

Cell 1 Regional Coastal Monitoring Programme

Bathymetric and Sea Bed Characterisation Surveys 2022 Update (Final Report)

Scarborough Borough Council

Cell 1 Regional Coastal Monitoring Programme

Bathymetric and Sea Bed Characterisation Surveys - 2022 Update (Final Report)

Contents Amendment Record

This report has been issued and amended as follows:

Issue	Rev	Description	Date	Authors	Authorised
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2	0	Interim Report (includes St. Abb's Head to Farne Islands survey)	22/11/2021	D. S. Brew & T. Cooper	N. J. Cooper
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Acronyms and Abbreviations

CCO	Channel Coastal Observatory
CD	Chart Datum
Cefas	Centre for Ecology, Fisheries and Aquatic Studies
CHP	Civil Hydrographic Programme
EUNIS	European Nature Information System
LiDAR	<u>L</u> ight <u>D</u> etection and <u>R</u> anging
MBES	Multi Beam Echo Sounder
MCA	Maritime & Coastguard Agency
MCZ	Marine Conservation Zone
MLWN	Mean Low Water Neaps
MMO	Marine Management Organisation
MMT	Marin Mätteknik
NECO	North East Coastal Observatory
OD	Ordnance Datum
RHDHV	Royal HaskoningDHV
SBC	Scarborough Borough Council
SMP2	Shoreline Management Plan 2
UK	United Kingdom
UKHO	United Kingdom Hydrographic Office

Units

°	degree(s)
km	kilometre(s)
m	metre(s)

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Preamble

The Cell 1 Regional Coastal Monitoring Programme covers approximately 300km of the northeast coastline of England, 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 (Plate 0.1). Within this frontage the coastal landforms vary considerably, comprising low-lying tidal flats with fringing saltmarshes, hard rock cliffs that are mantled with glacial till of varying thicknesses, softer rock cliffs, and extensive landslide complexes.

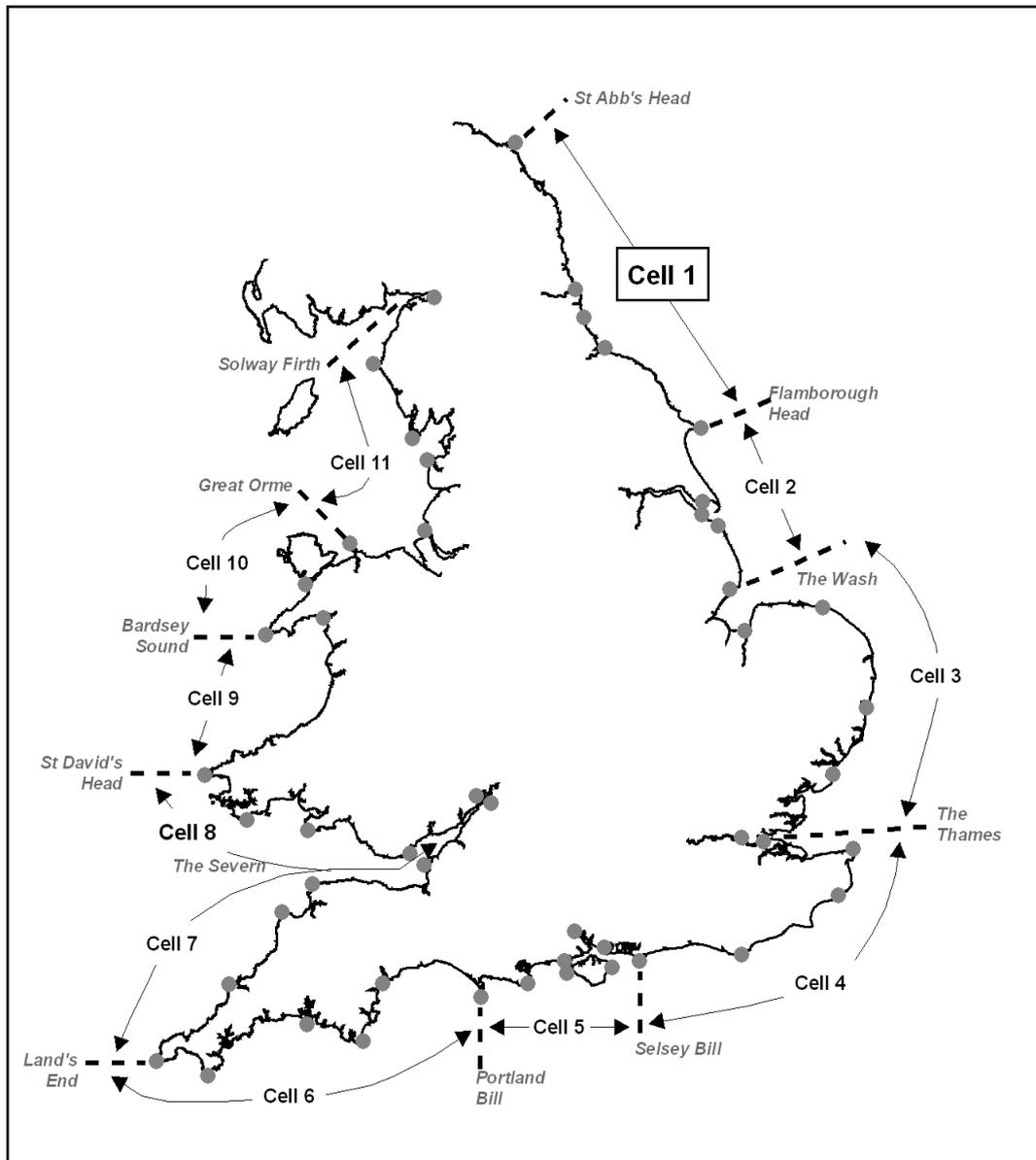


Plate 0.1 - Sediment Cells in England and Wales

The monitoring programme commenced in its present guise in September 2008 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.



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;
- LiDAR survey; and
- walk-over inspection surveys.

Royal HaskoningDHV has been appointed to provide Analytical Services in relation to the Cell 1 Regional Coastal Monitoring Programme between 2021 and 2027.

This report covers the **Bathymetric and Sea Bed Characterisation Surveys** and provides details of recent update surveys and a comparison with past surveys.

In addition, separate reports are produced for other elements of the programme as and when specific components are undertaken, such as beach profile, topographic and cliff top surveys, wave data collection, aerial photography and LiDAR surveys, and walk-over inspection surveys.

1. Introduction

1.1 Scope of Work

Coastal Sediment Cell 1 extends from St. Abb's Head, north of the Scottish Border, to Flamborough Head in East Yorkshire. The purpose of this report is to analyse and interpret the bathymetric and sea bed characterisation update surveys that were undertaken across the nearshore and offshore areas at various dates between 2015 and 2020, and to document notable changes between these update surveys, an earlier 2015 survey, and a baseline survey that was undertaken in 2010.

The work was first reported in a Draft Report in 2020, but at that time survey data from the completed Blyth to Sunderland survey were not available and the St. Abb's Head to Farne Islands survey remained ongoing.

When data from the St. Abb's Head to Farne Islands survey became available, it was included within an Interim Report issued in 2021.

This Final Report now includes available data from the Blyth to Sunderland survey as well as data from a separate survey undertaken on behalf of the Marine Management Organisation (MMO) in 2014 covering Alnmouth to Whitley Bay (collected for the purpose of characterising the Coquet to St. Mary's Marine Conservation Zone (MCZ)).

This report now represents a complete update of the available bathymetric surveys from across the Cell 1 Regional Coastal Monitoring Programme offering a near continuous coverage² of the bathymetry between St. Abb's Head and Flamborough Head.

1.2 Previous Surveys

The baseline bathymetric and sea bed characterisation surveys were completed in 2010 by Aspect Land & Hydrographic Surveys as part of the Cell 1 Regional Coastal Monitoring Programme. These surveys were undertaken along a series of 15 shore-normal transect lines extending between mean low water neap (MLWN) tide and the 20m Chart Datum (CD) sea bed contour, located at points between the River Tyne (South Tyneside) and Filey Bay (North Yorkshire). No surveys were completed north of the River Tyne. The surveys were undertaken in response to specific issues raised in the River Tyne to Flamborough Head Shoreline Management Plan 2 (SMP2) covering this frontage and are as follows (Plate 1.1):

- Transect 1: Herd Sands, South Shields (South Tyneside);
- Transect 2: South Bents, Whitburn Bay (Sunderland);
- Transect 3: Salterfen Rocks (Sunderland);
- Transect 4: Blast Beach, near Noses Point (County Durham);
- Transect 5: Hartlepool North Sands (Hartlepool Borough);
- Transect 6: Saltburn-by-the-Sea (Redcar & Cleveland Borough);
- Transect 7: Skinningrove (Redcar & Cleveland Borough);
- Transect 8: Runswick Bay (Scarborough Borough);
- Transect 9: Sandsend (Scarborough Borough);
- Transect 10: Whitby Sands (Scarborough Borough);
- Transect 11: Robin Hood's Bay (Scarborough Borough);
- Transect 12: Scarborough North Bay (Scarborough Borough);
- Transect 13: Scarborough South Bay (Scarborough Borough);
- Transect 14: Cayton Bay (Scarborough Borough); and
- Transect 15: Filey Bay (Scarborough Borough).

² The only remaining 'gap' in coverage is between the Farne Islands (Seahouses) and Alnmouth.

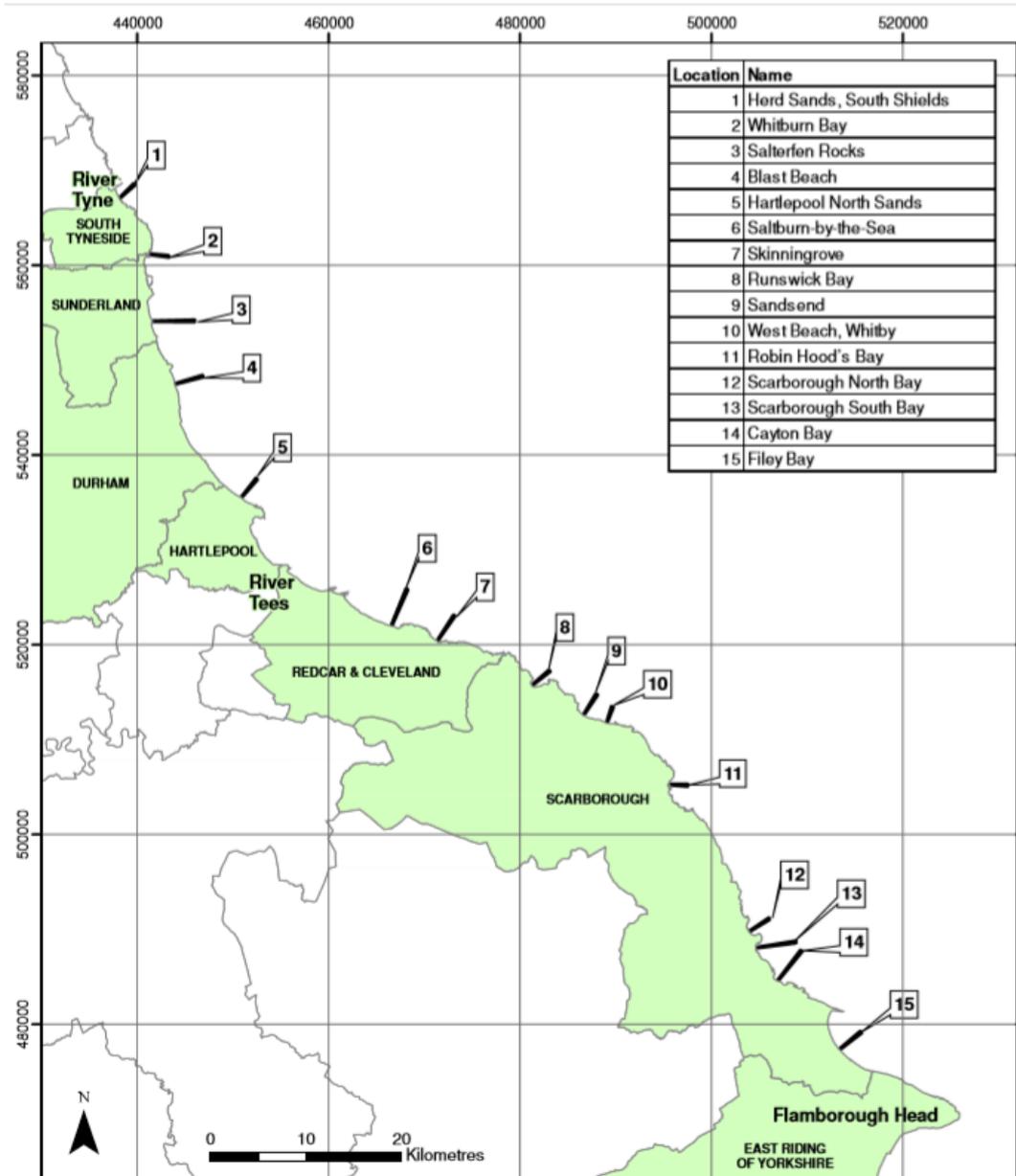


Plate 1.1 – Location of bathymetric and sea bed characterisation transects collected in 2010 (Royal Haskoning and Halcrow, 2010)

A 'baseline' report was produced in 2010 (Royal Haskoning and Halcrow, 2010) to present the survey findings and review the objectives of the monitoring at each transect.

The 2010 survey transects were repeated in March and April 2015 by the Environment Agency's Geomatics Group as part of the Cell 1 Regional Coastal Monitoring Programme. This was to identify areas of change in bathymetry and sediment composition. A report describing these comparisons was completed by CH2M (2015).

Further repeat surveys were initially planned for both 2016 and 2017 as part of the Cell 1 Regional Coastal Monitoring Programme, but these have been superseded by a change in approach for the most recent update surveys.

1.3 Update Surveys

The update surveys have been undertaken in a different way due to opportunities presented by the Maritime and Coastguard Agency's (MCA's) 'rolling programme' of offshore survey work using multibeam echosounder (MBES) technology as part of the United Kingdom's (UK's) Civil Hydrography Programme (CHP) for the UK Hydrographic Office (UKHO). The Cell 1 Regional Coastal Monitoring Programme funded the extension of these 'offshore' surveys into the 'nearshore' areas.

The MCA's programme involved (from north to south):

1. **St. Abb's Head to Farne Islands:** MBES covering 468km² of sea bed was completed between June 2019 and October 2020 (MCA and UKHO, 2021). Sea bed sediment and bedform location maps were also produced for this section.
2. **Blyth to Sunderland:** MBES covering 220km² of sea bed was completed between February and March 2019 (MCA and UKHO, 2019).
3. **Sunderland to Redcar:** MBES covering 140km² of sea bed was completed between November 2017 and January 2018 (Clinton Marine Survey, 2018a). Also, a sub-bottom profiler survey was completed in this area (Clinton Marine Survey, 2018a).
4. **Redcar to Robin Hood's Bay:** MBES covering 324km² of sea bed excluding Runswick Bay was undertaken in November-December 2016 (MMT, 2017). MBES of the sea bed offshore from Runswick Bay was completed in 2013 and then in December 2017 and January 2018 and covered 7km² (Clinton Marine Survey, 2018b). The Runswick Bay surveys informed the design and construction of the Runswick Bay Coastal Defence Scheme and do not form part of this report.
5. **Robin Hood's Bay to Flamborough Head:** MBES covering 366km² of sea bed was undertaken from November 2015 to March 2016. EUNIS level 3 habitat mapping and substrate mapping for this section was undertaken by the Channel Coastal Observatory (CCO, 2017).

In addition to these MCA surveys, the sea bed from the **Alnmouth to Whitley Bay** is covered by a survey from the MMO (available on the INSPIRE website) which was captured in 2014 to characterise the (then recommended) Coquet to St. Mary's Marine Conservation Zone (MCZ). These data have been downloaded for use in this report.

1.4 Report Structure

Due to the change in survey approach since the 2010 baseline and 2015 update, this report has a different structure to the previous Cell 1 Bathymetric Survey and Sea Bed Characterisation Reports (Royal Haskoning and Halcrow, 2010; CH2M, 2015). Each of the five main MCA survey areas is described in separate sections and, within each section, the relevant transects are described. In addition, a section is added for the MMO's Alnmouth to Whitley Bay survey covering the Coquet to St. Mary's MCZ, although there is some overlap (between Blyth and Whitley Bay) with the Blyth to Sunderland survey.

2. St. Abb's Head to Farne Islands Survey Results

2.1 General Overview

The sea bed between St. Abb's Head and the Farne Islands is covered by a bathymetric survey completed between June 2019 and October 2020. A map of sea bed sediments and bedforms was also completed for this section using the bathymetry (backscatter) and sea bed sediment samples (MCA and UKHO, 2021).

North of Berwick-upon-Tweed to St. Abb's Head, the sea bed is characterised by an almost-continuous, variable-width, rock shore platform changing offshore in to an essentially featureless and sloping sea bed out to about -70m Ordnance Datum (OD) (Figure 2.1). The slope of the sea bed increases offshore from the St. Abb's Head headland with less steep slopes to either side. The width of the rock shore platform varies from about 150m to 700m (Figure 2.2). It is mainly composed of interbedded limestone, shale and sandstone south of Eyemouth and mudstone and sandstone north of Eyemouth. The sediments of the sloping sea bed seaward of the rock shore platform are comprised predominantly of gravelly sand and gravelly muddy sand (Plate 2.1) (MCA and UKHO, 2021). The sea bed contains isolated patches of ripple bedforms.

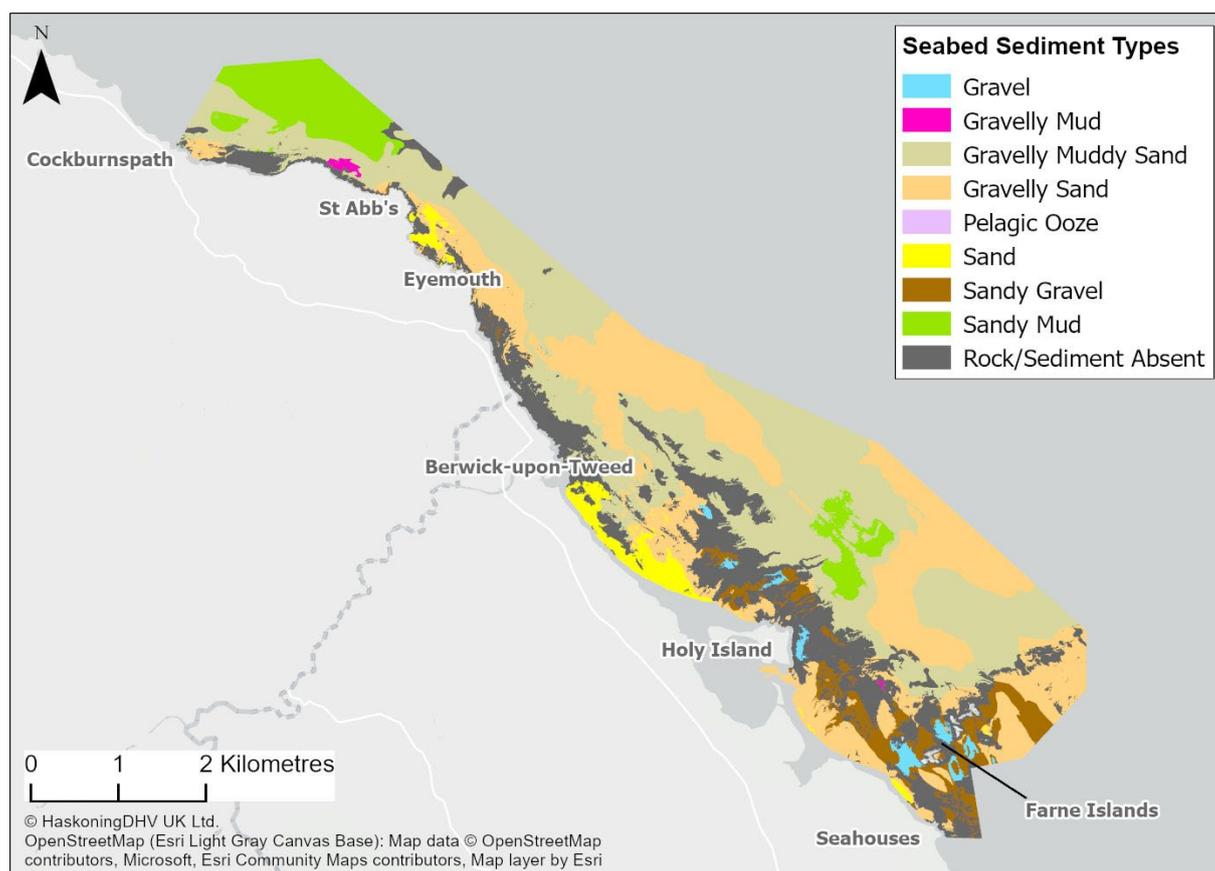


Plate 2.1 - Sea bed sediment map of St. Abb's Head to the Farne Islands (MCA and UKHO, 2021)

Areas deeper than -70m OD occur off St. Abb's Head, and here the sea bed slope shallows and becomes more irregular (Figure 2.2). The sea bed is mainly composed of gravelly muddy sand with an area of sandy mud north of St. Abb's Head (Plate 2.1, MCA and UKHO, 2021).

South of Berwick-upon-Tweed to the southern extent of the section, the bathymetry is complicated by the presence of larger coastal bays, and the Holy Island-Farne Islands complexes (Figure 2.3). The bays either side of Holy Island (Cheswick-Goswick Bay to the north and Budle Bay to the south) are sand and gravelly sand coasts (Plate 2.1) which slope seawards and transition offshore into large areas of rock exposure at the sea bed (Figure 2.3). The rock exposed at the sea bed is composed of interbedded limestone, shale and sandstone and lies to the northwest and southeast of Holy Island and the Farne Islands, the latter being the subaerial expression of the Great Whin Sill (dolerite).

The bathymetry highlights a couple of linear east-west features to the east of Holy Island which are the seaward sea bed extension of Holy Island dolerite dyke (Figure 2.3 and Plate 2.2). The features are rock ridges with their tops 8-10m above the surrounding sea bed.

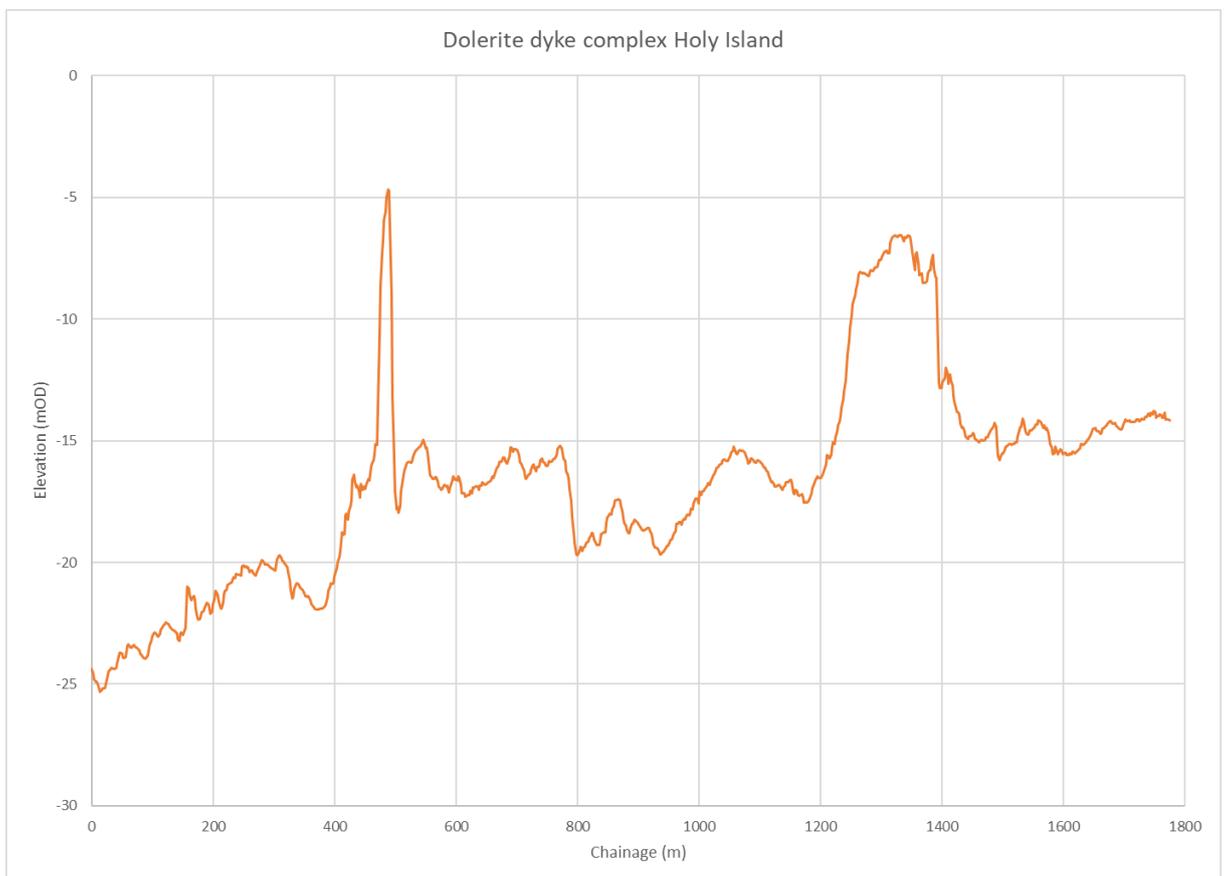


Plate 2.2 - Cross-section of the dolerite dyke ridges to the east of Holy Island. Location of the north (left) to south (right) cross-section is shown on Figure 2.1

The presence of the Farne Islands has created an irregular surrounding bathymetry. In the protected lee of the islands is a relatively shallow area of sea bed forming a salient composed of gravel (Plate 2.1) which extends towards the coast (Figure 2.4). There are also elevated areas (about 2.5km long and 1km wide) of gravelly sand which extend to the northwest and southeast of the innermost Farne Islands (Figure 2.4). These features may represent sand shoals driven by the flood and ebb tides as the currents flow between the coast and the inner islands.

