfill area.

2.5.3 Key Findings

- Beach changes over the past 5-years have generally been within the bounds of previous records, with variability but no clear trend.
- Cliff recession along the Hendon to Ryhope frontage has remained ongoing and average around 1m/year at the northern border of the Halliwell Banks waste site.
- There has been a slight overall improvement to condition of built assets along the Sunderland City Council frontage, largely due to the repair works undertaken to several structures within the Port of Sunderland since 2018, particularly the New South Pier, Stonehill seawall and deck south of New South Pier that all received significant storm damage pre-2018.
- However, there a number of assets within the port that remain in ‘poor’ to ‘very poor’ condition and continue to be a concern. Most notably the collapsed wall fronting the Sewage Treatment Works that has significantly deteriorated, resulting in a large wash out of material. Emergency works are recommended to repair the scour hole whilst a capital scheme is developed to replace the asset.
- Of all the assets along Sunderland City Council’s frontage, only 14% are in ‘good’ or ‘very good’ condition. Whilst it is recognised that this figure is skewed by the high proportion of deteriorating assets in the port, it does reinforce that many assets throughout the frontage would benefit from additional maintenance repairs.

2.5.4 Discussion and Future Recommendations

The data collected since 2008, combined with the earlier beach profile data, provides an excellent basis for identifying changes in beach level and cliff erosion in response to storms. However, to fully understand the mechanisms governing change, and to provide early warning of impending maintenance needs, the monitoring should be continued.

Particular attention should continue to be paid at Halliwell Banks where ongoing cliff erosion has cut-back to the edge of the historical landfill site and several deteriorating assets in the Port of Sunderland which are in need of maintenance and repair.

2.6 County Durham

2.6.1 Monitoring Activities

Durham County Council's frontage extends from Ryhope Dene to Crimdon Beck. For the purposes of data analysis, it has been sub-divided into five areas, namely:

- Featherbed Rocks
- Seaham (Dawdon)
- Blast Beach
- Hawthorn Hive
- Blackhall Colliery

Along Durham County Council's frontage, the following the following coastal monitoring has been undertaken since 2008:

- Full Measures survey annually each autumn/early winter comprising:
    - Beach profile surveys along nine transect lines
- Partial Measures survey annually each spring comprising:
    - Beach profile surveys along six transect lines
- Cliff top survey bi-annually at:
    - Seaham (Dawdon)
- Bathymetric multibeam transect surveys and sea bed characterisation using grab samples at Blast Beach in 2010 and 2015
- Bathymetric multibeam echo sounder and sub-bottom profiler survey (from Ryhope south to Redcar) undertaken between November 2017 and January 2018
- Aerial photography and LiDAR survey along the whole frontage in 2010, 2012-13, 2015, 2017 and 2019-20
- Walk-over inspections of coastal defences and natural assets in summer/early autumn (commenced 2008 and repeated every two years since).

Blast Beach, County Durham

2.6.2 Rationale

The monitoring programme along the County Durham frontage was initially designed in 2008 to incorporate beach profiles, cliff top monitoring, aerial photography, bathymetry and sea bed characterisation surveys, and walk-over inspections to better understand changes in areas highlighted by the River Tyne to Flamborough Head Shoreline Management Plan 2 (Royal Haskoning, 2007).

Some aspects of the programme are specifically intended to capture information relating to erosion of colliery spoil that historically was tipped along some County Durham beaches and the potential for re-activation of relict cliffs that are currently protected by these wide, but eroding, spoil beaches.

2.6.3 Key Findings

- Cliff recession at Dawdon near Seaham has a long term average recession rate of 0.1m/yr.
- The colliery spoil beaches along many parts of County Durham remain wide and protect the backing relict cliffs from exposure to marine action. However, the spoil is eroding, in particular in the more exposed southern part of Blast Beach, at Hawthorne Hive and Shippersea Bay, and along Blackhall Colliery / Horden beach, where the beach ridges can retreat by up to 1.5m over a winter period. All spoil has been eroded from Chemical Beach, north of Noses' Point and cliffs here are now reactivating.
- The outlet channels of Hawthorne Hive and Castle Eden Burn historically have exhibited only relatively modest changes in morphology and position in their respective locations across the foreshore and have only a minor influence on behaviour of the adjacent beaches and cliffs. Indeed, a recent change whereby the channel of the Castle Eden Dene now runs a further 30m south along the toe of the backing cliffs has not triggered any erosion in the cliffs.
- Erosion events of local note include those at Ryhope Dene, Shippersea Bay and Crimdon Dene Caravan Park before the 2018 walkover inspections and the cliff collapses between Shot Rock and Loom and near Easington Colliery in late 2019. In respect of the latter, The National Trust raising warning signs and social media alerts to footpath users. In addition, in January 2021 there was a slippage of the colliery spoil cliffs at Blackhall Colliery, south of (Castle Eden) Dene Mouth, following a period of prolonged intense rainfall and freezing weather conditions.
- Of the assets, some 85% are categorised as 'good' or 'fair' but there are known defects remaining along the Seaham Seawall, Seaham South Pier and Dawdon Dene Outfall.

2.6.4 Discussion and Future Recommendations

The data collected since 2008 provides an excellent basis for identifying changes. To fully understand the mechanisms governing change, and long-term trends and patterns the monitoring should be continued.

This is particularly relevant at the colliery spoil beaches along the frontage which continue to erode landwards. The greatest erosion appears to be occurring to the bay south of Horden Point where a large slip failure has occurred through the coastal footpath between Shot Rock and Loom. All the colliery spoil beaches should be monitored closely to understand when the cliffs will start to re-activate.

2.7 Hartlepool

2.7.1 Monitoring Activities

Hartlepool Borough Council's frontage extends from Crimdon Beck in the north to the North Gare Sands in the south. For the purposes of data analysis, it has been sub-divided into four areas, namely:

- North Sands (including the headland outside the breakwater)
- Middleton (including the headland inside the breakwater)
- Hartlepool Bay
- North Gare Sands

Along Hartlepool Borough Council's frontage, the following coastal monitoring has been undertaken since 2008:

- Full Measures survey annually each autumn/early winter comprising:
    - Beach profile surveys along twelve transect lines
    - Topographic survey along part of North Sands (referred to as Hartlepool North)
    - Topographic survey along Middleton (referred to as Hartlepool Central)
    - Topographic survey along Hartlepool Bay (referred to as Hartlepool South)
- Partial Measures survey annually each spring comprising:
    - Beach profile surveys along twelve transect lines
- Additionally, every five years (starting with 2008 as the baseline year), the Full Measures topographic survey at Hartlepool North is extended to fully cover the whole of North Sands and Hartlepool Headland with a topographic survey. This extends across the boundary between Hartlepool Borough Council and County Durham Council.
- Bathymetric multibeam transect surveys and sea bed characterisation using grab samples at North Sands in 2010 and 2015.
- Bathymetric multibeam echo sounder and sub-bottom profiler survey (from Ryhope south to Redcar) undertaken between November 2017 and January 2018
- Aerial photography and LiDAR survey along the whole frontage in 2010, 2012-13, 2015, 2017 and 2019-20.
- Walk-over inspections of coastal defences and natural assets in summer/early autumn (commenced 2008 and repeated every two years since).

2.7.2 Rationale

The monitoring programme along the Hartlepool frontage was initially designed in 2008 to incorporate beach profiles, cliff top monitoring, aerial photography, bathymetric and sea bed characterisation surveys, and walk-over inspections to better understand changes in key areas highlighted by the River Tyne to Flamborough Head Shoreline Management Plan 2 (Royal Haskoning, 2007).

The Headland, Hartlepool

2.7.3 Key Findings

- There can be considerable variation in beach level and form along the Hartlepool frontage, although the changes across the past 5 years are largely within the bounds of previous recorded changes.
- There are several assets in need of significant maintenance and/or a capital scheme. This is most notable at Middleton Beach (gabion baskets and blockwork wall), Spion Kop (undefended frontage backed by new development), Hartlepool Marina gate (concrete block revetment) and the Hartlepool North Pier.
- However, of the coastal defence assets, some 30% are now in 'very good' or 'good' condition, following completion of the capital works around the Hartlepool Headland, along Seaton Carew and at Hartlepool Town Wall.

2.7.4 Discussion and Future Recommendations

The data collected since 2008 provides an excellent basis for identifying short term changes. To more fully understand the mechanisms governing change, and longer-term trends and patterns it is strongly recommended that data collection continues uninterrupted into the future with no major amendments proposed for the future programme.

Discussion should be held with private defence owners (e.g. PD Teesport for the North Gare Breakwater) about future maintenance or capital scheme commitments, due to the importance of these structures in influencing coastal processes and morphological change along the frontage.

2.8 Redcar & Cleveland

2.8.1 Monitoring Activities

Redcar & Cleveland Borough Council's coastal frontage extends from the South Gare Breakwater in the north to Cowbar Nab, near Staithes, in the south. For data analysis purposes it has been sub-divided into five areas, namely;

- Coatham Sands
- Redcar Sands
- Marske Sands
- Saltburn Sands
- Cattersty Sands (Skinningrove)

Along the Redcar and Cleveland frontage, the following surveying has been undertaken between 2008 and 2011:

- Full Measures survey annually (since 2008) each autumn/early winter comprising:
    - Beach profile surveys along nine transect lines
    - Topographic survey along Coatham Sands
    - Topographic survey along Redcar Sands
    - Topographic survey along Marske Sands
    - Topographic survey along Saltburn Sands
    - Topographic survey along Cattersty Sands
- Partial Measures survey annually each spring (since 2009) comprising:
    - Beach profile surveys along nine transect lines
    - Topographic survey along Redcar Sands
    - Topographic survey along Saltburn Sands
    - Topographic survey along Cattersty Sands
- Cliff top survey annually at Staithes
- Bathymetric multibeam transect surveys and sea bed characterisation using grab samples in 2010 and 2015 at:
    - Saltburn Sands
    - Cattersty Sands (Skinningrove)
- Bathymetric multibeam echo sounder and sub-bottom profiler survey (from Ryhope south to Redcar) undertaken between November 2017 and January 2018
- Bathymetric multibeam echo sounder survey (from Redcar to Robin Hood's Bay) undertaken between November and December 2016
- Aerial photography and LiDAR survey along the whole frontage in 2010, 2012-13, 2015, 2017 and 2019-20.
- Walk-over inspections of coastal defences and natural assets in summer/early autumn (commenced 2008 and repeated every two years since).

This element of the Cell 1 Regional Coastal Monitoring Programme is complemented by a Local Monitoring Programme, which incorporates laserscan surveys of cliffs at Cowbar.

2.8.2 Rationale

The monitoring programme along the Redcar & Cleveland coast was initially designed in 2008 to incorporate beach profiles along nine transect lines, beach topographic surveys at five locations, cliff top monitoring at Staithes, aerial photography and walk-over inspections to better understand changes in areas highlighted by the River Tyne to Flamborough Head Shoreline Management Plan (Royal Haskoning, 2007).

The design of the programme adopted a risk-based approach, meaning monitoring was focused on those beaches fronting developed areas and important infrastructure. Changes in more isolated bays or in hard rock cliffs were recorded using aerial photography and walk-over inspections.

The beach profiles and topographic surveys were first surveyed in autumn 2008 and then were repeated annually thereafter during the Full Measures surveys. From spring 2009, repeat beach surveys were undertaken at three of the topographic survey locations and all nine beach profiles in the Partial Measures surveys in order that seasonal cycles of behaviour could be captured.

A baseline bathymetry and sea bed sediment survey was undertaken at Saltburn-by-Sea and Cattersty Sands (Skinningrove) in 2010 to explore sea bed changes below low water. These surveys were repeated in 2015 to document changes in sea bed elevation and sediment character over a 5-year period.

Skinningrove, Redcar & Cleveland

2.8.3 Key Findings

- Most built defence assets (65%) are in 'good' or 'fair' condition following capital schemes along the Redcar town frontage and at the village of Skinningrove. However, the South Gare Breakwater in particular remains in poor condition despite numerous *ad hoc* repairs by PD Teesport.
- Coatham Dunes are accreting at their western end in the lee of the German Charlies slag banks, just offshore. Erosion at the eastern end, by the caravan park, was observed after storms in 2013 and 2017, prompting a specific investigation in 2018 using historic and recent aerial photography and mapping.
- Redcar Sands, Maske Sands, Saltburn Sands and Cattersty Sands show short term changes (erosion and deposition along various sections and seasonal changes) but no overall net trend.
- The Redcar Sea Defences and Skinningrove Coastal Defence Scheme are both performing well, although both have some minor defects which could be rectified through maintenance.
- Huntcliff, near Saltburn, experienced a landslip in late January 2021, following a period of heavy rainfall and freezing temperatures. Redcar & Cleveland Borough Council closed a section of the Cleveland Way cliff top footpath while the site was being inspected.
- There is an area of ongoing concern at Cowbar, where cliff erosion has already prompted the inland relocation of the cliff top footpath and the access road to Cowbar Cottages. Work is ongoing as part of the Staithes Coastal Strategy to identify suitable management options.
- Overall, the majority of cliff behaviour units are locally active or partly active, with some where recent slippages have occurred being totally active and a small number of others being inactive or dormant. The general trend is therefore for occasional local slippages in many of the cliff behaviour units.

2.8.4 Discussion and Future Recommendations

The data that has been collected since 2008 provides an excellent basis for identifying short term changes, but to fully understand the mechanisms governing the changes and better identify longer term trends the monitoring should be continued. The cliffs at Cowbar should continue to be carefully monitored to determine the risk to the highway and residential cottages, and inform future management decisions. The road is the sole access to Cowbar and the north side of the harbour, which houses the lifeboat station.

Discussion should be held with private defence owners (e.g. PD Teesport for the South Gare Breakwater) about future maintenance or capital scheme commitments, due to the importance of these structures in influencing coastal processes and morphological change along the frontage.

2.9 Scarborough

2.9.1 Monitoring Activities

Scarborough Borough Council's frontage extends from Staithes in the north to Reighton in the south. For data analysis purposes, this area has been sub-divided into eight areas;

- Staithes
- Runswick Bay
- Sandsend Beach, Upgang Beach and Whitby Sands
- Robin Hood's Bay
- Scarborough North Bay
- Scarborough South Bay
- Cayton Bay
- Filey Bay

Along Scarborough Borough Council's frontage, the following surveying has been undertaken:

- Full Measures survey annually each autumn/early winter comprising:
    - Beach profile surveys along 20 transect lines
    - Topographic survey at Runswick Bay
    - Topographic survey along the Sandsend to Whitby frontage
    - Topographic survey at Robin Hood's Bay
    - Topographic survey at Scarborough North Bay
    - Topographic survey at Scarborough South Bay
    - Topographic survey at Cayton Bay
    - Topographic survey at Filey Bay

- Partial Measures survey annually each spring comprising:
    - Beach profile surveys along 20 transect lines
    - Topographic survey at Runswick Bay
    - Topographic survey at Robin Hood's Bay
    - Topographic survey at Filey Bay (Town coverage)

- Cliff top survey bi-annually at:
    - Staithes
    - Robin Hood's Bay (added Spring 2010)
    - Scarborough South Bay (added Spring 2010)
    - Cayton Bay
    - Filey

- Bathymetric multibeam transect surveys and seabed characterisation using grab samples in 2010 and 2015 at:
    - Runswick Bay
    - Sandsend
    - Whitby Sands
    - Robin Hoods Bay
    - Scarborough North Bay
    - Scarborough South Bay
    - Cayton Bay
    - Filey Bay

- Bathymetric multibeam echo sounder survey (from Redcar to Robin Hood's Bay) undertaken between November and December 2016.