Offshore from the rock outcrops, the sea bed becomes smooth and featureless out to the seaward limit of the survey, where it is mainly gravelly muddy sand, gravelly sand or sandy mud (Plate 2.1). An isolated north-northeast to south-southwest elevated feature (potentially a sand ridge connected to a slightly elevated area of sea bed further inshore, Figure 2.3) is present in this area offshore from Holy Island (Plate 2.3). The crest of the sand ridge is about 5m above the surrounding sea bed and extends from water depths of about -56m OD to -62m OD. The ridge is asymmetrical with the steeper side facing to the southeast.

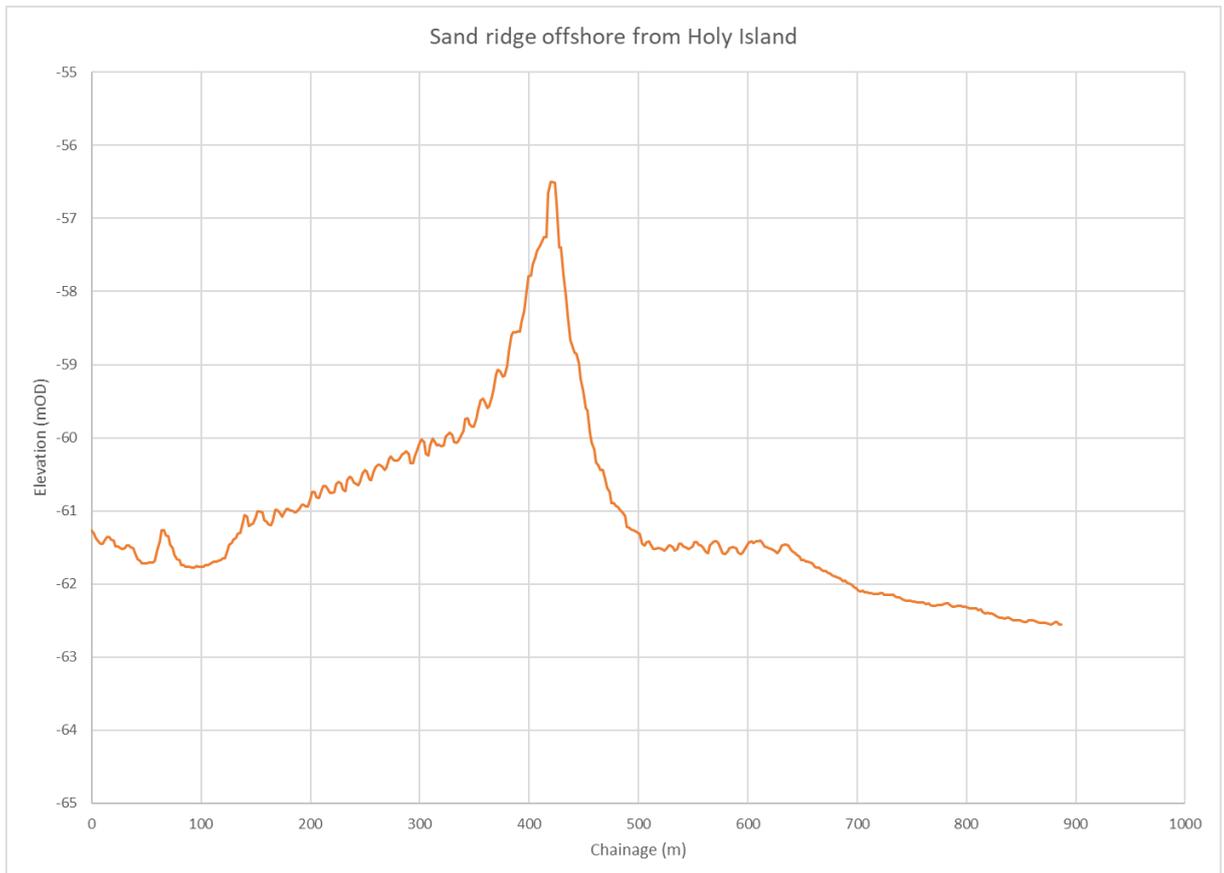


Plate 2.3 - Cross-section of the sand ridge offshore from Holy Island. Location of the northwest (left) to southeast (right) cross-section is shown on Figure 2.1

2.2 Transect Analysis

None of the 15 transect lines are located within this area of the sea bed, and so comparisons of the 2019/2020 survey with the 2010 baseline survey or the 2015 survey are not possible.

3. Alnmouth to Whitley Bay MMO Survey Results

3.1 General Overview

The MMO's 2014 survey between Alnmouth and Whitley Bay covered the (then recommended) Coquet to St. Mary's MCZ (now formally designated). There is some overlap (between Blyth and Whitley Bay) with the Blyth to Sunderland survey (see Section 4). A map of sea bed sediments was also completed for this section using the bathymetry (backscatter) and sea bed sediment samples (Cefas, 2014).

This stretch of coast is dominated by a headland-bay morphology, and the nearshore sea bed features reflect this. The four main bays of Alnmouth, Druridge, Cambois and Seaton comprise a gently sloping bathymetry from the coast to -20m OD (Alnmouth Bay) to -30m OD (Druridge, Cambois and Seaton Bays) about 3km offshore (Figure 3.1). The sea bed in the bays is dominated by sand (Plate 3.1) (Cefas, 2014). The bay bathymetry is bounded by headlands fronted by rock shore platforms, which extend greater than 1km offshore (Figure 3.2). The headlands and rock platform are mainly composed of mudstone and sandstone.

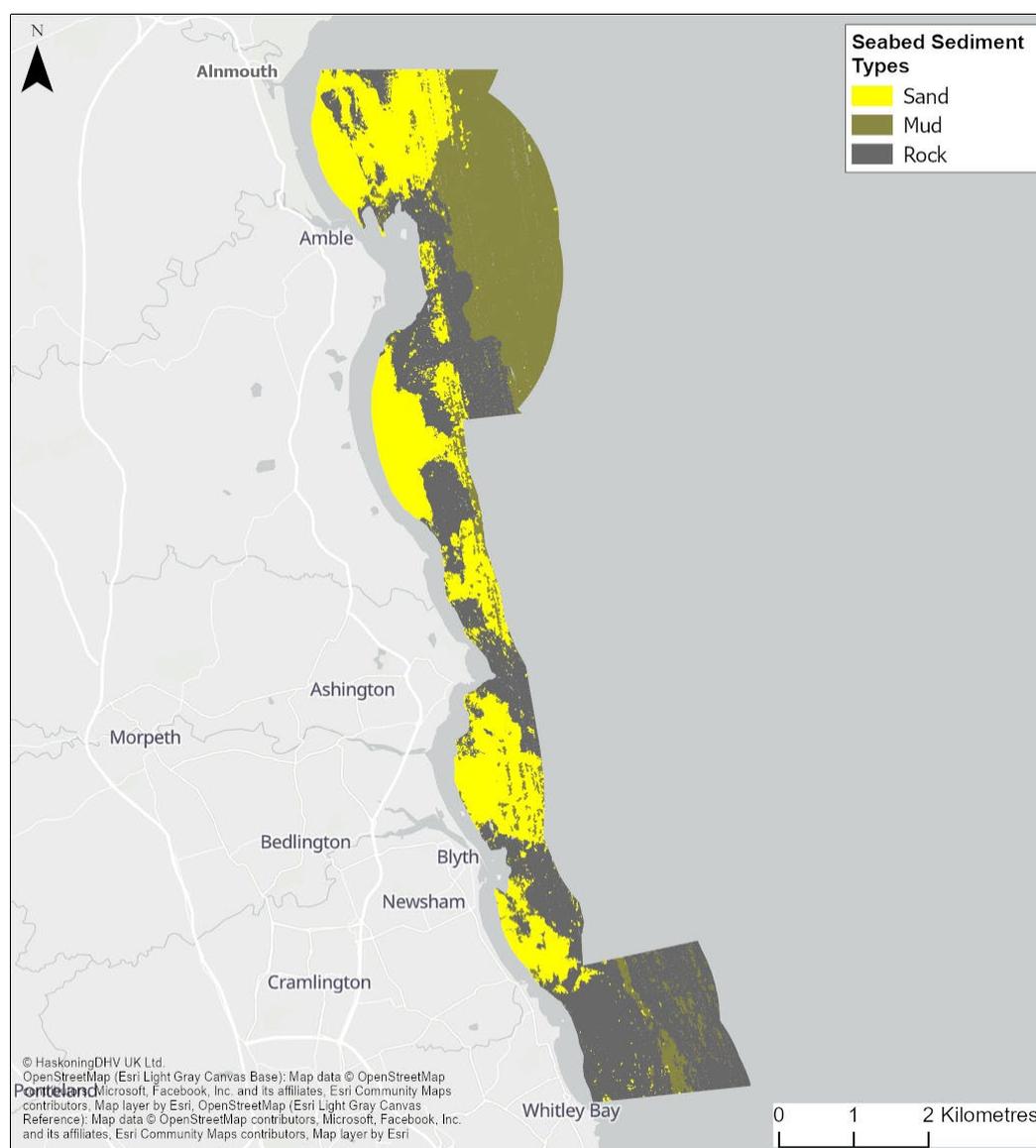


Plate 3.1 - Sea bed sediment map of Alnmouth to Whitley Bay (Cefas, 2014)

Bathymetry collected further offshore (out to greater than 5km at Amble and Whitley Bay) describes two different morphologies. Offshore from Amble is a planar sea bed with a shallow slope down to about -45m OD at the seaward extent of survey. Here, the deeper sea bed is composed of mud (Plate 3.1). Offshore from Whitley Bay the sea bed slopes down to -40m OD at the seaward limit, and contains texture interpreted to be mainly outcropping rock with some elongate mud patches. The sea bed within the bays and further offshore contains no bedforms.

In north Druridge Bay, the bathymetry highlights a linear west-southwest to east-northeast ridge extending seawards to about -35m OD. This is a dolerite dyke, which has a crest about 4-5m above the surrounding sea bed (Figure 3.2 and Plate 3.2).

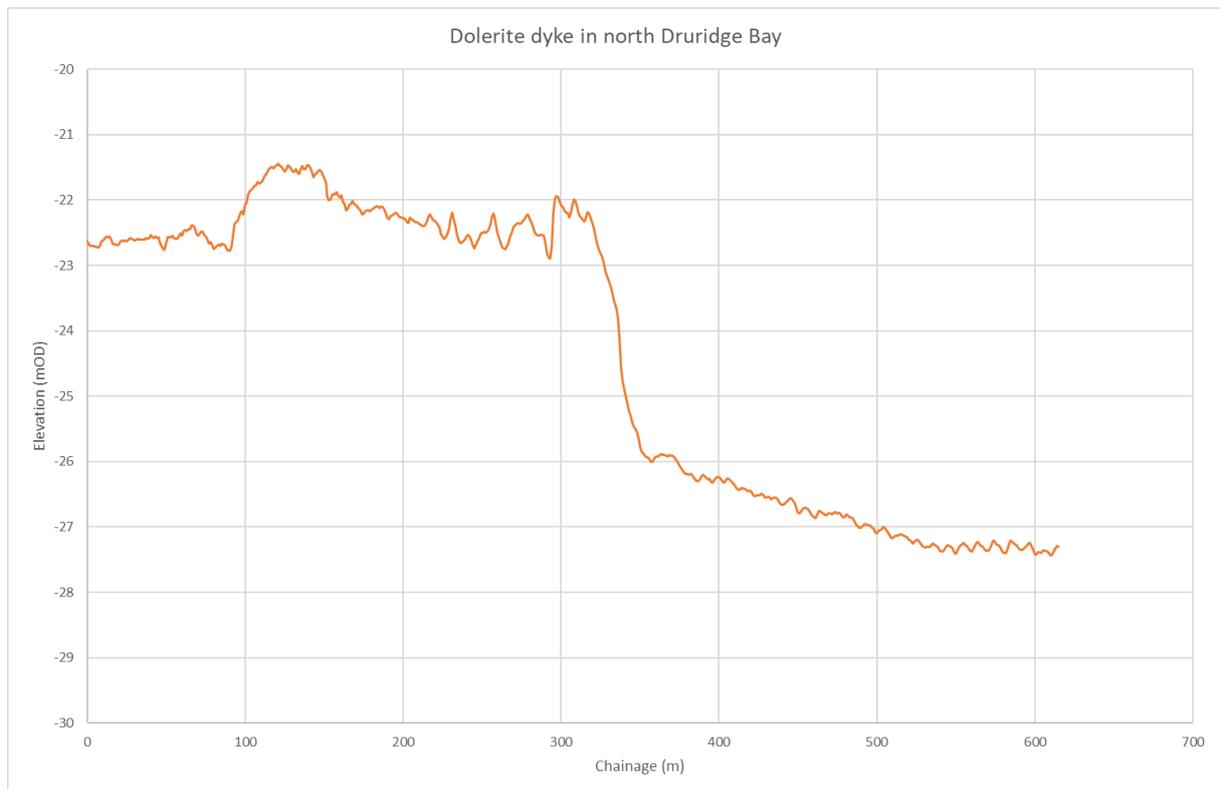


Plate 3.2 - Cross-section of the dolerite dyke in north Druridge Bay. Location of the north (left) to south (right) cross-section is shown on Figure 3.1

3.2 Transect Analysis

None of the 15 transect lines are located within this area of the sea bed, and so comparisons of the MMO's 2014 survey with the 2010 baseline survey or the 2015 survey are not possible.

4. Blyth to Sunderland Survey Results

4.1 General Overview

The sea bed between Blyth and Sunderland is covered by a bathymetric survey completed between February 2019 and March 2019. A map of sea bed sediments was also completed for this section using the bathymetry (backscatter) and sea bed sediment samples (MCA and UKHO, 2019).

The sea bed is characterised by a variable-width rock shore platform extending up to about 3km offshore to about -25m OD. The rock platform is mainly composed of interbedded mudstone and sandstone north of South Shields and halite south of North Shields. Offshore from this, the platform slopes gradually to the limits of the bathymetry survey around 8km from the coast at about -45m OD to -50m OD (Figure 4.1). Here, the rock is covered by gravel or gravelly sand and then at the offshore limit of the survey, the sea bed sediment becomes sandy mud (Plate 4.1).

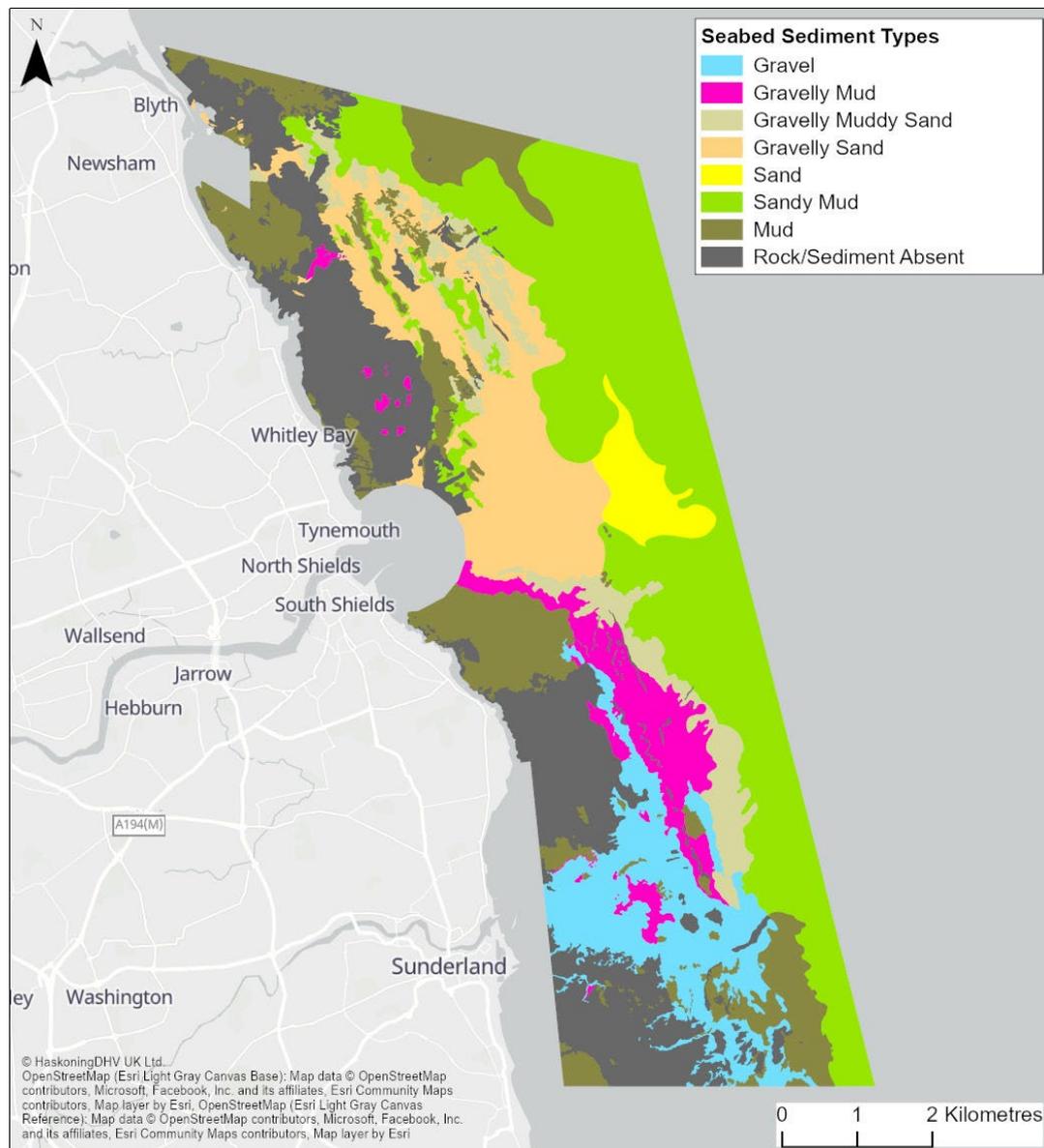


Plate 4.1 - Sea bed sediment map of Blyth to Sunderland (MCA and UKHO, 2019)

The coast also contains two bays; just south of the Blyth Estuary and just south of the Tyne Estuary. Here, the rock platform is absent and the sea bed is smoother and gradually slopes seaward (Figure 4.2). The predominant sea bed sediment in these bays is mud (Plate 4.1) deposited at the mouths of the two estuaries.

There are three 2010 and 2015 shore-normal transects along this section of Cell 1 (#1, #2 and #3). Only transects #2 and #3 overlap with the 2019 bathymetry data. Transect #1 falls within a gap in the latest data.

4.2 Transect Analysis #1: Herd Sands, South Shields

Background

Herd Sands comprises a sandy foreshore backed by dunes and a promenade. There are considerable recreational and amenity assets along the relatively low-lying hinterland which backs the dunes. At present, the frontage is relatively stable, although subject to seasonal variations in level and form. The SMP2 recognises that longer-term sea-level rise will put increasing pressure on this frontage as the dunes will tend to be constrained by the promenade in their natural tendency to migrate landwards.

The purpose of this transect is to observe, over time, the relationship between the foreshore and the sea bed, and to determine whether sea bed lowering is occurring and what is effect on the foreshore and dunes may be.

2010 and 2015 Survey Findings

The bathymetric survey at Herd Sands extends approximately 2.4km offshore to a depth of -24m OD (Royal Haskoning and Halcrow, 2010; CH2M, 2015). The long profile describes a homogeneous and essentially featureless sea bed composed of sand with gravel that gradually slopes offshore with a consistent gradient of about 0.4° (Figure 4.3).

Changes in elevation and character of the sea bed between 2010 and 2015 were interpreted by CH2M (2015):

- The 2010 survey was prone to ridging probably caused by rough seas and the 2015 data reveals several features not previously documented.
- Elevation changes in the nearshore zone offshore from about 150m (-2m OD) to 300m (-4m OD) can be divided into two zones. From 150m and 250m (-3m OD) is a zone of erosion up to about 2.3m, beyond which is a zone of accretion (up to 0.8m) offshore (Figure 4.3). CH2M (2015) suggest these changes are indicative of migrating sand bars.
- Change over the rest of the survey area is manifest in the form of several longitudinal strips of erosion and accretion (+/-0.4m) which are an artefact of errors in the 2010 survey data.
- From 500 to 600m offshore (-9m OD to -10m OD) the sea bed shows a shallow depression (identified in 2015) which is likely to be a scour hollow.

4.3 Transect Analysis #2: South Bents, Whitburn Bay

Background

Whitburn Bay comprises undefended till-mantled Magnesian Limestone cliffs in the north and protected near-continuous development in the south, leading to the River Wear. The SMP2 identifies that over the next 50 years, beach levels in the vicinity of South Bents may continue to drop due to both nearshore steepening and sea level rise.

The purpose of this transect is to record any evidence of beach and nearshore lowering or steepening to inform future management decisions at this frontage.

2010 and 2015 Survey Findings

The bathymetric survey at Whitburn Bay extends approximately 2.7km offshore to a depth of –24m OD (Royal Haskoning and Halcrow, 2010; CH2M, 2015). The long profile for Whitburn Bay shows that the sea bed is exposed rock covered in places with a veneer of sediment (Figure 4.4a).

Changes in elevation and character of the sea bed between 2010 and 2015 were interpreted by CH2M (2015). Change between the two surveys is limited to longitudinal strips of mainly erosion (-0.2m) with some minor accretion which are an artefact of small errors in the 2010 survey data (Figure 4.4b).

2019 Survey Findings

The 2019 survey only overlaps the seaward halves of the 2010 and 2015 data (from about 1.2km to 2.7km offshore. Comparison of the February-March 2019 with March-April 2015 (about four years) shows that the sea bed has generally accreted by up to about 0.4m (Figure 4.4b). Comparison of the results of the February-March 2019 survey with those of 2010 shows that the sea bed has generally accreted by up to about 0.2m. However, these elevation changes are manifest in the form of several longitudinal strips of accretion with some erosion which are likely to be artefacts of small errors in the 2010 survey data.

4.4 Transect Analysis #3: Salterfen Rocks

Background

Salterfen Rocks, together with other rock stacks and rock foreshore outcrops, exert a key control on the evolution of the coast between Hendon and Ryhope. The resilience to erosion of Salterfen Rocks will have a significant bearing on projected assessments of future shoreline position, and if assets such as roads and railway lines would be lost to erosion.

The purpose of this transect is to monitor the sea bed changes offshore of Salterfen Rocks which could have an influence on its stability.

2010 and 2015 Survey Findings

The bathymetric survey at Salterfen Rocks extends approximately 4.7km offshore to a depth of –25m OD (Royal Haskoning and Halcrow, 2010; CH2M, 2015). The 2010

and 2015 mapping and long profiles show that the sea bed can be characterised into three main zones (Figure 4.5a):

- Bedrock is exposed to about 800m offshore at about -11m OD, with pockets of sediment present between the outcrops.
- From 800m to about 2.4km offshore (at -18m OD), the sea bed is featureless mud and slopes seaward at an average gradient of 0.2°.
- From about 2.4km to 4.7km, the sea bed is rock interspersed with areas veneered with sediment in bathymetric lows.

The 2015 survey confirms the features described in 2010 and describes little change over that time period (Figure 4.5b). Small changes are limited to a series of strips of erosion and accretion (+/-0.2m) along the profile that are an artefact of error in the 2010 survey.

2019 Survey Findings

The 2019 survey overlaps the 2010 and 2015 data from about 1.3km offshore to 4.7km offshore. Comparison of the February-March 2019 with March-April 2015 (about four years) shows that the offshore sea bed has typically accreted by 0.2-0.4m, but up to about 1m in places (Figure 4.5b). Comparison of the results of the February-March 2019 survey with those of 2010 shows that the sea bed has accreted by similar magnitudes to the 2015 to 2019 period. However, these elevation changes are manifest in the form of several longitudinal strips of accretion with some erosion which are likely to be artefacts of small errors in the 2010 survey data.

5. Sunderland to Redcar Survey Results

5.1 General Overview

The sea bed between Sunderland and Redcar is covered by a bathymetric survey completed between November 2017 and January 2018. A substrate mapping exercise was also completed for this section highlighting sea bed texture and sand thickness derived from bathymetry (backscatter), sub-bottom profiling and 38 sea bed sediment samples (Clinton Marine Survey, 2018a).

The sea bed is characterised by a rock shore platform changing offshore in to an essentially featureless sea bed followed further offshore by gradation into what is likely to be rock overlain by a veneer of sediment (Figure 5.1). The boundary between the two main offshore sediment characters is difficult to define using the data available.

Where present, the rock shore platform has a variable width up to 1km, but more typically between 200m and 500m (Figure 5.2). It is mainly composed of dolomite (north of Hartlepool) becoming mudstone at Redcar. Where the platform is absent the nearshore sea bed is featureless, sloping offshore from the coast to about -20m OD (2.5-4.5km offshore) (Figure 5.2). This featureless sea bed is also present seaward of the rock shore platform to form an effectively continuous substrate along the entire section (before it is interrupted by a wider rock shore platform at Redcar headland). Clinton Marine Survey (2018a) indicated that this sea bed is dominated by fine sand and muddy sand. The dredged channel of the Tees Estuary cuts through the sloping foreshore south of Hartlepool (Figure 5.3). Offshore from the featureless sea bed to the seaward limit of the survey at about -25m OD, the sea bed is composed of rock with a veneer of sediment (Figure 5.2). Where sediment is present on the sea bed it is composed predominantly of sandy gravel (Clinton Marine Survey (2018a).

There are two 2010 and 2015 shore-normal transects along this section of Cell 1 (#4 and #5).

5.2 Transect Analysis #4: Blast Beach

Background

Blast Beach is characterised by a relatively wide foreshore composed of colliery spoil that protects dormant cliffs. The SMP2 identifies that with sea-level rise, material is likely to be eroded from the spoil beach and in the longer term will trigger recession of the cliffs. The objective of this transect is to observe trends in the sea bed that could lead to accelerated erosion of the spoil beach material.

2010 and 2015 Survey Findings

The bathymetric surveys at Blast Beach extend approximately 3.5km offshore to a depth of -24m OD (Royal Haskoning and Halcrow, 2010; CH2M, 2015). The 2010 and 2015 mapping and long profiles show that this area can be characterised into three main zones (Figure 5.4a):

- The nearshore sea bed to about -3m OD is dominated by a rock shore platform of dolomite strewn with boulders.

- The rest of the transect to about 2.2km offshore at a depth of about -22m OD is characterised by featureless sand. The long profile describes a subtle concave-convex morphology with an average gradient of 0.5°.
- Seaward of 2.2km is a relatively flat sea bed (-22m OD to -24m OD over about 1km) composed of rock covered with a veneer of gravel. The sea bed exhibits no geological structure due to the veneer of sediment.

Changes in elevation and character of the sea bed between 2010 and 2015 were interpreted by CH2M (2015):

- Elevation changes in the nearshore zone offshore to about 750m at a depth of -10m OD can be divided into two zones. From the coast to 200m offshore (-5m OD) is a zone of accretion up to 0.8m, beyond which is a zone of erosion (up to 0.5m) offshore (Figure 5.4b). CH2M (2015) suggest these changes are indicative of migrating sand bars.
- Change beyond about 750m offshore is manifest in the form of several longitudinal strips of erosion and accretion (+/-0.2m) which are an artefact of small errors in the 2010 survey data.

2017-2018 Survey Findings

Comparison of the November 2017 to January 2018 with March-April 2015 (about 2.5 years) shows that from the coast offshore for 50m, the sea bed has generally accreted (by up to 0.5m) (Figure 5.4b). From 50m to 200m offshore, the sea bed eroded by up to 0.3m, beyond which, to the seaward limit of the transect (3.5km), the sea bed has accreted by up to 0.3m. The nearshore changes (first 200m of the transect) are likely to be due to migration of nearshore sand bars and beach morphological change.

Comparison of the results of the November 2017 to January 2018 survey with those of 2010 show that from the coast to about 200m offshore (-5m OD) the sea bed has predominantly accreted up to 0.5m (Figure 5.4b). From 200m to 250m offshore (-6m OD), the sea bed eroded (up to 0.3m). From 250m to 750m offshore (-10m OD) elevation change is manifest in the form of several longitudinal strips of erosion and accretion (+/-0.2m) which are likely to be artefacts of small errors in the 2010 survey data.

5.4 Transect Analysis #5: Hartlepool North Sands

Background

Hartlepool North Sands comprises a wide sandy beach backed by dunes, with various industrial works (many now demolished), warehousing, residential development and a cemetery on the hinterland. The SMP2 identifies that projected 50- and 100-year erosion would result in loss of dune, land and regeneration opportunity on presently derelict land. There were also issues raised by the SMP2 relating to potential erosion of the cemetery, release of industrial waste material to the foreshore, and outflanking of defences elsewhere along the frontage.

The objective of this transect is to assess the interactions between the sea bed and the foreshore and determine whether any changes in the sea bed could influence the projected erosion of the coast.

2010 and 2015 Survey Findings

The bathymetric survey at Hartlepool North extends approximately 3.0km offshore to a depth of -25m OD. The 2010 and 2015 mapping and long profiles indicate that this area of sea bed can be categorised into two main zones (Figure 5.5a):

- Most of the transect is homogeneous, with featureless sand extending to a depth of about -23m OD with a small rock outcrop at about -21m OD (about 23km offshore). CH2M (2015) described a fining-offshore sediment composition, with medium sand in the nearshore, fine sand from about -10m OD to -20m OD and very fine sand deeper than -20m OD. The long profile describes a concave morphology in the nearshore 1.5km and a planar sea bed for the more seaward 1.5km.
- The sea bed from -23m OD to -24m OD is irregular and interpreted as rock outcrop close to the sea bed covered by a veneer of gravel.

Changes in elevation and character of the sea bed between 2010 and 2015 were interpreted by CH2M (2015):

- Erosion of up to 1.5m has occurred in the nearshore zone extending about 750m from the shore to a depth of about -9.5m OD (Figure 5.5b). The pattern of change alternates between very little change and erosion. CH2M (2015) suggested that sand bars that were present in 2010 have been eroded to create a smoother sea bed.
- Minor changes (up to +/-0.2m) further offshore are limited to within strips of sea bed, which are artefacts of errors in the 2010 data.

2017-2018 Survey Findings

Comparison of the November 2017 to January 2018 with March-April 2015 (about 2.5 years) shows that from the coast offshore for 30m, the sea bed has generally eroded (by up to 0.5m) (Figure 5.5b). From 30m to 150m offshore, the sea bed accreted by up to 0.7m, and then erosion of up to 0.3m has occurred from 150m to 400m (-8m OD) offshore. Seaward of 400m, to the seaward limit of the transect (3.0km), the sea bed has accreted by up to 0.2m. The nearshore changes (first 400m of the transect) are likely to be due to migration of nearshore sand bars and beach morphological change and suggest the offshore limit of wave-driven sediment transport is -8m OD.

Comparison of the results of the November 2017 to January 2018 survey with those of 2010 show that from the coast to about 80m offshore (-4m OD) the sea bed has predominantly eroded up to 1.5m (Figure 5.5b). The greatest erosion has occurred close to the coast. From 80m to about 140m offshore (-5m OD), the sea bed accreted (up to 0.3m). From 140m to 500m offshore (-10m OD) is a wider zone of erosion, up to 0.7m. From here to the seaward limit of the transect is a wide zone of accretion up to 0.2m.

6. Redcar to Runswick Bay Survey Results

6.1 General Overview

This area of sea bed is covered by a bathymetric survey completed in November and December 2016 (Redcar to Staithes) and December 2017 and January 2018 (Runswick Bay). A substrate mapping exercise was completed for the Redcar to Staithes section by MMT (2017) highlighting sea bed features using the bathymetry (backscatter) and sea bed sediment samples. Clinton Marine Surveys (2018b) provided substrate mapping in Runswick Bay highlighting sea bed texture and sand thickness derived from bathymetry (backscatter), sub-bottom profiling and three sea bed sediment samples.

Redcar to Staithes

The bathymetry between Redcar and Staithes is dominated by four morphological types (from landward to seaward) (Figure 6.1). The coast and nearshore sea bed between Redcar and Staithes are characterised by either a rock shore platform (1-2km wide) or a featureless sand or muddy sand (MMT, 2017) sea bed offshore to about -20m OD to -25m OD (Figure 6.1 and Figure 6.2). The rock shore platform is composed of mudstone and criss-crossed by numerous north-south aligned faults. Offshore from this to the seaward limit of the survey (-40m OD to -50m OD), the sea bed is composed of mudstone rock outcrops with complex structure across a large part of the section or rock covered with a variable thickness sandy gravel layer at the west-northwest and east-southeast ends (Figure 6.2). There is an absence of mobile bedforms of all scales in this section.

There are two 2010 and 2015 shore-normal transects along this section of Cell 1 (#6 and #7).

Runswick Bay

The bathymetric data from Runswick Bay was collected in 2013 and 2017/2018 (Clinton Marine Surveys, 2018b). Figure 6.3 shows the data from 2013 as there were complications with delivery of the 2017/2018 data in a digital form. The rock shore platform is distinguishable, extending offshore between 0.5km and 1km (out to -20m OD to -25m OD). The rock shore platform is composed of mudstone. Offshore from this, the sea bed does not contain any major bedforms. Most of the area consists of outcropping rock with no sediment cover and therefore, the sea bed is similar to the Redcar to Staithes section to the northwest rather than the Sandsend to Whitby section to the southeast (Section 7). Where it is present, the sediment cover is relatively smooth/flat and lacks morphological features and is predominantly sand (Plates 6.1 and 6.2).

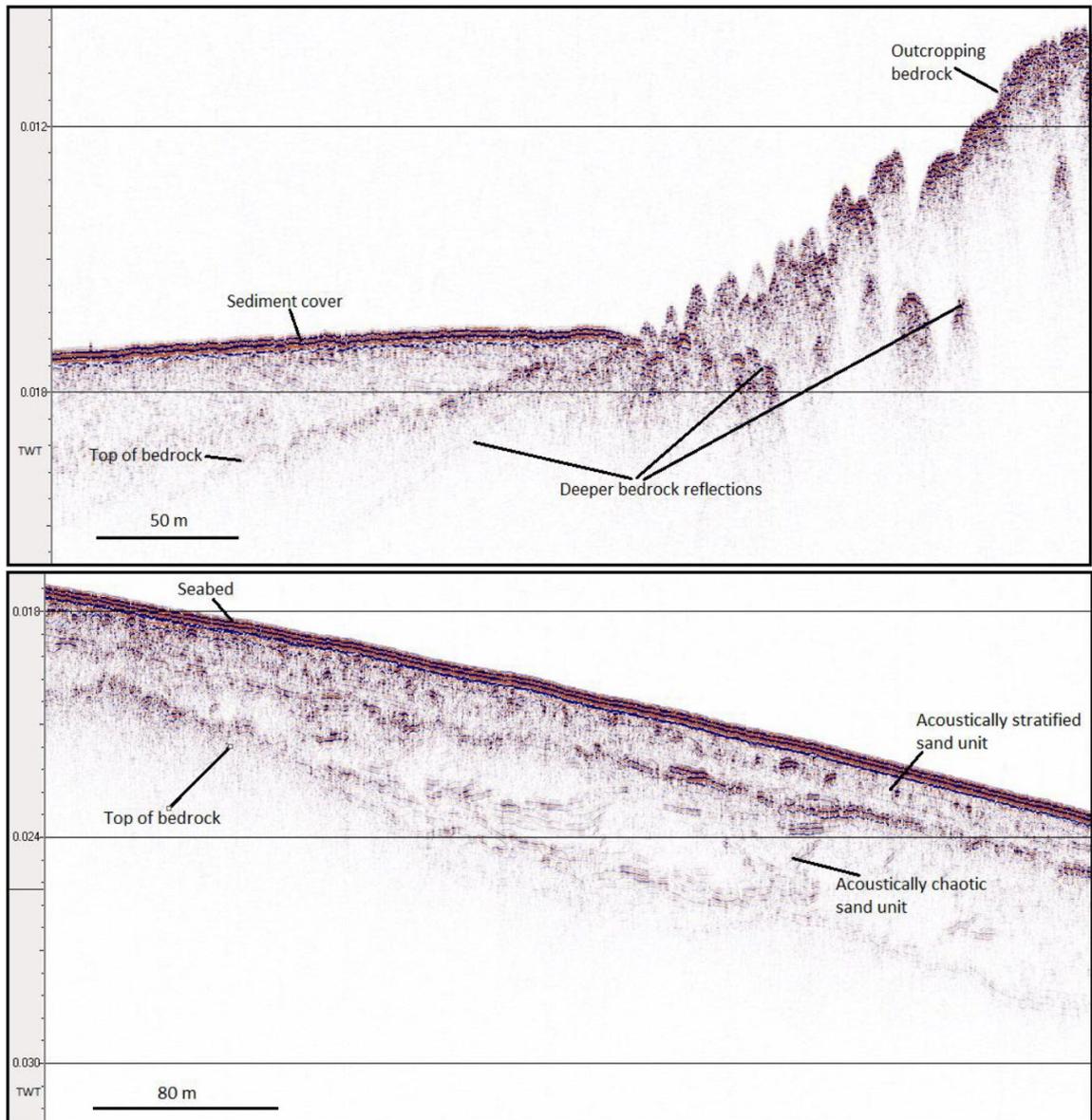


Plate 6.1 - Sub-bottom profiles showing the contact between outcropping rock and sediment cover (top) and an example of the sediment cover in the central-outer part where the sediment thickness reaches approximately 5m (Clinton Marine Surveys, 2018b)



Plate 6.2 - Sea bed texture chart of Runswick Bay. The different textures of the sea bed are represented by the coloured polygons, where red is rock, yellow is sand and brown-grey is mud (Clinton Marine Surveys, 2018b)

Where the bed is predominantly sand with some mud across the central part of Runswick Bay, the stratigraphy describes a north-south oriented channel infilled with this sediment up to 5m thick (Plate 6.3).

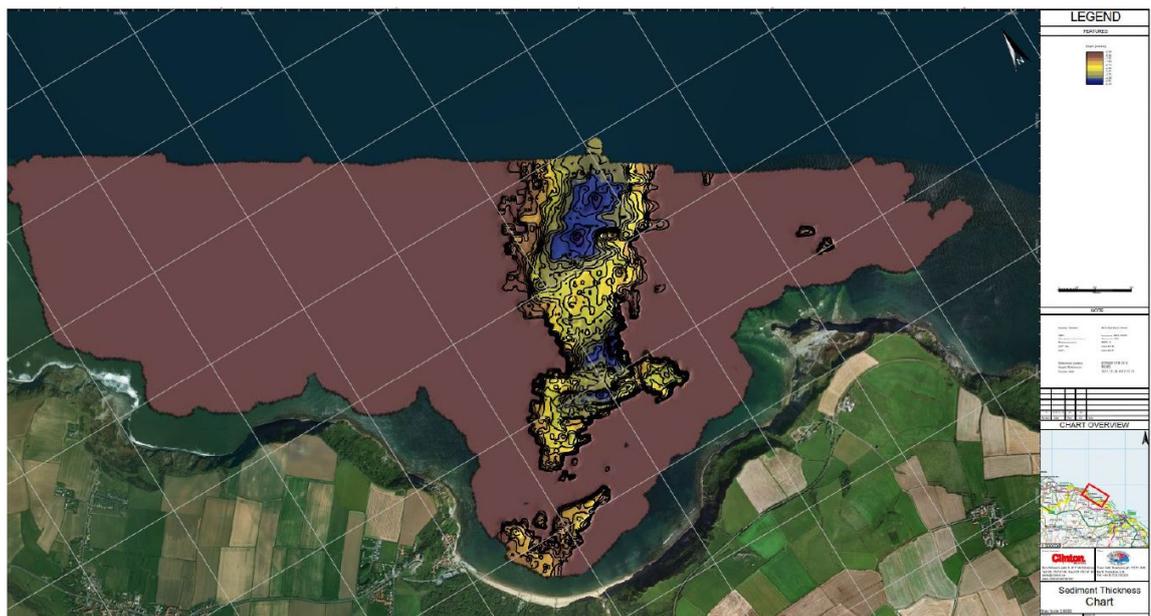


Plate 6.3 - Thickness of sediment infilling the channel through the centre of Runswick Bay. Brown represents areas without sediment cover. Blue represents areas where sediment is up to 5m thick (Clinton Marine Surveys, 2018b)

There is one 2010 and 2015 shore-normal transect line along this section of Cell 1 (#8).

6.2 Transect Analysis #6: Saltburn-by-the-Sea

Background

The SMP2 identifies that a significant area of Saltburn-by-the-Sea town, together with sections of the coast road, is situated close to the crest of the coastal slope or immediately behind defences. Consequently, considerable loss of assets would occur if the defences were not maintained or were breached.

The objective of this transect is to better understand the interactions between the beach and sea bed to ensure that coastal defences are appropriate.

2010 and 2015 Survey Findings

The bathymetric surveys extend 4.5 km offshore where the sea bed reaches -25m OD (Royal Haskoning and Halcrow, 2010; CH2M, 2015). The 2010 and 2015 mapping and long profiles for Saltburn-by-the-Sea indicate that this area is characterised by two main zones (Figure 6.4a):

- a featureless fine sand in the nearshore that extends to 2.5km from the coast to -20m OD depth with a uniform gradient of 0.4°. This zone has small outcrops of rock between 1.8km and 2.1km.
- an offshore zone that extends from 2.5km to 4km characterised by rock outcrop with a mean gradient of 0.1°. The rock exposure is characterised by bedding which strikes west-northwest to east-southeast, and dips gently to the south-southwest. The composition of sea bed sediment located between the bedding ranges from very fine sand to very coarse sand.

Changes in elevation and character of the sea bed between 2010 and 2015 were interpreted by CH2M (2015):

- Erosion of up to 1m in the nearshore zone extending about 750m to -8m OD (Figure 6.4b). The pattern of change in this area alternates between no detectable change and erosion, suggesting that sand bars recorded in 2010 have been eroded and replaced with a smoother sea bed.
- Change further offshore is limited to minor erosion along three strips of sea bed, which is an artefact of error in the 2010 data.

2016 Survey Findings

Between March-April 2015 and November-December 2016 (about 18 months), narrow alternating zones of erosion and accretion occurred within the nearshore zone out to about 250m from the coast (Figure 6.4b). Erosion up to about 0.3m occurred from the coast to about 100m offshore and from 150m to 250m offshore. Sandwiched between these two zones (100-150m offshore) is a zone of accretion up to 0.5m. Further offshore, the data shows that most of the transect has eroded by up to 0.15m between 2015 and 2016. This is likely to be within the vertical error of capture of the two datasets.

Comparison of the results of the November-December 2016 survey with those of 2010 describe similar strips of erosion to those between 2010 and 2015, and are errors related to data artefacts in the 2010 survey (Figure 6.4b). The large changes

in the nearshore zone may have more basis although their precise distribution (due to errors in the 2010 data) may not be accurate.

6.3 Transect Analysis #7: Skinninggrove

Background

The village of Skinninggrove rests on a low till platform with a stream running to the southern and eastern sides of the village. The defences which protect the village have been enhanced through the construction of a rock fishtail groyne to the eastern side of the stream. The SMP2 has identified that this structure, combined with the disused breakwater (jetty) to the west has encouraged significant build-up of sediment along the foreshore.

The objective of this transect is to better understand the interactions between the sediment on the sea bed and the shoreline, and how they are influenced by the coastal defence structures, especially the rock fishtail groyne.

2010 and 2015 Survey Findings

The bathymetric surveys for Skinninggrove extend approximately 3.6km offshore to a depth of -26m OD (Royal Haskoning and Halcrow, 2010; CH2M, 2015). The 2010 and 2015 mapping and long profiles for Skinninggrove indicate that this area is characterised by two main zones (Figure 6.5a):

- The nearshore zone out to 1.8km (-15m OD) comprises featureless fine sand with a mean gradient of 0.3°. There is a small rock outcrop between 0.8km and 1km offshore.
- From 1.8km offshore to 3.6km (-25m OD) the sea bed is characterised by outcrops of rock with a cover of fine sand in hollows.

Changes in elevation and character of the sea bed between 2010 and 2015 were interpreted by CH2M (2015):

- A zone of alternating accretion and erosion of +/-1.5m occurs in a nearshore sand zone extending 800m offshore to -8m OD (Figure 6.5b).
- Localised erosion of up to 0.5m is indicated on the offshore side of the rock outcrop at -9m OD.
- Changes in elevation in deeper water are an artefact of errors in the 2010 survey.

2016 Survey Findings

Between March-April 2015 and November-December 2016 (about 18 months), narrow alternating zones of erosion and accretion occurred within the nearshore zone out to about 500m from the coast (-6m OD). Erosion up to about 1.7m and accretion up to 1.3m occurred in five northwest-southeast linear zones. This suggests the offshore limit of wave-driven sediment transport is about -6m OD. There is no evidence that the fish-tail groyne or breakwater have led to sediment accumulation or starvation in the area surveyed. Further offshore the featureless sand has eroded by up to 0.2m. This is likely to be within the vertical error of capture of the two datasets.

Comparison of the results of the November-December 2016 survey with those of 2010 describe similar magnitudes of erosion (+/-1.5m) in the nearshore zone to those between 2010 and 2015. Further offshore, the comparison describes similar errors to the 2010-2015 comparison (data artefacts in the 2010 survey).

6.4 Transect Analysis #8: Runswick Bay

Background

Runswick Bay is formed between the headlands of Caldron Cliff and Kettleness and comprises a deeply indented sandy bay backed by cliffs that are subject to instability. The SMP2 identifies that consideration should be given to whether there is scope for modifying the shape of recent emergency works near the village and recommended urgent works that have been considered in a recent strategy update.

The objective of this transect is to improve understanding of the process interactions between the shore and sea bed to better inform management of the erosion risks.

No data has been supplied post the 2015 survey and so the comparison of transects is that described by CH2M (2015) and no update is provided.

2010 and 2015 Survey Findings

The bathymetric surveys for Runswick Bay extend approximately 2.4km offshore to a depth of -25m OD (Royal Haskoning and Halcrow, 2010; CH2M, 2015). The 2010 and 2015 mapping and long profiles for Runswick Bay indicate that the area can be categorised into two main zones (Figure 6.6a):

- A nearshore zone that extends to about 0.8km offshore to a depth of around -15m OD and slopes at about 0.6°. It is characterised by a rock and boulder-strewn bed with isolated patches of smooth sand. Fine to medium sand predominates in the nearshore 200m.
- Further offshore, from 0.8km to 2.4km between water depths of about -15m OD and -25m OD, the sea bed is characterised by smooth fine to medium sand with a rock outcrop around 1.1km offshore. The long profile shows a gentle convex form, with an average slope of under 0.5°. The feature is interpreted as a large sand bank.