- Bathymetric multibeam echo sounder surveys of Runswick Bay undertaken in 2013, 2017 and 2018.

- Bathymetric multibeam echo sounder survey (from Robin Hood's Bay to Flamborough Head) undertaken between November 2015 and March 2016.

- Aerial photography and LiDAR survey along the whole frontage in 2010, 2012-13, 2015, 2017 and 2019-20.

- Walk-over inspections of coastal defences and natural assets in summer/early autumn (commenced 2008 and repeated every two years since). An additional inspection of the built assets was also undertaken in 2009 and 2015.

2.9.2 Rationale

The monitoring programme along the Scarborough Borough Council frontage was initially designed in autumn 2008 to incorporate beach profiles along 20 transect lines, beach topographic surveys at seven locations, cliff top monitoring at three locations, aerial photography and walk-over inspections to better understand changes in areas highlighted by the River Tyne to Flamborough Head Shoreline Management Plan (Royal Haskoning, 2007). Cliff top monitoring at a further two locations was added in 2010.

The design of the programme adopted a risk-based approach, meaning monitoring was focused on beaches backed by developments or coastal communities. Changes in more isolated bays or in hard rock cliffs were recorded using aerial photography and walk-over inspections.

The beach profiles, topography and cliff top monitoring were first carried out in autumn 2008 and then were repeated annually thereafter during the Full Measures surveys. From spring 2009, repeat Partial Measures surveys were undertaken along a representative sample of the topographic surveys and all beach transects to document seasonal cycles of behaviour.

During the 2011 Partial Measures survey, additional topographic surveys were undertaken at Scarborough North and South Bays and along the Sandsend to Whitby frontage. This resulted from concerns about exceptionally low beach levels fronting the revetments protecting Sandsend Road, running between Sandsend and Whitby, which were observed in January 2011. Additional data were also collected at Scarborough to support potential project appraisal reports in both the North and South Bays.

Baseline bathymetry and sea bed sediment surveys were undertaken in 2010 to characterise beach profile changes below MLW. A repeat survey was undertaken in 2015 to determine changes in sea bed elevation and sediment character. These data will help understanding of the links between beach erosion and offshore sediment movement.

South Cliff, Scarborough

South Cliff, Scarborough

2.9.3 Key Findings

- Beaches along Runswick Bay, Sandsend-Upgang-Whitby, Robin Hood's Bay, Scarborough North Bay, Scarborough South Bay, Cayton Bay and Filey Bay show evidence of seasonal variations and, at times, storm-induced lowering, but there are no significant long term net trends. In general, surveyed beach levels remained within the envelope of previous records during the period 2016 – 2021.
- Over this period, the clear majority (approximately 85-95%) of cliff behaviour units showed little significant change along the frontage. The majority are locally active or partly active, with some where recent slippages have occurred being totally active and a small number of others being inactive or dormant. The general trend is therefore for occasional local slippages in many of the cliff behaviour units. However, general ongoing changes were noted along parts of Tenants' Cliff in Cayton Bay, along the south side of Filey Brigg and at Hunmanby Gap. More specific rock fall or landslip events were recorded at:
    - **Runswick Bay** (landslip) - In late January 2021, following a period of heavy rainfall and freezing temperatures. The HM Coastguard estimated 200 tonnes of cliff material fell onto the beach.
    - **Port Mulgrave** (landslip) - In late January 2021, following a period of heavy rainfall and freezing temperatures. This was reactivation of part of an earlier, 2016, landslip that left recently installed metal access steps to the beach dangling precariously.
    - **Whitby** (landslip) - In early January 2021 following a period of heavy rainfall. The North York Moors Park Authority closed a 1.4 km section of the Cleveland Way between Whitby Abbey Farm and Saltwick Bay, diverting the National Trail to an alternative route. The intention is to set-back the path once it is known if any subsequent slippages occur along this section.
    - **Boggle Hole** (rock fall) - A small cliff collapse at the narrow, steep cove of Boggle Hole hospitalised a young girl with serious, but not life-threatening injuries. The collapse was described as "a square metre of material falling from a height of 30 feet".
    - **Staithes** (rock fall) – Tragically, a young child was killed in August 2018 due to a local rock fall in section of cliff to the east of Staithes.
    - **South Cliff Clock Café** (landslip) – In early 2018, a shallow-seated slippage occurred which lead to the collapse of an historic masonry retaining wall and resulted in the closure of the Victorian beach chalets.
    - **Port Mulgrave** (landslip) - In 2016 a large landslip occurred, resulting in the North York Moors National Park Authority closing public footpath access.
- 85% of the built defences across Scarborough Borough Council's frontage are in 'fair' or better condition. The following capital schemes were successfully completed between 2016 and 2021:
    - **South Cliff Clock Café** – Stabilisation of the landslip-affected area of cliff and construction of a new retaining wall, completed in December 2020.
    - **Scarborough Spa** – A £13.5M cliff stabilisation scheme to the rear of the Spa Complex was completed in February 2020, involving a pile array augered into bedrock to protect against deep-seated landslips, soil nails to protect against shallow and superficial slippages, and various retaining walls, drainage and landscaping works. Capital refurbishment to the seawall was also undertaken in 2018.
    - **Whitby**– An £9M refurbishment of the piers was undertaken in 2019 and a £2M flood wall was constructed along Church Street in 2019-2020.

- **Filey Flat Cliffs** – Urgent (temporary) works were undertaken to improve the stability of the cliffs at the sole access road to the Flat Cliffs hamlet. These works were completed in 2018.
- **Runswick Bay** – A £2M coastal protection scheme involving construction of a rock fillet (incorporating novel ecological enhancements), placed against the existing masonry blockwork seawall, was completed in 2017. To enable this scheme, Yorkshire Water relocated its sewer asset that ran across the foreshore seaward of the seawall in September 2016.
- **Cayton Bay** – Repairs were made to the toe of the access steps in 2016.
- **Sandsend Road** – A coast protection and slope stabilisation scheme was completed in 2016 (having commenced in 2015) involving a stepped pre-cast concrete revetment with upper Dycel units and a concrete toe beam, along with drainage and re-grading works in the backing coastal slopes.

2.9.4 Discussion and Future Recommendations

The data that has been collected since 2008 provides an excellent basis for identifying changes, but to fully understand the mechanisms governing the changes the monitoring should be continued. It is strongly recommended that data collection continues uninterrupted into the future with no major amendments proposed for the future programme.

This will be of particular use in informing forthcoming coastal strategies, studies and capital schemes, such as Staithes Coastal Modelling, Filey Seawall (wall repairs and outflanking works) and the Scarborough Coastal Defence Strategy Refresh.

3 Case Studies

3.1 Holy Island

The Holy Island of Lindisfarne is an island which lies approximately 1.5km off the coast of Northumberland. Prior to construction of the causeway in the mid-20th Century, access to Holy Island from the mainland was across the intertidal area between the two.

The causeway, which is at similar elevations to the adjacent intertidal flats, was constructed between 1954 and 1966 across the shortest distance between the mainland and the island. At the request of Natural England (then English Nature), monitoring of the morphological changes either side of the causeway has been undertaken as part of the Cell 1 Regional Monitoring Programme since 2004. This was instigated in response to concerns by the organisation that the causeway was causing increased rates of sedimentation, leading to greater colonisation of the muddy sandflats with saltmarsh species, especially the common cordgrass *Spartina anglica*[5]. The availability of wide expansive inter-tidal muddy sandflats is seen as one of the principal features of the Lindisfarne National Nature Reserve (NNR) since it attracts over-wintering wader bird species in vast numbers. Attempts to manage the spread of the invasive *Spartina anglica* have included hand-pulling and digging in the early 1970s, chemical control between 1977 and 1994 and most recently roto-burying between 1995 and 2002. Since 2002 there has been no management of the *Spartina anglica*.

It is important to note that processes at, and near to, the causeway are part of a wider dynamic geomorphological system that comprises:

- Goswick Sands – a barrier beach extending towards Holy Island which has naturally extended in length and prograded further offshore since historic maps began in 1860 to the present day;
- Stable or accreting sand dunes on Holy Island at The Snook
- Accreting inter-tidal muddy sandflats and fringing coastal saltmarsh of Holy Island Sands and Fenham Flats (south of the causeway); and
- Wide sandy beaches of Ross Back Sands, with backing sand dunes at Ross Links and Old Law which have been accreting and prograding seawards since at least the 1940s.

These features can be seen in Figure 3-1 based on the 2020 aerial photography of Lindisfarne NNR collected as part of the Cell 1 programme, whilst the corresponding LiDAR imagery in Figure 3-2 shows the bathymetry and topography of the area. The mapped coastal saltmarsh and seagrass (*Zostera*) habitats from the terrestrial ecological mapping element of the Cell 1 programme can be seen in Figure 3-3 based on the 2017 aerial photography (the 2020 ecological mapping is not available at the time of writing).

[5] *Spartina anglica* was re-classified as *Sporobolus anglicus* after a taxonomic revision in 2014, but is still commonly referred to by its original name in wider parlance.

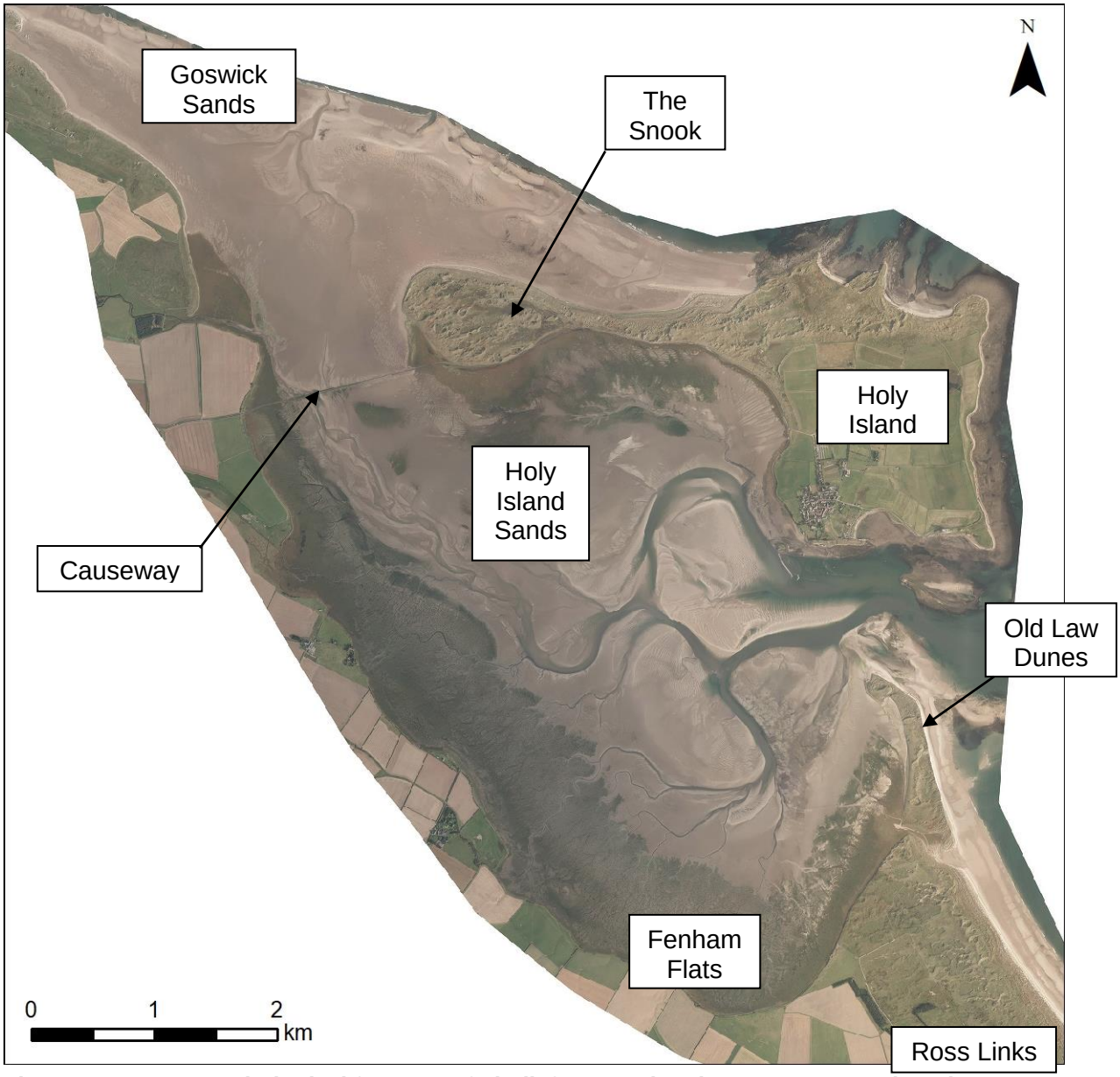


Figure 3-1 – Geomorphological features of Lindisfarne National Nature Reserve (2020)

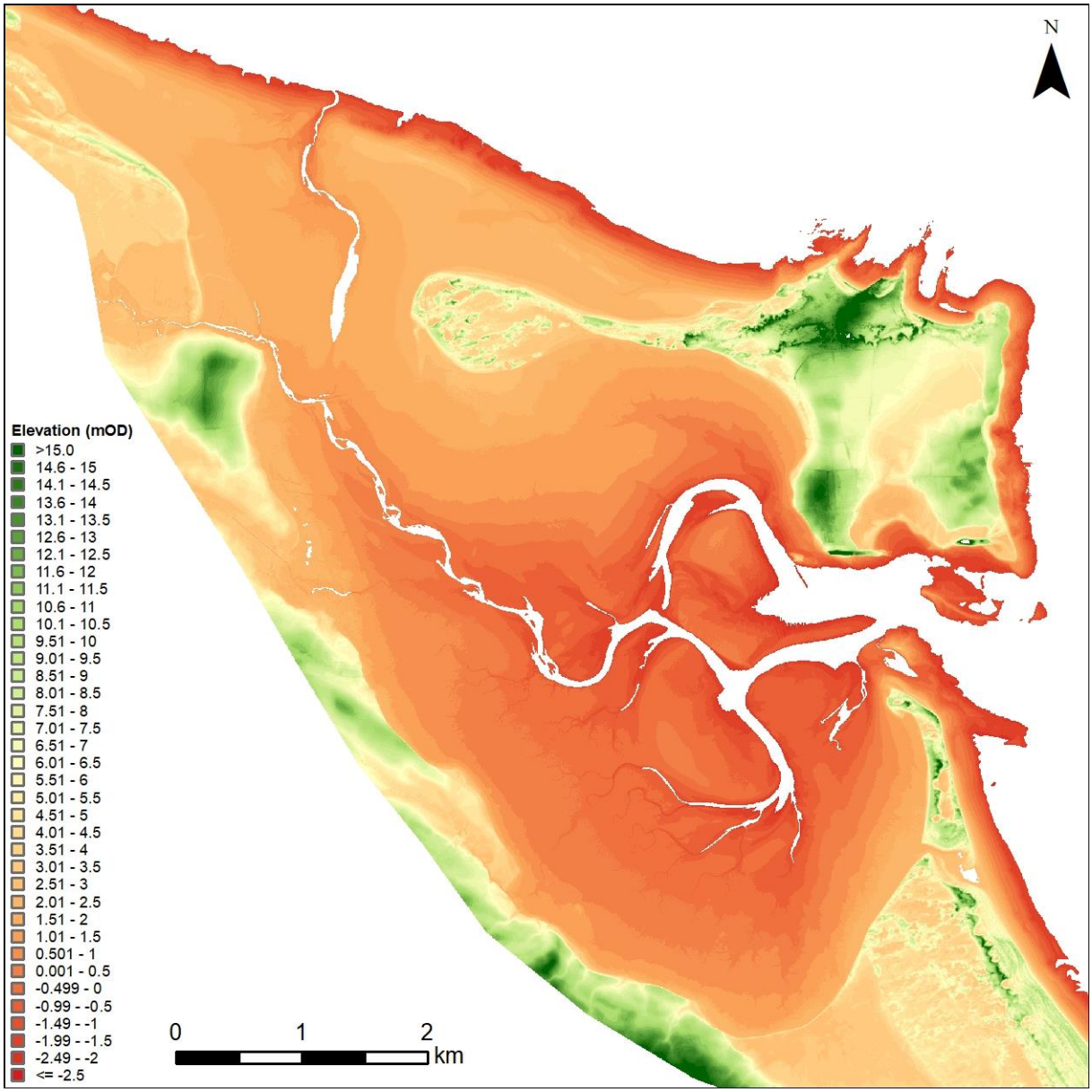


Figure 3-2 – Bathymetry and topography of Lindisfarne National Nature Reserve (2020)