Changes in elevation and character of the sea bed between 2010 and 2015 were interpreted by CH2M (2015):

- The sandy nearshore zone that extends from about 0.3km to -7m OD describes an alternating pattern of accretion and erosion of +/-1m that is indicative of sand bars moving over a rock shore platform (Figure 6.6b).
- Localised erosion of up to 0.5m is indicated in the nearshore rocky area between 0.3km and 0.8km offshore. This suggests mobilisation of sand deposited in depressions.
- The nearshore face of the large sand bank between -12m OD and -14m OD, from 0.8km to 1.1km offshore shows widespread accretion of up to 1.5m.
- Further offshore, strips of erosion are an artefact of errors in the 2010 data.

7. Runswick Bay to Robin Hood's Bay Survey Results

7.1 General Overview

This area of sea bed is covered by a bathymetric survey completed in November and December 2016. A substrate mapping exercise was completed for the Runswick Bay to Robin Hood's Bay section by MMT (2017) highlighting sea bed features using the bathymetry (backscatter) and sea bed sediment samples.

Sandsend to Whitby

The coast and nearshore sea bed between Sandsend and Whitby are dominated by a variable width rock shore platform (500m to 2km wide) interspersed with featureless sand or muddy sand (MMT, 2017) offshore to about -20m OD (Figure 7.1). The rock shore platform is composed of mudstone. In the nearshore zone of Saltwick Bay, there is evidence for a small antecedent river channel cutting through the rock shore platform (Figure 7.2).

Further offshore, the sea bed is characterised by an area of rippled sand (Figure 7.3). The ripples have wavelengths of about 15m and heights of about 0.2-0.3m (Plate 7.1). The rippled sand is about 2km wide in the northwest (extending to about 4.5km offshore), narrowing to around 200m in the east-southeast (extending to about 2-2.5km offshore). The extent of the rippled sand appears to be controlled by bathymetry, as they occur in water depths from about -20m OD to -45m OD.

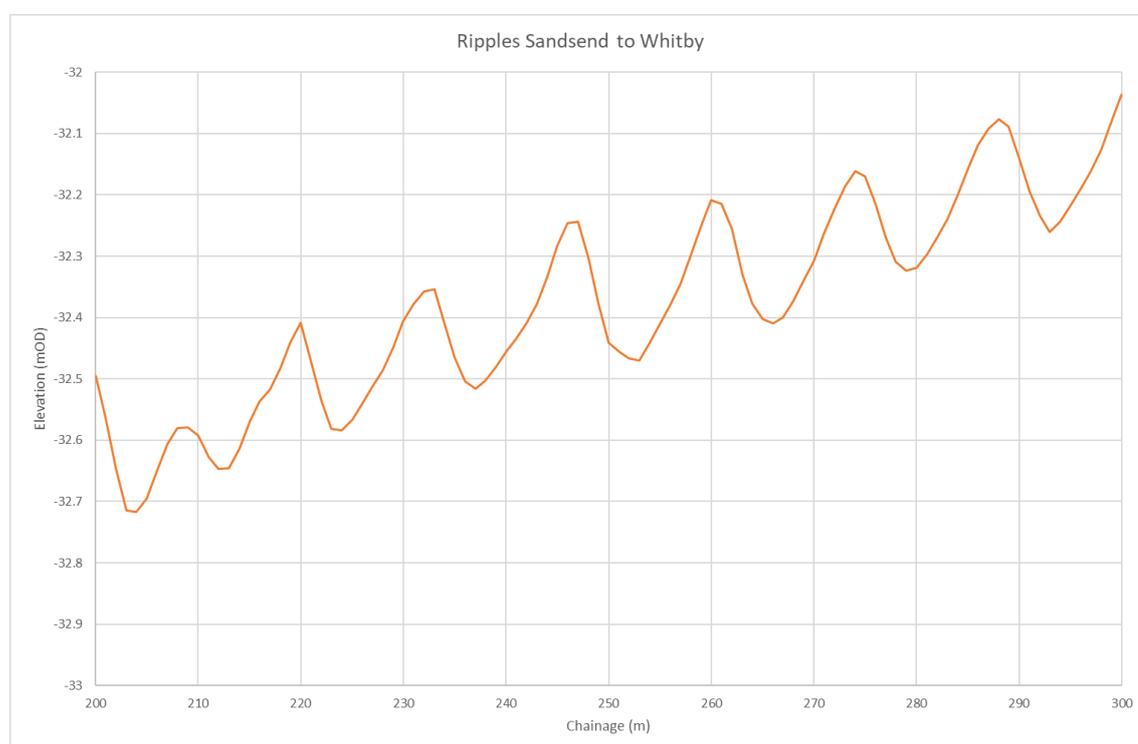


Plate 7.1 - Cross-section of the rippled sand offshore between Sandsend and Whitby. Location of the northwest (left) to southeast (right) cross-section is shown on Figure 7.1

From 4km to 4.5km offshore from Sandsend, the rippled sand is superimposed upon a series of larger sand waves oriented south-southwest to north-northeast with a single longer sand ridge (with a couple of bifurcations at its seaward end) extending shoreward for about 2km, which is oriented southwest-northeast (Figure 7.3). The sand wave crests are spaced about 150-300m apart, and they are about 1.5-2.5m high in water depths of about -40m OD to -45m OD (Plate 7.2). The bedform crest orientation indicates gross sediment transport along a west-northwest to east-southeast axis. The sand waves are asymmetrical with the steeper side facing to the east-southeast indicating net migration and dominant transport direction to the east-southeast. The crest of the isolated sand ridge is about 3-4m above the surrounding sea bed and extends from water depths of about -25m OD to -45m OD (Plate 7.3).

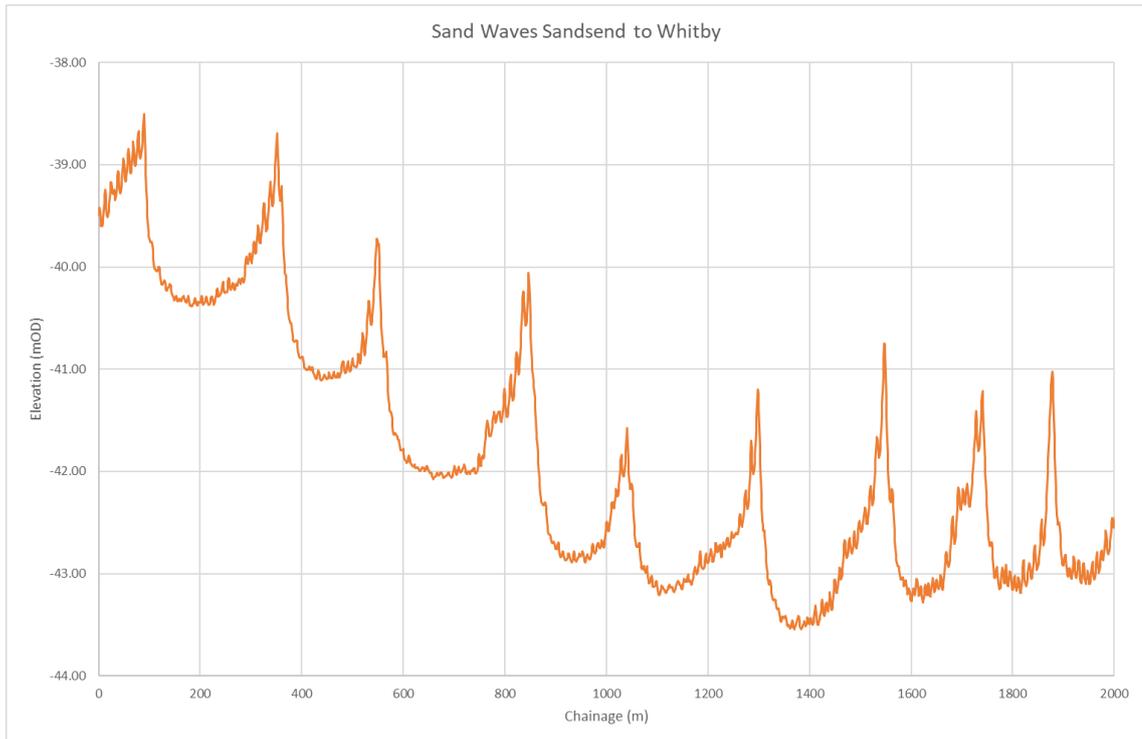


Plate 7.2 - Cross-section of the sand waves offshore between Sandsend and Whitby. Location of the west-northwest (left) to east-southeast (right) cross-section is shown on Figure 7.1

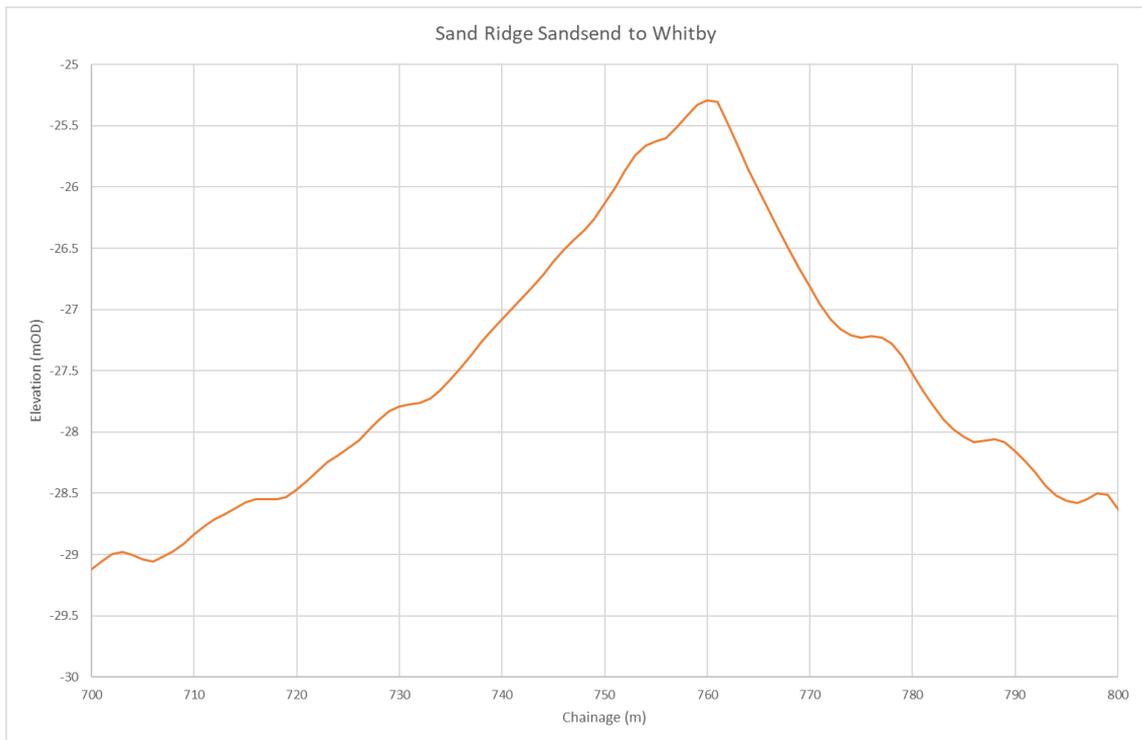


Plate 7.3 - Cross-section of the sand ridge offshore between Sandsend and Whitby. Location of the northwest (left) to southeast (right) cross-section is shown on Figure 7.1

About 4.5km offshore in water depths greater than -45m OD to the seaward limit of the survey area, the rippled sand thins and disappears, and rock is exposed at the sea bed (predominantly mudstone) partially obscured by a veneer of sandy gravel (MMT, 2017). Bedding is evident at the sea bed and a large anticlinal feature occurs with a centre about 6km offshore (Figure 7.1).

There are two 2010 and 2015 shore-normal transects along this section of Cell 1 (#9 and #10).

Whitby to Robin Hood's Bay

Between Whitby and Robin Hood's Bay, the bathymetry is dominated by three main zones (Figure 7.1). Stretching out from the coast is a southeast continuation of the mudstone rock shore platform between Sandsend and Whitby. The platform is up to 600m wide, offshore of which it is partially obscured by sediment, although structure (bedding) is still visible at the sea bed (Figure 7.4). At Stainsacre, a small gap in the rock shore platform comprises a featureless sand sea bed occupied by several small northeast-southwest depressions. The depressions are about 120-180m long, up to 25-30m wide and 0.6-0.9m deeper than the surrounding sea bed (Figure 7.4). According to CCO (2017), similar features offshore from Robin Hood's Bay to Flamborough Head are composed of 'coarse sediment' within a surrounding sand sea bed.

The rock is eventually covered offshore by a narrow zone of sand waves (about 1.5-2km offshore in -30m OD to -45m OD water depths) (Figure 7.4). The crests of the sand waves gradually lengthen to the southeast as do the crest spacings from 50-100m in the northwest to 100-200m in the southeast. The sand waves are about 1-2m high (Plate 7.4). Towards Robin Hood's Bay, there are some significantly larger sand waves, with crest lengths up to 1.5km (extending seawards to -50m OD) and heights of about 3m (Figure 7.4) (Plate 7.5). The bedform crest orientation indicates gross sediment transport along a northwest to southeast axis. The sand waves are asymmetrical with the steeper side facing to the southeast indicating net migration and dominant transport direction to the southeast. Towards Robin Hood's Bay there is also a transitional area of rippled sand between the rock and the large bedforms.

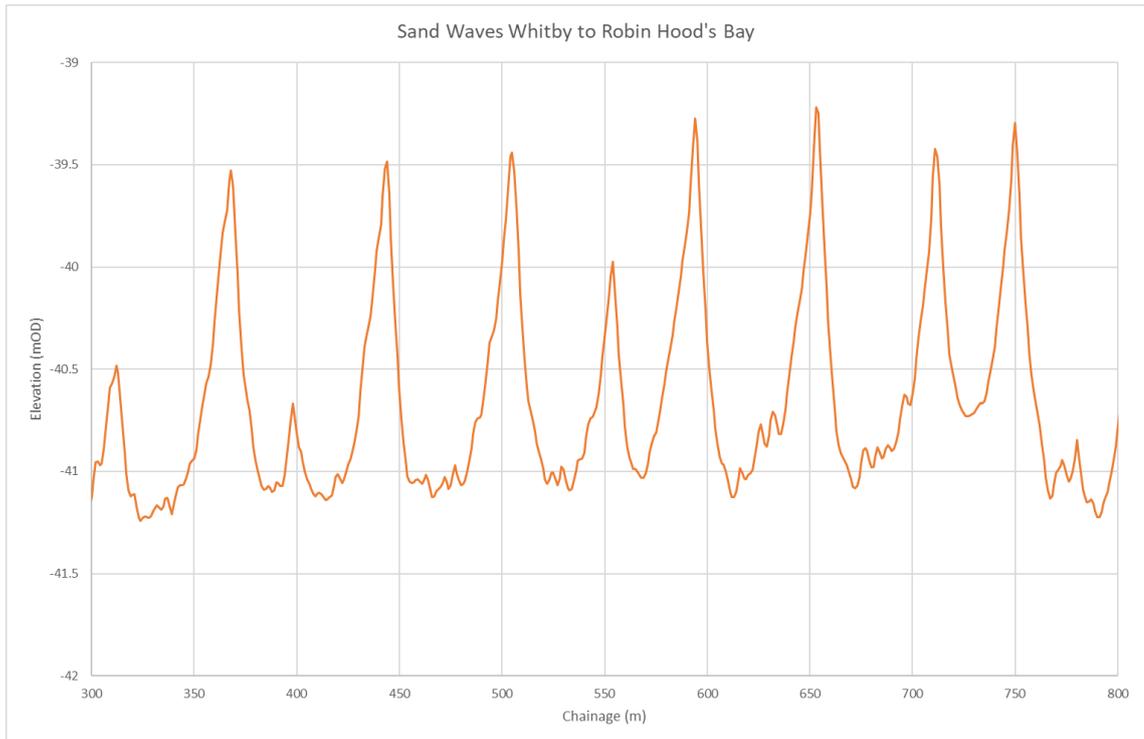


Plate 7.4 - Cross-section of the sand waves offshore between Whitby and Robin Hood's Bay. Location of the northwest (left) to southeast (right) cross-section is shown on Figure 7.1

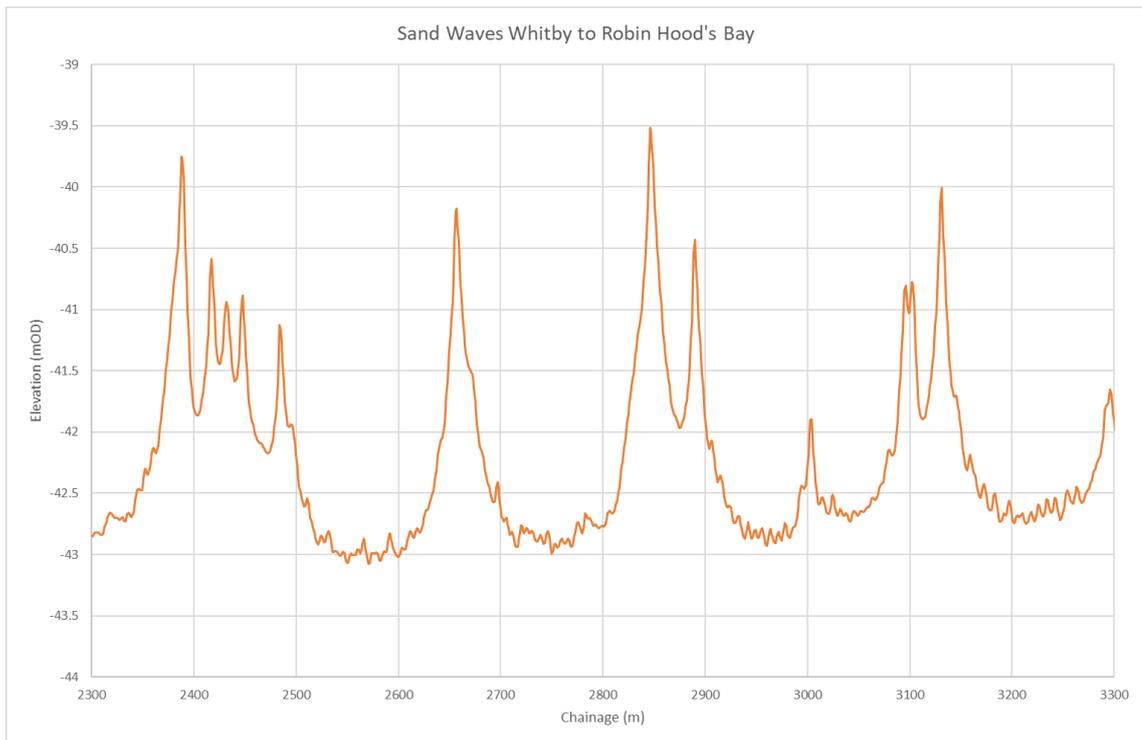


Plate 7.5 - Cross-section of the sand waves offshore between Whitby and Robin Hood's Bay. Location of the northwest (left) to southeast (right) cross-section is shown on Figure 7.1

Offshore from the sand bedforms, from about 1.5-2km (about -45m OD) from the coast to the seaward limit of the survey area, is a wide area of rock outcrop composed of mudstone or mudstone and sandstone. The surface expression indicates a variety of folds partially obscured by a veneer of sediment. This zone forms a southeast continuation of the rock with sediment veneer zone between Sandsend and Whitby.

There are no 2010 and 2015 shore-normal transect lines along this section of Cell 1.

Robin Hood's Bay

Within Robin Hood's Bay is a well-defined shore platform composed of mudstone which is overlain by featureless sand further offshore in the bay (to about 2km from the coast, water depths of -20m OD from the centre of the bay). The featureless sea bed transitions offshore into a large area of rippled sand superimposed upon larger sand waves (Figure 7.5). The crests of these bedforms are oriented southwest to northeast and form a wider continuation of the same band of sand waves further northwest. Crest lengths of individual bedforms can be 2km long. They are spaced about 200-300m apart, are about 4-5m high, and in water depths of about -30m OD to -45m OD (Plate 7.6). The sand wave crest orientation indicates gross sediment transport along a northwest to southeast axis. The sand waves are asymmetrical with the steeper side facing to the southeast indicating net migration and dominant transport direction to the southeast.

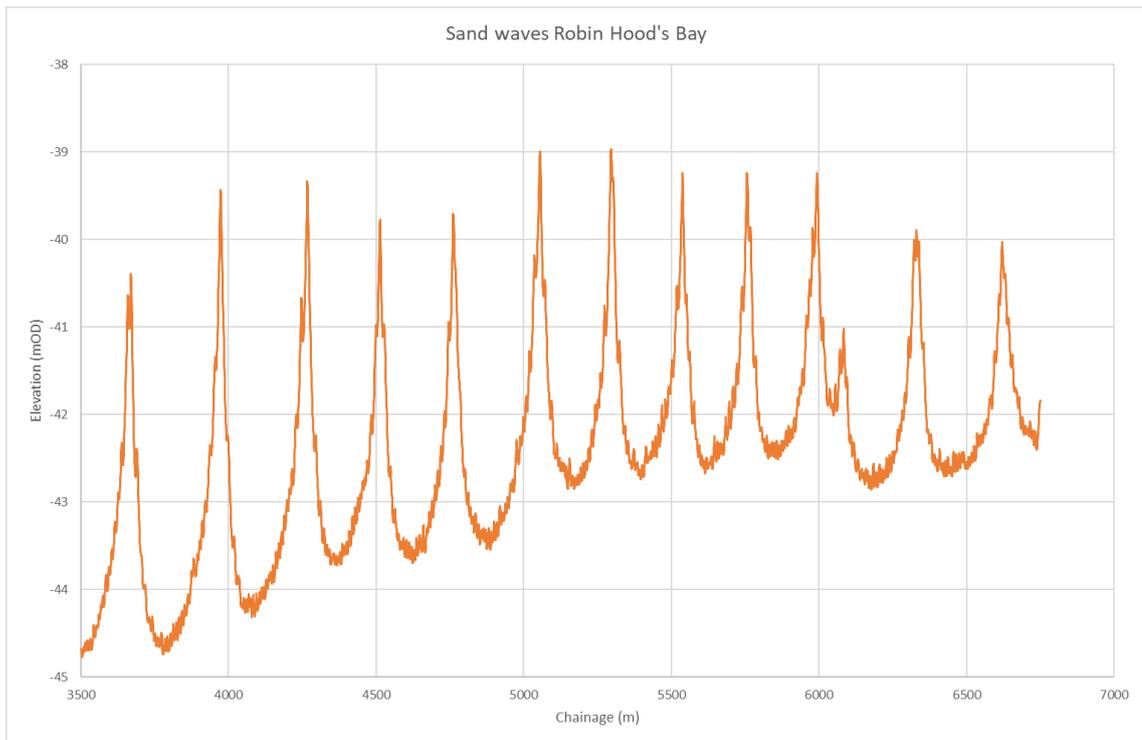


Plate 7.6 - Cross-section of the sand waves offshore from Robin Hood's Bay. Location of the northwest (left) to southeast (right) cross-section is shown on Figure 7.1

Offshore from bedforms, from about 3-5km from the coast to the seaward limit of the survey area, is wide area of mudstone rock outcrop with a veneer of sediment. This zone forms a southeast continuation of the rock with sediment veneer zone to the northwest.

There is one 2010 and 2015 shore-normal transect line along this section of Cell 1 (#11).

7.2 Transect Analysis #9: Sandsend

Background

The coast road at Sandsend is under pressure from erosion and the SMP2 recommends a policy of managed realignment of the road in the medium- and long-term epochs, supported by further investigations of options for achieving this. North Yorkshire County Council is currently improving the revetment at the toe of cliff to reduce instability risk to the adjacent road.

The objective of this transect is to improve understanding of the interactions between the sea bed and the shoreline, to inform further investigations for realignment of the coast road.

2010 and 2015 Survey Findings

The bathymetric surveys for Sandsend extend approximately 2.7km offshore to a depth of -24m OD (Royal Haskoning and Halcrow, 2010; CH2M, 2015). The 2010 and 2015 mapping and long profiles for Sandsend indicate that this area is characterised by three main zones (Figure 7.6a):

- A nearshore zone composed of coarse sand that extends about 150m offshore to a depth of about -5m OD at a mean gradient of 0.8°. There is a break of slope about 90m offshore where the gradient increases.
- A featureless sand (fine to medium-grained) sea bed which covers the remainder of the transect with a subtle convex form and mean gradient of 0.4°.
- At the seaward end of the transect, in water depths of -22m OD to -24m OD is an area of linear, northeast-southwest trending ripples offshore from 2.5km. They have an elongated and branched form with spacings of 10m to 15m. They are symmetrical indicating movement in both northeast and southwest directions.
- The 2015 bathymetry recorded several small pits in the sea bed. A cluster of pits is located about 200m from shore with a single pit at 900m offshore at -10m OD. These pits are probably fluid escape structures.

Changes in elevation and character of the sea bed between 2010 and 2015 were interpreted by CH2M (2015):

- A zone of change extending 600m offshore to a depth of -8m OD. Accretion was up to 1.5m and erosion was up to 1m (Figure 7.6b). The alternating pattern of change is indicative of migration of shore-parallel sand bars.
- The rest of the sea bed shows several linear strips of erosion that are errors related to data artefacts in the 2010 survey.

2016 Survey Findings

Between March-April 2015 and November-December 2016 (about 18 months), narrow alternating zones of erosion and accretion occurred within the nearshore zone out to about 350m (-7m OD) from the coast (Figure 7.6b). Erosion up to about 1.2m occurred from the coast to about 100m offshore and from 250m to 350m offshore (up to 0.8m). Sandwiched between these two zones (100-250m offshore) is a zone of accretion up to 1.5m. The data suggests the closure depth, which defines the offshore boundary of wave-driven sediment transport, is at approximately -7m OD. Further offshore, the data shows that most of the transect has eroded by up to 0.2m between 2015 and 2016. This is likely to be within the vertical error of capture of the two datasets.

Comparison of the results of the November-December 2016 survey with those of 2010 describe similar linear strips of erosion to those between 2010 and 2015 (Figure 7.6b), and are errors related to data artefacts in the 2010 survey. The large changes in the nearshore zone may have more basis although their precise distribution (due to errors in the 2010 data) may not be accurate.

7.3 Transect Analysis #10: Whitby Sands

Background

Whitby Sands, to the west of Whitby Harbour, comprises a sand beach that affords natural protection to the built defences and coastal slope. The beach is influenced by the presence of the harbour structures, which intercept sediment transported east and help retain the beach. The SMP2 identifies onshore-offshore exchange of sediment which, at times of lower beach levels, can lead to overtopping of the coastal defences.

The purpose of this transect is to further examine the onshore-offshore exchanges of sediment along the foreshore, and any longer-term trends of lowering or steepening which may occur.

2010 and 2015 Survey Findings

The bathymetric surveys for Whitby West Beach extend approximately 1.9km offshore to a depth of -26m OD (Royal Haskoning and Halcrow, 2010; CH2M, 2015). The 2010 and 2015 mapping and long profiles for Whitby Sands indicate the sea bed can be categorised into five zones (Figure 7.7a):

- The nearshore area, to 650m offshore at a depth of -12m OD, comprises a featureless sand sea bed, with a mean gradient of 1°.
- From around 650m or 950m offshore, rock outcrop with ridges with a north-northeast to south-southwest alignment between -11.5m OD and -12m OD. The ridges rise to about 1.5m above the intervening trough areas composed of sand.
- The sea bed from 950m to 1.9km and a depth of -26m OD is featureless sand. The long profile describes a distinct convex morphology.
- The seaward 150m of the transect (in water depths of -22m OD to -26m OD) is an area of slightly sinuous, north-northeast to south-southwest aligned sand ripples. They are typically spaced 10m to 15m apart and the crests are up to 60m long. Asymmetry of the bedforms suggest movement towards the north-northwest.
- Also, at the seaward end of the transect are two sharp breaks of slope that trend northwest-southeast. They represent a rapid seaward drop in sea bed elevation of over 1m. It is unclear what these structures represent; they may be bedding in Lias Group rock and/or an expression of faults.

Changes in elevation and character of the sea bed between 2010 and 2015 were interpreted by CH2M (2015):

- A zone of up to 1m erosion in a nearshore zone that extends about 200m offshore to a depth of -5m OD (Figure 7.7b).
- Erosion is indicated on both the landward and seaward sides (both up to 0.3m) of the rock outcrop. The area immediately offshore of the rocks has accreted by up to 0.5m.
- The ripples recorded in 2010 were documented more clearly in 2015 and can be seen to extend from depths of -21m OD to -27m OD. Widespread strips of 0.5m erosion alternating with strips of no detected change that correspond with the bedform alignment, suggest these features may have been active over the five-year monitoring period. This is likely to be within the horizontal error of capture of the two datasets.

2016 Survey Findings

Between March-April 2015 and November-December 2016 (about 18 months), the sea bed continued to evolve in a similar way to 2010 to 2015 apart from the nearshore 200m. Here, the sea bed accreted up to 0.5m, opposite to the previous trend of erosion (Figure 7.7b). Elsewhere, erosion of up to 0.3m occurred north and south of the rock outcrop. Change in the nearshore zone out to -5m OD is indicative of the closure depth that defines the offshore boundary of normal wave-driven sediment transport.

Comparison of the results of the November-December 2016 survey with those of 2010 describe similar trends to those between 2010 and 2015. The featureless sand between the coast and the rock outcrop shows consistent erosion of up to 0.5m, with local patches up to 1m closer to shore (Figure 7.7b). For about 200m seaward of the rock outcrop the sea bed accreted by up to 0.5m with erosion of up to 0.3m along most of the transect seaward of that.

7.4 Transect Analysis #11: Robin Hood's Bay

Background

Robin Hood's Bay comprises a rock shore platform, backed by cliffs cut in weak glacial sediments or Jurassic mudstones that are prone to cliff instability, with occasional sand beaches at the toe. The SMP2 identifies that there are some specific properties in Robin Hood's Bay, beyond the main village centre, that are likely to be lost to erosion and land sliding in the future.

The purpose of this transect is to improve understanding of sea bed and shoreline processes so that better-informed assessments can be made of the timing of potential loss of these properties.

2010 and 2015 Survey Findings

The bathymetric surveys for Robin Hood's Bay extend about 2km offshore to a depth of -27m OD (Royal Haskoning and Halcrow, 2010; CH2M, 2015). The 2010 and 2015 mapping and long profiles for Robin Hood's Bay indicate this area of sea bed is characterised by three zones (Figure 7.8a):

- A nearshore zone to a depth of about -8m OD at about 600m offshore where mudstone outcrops as a set of ridges in a shore platform and there is an intermittent and thin cover of sand in the troughs. Bedding is clearly visible trending east-northeast to west-southwest. An east-southeast to west-northwest trending fault cuts through the centre of rock shore platform in the transect.
- Offshore from the rock outcrop to the seaward end of the transect about 2km offshore at a depth of about -27m OD, the sea bed is featureless sand. The long profile shows that this zone has a convex form.
- The deepest section of sea bed, from -25m OD to -27m OD, is characterised by subtle linear ridges that are spaced 40 to 100m apart and aligned northeast-southwest. They likely represent an expression of rock close to the sea bed.

Changes in elevation and character of the sea bed between 2010 and 2015 were interpreted by CH2M (2015):

- A complex pattern of elevation changes in the rock shore platform with patches of erosion and accretion of up to +/-1m extending about 600m offshore to -8m OD (Figure 7.8b). This is likely to be within the horizontal error of capture of the two datasets.
- Strips of sea bed elevation change further offshore are errors caused by artefacts in the 2010 data.

2016 Survey Findings

Between March-April 2015 and November-December 2016 (about 18 months), the featureless sand offshore from the rock outcrop has both eroded (up to 0.2m) and accreted (up to 0.15m) (Figure 7.8b). This is likely to be within the vertical error of capture of the two datasets. However, there is evidence for linear strips which may indicate error in one or both surveys.

Comparison of the results of the November-December 2016 survey with those of 2010 describe similar linear strips of erosion to those between 2010 and 2015, and are errors related to data artefacts in the 2010 survey.

8. Robin Hood's Bay to Flamborough Head Survey Results

8.1 General Overview – 2015-2016 Survey Findings

This area of sea bed is covered by a bathymetric survey completed between November 2015 and March 2016. EUNIS level 3 habitat mapping and substrate mapping for this section was undertaken by the Channel Coastal Observatory (CCO, 2017).

Ravenscar to Cloughton

Immediately offshore from Ravenscar to Cloughton, the sea bed is dominated by a rock shore platform composed of mudstone and sandstone (with cobbles and boulders) extending offshore between 150m and 1.3 km (Figure 8.1). Further offshore, the rock is overlain by sand (CCO, 2017), which is sculpted into a variety of bedforms changing with distance offshore. At the landward boundary, the sand surface appears relatively smooth with no significant bedforms. The smooth sea bed transitions at around -20m OD into a bed covered in many ripples, with wavelengths of 5-15m and heights of about 0.1-0.3m (Figure 8.2) (Plate 8.1). At the landward edge of the rippled sand are a series of north-northeast to south-southwest aligned sea bed depressions composed of 'coarse sediment'. The depressions are about 1m deeper than the surrounding sea bed (Plate 8.1).

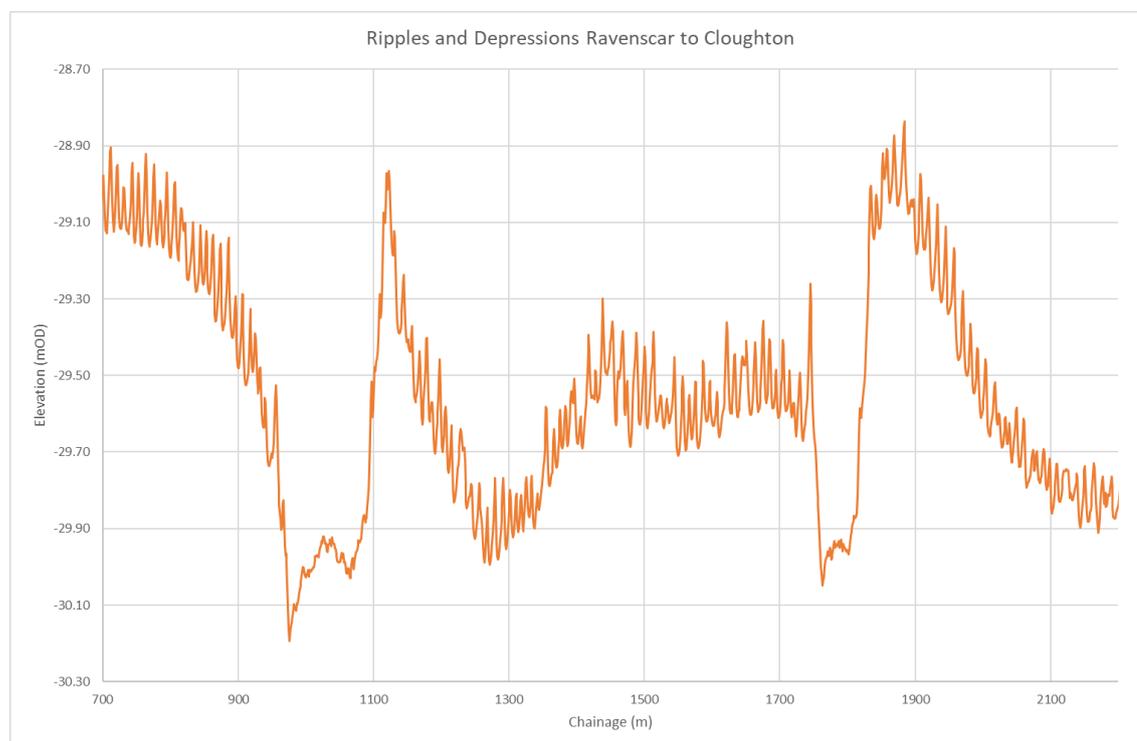


Plate 8.1 - Cross-section of the ripples and depressions offshore from Ravenscar to Cloughton. Location of the northwest (left) to southeast (right) cross-section is shown on Figure 8.1

The ripples extend to about 3.5km offshore (-45m OD), at the eastern boundary of the sand unit. However, beyond about 2km offshore (-35m OD) from Cloughton they are superimposed by a series of larger southwest to northeast (crests) oriented sand waves extending northwest to southeast for about 3km (Figure 8.2). Their crests are spaced about 100-650m apart, and they are about 1-2m high (Figure 8.2) (Plate 8.2). The bedform crest orientation indicates gross sediment transport along northwest-southeast and southeast-northwest axes. The sand waves are asymmetrical with the steeper side facing to the southeast indicating net migration and dominant transport direction to the southeast.

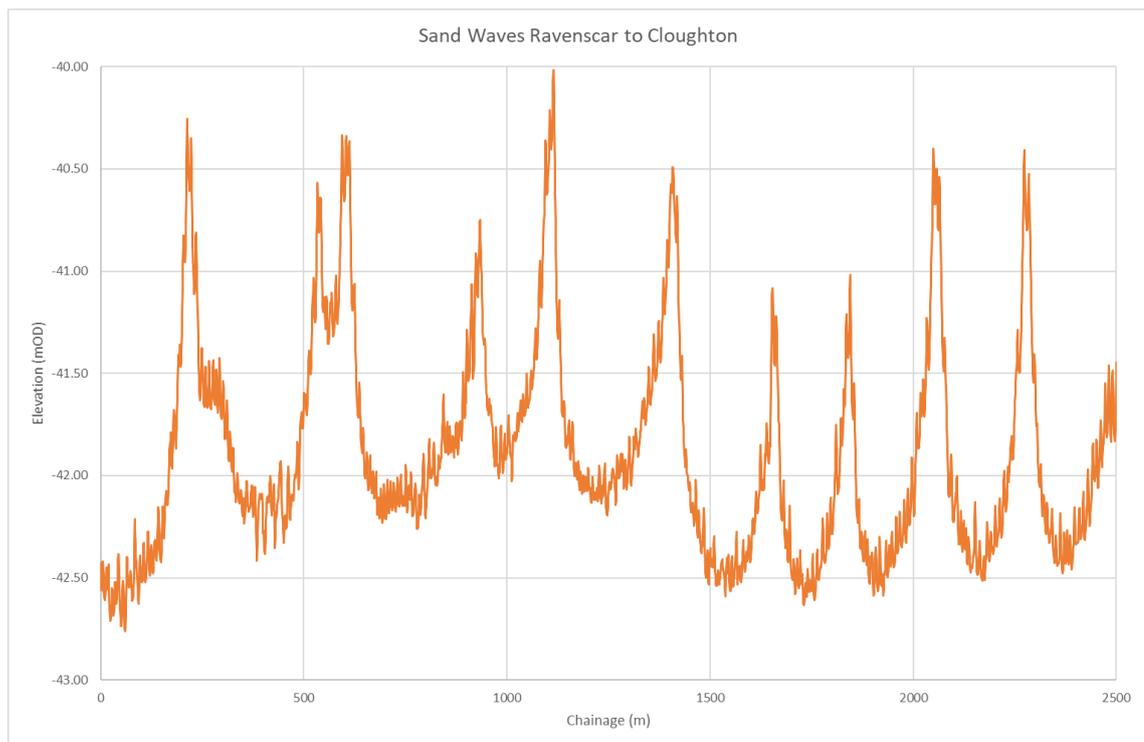


Plate 8.2 - Cross-section of the sand waves offshore from Ravenscar to Cloughton. Location of the northwest (left) to southeast (right) cross-section is shown on Figure 8.1

About 3.5km offshore, the sand thins and disappears, and mudstone rock is exposed at the sea bed to the seaward limit of the survey (-50m OD). Rock layers are evident at the sea bed and a large anticlinal (or synclinal) feature occurs with a centre about 5km offshore (Figure 8.2).

There are no 2010 and 2015 shore-normal transect lines along this section of Cell 1.

Cloughton to Gristhorpe

Between Cloughton and Gristhorpe (immediately north of Filey Brigg), the bathymetry is dominated by three main zones. Stretching out from the coast is a southern continuation of the mudstone and sandstone rock shore platform between Ravenscar and Cloughton. The platform is generally narrower (up to 800m wide) after which it is covered by smooth sand (CCO, 2017) up to about 6km offshore (Figure 8.1). The fields of ripples and larger bedforms evident between Ravenscar and Cloughton do not occur between Cloughton and Gristhorpe. Offshore from the sand, the sea bed is dominated by rock overlain by thin 'mixed sediment' partially obscuring the structure at sea bed.

The smooth sand is interrupted along its seaward side by large sand waves in a small area about 5-7km offshore from Gristhorpe (Figure 8.3). These sand waves are 2-3m high, approximately symmetrical, and covered in ripples (Plate 8.3).

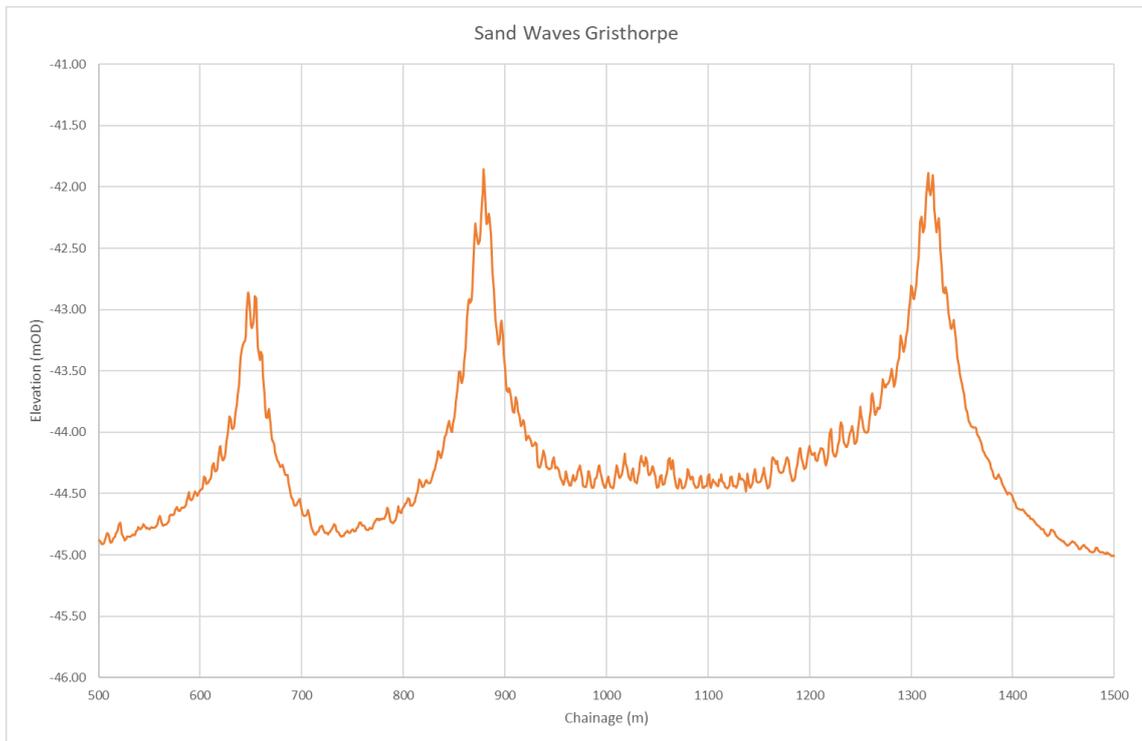


Plate 8.3 - Cross-section of the sand waves offshore from Gristhorpe. Location of the northwest (left) to southeast (right) cross-section is shown on Figure 8.1

The bathymetry of the smooth sand is predominantly a gentle slope from the coast seawards to its boundary with the rock and 'mixed sediment'. However, an exception to this occurs immediately north of Filey Brigg where a 3km long, northwest to southeast oriented sand bank feature is present forming the southern end of the sand area (Figure 8.4). The bank has steep eastern (seaward) and southern slopes which are sculpted into a series of 0.2-0.4m-high ripples.

There are three 2010 and 2015 shore-normal transect lines along this section of Cell 1 (#12, #13 and #14).

Gristhorpe to Filey

The sea bed offshore from Gristhorpe to Filey is dominated by east-west oriented rock outcrops extending seawards from the coast. The dominant feature is a 200-450m wide set of rock ridges forming an extension of the coastal headland at Filey Brigg (Figure 8.5) composed of resistant limestone and sandstone. Nearshore the ridge is cut by a 250m north-south 'channel' before being a continuous feature gradually increasing in depth and becoming less prominent above the surrounding sea bed. Closer to shore, west-east oriented rock outcrops extend north and south of the main ridge covered in part by a veneer of mixed sediment sand.

About 10km offshore and adjacent (and abutting) to the southern side of the main ridge is a set of large sand waves (with superimposed smaller ripples) with southwest to northeast and north to south orientations (Figure 8.5). The sand waves are up to 7m high and asymmetrical with the steeper side facing northwest indicating migration and sediment transport to the northwest (Plate 8.4). The main sand ridge bifurcates to the northeast, and the spacings of the ridges vary from 200m to 1km.

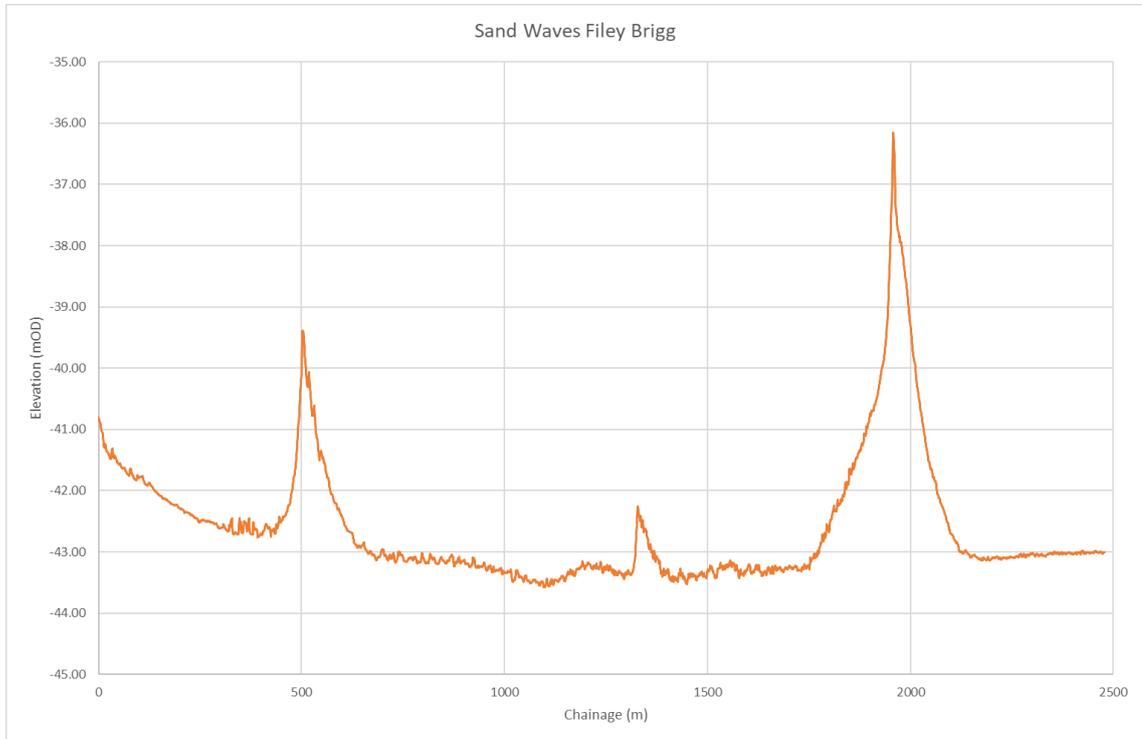


Plate 8.4 - Cross-section of the sand waves offshore from Filey Brigg. Location of the northwest (left) to southeast (right) cross-section is shown on Figure 8.1

Filey to Flamborough Head

The coast changes orientation at Filey Brigg and forms Filey Bay, a large sandy bay. Offshore, the sea bed is composed of sand with no bedforms (CCO, 2017) and gradually deepens to a depth of -25m OD. Fingers of coarse sediment extend south as bathymetric 0.5-1m depressions into the seaward extent of the sand sediment within Filey Bay between Reighton and Speeton (like those found between Ravenscar to Cloughton) (Figure 8.6) (Plate 8.5). Nearshore data is absent southeast of Speeton, and further offshore from Flamborough Head the sea bed is composed of featureless mixed sediment (CCO, 2017).