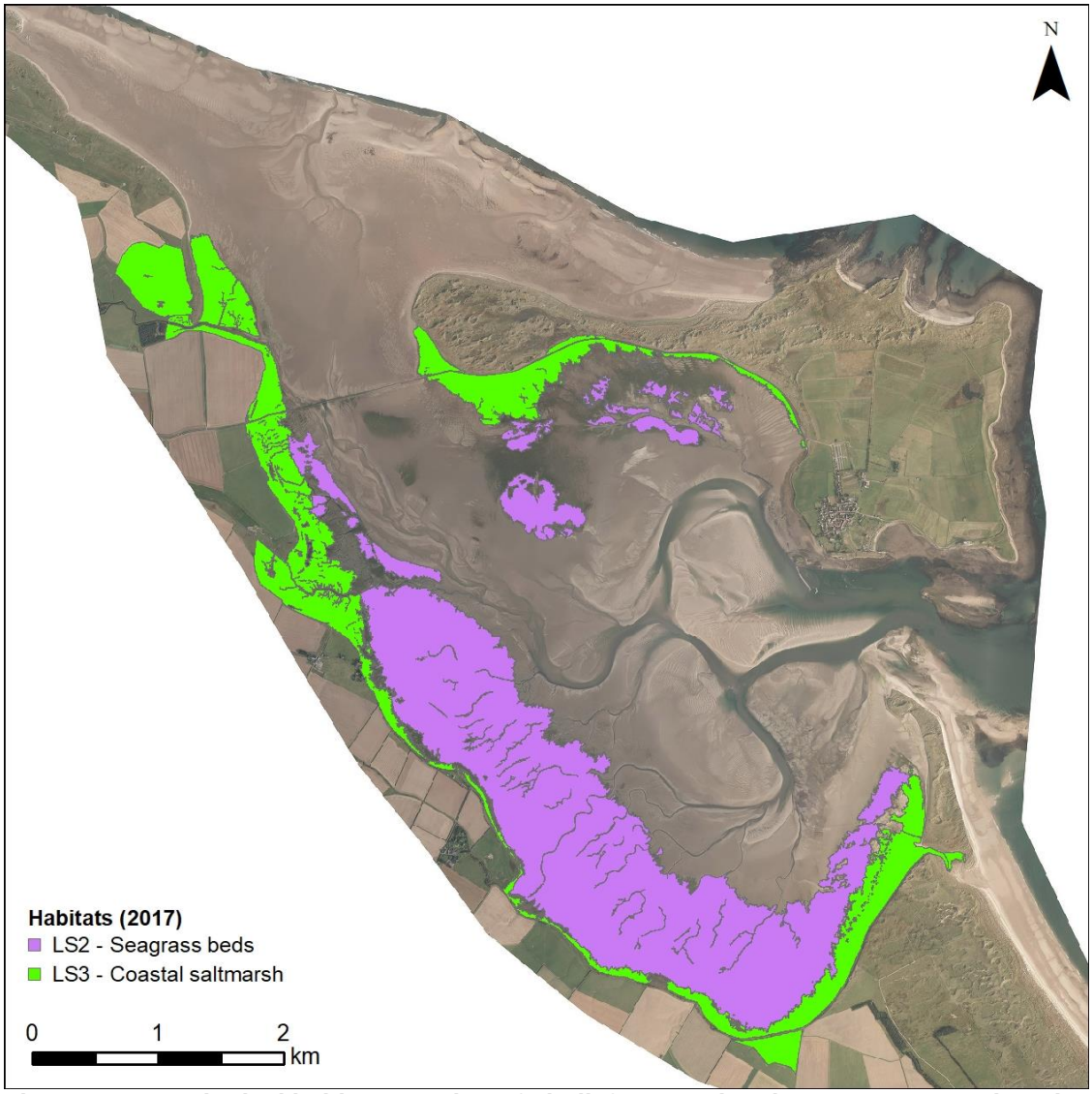


Figure 3-3 – Ecological habitat mapping of Lindisfarne National Nature Reserve (2017)

The areas of saltmarsh that was mapped in 2017 can be compared against those mapped from the 1940s aerial photography in Figure 3-4. It can be seen that there has been an expansion in saltmarsh area over the past decades. However, monitoring the topography of the tidal flats either side of the causeway between 2004 and 2020 has identified no trend in sedimentation that can specifically be attributed to the causeway itself (example shown in Figure 3-5). Furthermore, a comparison of LiDAR data from 2010 and 2020 (Figure 3-6) shows that the deposition rates across Lindisfarne NNR are relatively consistent and there is no tendency for greater sedimentation in the vicinity of the causeway.

This demonstrates that sedimentation rates across the NNR are driven by landscape-scale geomorphological change, strongly influenced by the prograding barrier beach at Goswick Sands and the prograding dunes at Ross Links and Old Law. As sedimentation occurs, currently at a rate that outpaces sea level rise, so the tidal flats become more conducive to colonisation by saltmarsh species, initially the pioneering *Spartina anglica* and then a succession of other species. This, coupled with cessation of management of the *Spartina anglica* by roto-burying in 2002, has led to the observed increase in saltmarsh habitat in Lindisfarne NNR over recent decades.

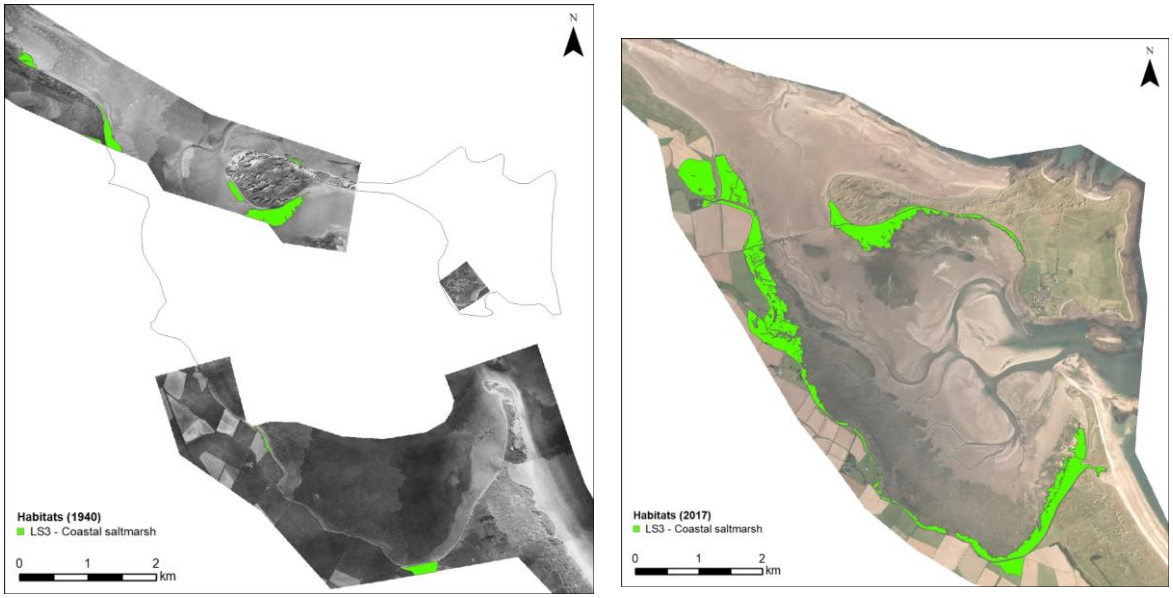


Figure 3-4 – Saltmarsh extent in 1940s (left) and 2017 (right)

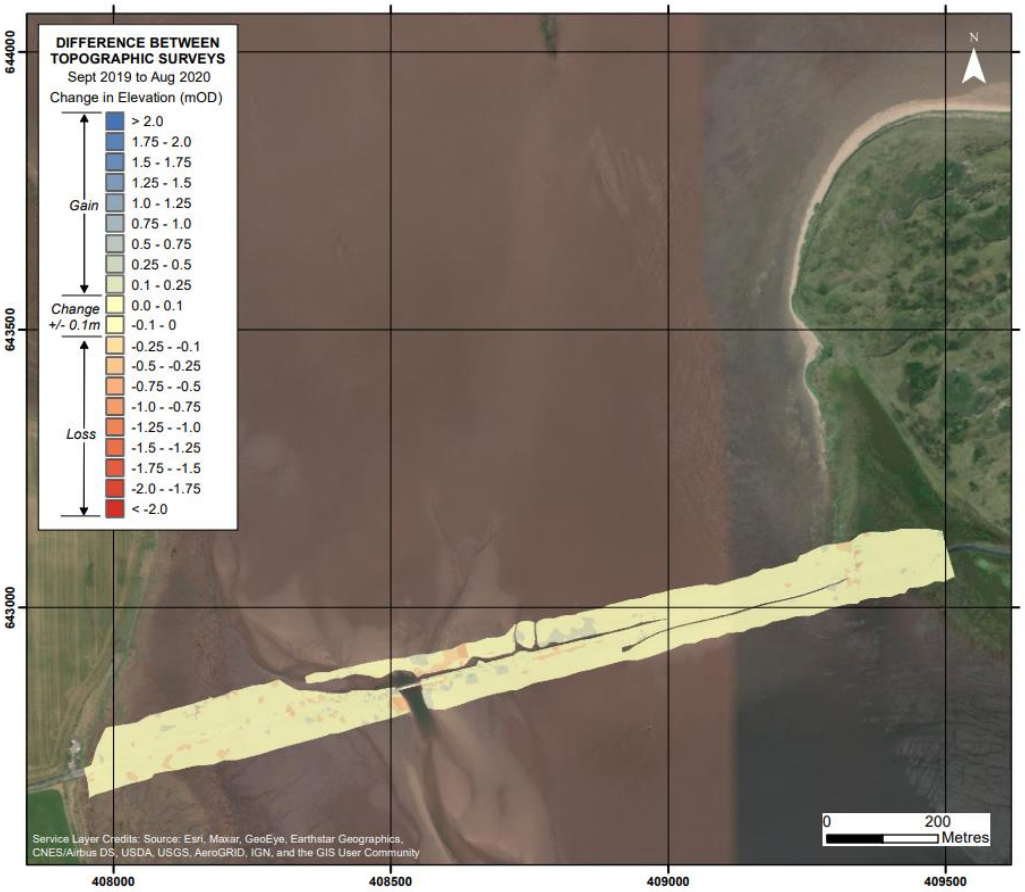


Figure 3-5 – Difference in elevation between 2019 and 2020 topographic surveys adjacent to the causeway

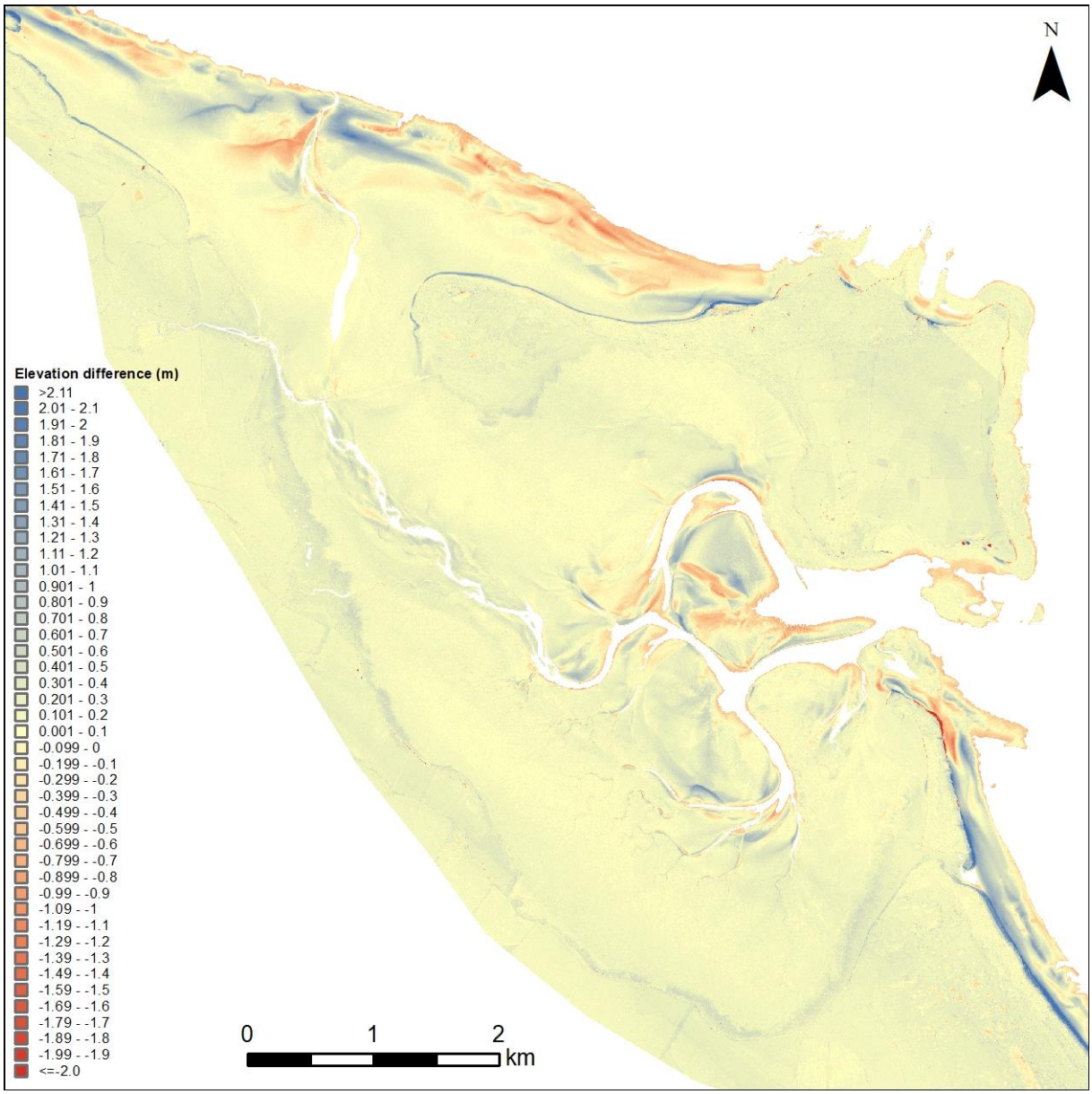


Figure 3-6 – Difference in elevation between 2010 and 2020 LiDAR surveys showing no notable exacerbation of deposition in the vicinity of the causeway

3.2 Lynemouth Bay

Lynemouth Bay extends between Snab Point in the north and Beacon Point in the south, and is intercepted by the narrow, unconstrained channel of the River Lyne.

The beaches in Lynemouth Bay experienced extensive tipping of colliery spoil from 1934 to 2005, resulting in an artificially advanced shoreface, which led to subsequent reclamation and development with the Lynemouth Power Station and coal stocking yard.

At the peak of the recorded tipping, over 1.5m tonnes was tipped in one year, and in each year from 1965 to 1983 around 1m tonnes was tipped annually. In total, it is likely that over 30m tonnes of colliery waste was tipped at Lynemouth over seven decades.

The backing sea cliffs and coastal slopes to the north of the bay and the backing sand dunes to the south became detached from marine processes and currently are stable, relict features, but the colliery spoil cliffs or colliery spoil beaches in front of them are actively eroding landwards since cessation of colliery spoil tipping in 2005.

Monitoring of coastal change in Lynemouth Bay has been undertaken as part of the Cell 1 Regional Coastal Monitoring Programme (or its predecessor programme across Northumberland) since 2002, with aerial photography and beach profile surveys. Various profiles have been added or removed over time in accordance with Table 3-1 and the location of these profiles is shown in Figure 3-7. Annual average erosion rates, based upon the most up to date data, are also shown in the table.

Table 3-1 – Beach profile surveys in Lynemouth Bay

Profile	Location	First Survey	Latest Survey (at the time of writing)	Landward recession of MHWS over period stated		Comments
				Total recession (m)	Average annual rate (m/year)	
1aCMBC03	Northern end of Lynemouth Bay, near Snab Point	02/05/2002	28/11/2019	2	0.1	Stable cliffs
1aCMBC03A	Northumberland County Council land	01/10/2007	21/04/2020	29	2.3	Profiles CMBC03A and CMBC03B were added to the programme in October 2007
1aCMBC03B	Coal Authority land	01/10/2007	21/04/2020	58	4.6	
1aWDC01	Power Station Revetment	03/05/2002	22/04/2016	67	4.8	No longer surveyed as the fronting spoil beach has eroded back to the revetment
1aWDC02	Lyne Sands	03/05/2002	28/11/2019	54	3.1	Recession based on seaward berm
1aWDC03	Southern end of Lynemouth Bay	03/05/2002	28/11/2019	55	3.1	

Figure 3-7 – Beach Profile Survey Locations in Lynemouth Bay

Management works are proposed at Lynemouth Bay in 2021/22 as a capital scheme to manage the unwanted release of plastics and other refuse wastes from four locations within the bay into the wider environment as the surrounding colliery spoil is eroded. To investigate recent changes in the shoreline position, LiDAR survey data have been compared for the years 2000 and 2019. The 2000 data is available from the Environment Agency at 2m horizontal resolution, with the 2019 data being obtained from the Cell 1 Regional Coastal Monitoring Programme at 1m horizontal resolution.

These data have been used to develop Digital Ground Models (DGMs) in a Geographical Information System (GIS) for each year. Output plots very clearly show significant changes in coastline position over this 19 year period. Figure 3-8a shows a representation of the shoreline in the vicinity of Locations 1 and 2 of the capital scheme, where the plastics and refuse is proposed to be removed, from 2000, with a corresponding plot from the year 2019 shown in Figure 3-8b. Similar plots are shown in the vicinity of Locations 3 and 4 of the capital scheme for the years 2000 and 2019 in Figures 3-9a and 3-9b, respectively. All plots show that the coastline has eroded back to encroach upon areas of tipped colliery spoil, and this is the reason why plastics and other refuse material buried within the colliery spoil in Locations 1 – 4 has become progressively exposed and released into the wider environment.

A typical rate of retreat in the vicinity of the most rapidly eroding section (in the vicinity of Location 2) over this 19 year period is around 3 m / year, although this value might be misleading because tipping continued until 2005 and will have influenced the net rate of recession. Therefore, the beach profiles provide a more accurate rate of recession since cessation of tipping in the most rapidly eroding areas, since the profiles in those locations began in 2007.

The significant erosion since 2000 can also be observed in Figures 3-10a and 3-10b, showing slope gradient (i.e. the demarcation of flatter areas (in yellow) and steeper areas (in red)) in the years 2000 and 2019 respectively. The red zones reflect the edge of the colliery spoil beach and the edge of the colliery spoil cliffs. It can clearly be seen that in the vicinity of Location 3 the existing cliffs were better protected by the presence of a colliery spoil beach, but as that had been eroded away entirely at this location by 2019, erosion of the backing cliffs had commenced.

Figure 3-11 presents a difference plot of elevation changes between 2000 and 2019 at Lynemouth Bay and it can very clearly be seen by the areas of yellow and red that significant areas of erosion have occurred between Locations 1 and 4 (and indeed along the land south of Location 1). Elsewhere there are no changes in land elevation (grey areas) except for some land areas where deposition has occurred (blue areas), presumably reflecting the areas that were worked as part of an earlier Lynemouth Land Reclamation Scheme in around 2006 when the travellers' site formerly on the cliff top was moved to landward of the road and some of the seaward colliery spoil was excavated and buried at the original travellers' site.

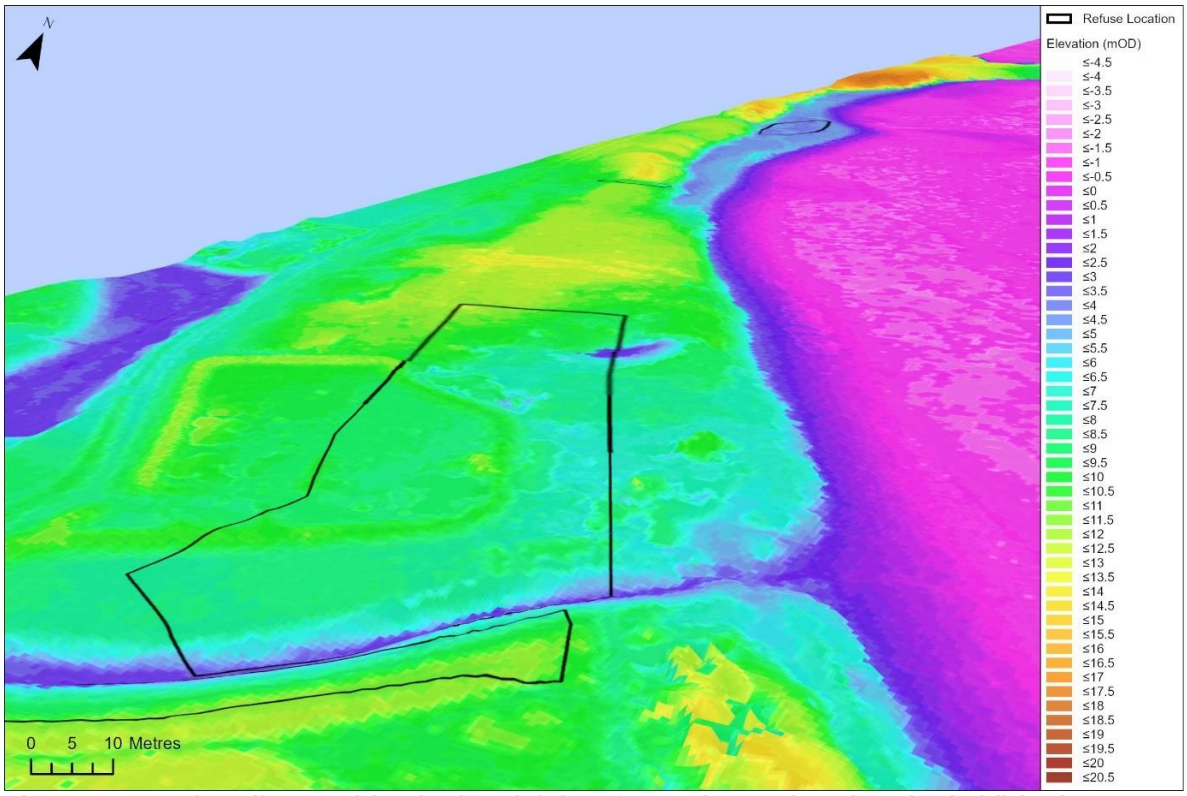


Figure 3-8a – Shoreline Position in the Vicinity of Locations 1 (near) and 2 (mid) in the Year 2000

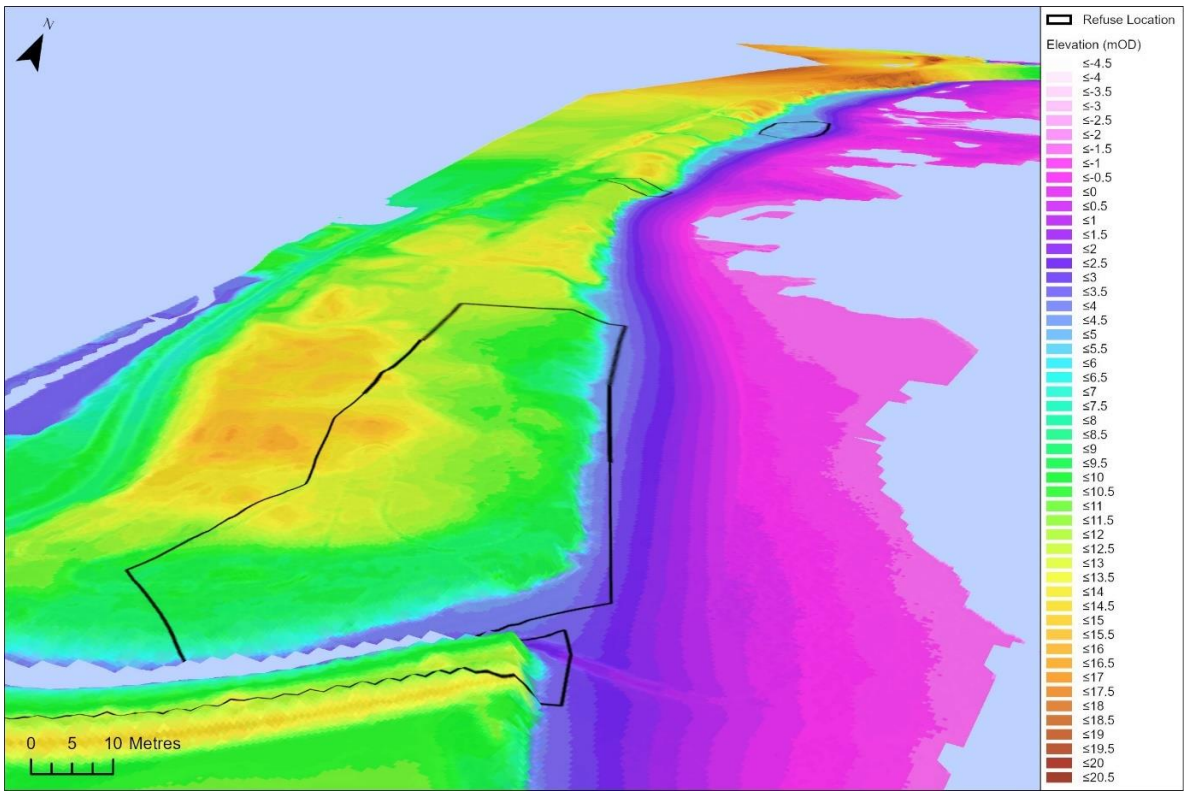


Figure 3-8b – Shoreline Position in the Vicinity of Locations 1 (near) and 2 (mid) in the Year 2019

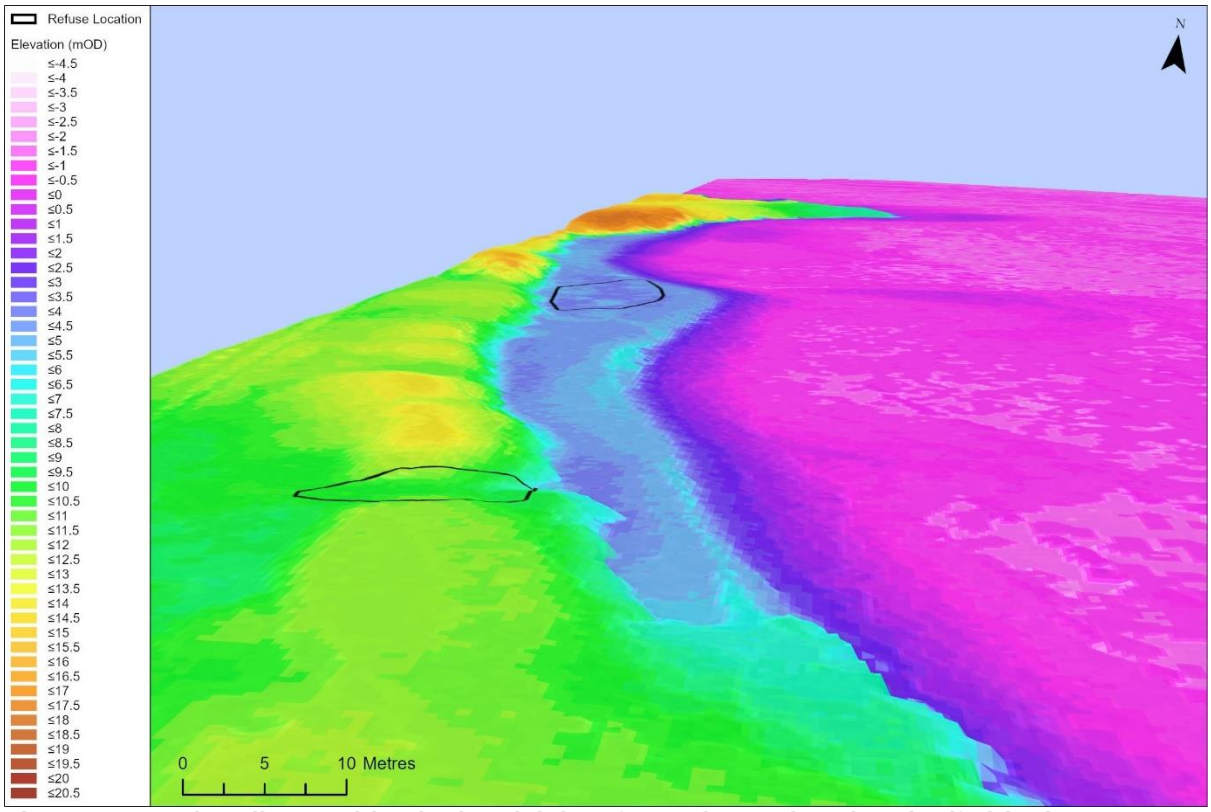


Figure 3-9a – Shoreline Position in the Vicinity of Locations 3 (near) and 4 (far) in the Year 2000