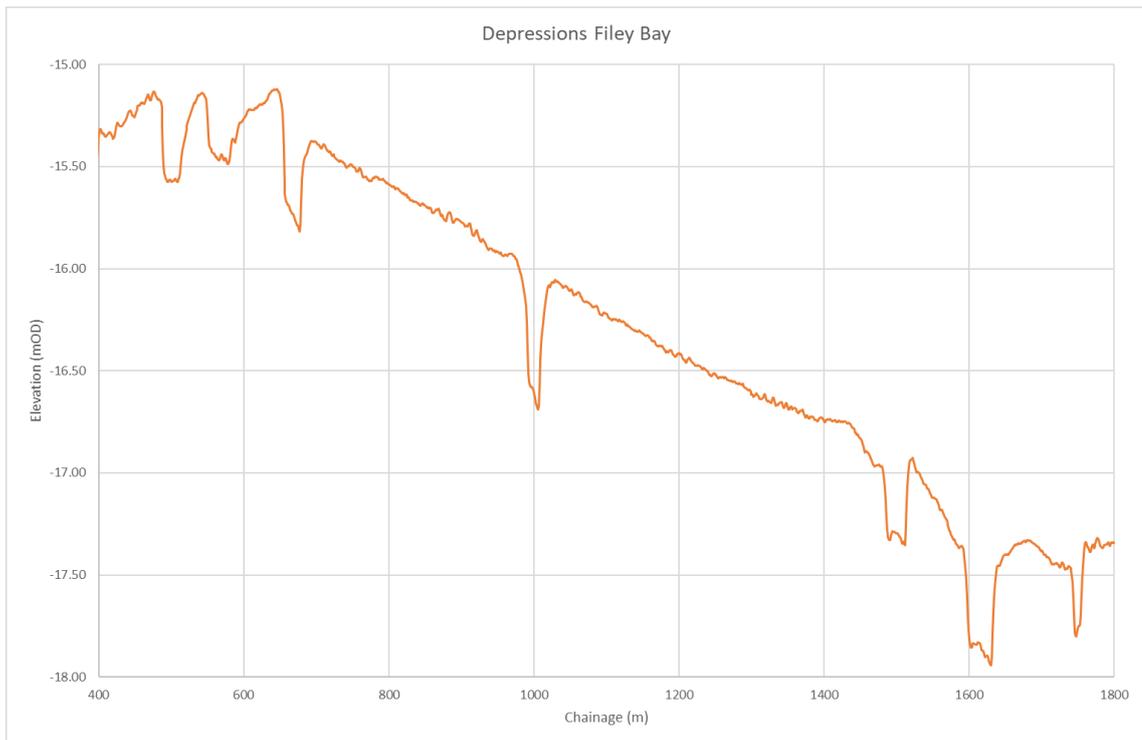


Plate 8.5 - Cross-section of the depressions offshore from Filey Bay. Location of the west-northwest (left) to east-southeast (right) cross-section is shown on Figure 8.1

There is one 2010 and 2015 shore-normal transect line along this section of Cell 1 (#15).

8.2 Transect Analysis #12: Scarborough North Bay

Background

Scarborough North Bay comprises a sandy beach backed by coastal defences that protect a promenade, residential properties and amenity assets. The SMP2 identifies complex wave patterns in the bay that could influence shoreline behaviour and that the condition of coastal defences needs improvement. The recent strategy update identifies a programme of capital works for North Bay.

The purpose of this transect is to better inform understanding of the interactions between sea bed and shoreline processes, particularly in the context of wave patterns, with a view to informing future capital defence schemes recommended by the strategy review.

2010 and 2015 Survey Findings

The bathymetric surveys for Scarborough North Bay extend approximately 2.8km offshore to a depth of -25m OD (Royal Haskoning and Halcrow, 2010; CH2M, 2015). The 2010 and 2015 mapping and long profile graphs for Scarborough North Bay show that the sea bed is characterised by two main zones (Figure 8.7a):

- A complex nearshore zone, which extends about 0.9km to a depth of about -10m OD with an average gradient of 0.5° . The character of this zone is variable and

comprises rock exposed at the sea bed or overlain by patches of smooth and featureless sand.

- Further offshore and extending to -25m OD at the limit of the survey, the sea bed is smooth and composed of fine sand. The long profile shows that from 0.9km to 1.6km offshore the sea bed has a convex form, whereas from 1.6km to 2.8km it is smooth and slightly concave.
- The 2015 bathymetry captured two small pits in the sea bed about 2km offshore at -19.5m OD and -20.5m OD depth which are probably fluid escape structures.
- A subtle rock ridge feature occurs at the northwest margin at -16.5m OD about 1.5km offshore.

Changes in elevation and character of the sea bed between 2010 and 2015 were interpreted by CH2M (2015):

- Strips of sea bed elevation change offshore are artefacts related to error in 2010 survey (Figure 8.7b).

2015-2016 Survey Findings

The results of the 2015-2016 survey along this transect confirms the findings made in 2010 and 2015, with similar magnitudes of change between 2010 and 2015-2016 as those between 2010 and 2015 (Figure 8.7b). This is because the latest bathymetry was completed between November 2015 and February 2016, only about eight months after the March April 2015.

Within the sand area offshore from the rock outcrops, the differences in elevation are up to 0.2m of accretion between March-April 2015 and November 2015-February 2016 (Figure 8.7b). This is likely to be within the vertical error of capture of the two datasets.

8.3 Transect Analysis #13: Scarborough South Bay

Background

Scarborough South Bay comprises a sand beach that thins to the south to expose a rock shore platform. The beach is backed by coastal defences that protect a promenade, commercial and residential properties, and amenity assets. The SMP2 identified complex sediment patterns in the bay that require periodic excavation of sediment from the harbour wall and transport to the south of the bay.

The purpose of this transect is to better inform understanding of the interactions between sea bed and shoreline processes, particularly in the context of sediment transfers, with a view to informing future capital defence schemes recommended by the strategy review.

2010 and 2015 Survey Findings

The bathymetric surveys for Scarborough South Bay extend approximately 4.6km offshore to a depth of -24m OD (Royal Haskoning and Halcrow, 2010; CH2M, 2015). The 2010 and 2015 mapping and long profile graphs for Scarborough South Bay show that the sea bed is broadly characterised by two main zones (Figure 8.8a):

- The nearshore sea bed out to 400m (-6m OD), is characterised by mainly sand with outcrops of rock that are about 0.5m higher than the surrounding sand.

- Most of the survey area deeper than -6m OD, is characterised by featureless sand with an average gradient of around 0.3°. The long profile describes a convex then concave form.
- The 2015 bathymetry captured an area of small, isolated depressions from 1.3km to 2km offshore are interpreted as fluid-escape structures.

Changes in elevation and character of the sea bed between 2010 and 2015 were interpreted by CH2M (2015):

- Linear strips of erosion of up to 0.5m from 1km to 4.5km offshore are artefacts associated with errors in the 2010 data (Figure 8.8b).

2015-2016 Survey Findings

The results of the 2015-2016 survey along this transect confirms the findings made in 2010 and 2015, with similar magnitudes of change between 2010 and 2015-2016 as those between 2010 and 2015 (Figure 8.8b). This is because the latest bathymetry was completed between November 2015 and February 2016, only about eight months after the March April 2015.

Within the sand area offshore from the rock outcrops, the differences in elevation are up to 0.2m of accretion between March-April 2015 and November 2015-February 2016 (Figure 8.8b). This is likely to be within the vertical error of capture of the two datasets.

8.4 Transect Analysis #14: Cayton Bay

Background

The planform of Cayton Bay is strongly influenced by the presence of Knipe Point headland and geological composition. Properties have already been lost to cliff instability at Knipe Point, and other properties and the coast road remain at risk. The SMP2 largely recommends a policy of No Active Intervention. Further investigations into the cliff instability risk at Knipe Point have been undertaken together with a Coastal Pathfinder scheme that supports residents' plans for adaptation (Siddle *et al.*, 2015).

The purpose of this transect is to inform understanding of the interactions between the shoreline and sea bed, particularly platform lowering that may have implications for cliff slope stability.

2010 and 2015 Survey Findings

The bathymetric surveys for Cayton Bay extend approximately 4.2km offshore to a depth of -23m OD (Royal Haskoning and Halcrow, 2010; CH2M, 2015). The 2010 and 2015 mapping and long profile graphs show the sea bed is characterised by two main zones (Figure 8.9a):

- A nearshore zone with a gradient of around 0.5° that extends to about 1.9km offshore to a depth of about -17m OD. The sea bed is predominantly featureless and composed of sand, but is punctuated by occasional rock outcrops and occasional isolated boulders. At the seaward end of this zone, the rock outcrop in the transect forms a low linear ridge at about -17m OD which is about 90m long and 30m wide. This ridge extends for 700m to the southeast of the transect.

- Offshore of 1.9km, at depths between -17m OD and -23m OD, the sea bed is featureless with an average gradient of 0.1° and composed of fine sand.

Changes in elevation and character of the sea bed between 2010 and 2015 were interpreted by CH2M (2015):

- Changes in elevation of between -1m (erosion) and +0.5m (accretion) have occurred in the nearshore zone that extends about 600m offshore to -7m OD (Figure 8.9b). CH2M (2015) suggest these changes are indicative of migrating sand bars.
- Lowering of the sea bed by up to 0.5m extending from the nearshore zone offshore to -23m OD at the seaward end of the transect are described along a series of strips. This is an artefact of localised errors in the 2010 data.
- Accretion of up to 1m occurred locally in silty sand around a the rock outcrop at -17m OD from 1.8km to 1.9km offshore. This change does not appear to relate to survey error. CH2M (2015) suggest the accretion is due to mobilisation of this sediment by tidal currents.

2015-2016 Survey Findings

The results of the 2015-2016 survey along this transect confirms the findings made in 2010 and 2015, with similar magnitudes of change between 2010 and 2015-2016 as those between 2010 and 2015 (Figure 8.9b). This is because the latest bathymetry was completed between November 2015 and February 2016, only about eight months after the March April 2015.

Within both the nearshore and offshore sand areas, the differences in elevation are up to 0.2m of accretion between March-April 2015 and November 2015-February 2016 (Figure 8.9b). This is likely to be within the vertical error of capture of the two datasets.

8.5 Transect Analysis #15: Filey Bay

Background

Filey Bay extends between the headland of Filey Brigg and the village of Speeton north of Flamborough Head and comprises sand beaches backed by till or Lower Cretaceous clay cliffs of varying height and behaviour. There are settlements at Filey, Flat Cliffs, Hunmanby Gap and Reighton Gap, and large holiday villages at Primrose Valley and Reighton Sands, all of which are at risk from cliff recession.

Other than at the town of Filey, the SMP2 recommends a policy of No Active Intervention. The importance of the residential communities and the economic value of the holiday villages to the wider area were recognised. However, providing defences over the 100-year lifetime of the plan was considered unsustainable. The SMP2 recommends that monitoring is undertaken to assist people in planning for the eventual loss of property.

The purpose of this transect is to provide improved understanding of the links between the sea bed and the shoreline, to enable improved assessments of the timescales of loss due to erosion.

2010 and 2015 Survey Findings

The bathymetric surveys for Filey Bay extend about 3.1km offshore to a depth of -24m OD (Royal Haskoning and Halcrow, 2010; CH2M, 2015). The 2010 and 2015 mapping and long profile graphs for Filey Bay indicate that this area is characterised by three main zones (Figure 8.10a):

- A featureless sand sea bed occurs across most of the survey area from the shoreline to -14m OD (2.4km offshore). Bedforms are not obvious in the bathymetry map, but the long profile is generally concave but superimposed with small bars up to 500m from the shoreline associated with the beach bar system.
- A small zone about 2.4-2.7km offshore is characterised by a series of slightly curved bedforms or scour hollows aligned northeast-southwest that are typically 40m to 130m long, 10-15m wide and 0.5m deep.
- Offshore of about 2.7km, the sea bed is rougher and there is a small area of rock covered by a veneer of mixed (sand and gravel) sediment (CCO, 2017).
- The 2015 bathymetry captured an area of small, isolated depressions around 1.2km offshore which are interpreted as pockmarks formed by fluid water-escape.

Changes in elevation and character of the sea bed between 2010 and 2015 were interpreted by CH2M (2015):

- Changes in elevation ranging from 1.5m of erosion to 1m of accretion occurred in the 600m wide nearshore zone extending to -7m OD (Figure 8.10b).
- Only small changes are described across the surface of the featureless sand that extends offshore to about 2.4km.
- The bedforms or scour hollows show localised erosion of up to 0.5m, but this is probably an artefact of errors in the 2010 data.
- Offshore of 2.7km the sea bed was classified as smooth sand in 2010, but the 2015 data suggests it may be rock overlain by a veneer of mixed sediment. Lowering of the sea bed of up to 1m relate to errors in the 2010 data and do not represent real change.

The comparison of the 2010 and 2015 data indicates a nearshore zone extending about 600m from the shore to a depth of -7m OD characterised by migrating sand bars. No changes were detected offshore of 600m, suggesting -7m OD was the closure depth (i.e. limit of onshore-offshore sediment exchange) over the monitoring period.

2015-2016 Survey Findings

The results of the 2015-2016 survey along this transect confirms the findings made in 2010 and 2015, with similar magnitudes of change between 2010 and 2015-2016 as those between 2010 and 2015 (Figure 8.10b). This is because the latest bathymetry was completed between November 2015 and February 2016, only about eight months after the March April 2015.

Changes in elevation across the featureless sand sea bed are up to 0.2m of accretion between March-April 2015 and November 2015-February 2016 (Figure 8.10b). This is likely to be within the vertical error of capture of the two datasets. However, larger changes in elevation occur along northwest-southeast oriented bands within the nearshore zone up to 200m from the coast. Within 50m of the coast accretion of up to 1m has occurred, with erosion of up to 1m between 50m and 100m

from the coast. From 100m to 200m, accretion of up to 2m has occurred. These significant changes over a short period of time may be related to the onshore-offshore migration of sand bars along this coast.

9. Summary of Comparison with 2010 and 2015 Transect Assessments

Review of the November 2015 to October 2020 bathymetry data and sediment samples has confirmed the general patterns documented in 2010 and 2015 along the 15 transects. The key findings are summarised in Table 9.1.

Table 9.1 - Summary of key findings from comparison of update surveys with 2010 and 2015 transect assessments

Ref.	Transect Location	Width and elevation limit of nearshore change	General pattern and other features of note
1	Herd Sands	300m / -4m OD	<ul style="list-style-type: none"> Homogeneous and essentially featureless sea bed composed of sand with gravel.
2	South Bents, Whitburn Bay	None recorded	<ul style="list-style-type: none"> Exposed rock covered in places with a veneer of sediment
3	Salterfen	None recorded	<ul style="list-style-type: none"> Bedrock is exposed to about 800m offshore at about -11m OD, with pockets of sediment present between the outcrops. From 800m to about 2.4km offshore (at -18m OD), the sea bed is featureless mud. Seaward of 2.4km, the sea bed is rock interspersed with areas veneered with sediment.
4	Blast Beach	250m / -6m OD	<ul style="list-style-type: none"> Nearshore sea bed to about -3m OD is dominated by a rock shore platform. The rest of the transect to about 2.2km offshore at a depth of about -22m OD is characterised by featureless sand. Seaward of 2.2km is a relatively flat sea bed (-22m OD to -24m OD over about 1km) composed of rock covered with a veneer of gravel.
5	Hartlepool North Sands	500m / -10m OD	<ul style="list-style-type: none"> Featureless sand extends to a depth of about -23m OD. The sea bed from -23m OD to -24m OD is rock covered by a veneer of gravel.
6	Saltburn-by-the-Sea	250m / -4m OD	<ul style="list-style-type: none"> Featureless sand in the nearshore that extends to 2.5km from the coast to -20m OD depth.

Ref.	Transect Location	Width and elevation limit of nearshore change	General pattern and other features of note
			<ul style="list-style-type: none"> An offshore zone that extends from 2.5km to 4km characterised by rock outcrop.
7	Skinningrove	900m / -9m OD	<ul style="list-style-type: none"> Nearshore zone out to 1.8km (-15m OD) comprises featureless fine sand. From 1.8km offshore to 3.6km (-25m OD) the sea bed is characterised by outcrops of rock.
8	Runswick Bay	300m / -7m OD	<ul style="list-style-type: none"> Nearshore zone that extends to about 0.8km offshore to a depth of around -15m OD is characterised by rock and boulders with isolated patches of smooth sand. Further offshore, from 0.8km to 2.4km between water depths of about -15m OD and -25m OD, the sea bed is characterised by smooth sand.
9	Sandsend	600m / -9m OD	<ul style="list-style-type: none"> Nearshore zone composed of sand that extends about 150m offshore to a depth of about -5m OD. Featureless sand covers most of the remainder of the transect. At the seaward end of the transect, in water depths of -22m OD to -24m OD is an area of ripples offshore from 2.5km.
10	Whitby Sands	200m / -5m OD	<ul style="list-style-type: none"> The nearshore area, to 650m offshore at a depth of -12m OD, comprises a featureless sand sea bed. From around 650m or 950m (-11.5m OD to -12m OD) offshore is rock outcrop with ridges. The sea bed from 950m to 1.9km and a depth of -26m OD is featureless sand. The seaward 150m of the transect (in water depths of -22m OD to -26m OD) is an area of sand ripples.

Ref.	Transect Location	Width and elevation limit of nearshore change	General pattern and other features of note
11	Robin Hood's Bay	600m / -8m OD (shore platform)	<ul style="list-style-type: none"> • A nearshore zone to a depth of about -8m OD at about 600m offshore where mudstone outcrops as a shore platform. • Offshore from the rock outcrop to the seaward end of the transect about 2km offshore at a depth of about -27m OD, the sea bed is featureless sand. • The deepest section of sea bed, from -25m OD to -27m OD, is characterised by rock formed into subtle linear ridges.
12	Scarborough North Bay	900m / -10m OD (shore platform)	<ul style="list-style-type: none"> • A complex nearshore zone of rock outcrop and featureless sand., which extends about 0.9km to a depth of about -11m OD. • Further offshore and extending to -25m OD at the limit of the survey, the sea bed is smooth and composed of fine sand.
13	Scarborough South Bay	400m / -6m OD	<ul style="list-style-type: none"> • The nearshore sea bed out to 400m (-6m OD), is characterised by mainly sand with outcrops of rock. • Most of the survey area deeper than -6m OD, is characterised by featureless sand.
14	Cayton Bay	600m / -7m OD	<ul style="list-style-type: none"> • The sea bed along the entire transect to a depth of -23m OD is featureless sand.
15	Filey Bay	600m / -7m OD	<ul style="list-style-type: none"> • A featureless sand sea bed occurs across most of the survey area from the shoreline to -14m OD (2.4km offshore).

As documented in the 2010 and 2015 reports, there is variation in the nearshore form along the coast determined by the broad scale form of the coast and its aspect. In the north of the study area, the northeast-facing coast at Herd Sands, which lies within a bay formed between the breakwater piers at the mouth of the Tyne and Souter Point, is sandy. In contrast, the east-facing shores at Whitburn, Salterfen, Blast Beach and Hartlepool North Sands are on the open coast and are dominated by rock with very little overlying sediment.

The profiles at Saltburn-by-the-Sea and Skinningrove face northeast and are within subtle bays resulting in a nearshore zone about 2km wide dominated by sand with exposed rock further offshore. Runswick Bay, Sandsend and Whitby Sands profiles also face northeast to east and lie within bays with profiles dominated by sand. Robin Hood's Bay is similar, but the nearshore zone to -8m OD is a rock platform. Bedforms indicating northwest to southeast sediment transport (i.e. parallel to the coast) were recorded in the offshore limit of the Sandsend and Whitby Sands profiles at over -20m OD.

The profiles at Scarborough North Bay, Scarborough South Bay and Cayton Bay are located on an indented coast that faces northeast to east and the profiles are also dominated by sand. In contrast, the profile at Filey has sand to about 2.5km offshore with rock further offshore, reflecting the impact of Filey Brigg.

Changes between the three surveys has also been calculated and plotted. The greatest change occurs in the nearshore zone, where an alternating pattern of erosion and accretion of up to +/-1.5m is common. The offshore limit of these areas of change is between about 200m and 900m, at depths between about -4m OD and -9m OD. This depth marks the approximate limit of sediment transport between the beach system and the offshore sea bed, which defines the offshore limit where waves can entrain and transport sediment (often known as the closure depth). The pattern of change is interpreted as nearshore sand bar migration and highlights that data collected during biannual beach surveys, which only extend to mean low water, may only show less than 25% of the foreshore area in which transport is taking place. Examples of this pattern of change between 2010 and 2015 are shown in Plate 9.1 and Plate 9.2, from Sandsend and Skinningrove, respectively.

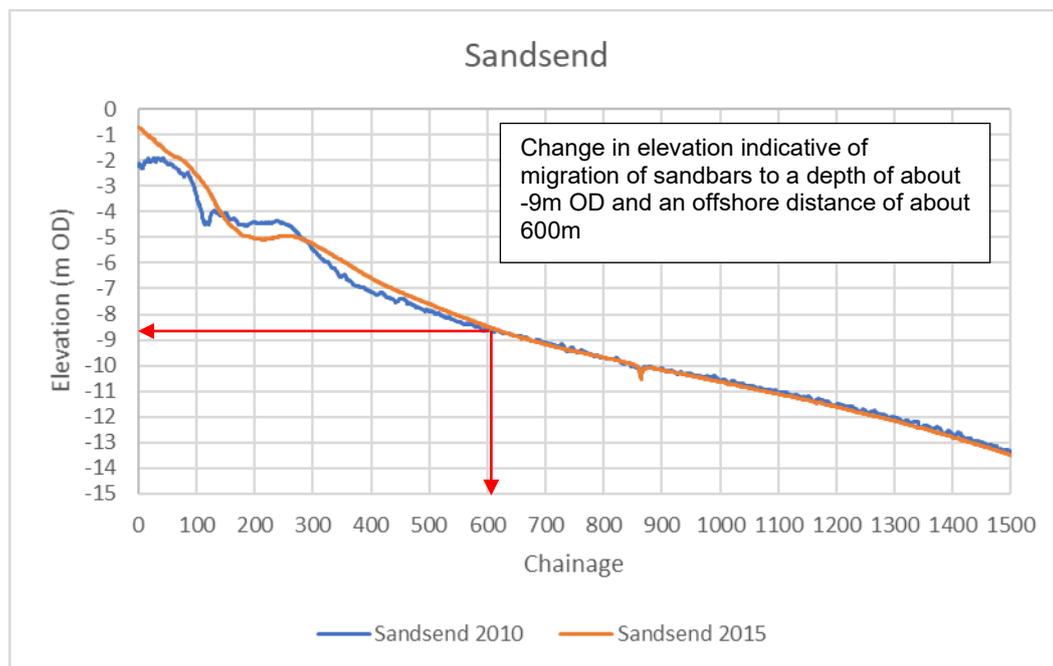


Plate 9.1 - Change in bathymetry at Sandsend showing migration of sand bars between 2010 and 2015

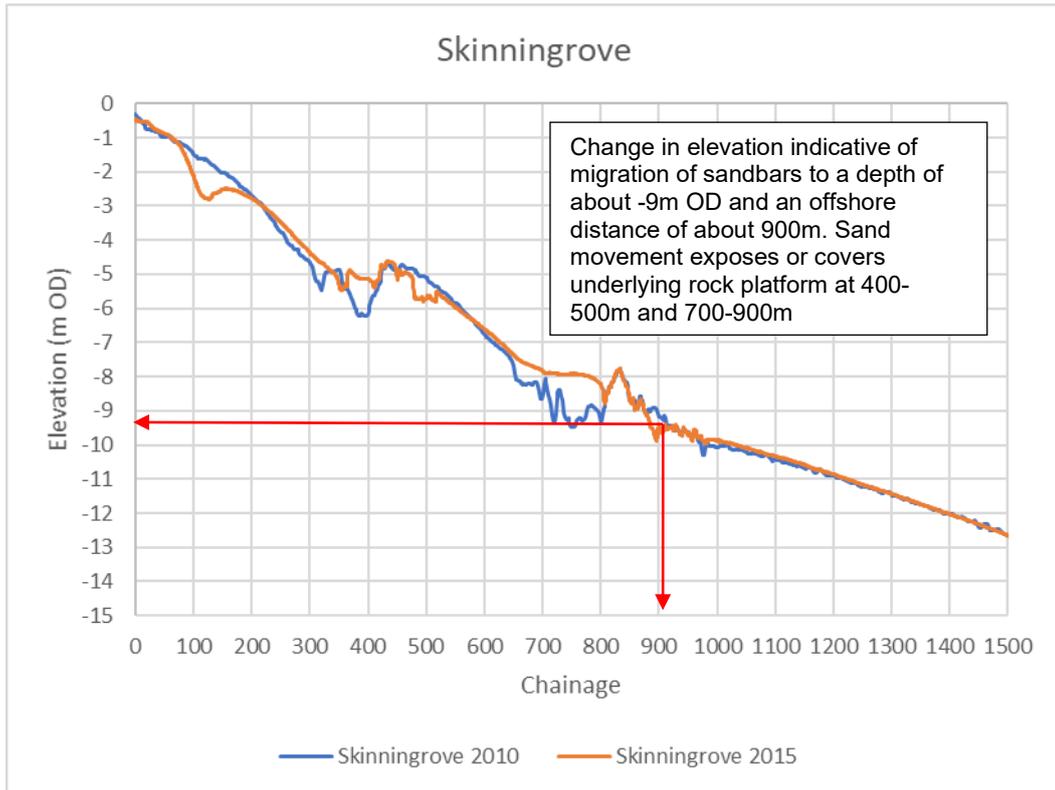


Plate 9.2 - Change in bathymetry at Skinningrove showing variable exposure of rock platform between 2010 and 2015

10. Problems Encountered and Uncertainty in Analysis

The overall accuracy of the survey data has been very good, although occasional ridge-effects resulting from rough seas are seen in the 2010 data and occasionally in the offshore parts of the 2015 data. This has led to erroneous suggestions of change when the surveys are compared. The resolution of the data sets is high and the general lack of ridge-effects in the 2015 data means sea bed features not recorded in 2010 have been recognised. The latest data collected between late 2015 and late 2020 over much wider areas is also very good quality with the high resolution sufficient to be able to map in detail small bedforms such as ripples. Hence, the comparison between the latest data and the 2015 data is the most reliable and accurate.