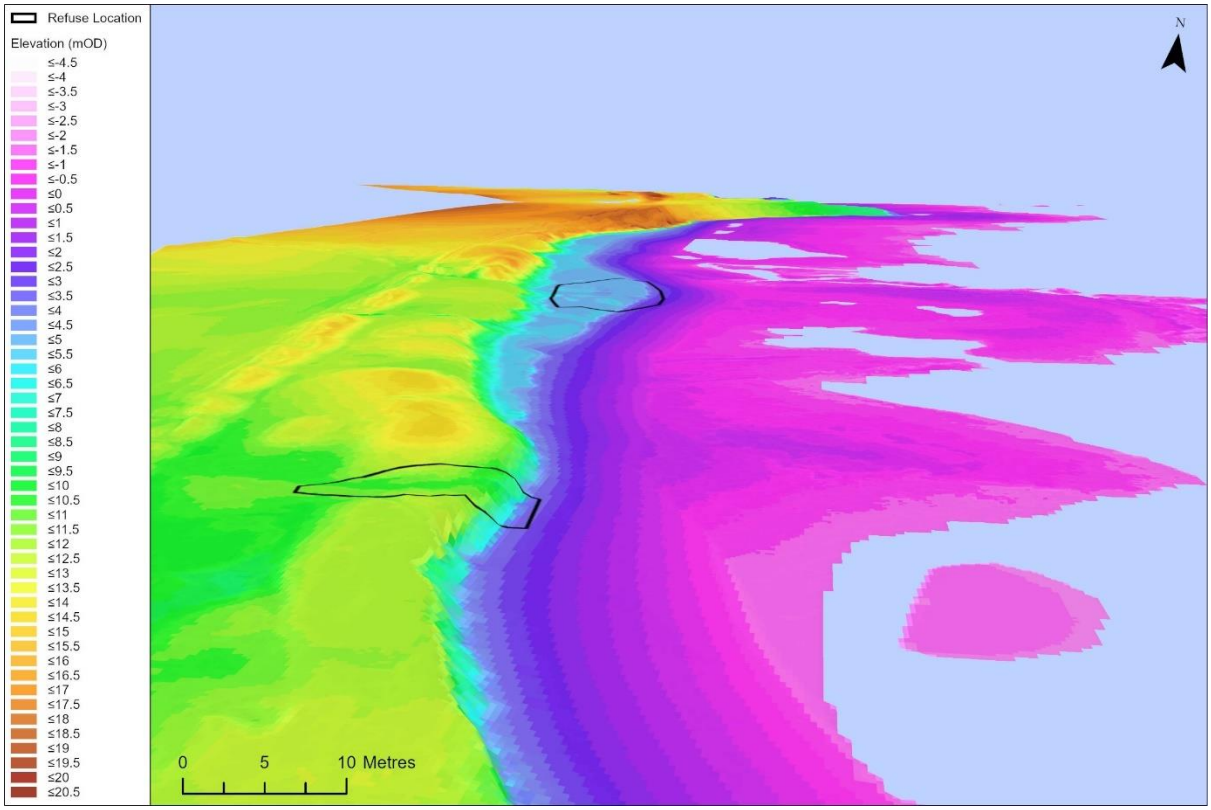
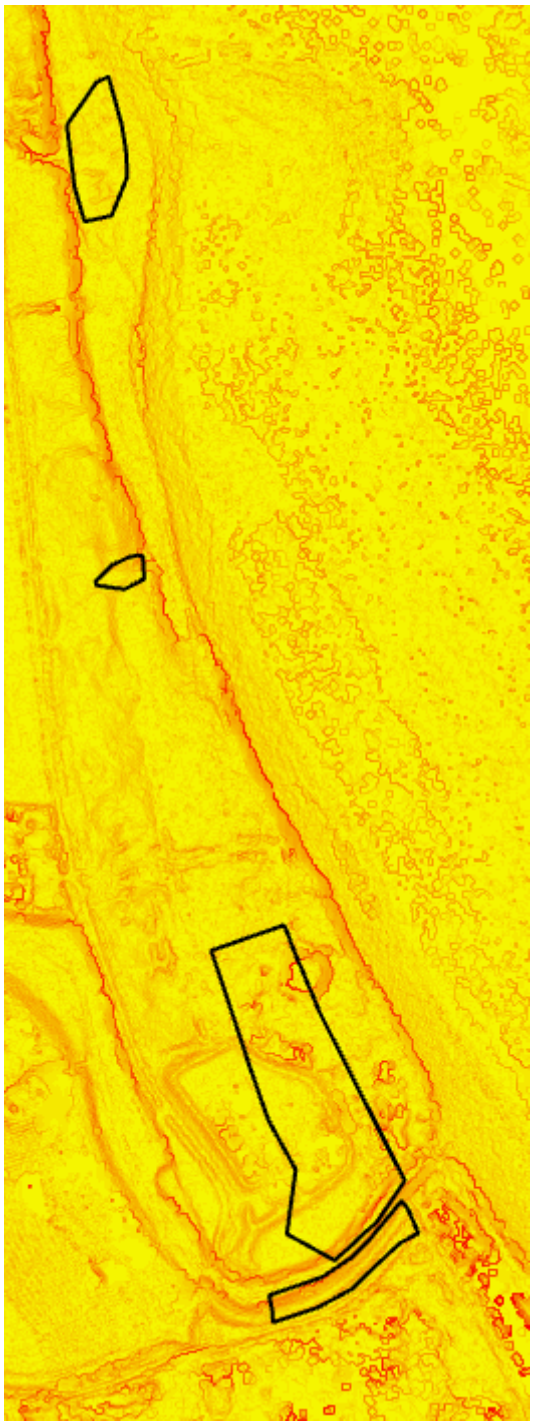


Figure 3-9b – Shoreline Position in the Vicinity of Locations 3 (near) and 4 (far) in the Year 2019



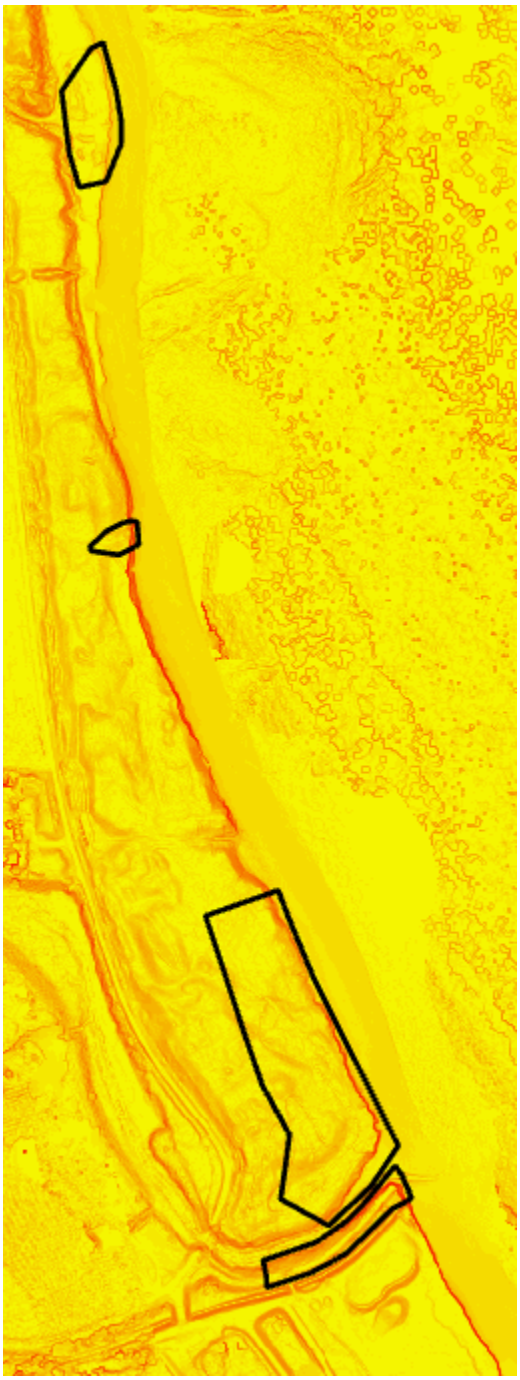


Figure 3-10a – Slope Gradients (2000) **Figure 3-10b – Slope Gradients (2019)**

Note: Locations 1 – 4 are shown in black boundaries, numbered from bottom to top

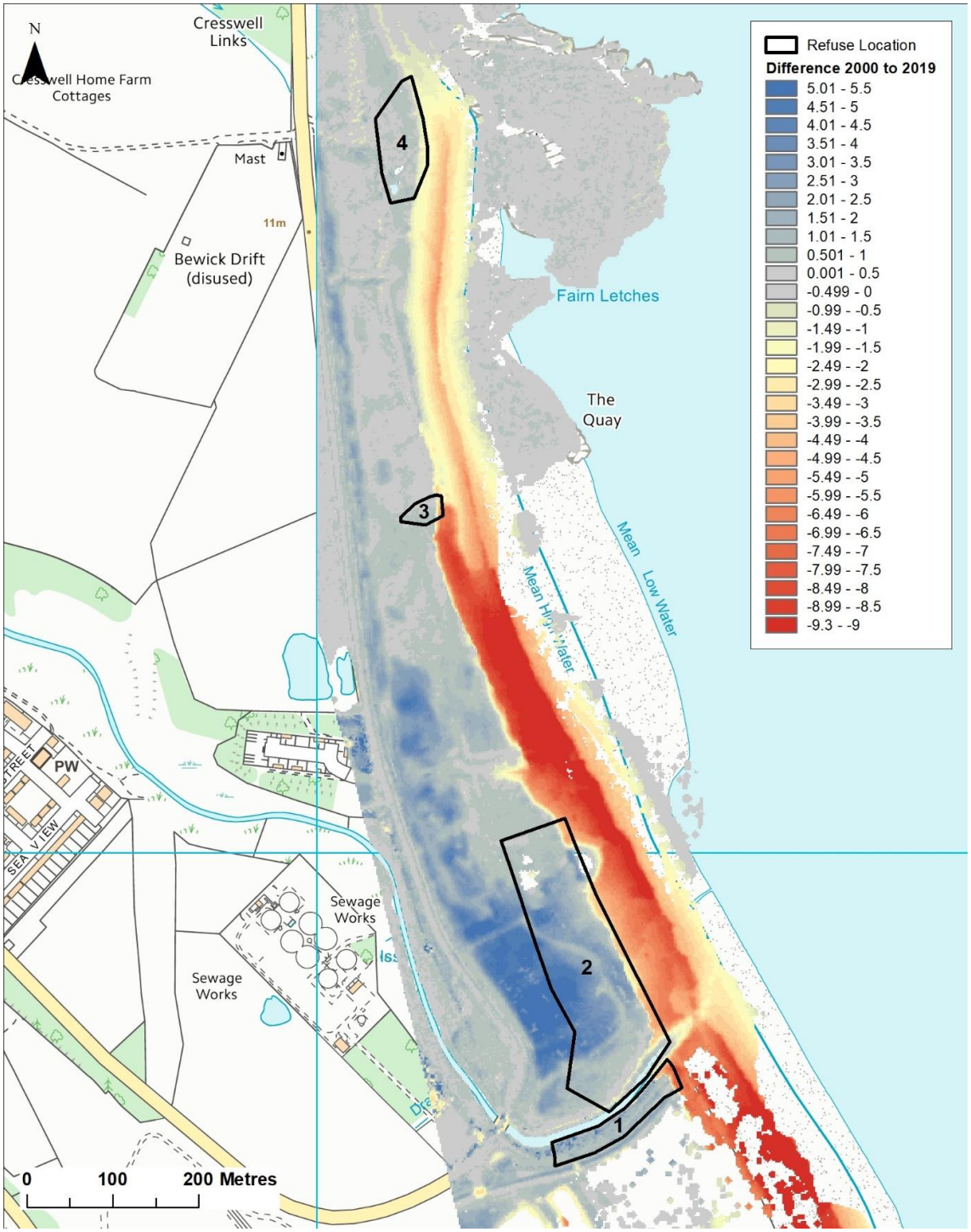


Figure 3-11 – Difference Plot of Elevation Changes between 2000 and 2019
Note: Locations 1 – 4 are shown in black boundaries, numbered from bottom to top

To further support development and post-project evaluation of the imminent capital scheme, Lynemouth Bay is now also being covered by a topographic survey (from the toe of the cliffs/slopes down to low water) and a cliff top survey along the line of the colliery spoil cliffs. This commenced in December 2020 will be repeated every 6 months (i.e. during each Partial Measures and each Full Measures survey campaign; although surveys will temporarily be interrupted by construction activities during delivery of the proposed scheme).

3.3 Meggies Burn

Blyth South Beach is located in south-east Northumberland and extends approximately 4.2km in length from the River Blyth estuary in the north to Seaton Sluice Harbour in the south. The northern 1.5km of beach is backed by hard defences (seawall and promenade), whilst the southern 2.7km is formed by a sand dune system. The long sandy beach, dunes and, where present, promenade are of significant amenity and recreation value, whilst the dunes are of important ecological value being designated as the Blyth to Seaton Sluice Dunes Local Nature Reserve and being located immediately adjacent to the Northumberland Shore Site of Special Scientific Interest (SSSI). A combined footpath and cycle way, which passes through the dune, is heavily used walkers, cyclists and dog-walkers.

Surface water from the low-lying agricultural fields landward of the dunes is drained into the culverted Meggies Burn, the outfall of which is just to the south of the end of the promenade towards the northern end of Blyth South Beach. The alignment of the unconstrained channel of the burn, as it leaves the outfall pipe and crosses the inter-tidal shore, has historically been variable.

Figure 3-12 shows the aerial imagery from the 1940s that was acquired by the Cell 1 Regional Coastal Monitoring programme. It can be seen that in the 1940s the channel left the outfall and meandered across the foreshore. Also, at this time, the dune crest was 'embayed' back to near the edge of the highway. Note that no groynes were visible in this image and a small spit-like feature extended across the mouth of the shallow embayment, pushing the initially northwards-tending burn channel back towards the south before it discharged to sea.

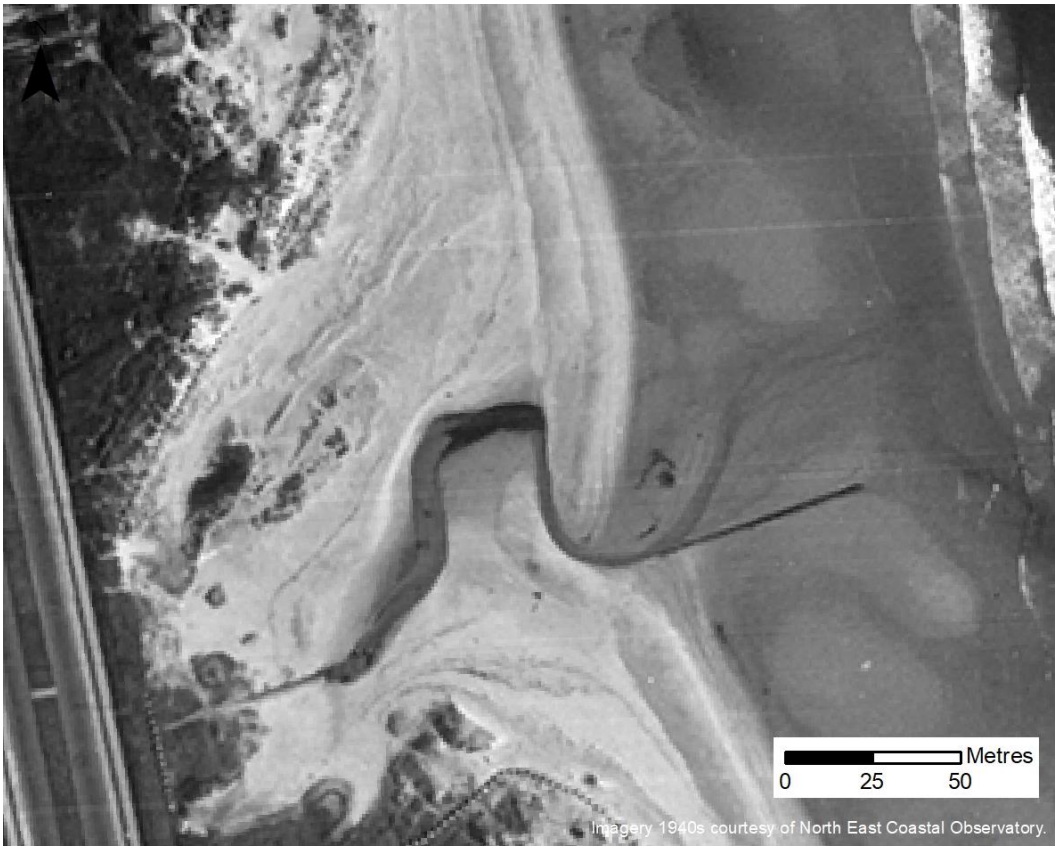


Figure 3-12 – Meggies Burn in the 1940s

At some point between the 1940s and the start of the predecessor to the Cell 1 Regional Coastal Monitoring programme in the early 2000s, a series of three timber groynes were constructed to the north of the burn and the shallow embayment at the outfall had become infilled with accretion of sediment and dune vegetation growth. Whilst this accretion is presumed to be naturally occurring, it has been assisted by soft management approaches, such as laying Christmas trees from local residents on areas of bare sand to encourage sediment deposition by locally breaking up the wind forces acting on the surface.