11. Conclusions and Recommended Actions

The principal conclusion of this work has been the identification of a wide nearshore area where sediment is in flux to around -4 to -9m OD water depth. It is likely that the bathymetry in this zone changes with each tidal cycle and is associated with migration of sand bars that have been consistently documented in the biannual analysis of beach survey data.

The principal objective of most of the bathymetric surveys is to document changes in the nearshore zone that may have implications to the beach or hinterland assets. However, because the nearshore zone is in flux and probably changes each tide and during storms, surveys over many years are likely to be needed to document any long-term net changes in elevation. Such an observation is supported by the analysis of long-term change in beaches, where comparisons over a thirteen year period, show that net changes over that time period are less than seasonal variations.

Nevertheless, there is benefit in continuing to undertake future surveys, characterisation and data analysis to document:

- changes in elevation, to highlight patterns and magnitudes of change
- changes in morphological character to define sea bed processes (for example migration of bedforms, changes in the pattern of exposure of sand and rock, etc.)
- changes in sea bed character, to indicate the nature of the sediment being transported in the coastal system.

It is suggested that the intervals of future surveys should continue to be every five to ten-years (depending on funding) and ideally the data collection should be synchronised with beach profile or beach topographic or LiDAR surveys to ensure a continuous survey from the upper foreshore to about the -20m OD sea bed contour. Future surveys should continue to cover the large areas of sea bed mapped by the 2015 to 2020 campaign, working from one area to another on a 'rolling' programme over several years. This would allow comparison of landscape-scale changes to sea bed morphology as well smaller-scale changes along the previously mapped coastal transects to infer sediment transport. If this was not possible (e.g. due to lack of available budgets or not coinciding with MCA programmes to enable cost-effective approaches), then repeat of the transects would offer an affordable alternative.

12. References

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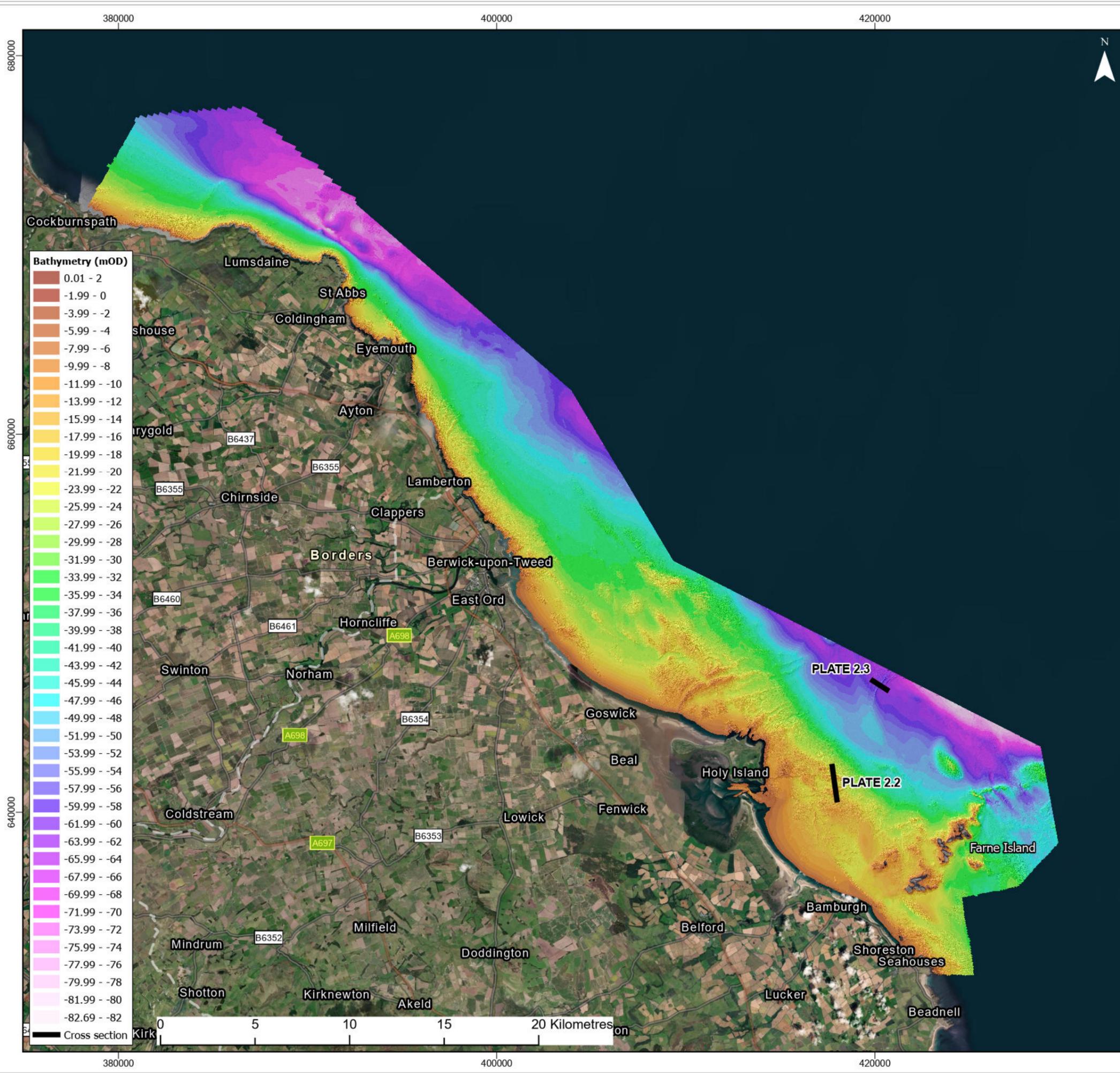
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Royal Haskoning and Halcrow (2010) Cell 1 Regional Coastal Monitoring Programme: Bathymetric and Sea Bed Characterisation Survey. October 2010.

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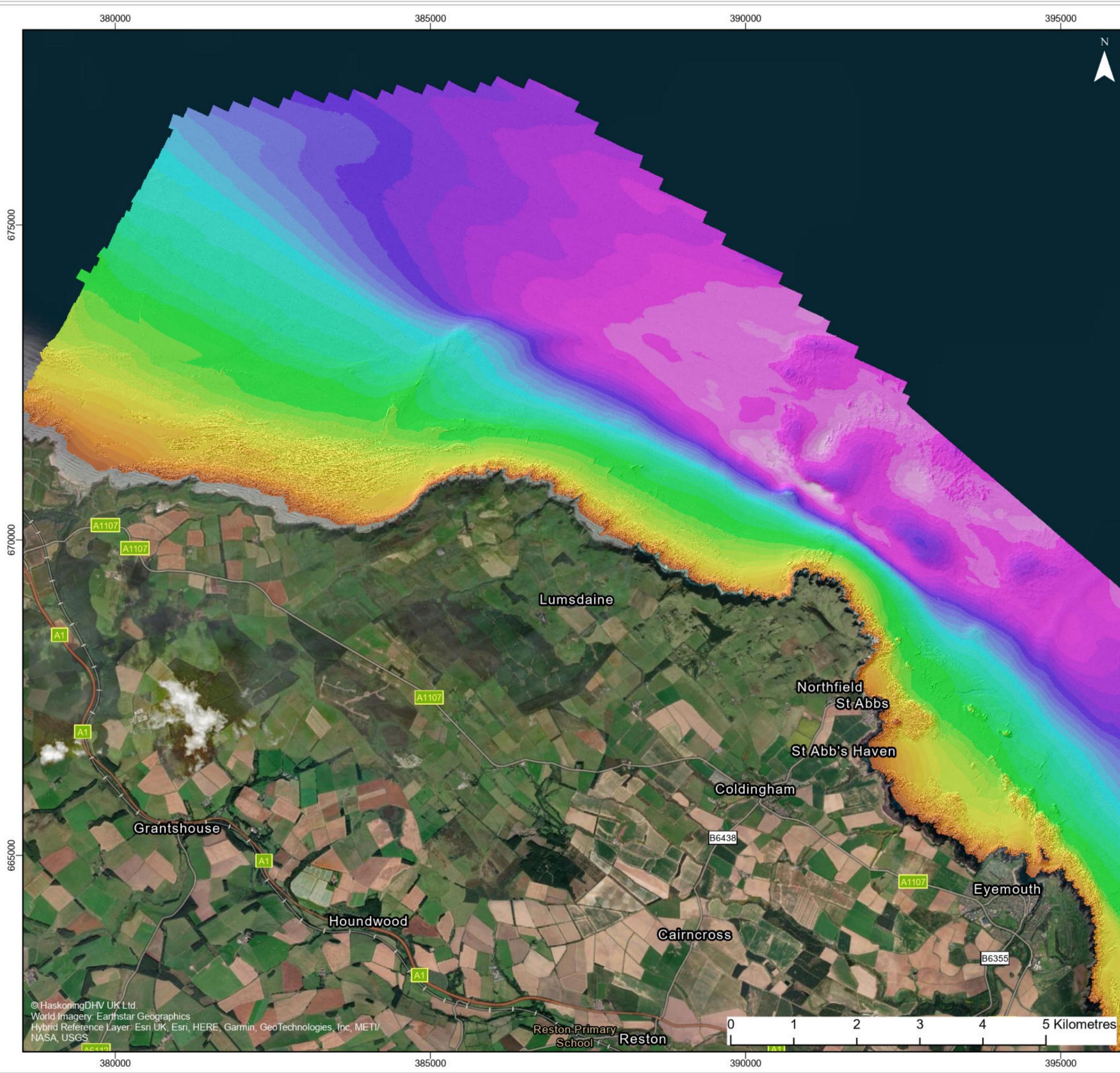
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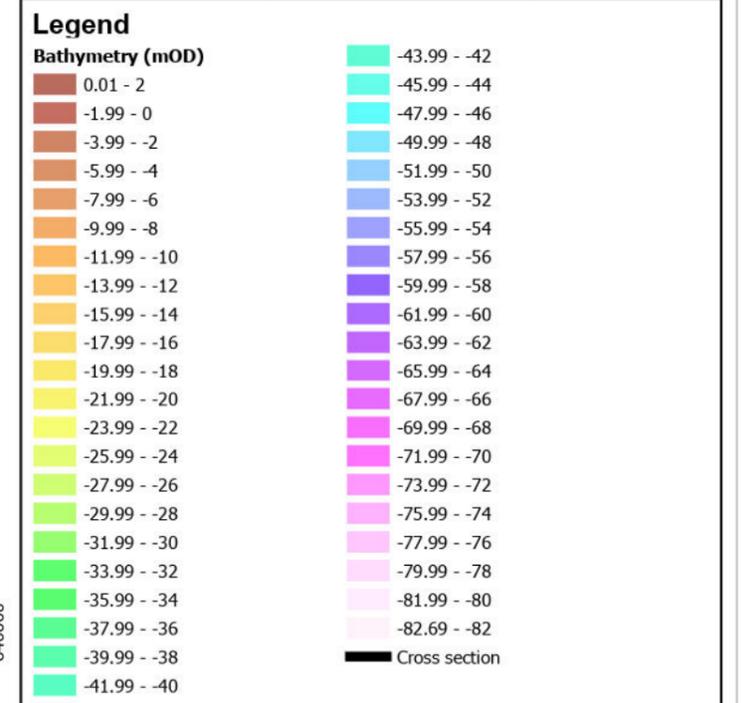
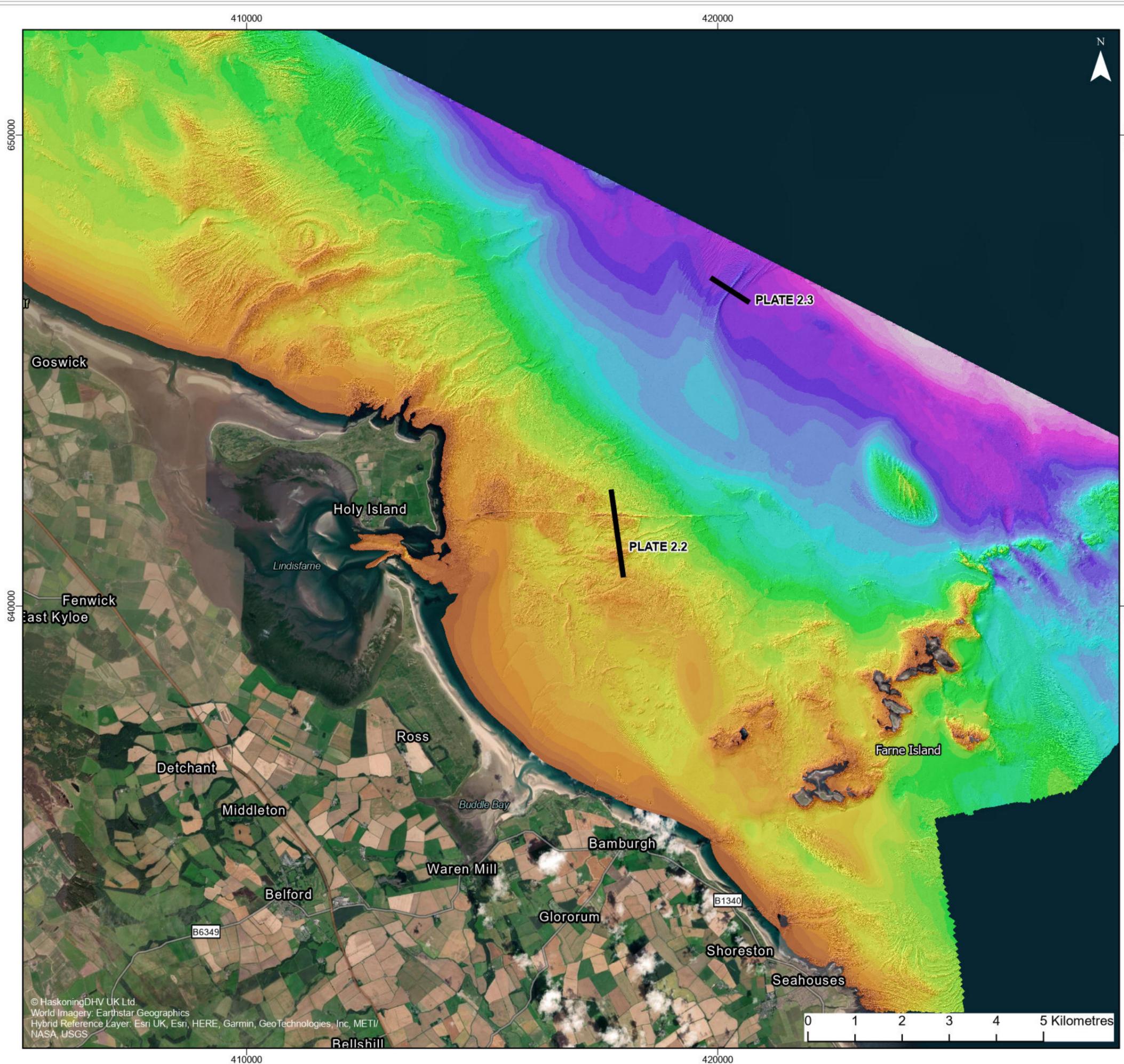
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North East Coastal Group	Cell 1 Regional Coastal Monitoring Programme