Changes in alignment of the burn's channel between 2002 and 2020 have been well document by the aerial photography from the Cell 1 Regional Coastal Monitoring programme (Figure 3-13). Note that in some years, the channel adopted a more central alignment (such as 2008 and 2017), in other years a more southerly alignment (such as 2013), and the remainder a more northerly alignment (such as 2009 and 2020). In 2002, 2006 and 2015 a more southerly alignment was initially adopted upon leaving the outfall, closely hugging the dune toe to the south of the burn, before swinging markedly to adopt a more central or northerly discharge across the rest of the foreshore.

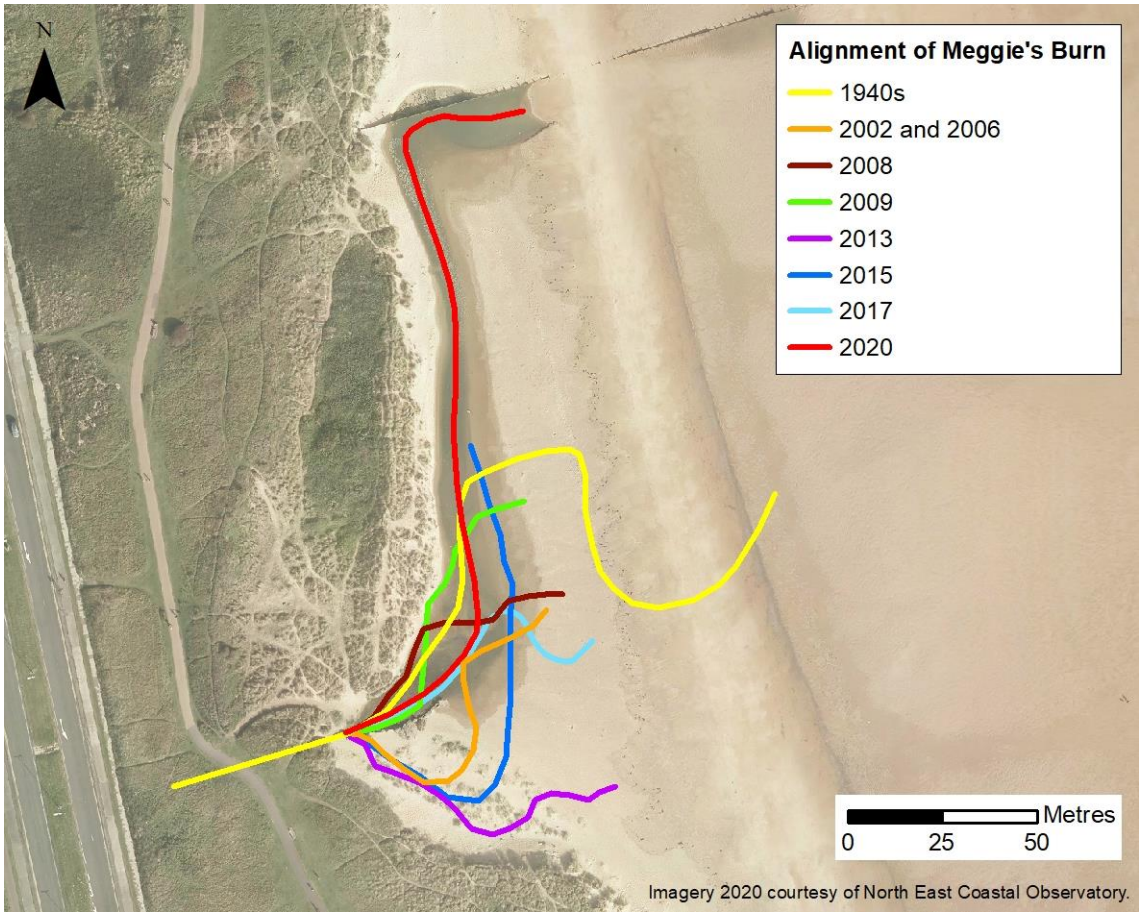


Figure 3-13 – Centreline of the channel of Meggies Burn from the 1940s to 2020

The burn had persistently been adopting a more southerly alignment, at least directly at the toe of the southern dunes, between 2013 and 2015. This caused erosion of the dune toe and localised slumping in the dune face and prompted local concerns about erosion potentially affecting the footpath if left unattended. In response to this, a small scheme was introduced in 2016 involving the placement of 1,300 geotextile bags filled with a total of 1,300m^3 of sand won locally from dredging of the entrance to Seaton Sluice Harbour. The bags were topped with a minimum 300mm covering of sand to restore the dune profile (Figure 3-14). Around this time, rock armourstones were also placed along the southern flank of the channel, in attempt to prevent the flow reaching directly the toe of the newly 'repaired' dunes.

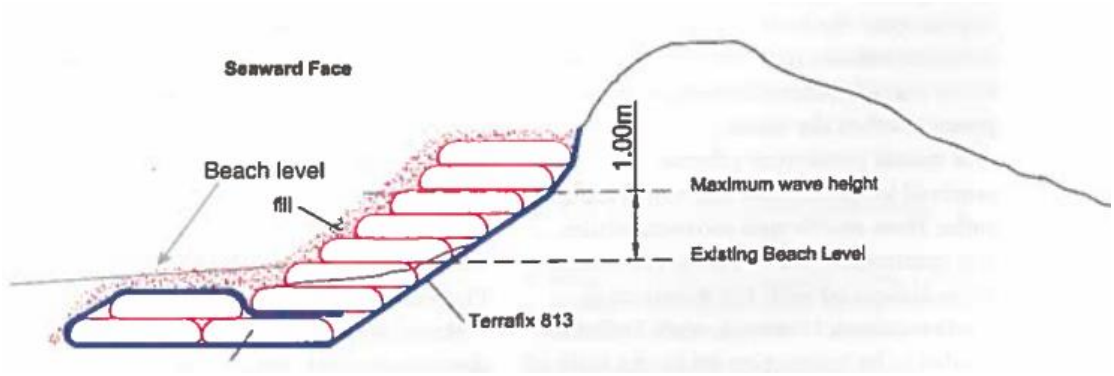


Figure 3-14 – Dune stabilisation scheme at Meggies Burn, 2016

On 7th October 2019, the channel of the burn had moved north along the toe of the dunes to reach the last timber groyne, causing a large sink hole to be created in the beach as the channel meandered beneath it (Figures 3-15 & 3-16). The sinkhole developed following a period of very heavy rainfall over a few days which caused the burn to be in spate. When coupled with high equinox tides, the channel flow diverted northwards until reaching the groyne. The sand level was higher on the north side of the groyne, so the force of water from the burn washed away the sand underneath the groyne causing the hole to form. The hole was cordoned off and then infilled with adjacent beach sand using mechanical plant (Figure 3-17). After the spate abated, and the newly formed channel bed dried, it left exposed former anti-tank defences that were installed along Blyth South during World War II as a military measure against armed invasion, but which had subsequently become buried by beach sand and had not previously been observed for at least a decade (Figure 3-18).

Figure 3-15 – Sink hole in the beach due to changes in the channel alignment of Meggies Burn, October 2019

Figure 3-16 – Sink hole in the beach due to changes in the channel alignment of Meggies Burn, October 2019

Figure 3-17 – Infilling of sink hole

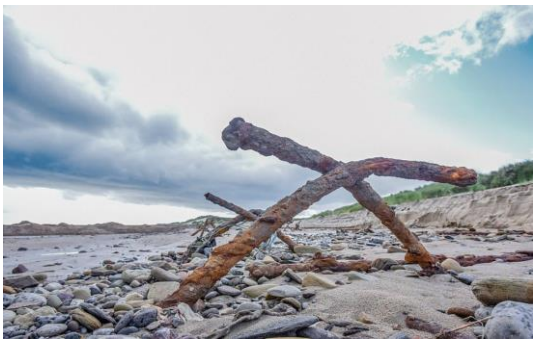


Figure 3-18 – Exposed WWII anti-tank defences

This situation has been captured by the most recent aerial photography available from the Cell 1 Regional Coastal Monitoring programme from the year 2000, as shown in Figure 3-19.

Figure 3-19 – Meggies Burn in 2020

3.4 Marsden Bay

As well as collecting coastal data routinely across the Cell 1 frontage, the Cell 1 Regional Coastal Monitoring programme provides a mechanism by which additional surveys, of various types and frequencies, can be undertaken using the appointed Surveyors and Analytical Scientists in the form of bespoke local surveys and studies.

One such example is the Marsden Bay Risk Management and Emergency Response Plan, which was completed in 2019. Due to long-standing concerns about coastal erosion in Marsden Bay, and in particular the risk posed by such erosion to the cliff top public footpath and adjacent coastal highway, South Tyneside Council requested that repeat laserscan surveys be undertaken. These data were used to inform a risk assessment and subsequent emergency response plan.

This work built upon a baseline of laserscan monitoring that was undertaken by the University of Northumbria between February 2015 and March 2017 at monthly intervals. The Cell 1 programme commenced its laserscan surveys in Marsden Bay in June/July 2019 and is repeating these at 6-monthly intervals, with specific post-rockfall surveys as and when needed.

There have been a number of notable rockfalls along the South Tyneside frontage in recent years, particularly at Frenchman's Bay and Lizard Point in 2010 and in Marsden Bay adjacent to the (now demolished) Lifeguard Station by the Redwell Steps (Figure 3-20). In fact, the history of rockfalls in these cliffs has left a series of rock stacks, arches and caves along the frontage and is representative of the characteristic behaviour of cliffs of this type.

Figure 3-20 – Marsden Bay rockfall, 2010

Recognising this, the Risk Management approach has been to identify locations where caves are undercutting the cliff toe, based upon both laserscan surveys and the Cell 1 programme's 2-yearly walkover inspections, and ensure that the cliff top path is set back beyond the inland extent of cave penetration plus a suitable buffer (see Figure 3-21) to safeguard the public using the cliff top path against potential rock falls. Where the coast road is affected by such caves, a local diversion is planned in the short term, with a more permanent re-modelling of the road layouts a potential intervention in the longer-term. Suitable warning signs have been erected and the cliff top path and existing low-level fencing has been realigned where necessary between The Grotto and the southern end of the bay. This shows the value of data and studies from the Cell 1 Regional Coastal Monitoring programme informing local management decisions and actions.

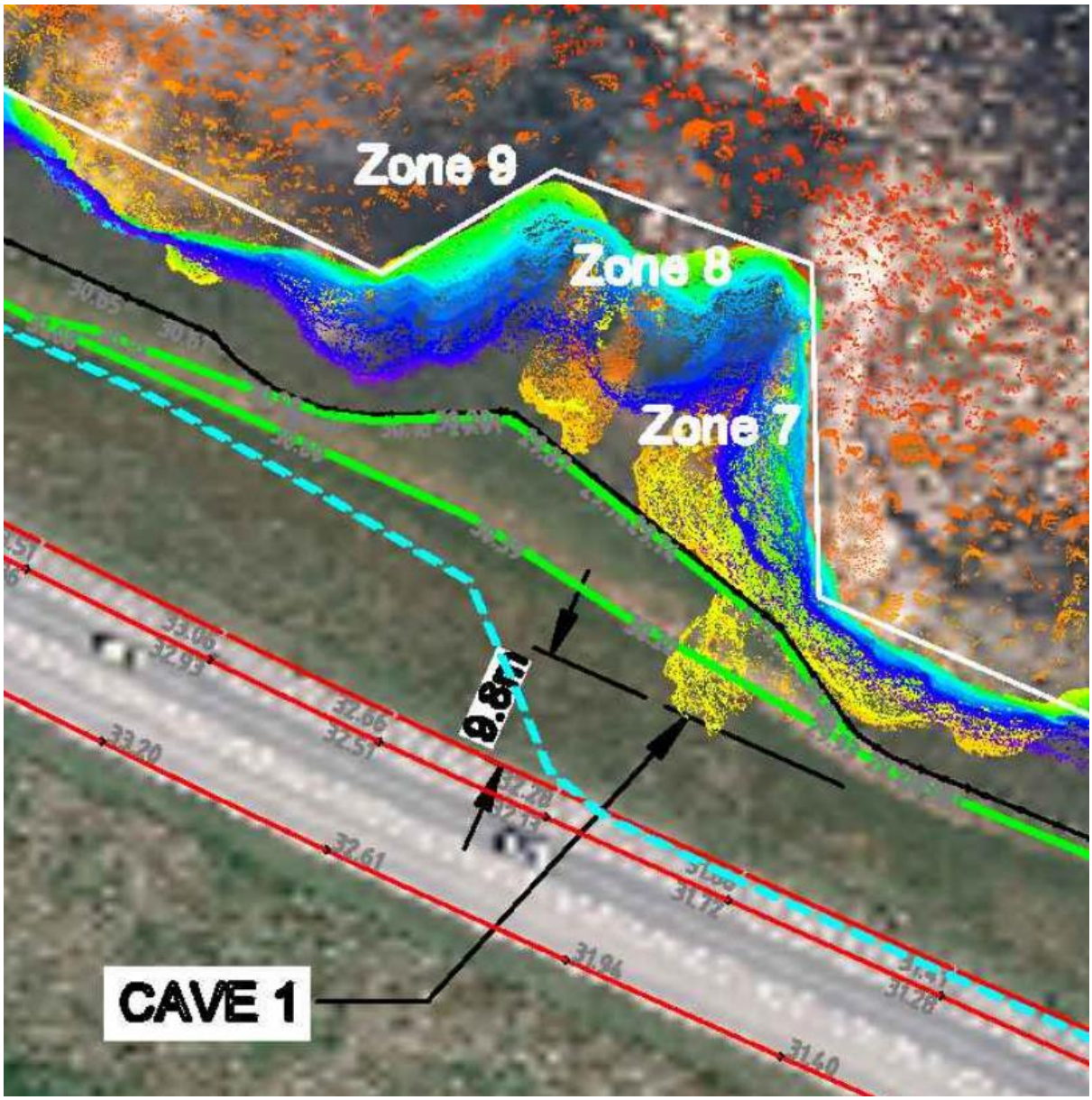


Figure 3-21 – Depth of cave penetration at base of cliff (yellow areas), informing decisions to locally realign the cliff top footpaths (moving from green lines to light blue in vicinity of 'Cave 1')

A further laserscan survey of this cliff area was undertaken in early February 2021, following a local rock fall which occurred on 30th January 2021. This event was video-recorded by a member of the public, gaining much social media and local media interest. The post-rockfall laserscan data was compared against an earlier laserscan survey of the cliffs along this frontage from November 2020. In fact, this revealed that two rock falls had occurred, very close to each other, with one being significantly larger than the other.

The yellow, red and purple shading in the normal perspective (Figure 3-22) and oblique perspective (Figure 3-23) plots below show areas of material loss from the cliff face, of increasing magnitude, during the rock falls. The grey area in the cliff face at the largest rockfall shows an area of loss greater than the 2m banding limit depicted on the colour scale of the three-dimensional surface model, whereas the grey area at the cliff toe below the largest rockfall shows deposition of the debris, again changing the surface elevation of the three-dimensional model by more than the 2m banding limit. Areas of green show little change (light green) or no change (dark green) in surface elevation between surveys.

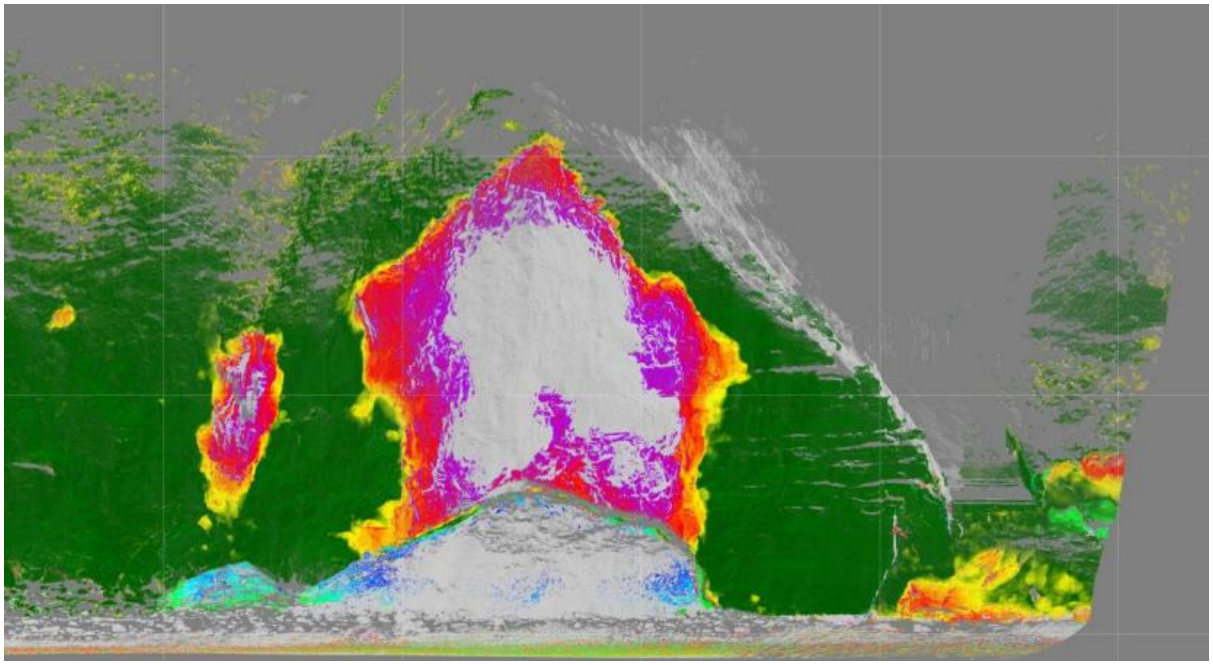


Figure 3-22 – Normal perspective of rockfalls from laserscan imagery

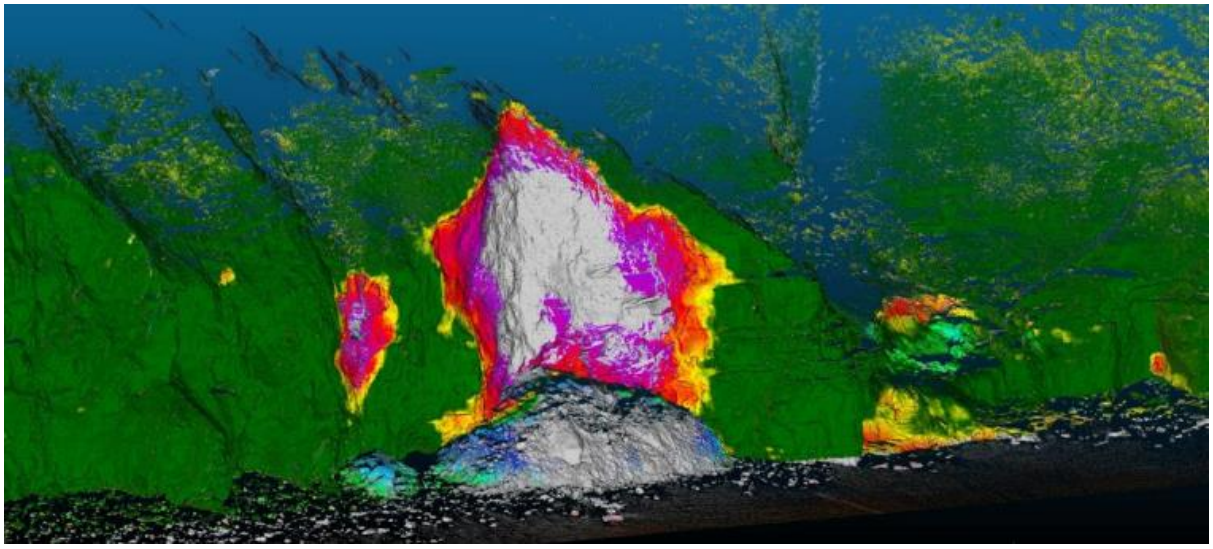


Figure 3-23 – Oblique perspective of rockfalls from laserscan imagery

The smaller rockfall involved the movement of approximately 18m^3 of material from the cliff face to the cliff toe, cutting the cliff face back by up to 2.3m at the point of deepest change. This rockfall was caused by the collapse of an overhanging section of rock mid-way up the cliff (Figure 3-24).

During the larger rockfall around 311m^3 of material dropped suddenly from the cliff face to the cliff toe, with the greatest depth of incision into the cliff face being 3.6m. This rockfall occurred in an area where two small caves were observed in the November 2020 laserscan data, which have now become blocked by the toe debris. This rockfall involved the shearing of a larger section of cliff face from directly above the caves, with failure movement along a near-vertical plane (Figure 3-25).

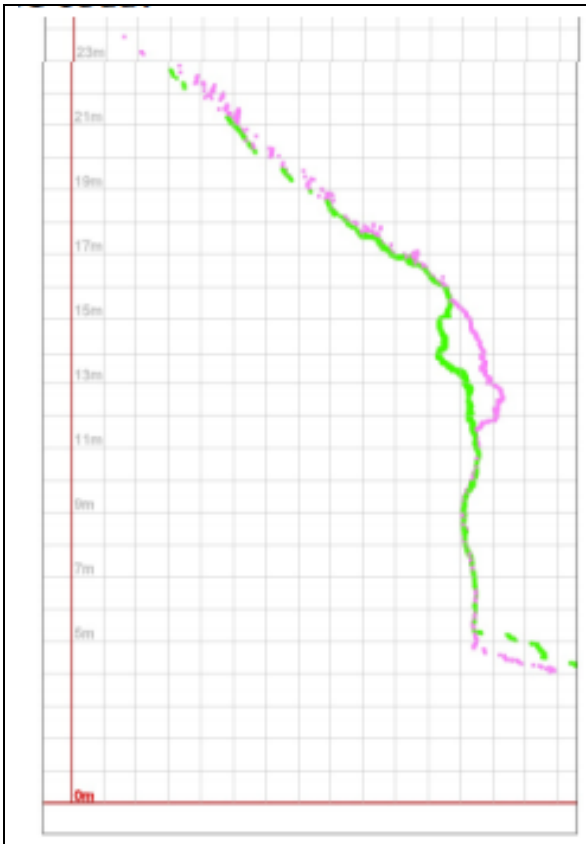


Figure 3-24 – Small rockfall of overhanging cliff face

Figure 3-25 – Larger rockfall of cliff face above caves at the cliff toe

Note: Pink line shows November 2020 survey, green line shows February 2021 survey.

4 Data Sharing

Data and reports from the Cell 1 Regional Coastal Monitoring Programme have been stored on a purpose built and ongoing maintained website called the North East Coastal Observatory (NECO) (Figure 4-1).

Figure 4-1 – NECO Homepage

The website contains the following pages:

- **Home** – background information about the programme
- **General** – comprising:
    - **Contact** – contact details for the lead officer managing the programme and a direct messaging facility
    - **Data Policy** – a statement of the conditions of use of the data
    - **Glossary** – a definition of commonly used terms in the various reports
    - **Links** – hyperlinks to organisations and other useful websites
- **News** – comprising:
    - **Latest News** – updates on progress with surveys and reporting
- **Programme** – comprising:
    - **Aims** – description of the overall aims of the programme
    - **Detail** – a more detailed description of the scope of the programme
    - **Partners** – details of all the programme's partners
    - **Quality Control** – a statement on the quality control procedures that have been used, with links to detail about file specifications
- **Data** – comprising:

- **Reports** – access to PDF versions of all reports produced from the programme as well as available SMPs and Strategy Studies

- **Data View & Download** – a GIS-enabled map viewer facility for undertaking a search of the site for data that are available and for downloading these data

- **Wave & Tide Data** – a facility to plot or tabulate, in near-real time, wave height, period and direction data (and sea temperature data) from the three wave buoys deployed as part of the programme and both measured and predicted tidal levels from the two tide gauges available to the programme.

The first version of the NECO website went live on 6th October 2009. Between this date and 7th July 2011 (i.e. during Phase 1 of the programme), the site received 435,699 hits. In terms of report downloads, the most common download during Phase 1 was of the Summary Paper of the programme (33% of the report downloads), with the File Specifications also providing popular (20% of the report downloads). During Phase 1, site location photographs and aerial photographs were by far the greatest data downloads (60% of all data downloads), with beach profile and beach topographic surveys accounting for a further 20% of data downloads.

An updated version of the NECO website superseded the first version in 2011 and since that time it has been possible to monetarise the value of the report and data downloads from the NECO website (Figure 4-2) through the programme's close association with the Channel Coastal Observatory (CCO) and due to the manner in which the NECO website interacts with the CCO website.

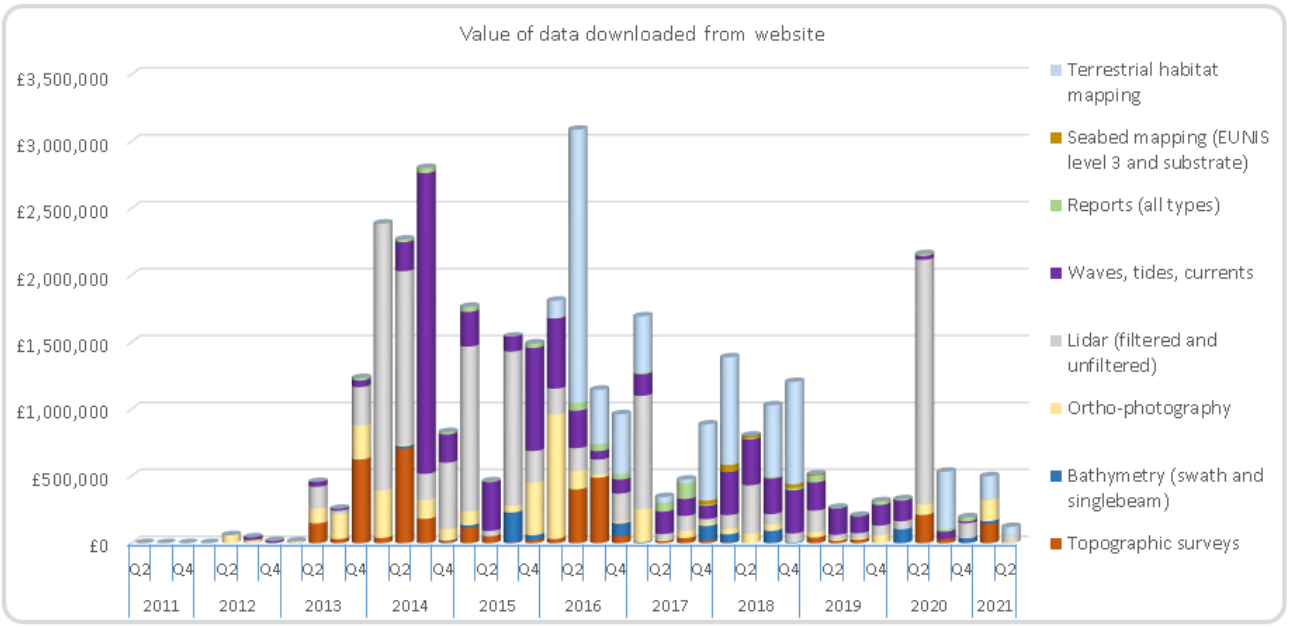


Figure 4-2 – Value of data downloaded from the NECO website

It can be seen that in the years 2011 and 2012 report and data downloads were very low – perhaps suggesting that the linkages between the NECO and CCO sites were not fully functioning at that time. However, since 2013 there has been a fairly high usage of the NECO site, with a lot of focus on downloads of LiDAR data, aerial photography, beach profile and topographic surveys and, since around 2016, terrestrial/inter-tidal habitat mapping.

In the current phase of the programme, between 1st April 2016 and 31st March 2021 (Phase 3), there have been 19,737 sperate downloads of data or reports and these downloads total a value of £18,035,125. This demonstrates the undeniable value in the coastal monitoring data that has been collected as part of the Cell 1 Regional Coastal Monitoring programme since 2008, as part of a coordinated National Coastal Monitoring Framework.

The data that have been collected and downloaded fulfil a practical function in enabling sustainable coastal management decisions to be made at a regional level, whilst also providing data in a manner that enables national-level assessments, when required, due to the consistency of its specification, format and storage.

5 Knowledge Sharing

Since its inception in 2008, the Cell 1 Regional Coastal Monitoring programme has been keen to share knowledge, practices and findings with a wider audience of regional, national and international coastal partners.

During the present phase, the programme has reached out to European colleagues to share its best practices and disseminate learning to other coastal managers. This knowledge sharing helped the Portuguese Government to implement the 'COSMO' (COaStal MOnitoring programme). Representatives from the COSMO programme have also delivered presentations in the UK to the North East Coastal Group & Scarborough Borough Council. In return presentations (Figure 4-3) have been delivered to the Portuguese Environment Agency in Lisbon with an audience including the Vice-President of the Portuguese Environment Agency and the Secretary of State of Territorial Management and Nature Conservation. Others attendees included representatives from Denmark (Danish Hydraulic Institute) and the Netherlands (Dutch Ministry of Infrastructure and the Environment).

Of particular interest is that the funding business case developed by the English Network of regional coastal monitoring programmes, along with specific details about the structure and methodology of Cell 1 programme, was shared with the Portuguese. This business case highlighted the aims and objectives of the programmes along with demonstrating the value for money of long term strategic monitoring. The Portuguese Environment Agency officers made use of this business case to aid their successful multi-million Euro bid to the European Union to fund their newly created COSMO coastal monitoring programme for 3 years. The COSMO programme is now undertaking activities similar to the Cell 1 programme, such as aerial photography, beach topographic surveys and hydrodynamic surveys.

Survey specifications developed by the English Network of regional coastal monitoring programmes were also shared and are being used by Portuguese colleagues. A key lesson learned by the COSMO programme from the UK was to make their data easily accessible and free to download from the internet.

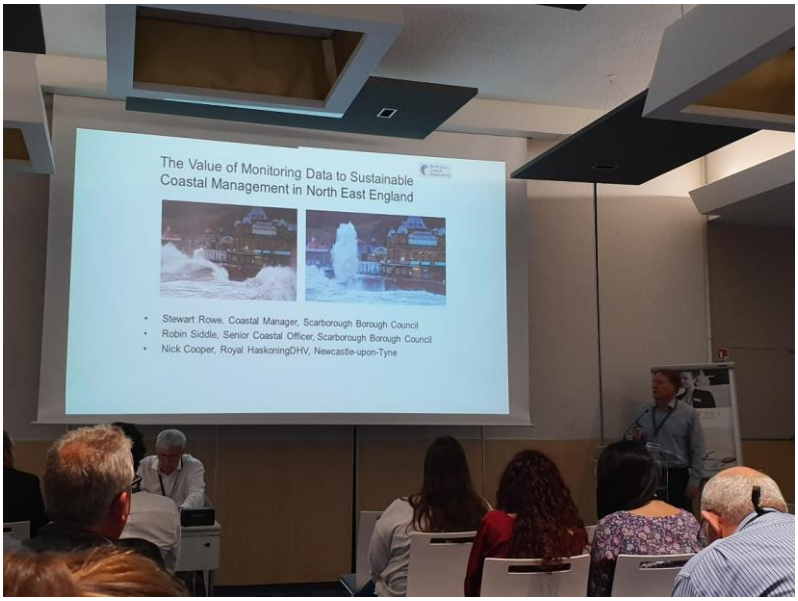


Figure 4-3 Presentation in 2019 at the COSMO coastal monitoring seminar, Lisbon

Shared learning on coastal monitoring has also been disseminated through peer reviewed papers and delivered via presentations at international conferences during the present phase of the programme. Particular examples include:

2017 Rowe S, Siddle R and Cooper NJ. Valuing coastal monitoring data. Flood & Coast Conference 2017, Telford.

This paper presented thoughts on how the value of coastal monitoring data can be monetarised, to inform future business case development. Its intention was to seek dialogue and debate, aiming to lead towards an agreed approach prior to submission of the busines case for the next phase of the Cell 1 programme (2021-2027), which was subsequently successfully submitted.

2017 Cooper NJ, Benson N, McNeill A & Siddle R. Changing coastlines in NE England: a legacy of colliery spoil tipping and the effects of its cessation. Proceedings of the Yorkshire Geological Society, Vol. 61, pp. 217–229.

This paper provides analysis of the changes that have occurred along parts of the Northumberland and County Durham coastlines due to the historic legacy of colliery spoil tipping and, particularly, its more recent cessation.

2019 Cooper NJ, Siddle R & Rowe S. The value of monitoring data to sustainable coastal management in northeast England. Proceedings Institution of Civil Engineers' Coastal Management Conference, 2019, La Rochelle.

This paper furthers the debate of the 2017 paper and provides evidence of the monetarised benefits of the value of monitoring data from the Cell 1 programme.

2020 See M, Gilchrist C, Cooper NJ, Ratcliffe D & Siddle R. Microplastics in the marine environment: a literature review and northeast England case study. Water and Environment Journal Vol. 34, Issue 3, August 2020, pp 489-505. Print ISSN 1747-6585.

This paper focused on the cutting edge research and analysis of the Cell 1 programme's pilot project focused on micro plastics in seabed sediments. This research is believed to be the first of an applied nature in the UK, providing a baseline against which any future changes in extent or percentage content of microplastics in sea bed areas can be assessed, potentially informing environmental legislation and control. The sampling method has been defined in a way in which it can be replicated by other coastal managers around the world.

2021 Cooper NJ, Brew D, Guthrie G, Cooper T, Scullion A, Richardson E, Ward T & Siddle R. Coastal geomorphological change in northeast England: the role of regional-scale monitoring. Northumbrian Naturalist.

This paper provided a summary of the Overview Report of the 2011-2016 phase of the programme, aiming to demonstrate some of the observed geomorphological changes through case studies and exemplifying the benefits of regional-scale monitoring to sustainable coastal management decisions.

6 Conclusions and Recommendations

Regional scale monitoring is important to ensure that coastal management decisions made by local maritime authorities are based upon accurate and up-to-date information on coastal geomorphological change. This helps inform ongoing management and maintenance of beaches and structural defences, as well as planning the type and timing of major capital investments in new or improved defences, or their removal for purposes of adaptation to coastal change or inter-tidal habitat creation.

Data from this type of monitoring also provides understanding that is useful for other purposes such as exercising appropriate development control on coastal land and assessing the potential geomorphological impacts arising from the landfall of marine infrastructure, such as pipelines and cables.

The Cell 1 Regional Coastal Monitoring Programme covers approximately 300km of the northeast coast, from St. Abb's Head (just across the border into Scotland) to Flamborough Head in the East Riding of Yorkshire, covering Northumberland, Tyne & Wear, County Durham, Hartlepool, Redcar & Cleveland and Yorkshire. This coast is often referred to as 'Coastal Sediment Cell 1', after the esteemed work that was undertaken on mapping of littoral cells in England and Wales in the 1990s.

Within Cell 1, the coastal landforms vary considerably. They variously comprise low-lying tidal flats with fringing saltmarshes; wide, sweeping sandy beaches backed by coastal dunes; hard rock cliffs that are mantled with glacial till of varying thicknesses; and softer rock cliffs prone to extensive landslides. There are also many different forms of coastal defence including offshore breakwaters; revetments; sea walls; harbour piers; quay walls, as well as different management activities, such as beach recharge and sediment recycling; dune management; and adaptation to coastal change (e.g. abandonment and re-wilding, roll-back of coastal footpaths, etc.). Some areas in Northumberland and through much of County Durham have been significantly affected by historic tipping of colliery spoil, leading to 'artificial' spoil beaches and cliffs.

Cell 1 monitoring commenced in its present form in September 2008 and is managed by Scarborough Borough Council on behalf of the North East Coastal Group. Prior to 2008, coastal monitoring was undertaken on a consistent basis across Northumberland and North Tyneside as part of the (then) Northumbrian Coastal Authorities Group's monitoring programme which commenced in 2002, whilst several authorities elsewhere within Cell 1 undertook their own local monitoring programmes.

The main elements of the Cell 1 monitoring are:

- beach profile surveys;
- beach topographic surveys;
- cliff-top recession surveys;
- real-time telemetered wave and tidal level data collection;
- bathymetric and sea bed characterisation surveys;
- vertical and oblique aerial photography;
- Light Detection and Range (LiDAR) surveys;
- ecological habitat mapping; and
- walk-over visual inspection surveys of built and natural assets

The overall aim of the Cell 1 monitoring is to provide a comprehensive integrated suite of information, complimented by expert observational information provided by the walk-over visual inspections on the ground. Key aspects of the programme are the need for sound quality assurance of data and the ongoing collation, storage and use of this major resource. All data and routine interpretative reports for the programme are available on the project website:

http://www.northeastcoastalobservatory.org.uk

General findings from the programme to date have revealed the seasonal changes in beach profile morphology, and in particular the storm-related lowering that can occur on the upper beach.

However, the response in calmer periods is for beach recovery, with no longer-term trends currently evident other than in areas of foreshore that have been affected by historical colliery spoil tipping which, since its cessation, have been experiencing net erosion, with rates approaching around 5 m per year in places.

Several areas of cliffs exhibit signs of activity, especially after adverse weather when rock falls or landslips can occur, depending on the geological type. In several areas of the Cell 1 frontage, understanding of the locations and rates of erosion is leading to adaptation to the ongoing change by relocating footpaths, access roads or coastal highways, removing car park infrastructure and re-wilding areas of cliff top. Other areas of cliff experience erosion at their base, leading to the long-term formation of caves and the subsequent opening of 'sink holes' in cliff top land or the long-term development of sea stacks.

Some of the most notable changes along the Cell 1 frontage are three-dimensional in nature and are best captured by the beach topographic surveys, aerial photography and LiDAR surveys. These focus around areas where channels of small rivers and burns outflow across the foreshore in an unconstrained manner, with their alignment influence by antecedent weather and marine conditions. At times, changes in channel alignment can lead to increased (or decreased) erosion pressure on dunes adjacent to the river mouth.

The walkover inspections surveys also lead to routine awareness of changes in condition of coastal defence structures or natural features that can be fed back to coastal managers for appropriate interventions or other risk management actions.

Overall, the data collected so far demonstrate the value of long term monitoring to the Cell 1 coastline and the principal recommendation from the current programme is that the data collection should be continued uninterrupted into the future with no major amendments to the programme, and with only a minor enhancement at Lynemouth Bay, which has already been incorporated in December 2020. There is opportunity, subject to Natural England agreement, for the Holy Island causeway and Spital Carrs (Newbiggin Bay) 'edge of sand' surveys to be removed from the programme as all past surveys have shown no environmental impacts arising from the works the surveys were designed to investigate.

The only identified area where there has been an operational requirement that is difficult to meet with data collected in its current format is in providing information on defence crest levels. In recent years, the Environment Agency has become increasingly interested in collating information from Coastal Groups on coastal assets within their areas. This informs ongoing Environment Agency projects, such as National Coastal Erosion Risk Mapping (NCERM) and National Flood Risk Assessment (NaFRA), and also creates a useful national database of assets. Defence crest levels are particularly important for assessments of wave overtopping. The Cell 1 programme's beach topographic surveys generally only cover the foreshore areas and whilst beach profile surveys do cross and pick up detail of the defence crest where surveyed, they are not located at all locations throughout the region. In those locations, reliance is made on LiDAR data, but this can easily pick out false features, such as hand railing, rather than the critical defence crest level. In areas where defence crest level is important, bespoke topographic survey is recommended to ascertain these and inform future local, regional and national studies.

As the programme has developed, there has been an increased focus on the need for information to support discussion and engagement with wider stakeholders and coastal communities, refining the understanding of SMP policy and management delivery, using new information to support ongoing adaptive shoreline management in many locations. To this end, there would be further benefits to be gained from disseminating information about and key findings from the Cell 1 programme more widely, in the form of regular annual meetings or bespoke events such as site visits or talks/ presentations. Consideration could also be given to making the accessibility of the available data better by more visual means. Whilst efforts were made to investigate this during the present phase of the Cell 1 programme through the creation of an iViewer for pre- and post-scheme laserscan data at Runswick Bay, that approach places a great reliance on the computer systems of the end-user. A potential alternative means of providing a more visual and accessible route to the Cell 1 programme's data and outcomes is through an online GIS Viewer. This generally can be used by anyone who is sent a link and operates in Chrome, Edge and Firefox. However, there would be a considerable

amount of time required to translate some of the key Cell 1 findings into a format that enables such use.

Furthermore, as technology advances throughout the next phase of the programme (2021-27), it is also recommended that consideration is given to trialling innovative approaches alongside the tried-and-tested methods used on the programme since its inception. This particularly relates to the potential benefits of using targeted drone survey or laserscan survey in areas of poor accessibility, significant change (e.g. landslips) or where more regular local data is required than that which currently is provided by the programme.

In conclusion, the region-wide coastal monitoring data have proven invaluable in informing maintenance activities and capital schemes along many parts of the frontage, as well as informing management plans to enable adaptation to ongoing coastal change in some areas of greatest change, such as Marsden Bay, Sandsend (landslip), Cowbar Lane or Knipe Point. The programme has provided valuable data that enables:

- Selection of sustainable shoreline management plan policies or coastal strategy options;
- Development of outline and detailed design of effective schemes;
- Evaluation of performance of implemented schemes;
- Planning and securing investments in capital and revenue expenditure; and
- Prioritising of maintenance budgets to areas of most need.

The SMP Refresh project, which is currently ongoing in Cell 1, provides a unique opportunity for local authorities, the Environment Agency and other coastal partners to re-consider their own needs from coastal monitoring data delivered by the Cell 1 programme and request any fine-tuning that they deem necessary at the outset of the next phase (2021–27). This should be considered as a key part of that process to ensure that the programme remains relevant and of practical usefulness, as it was when first conceived in 2008 to address identified uncertainties and emerging issues that arose when preparing the original SMP2 documents covering the frontage.
A summary of the key recommendations is provided in Table 6-1.

Table 6-1 Recommendations for the Cell 1 Regional Coastal Monitoring Programme (2021-27)

Location	Recommendation	Responsibility
Cell 1	Continue monitoring uninterrupted beyond the 2016-21 phase, with no major amendments	North East Coastal Group
Cell 1	Bespoke defence crest level survey to inform future wave overtopping studies	North East Coastal Group
Cell 1	Annual meeting or bespoke events (site visits or talks/presentations)	North East Coastal Group
Cell 1	Consider merits of iViewer or Online GIS to present key findings from the programme	North East Coastal Group
Cell 1	Trial innovative survey technologies (e.g. drone, laserscan) alongside tried-and-tested approaches	North East Coastal Group
Cell 1	Consider need for fine-tuning programme to meet local requirements and emerging issues from the SMP Refresh project	North East Coastal Group
Druridge Bay, Newbiggin Bay, Lynemouth Bay, Blyth South Beach	Extend one existing beach profile line in each bay seaward to the 20m sea bed contour during the 2023 bathymetric surveys	Northumberland County Council
Lynemouth Bay	Enhancement of monitoring pre- and post-capital scheme	Northumberland County Council
Holy Island	Discussion with Natural England about removing	Northumberland County

Location	Recommendation	Responsibility
	the ‘edge of causeway’ surveys based on no environmental impacts from past surveys	Council
Spital Carrs (Newbiggin Bay)	Discussion with Natural England about removing the ‘edge of sand’ surveys based on no environmental impacts from past surveys	Northumberland County Council
Lindisfarne National Nature Reserve	Consider value of collecting and analysing sediment samples from the tidal flats and sea bed	Natural England
Tynemouth Longsands	Extend one existing beach profile line seaward to the 20m sea bed contour during the 2023 bathymetric surveys	North Tyneside Council
Marsden Bay	Continue the recent laserscan surveys of cliffs in Marsden Bay	South Tyneside Council
Port of Sunderland	Consider need for increased frequency of asset inspections in some areas of poor condition assets	Port of Sunderland / Sunderland City Council
Halliwell Banks	Consider need for enhanced monitoring along eroding cliff edge, fronting former landfill site	Sunderland City Council / Environment Agency
Colliery Spoil Beaches	Continue (or enhance) monitoring of erosion of colliery spoil beaches to determine when backing cliffs will become re-activated	Durham County Council
North Gare Breakwater	Discussions about future maintenance /capital commitments to avoid deterioration of structure	PD Teesport / Hartlepool Borough Council
South Gare Breakwater	Discussions about future maintenance /capital commitments to avoid deterioration of structure	PD Teesport / Redcar & Cleveland Borough Council
Cowbar	Continue the recent laserscan surveys of cliffs along Cowbar Lane	Redcar & Cleveland Borough Council
Staithes	Bespoke defence crest level survey to inform future wave overtopping studies as part of Staithes Coastal Monitoring	Scarborough Borough Council
Scarborough North Bay, Headland & South Bay	Bespoke defence crest level survey to inform future wave overtopping studies as part of Scarborough Coastal Defence Strategy Review	Scarborough Borough Council