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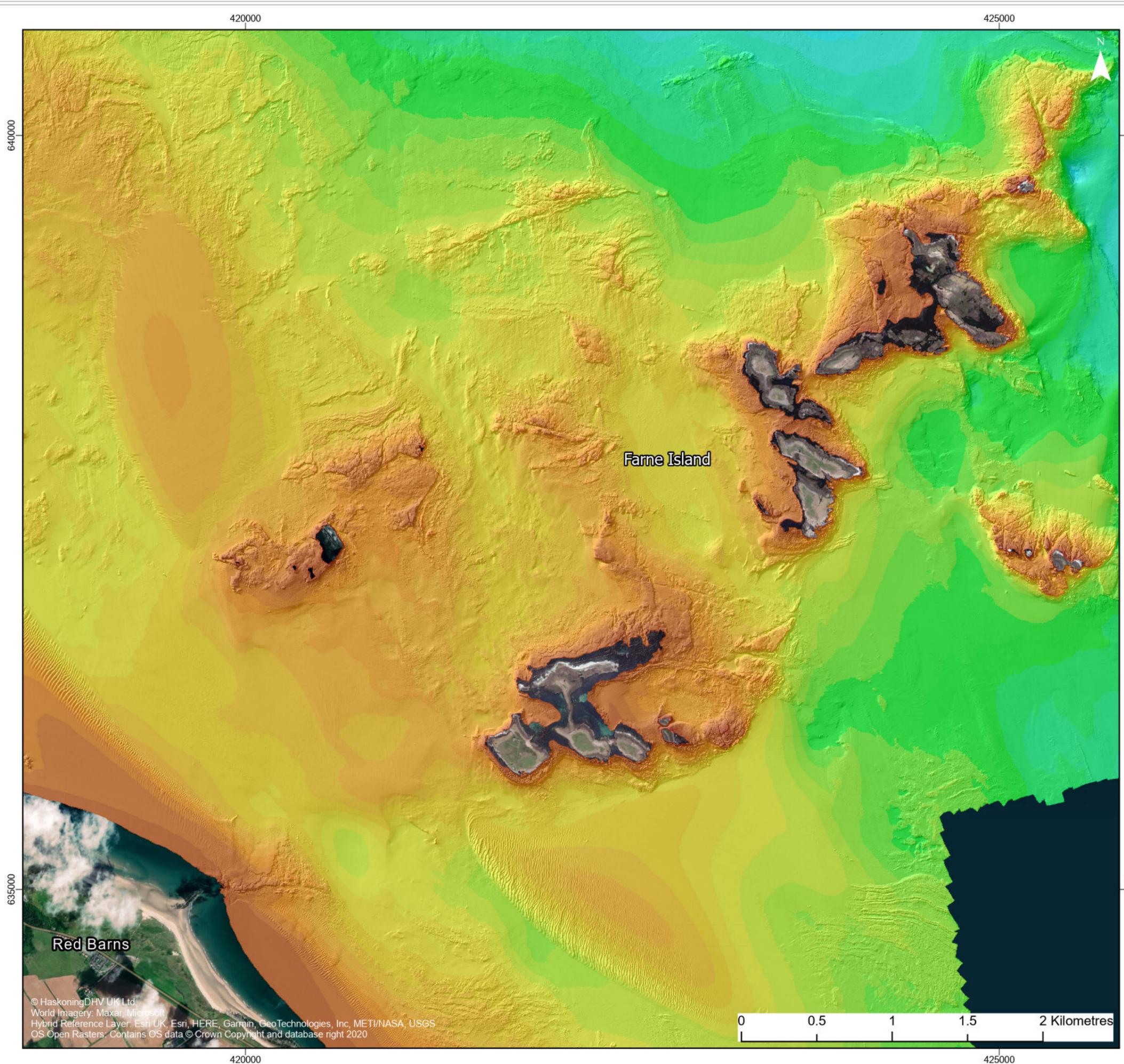
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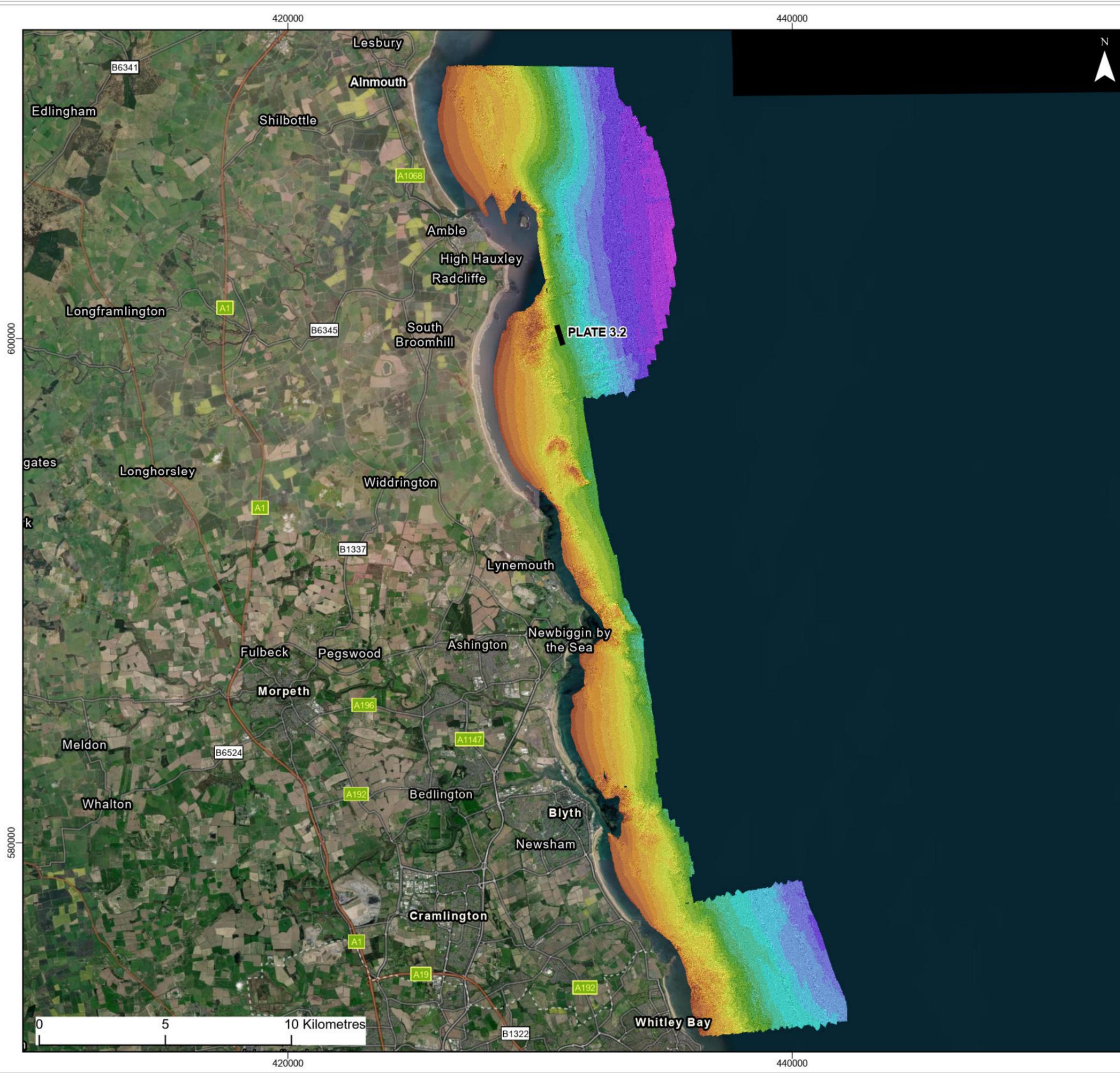
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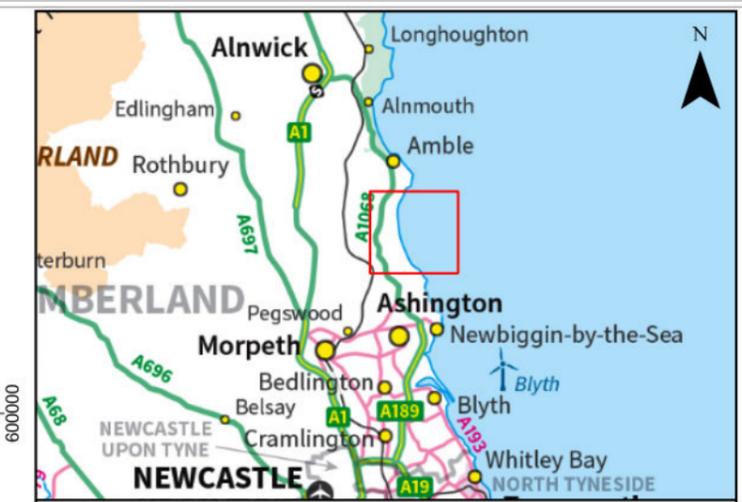
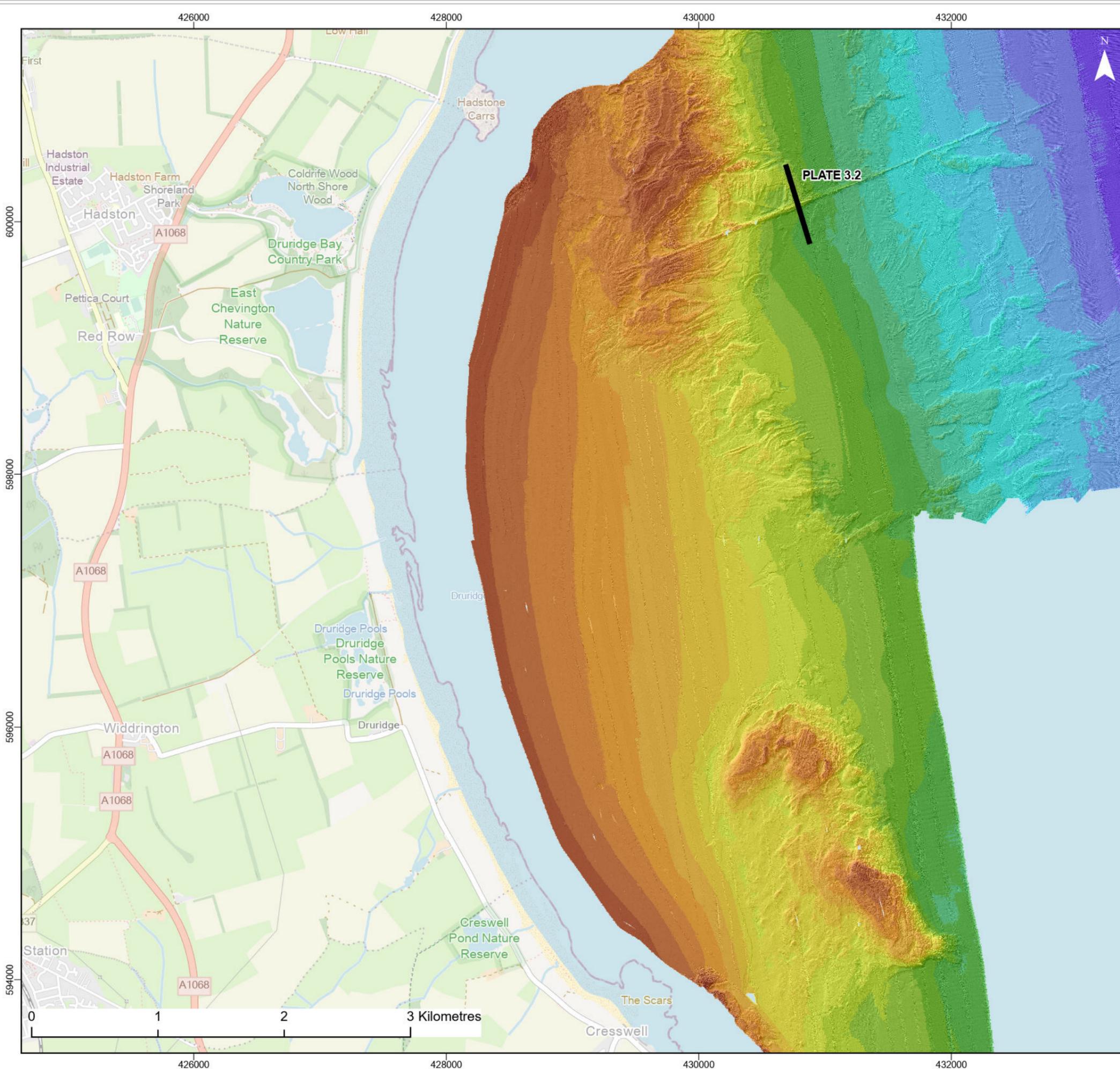
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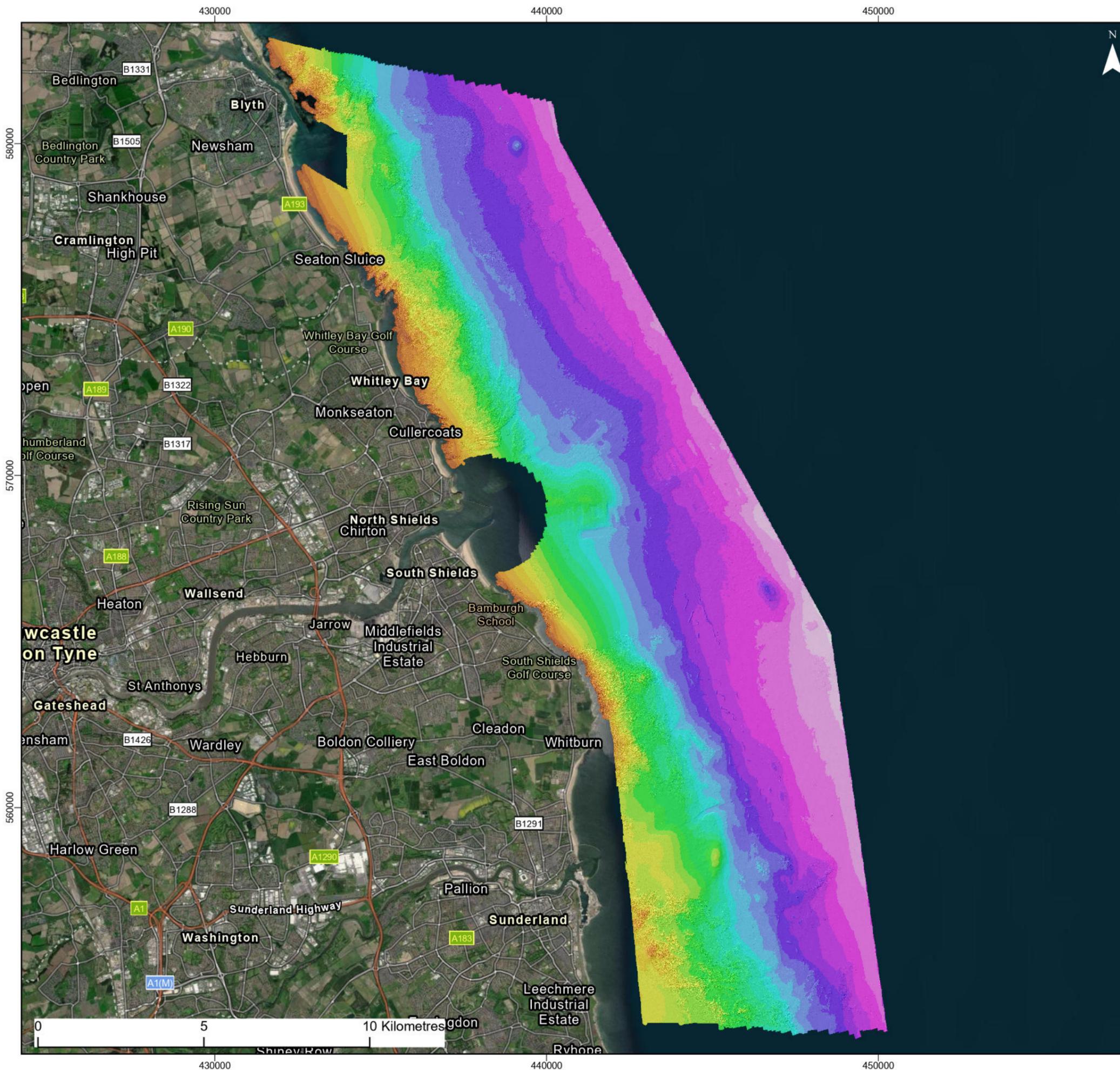
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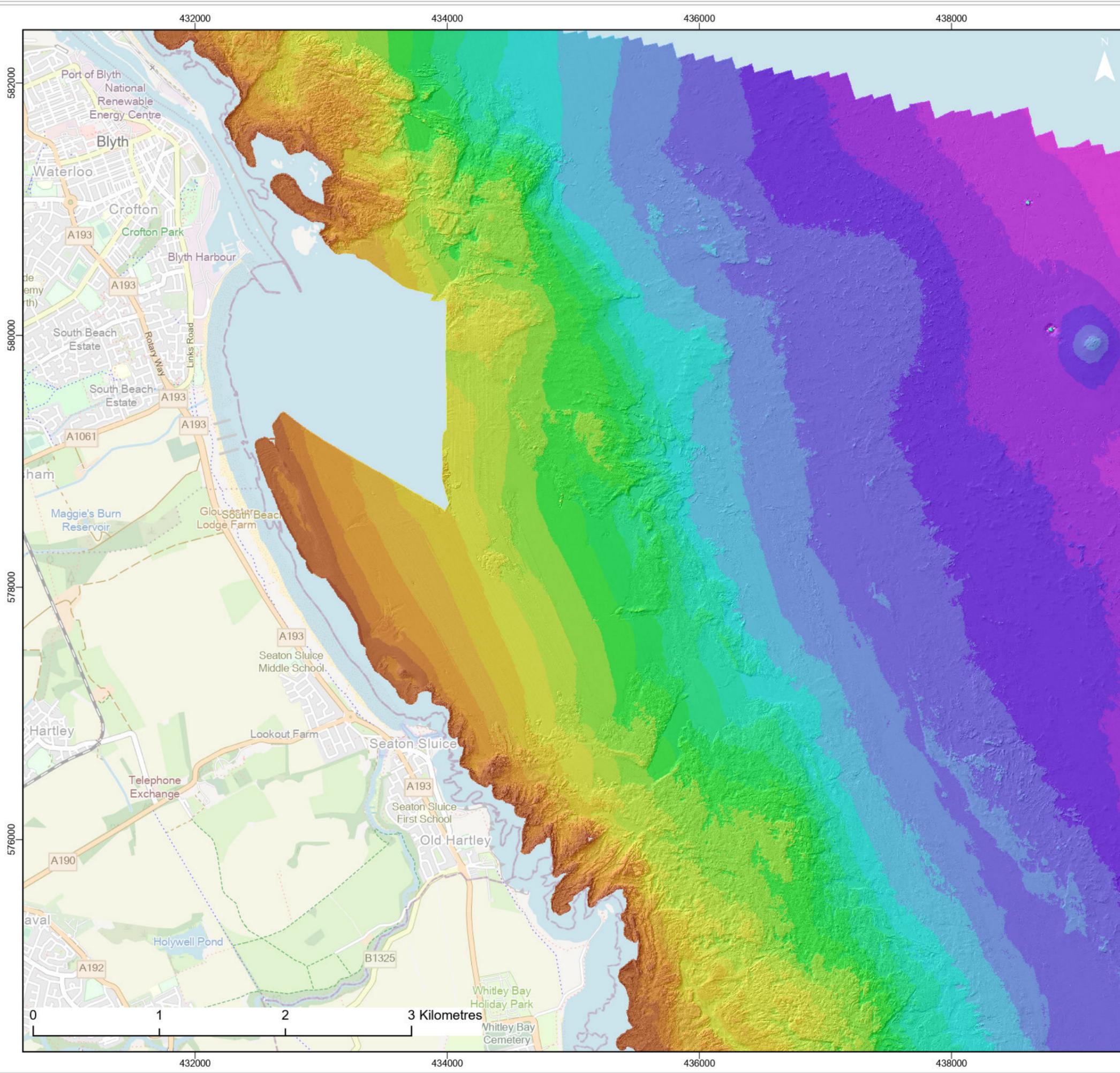
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Client:	Project:
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Title: Close up of bay south of Blyth

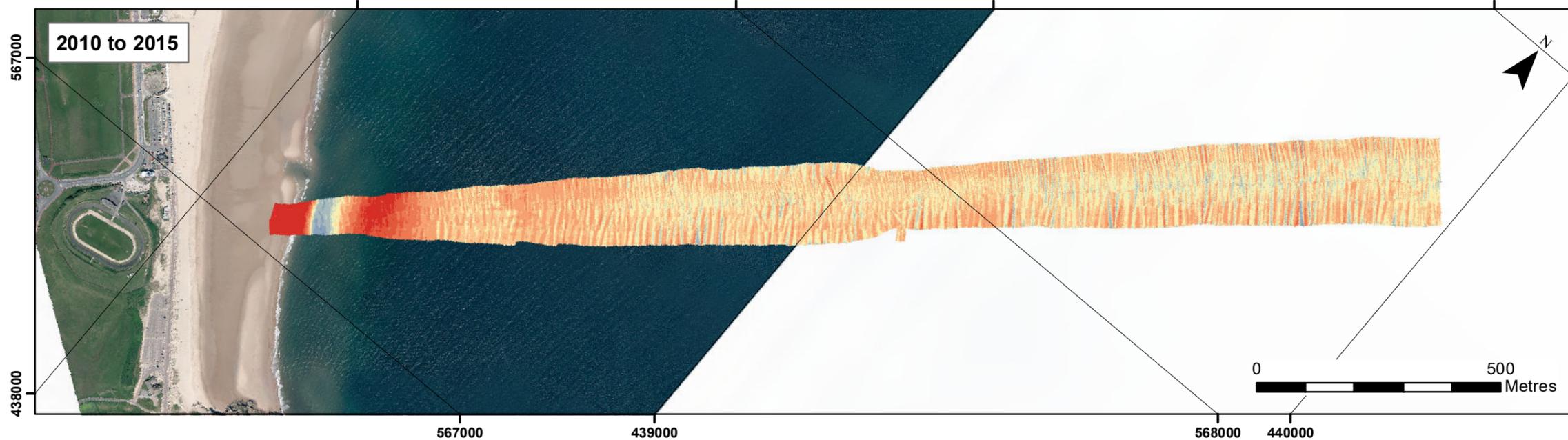
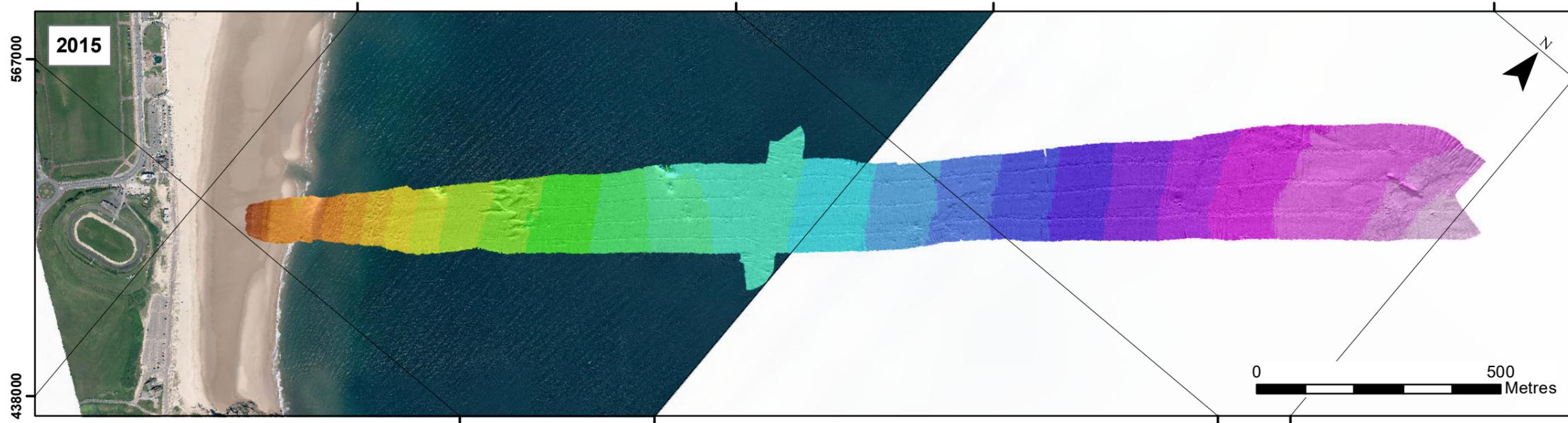
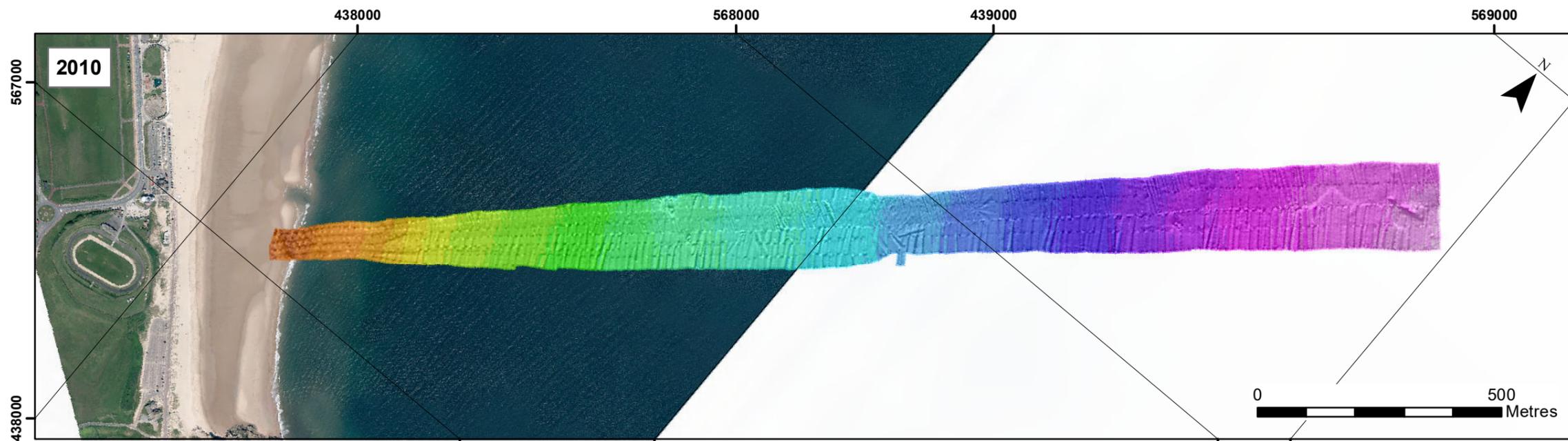
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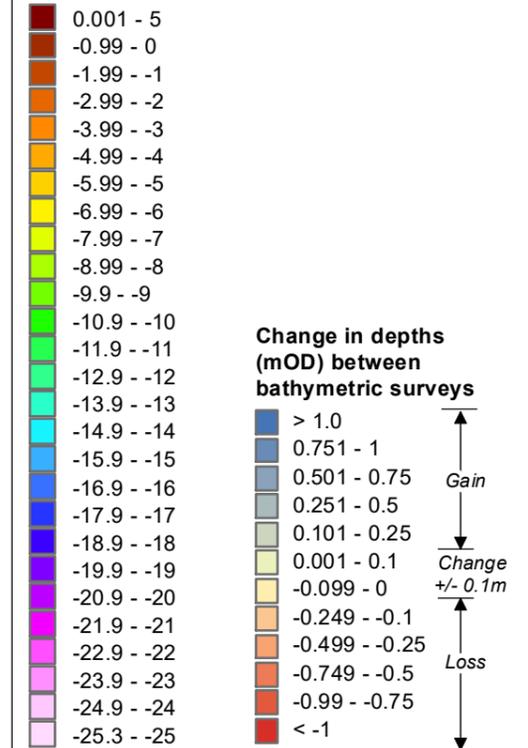
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Bathymetry (mOD)



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Figure 4.3

HERD SANDS

South Tyneside Council Frontage

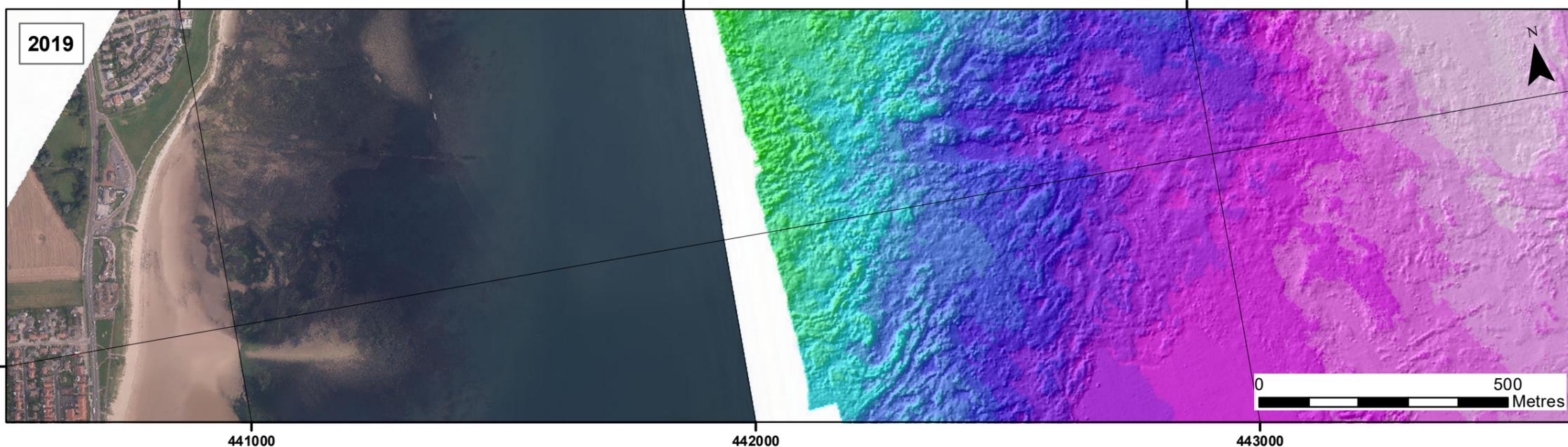
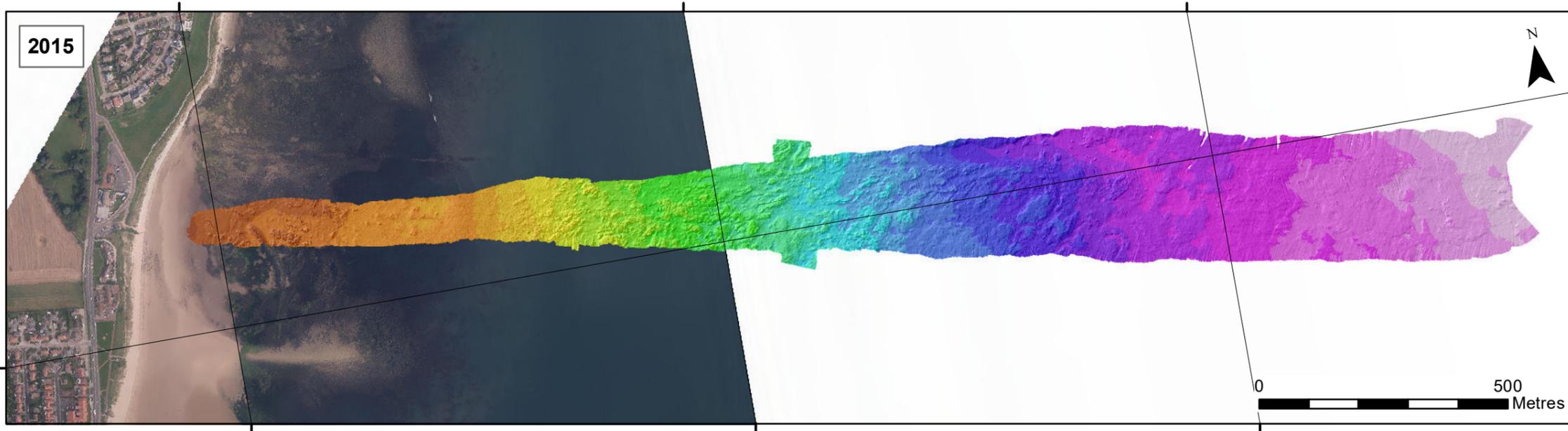
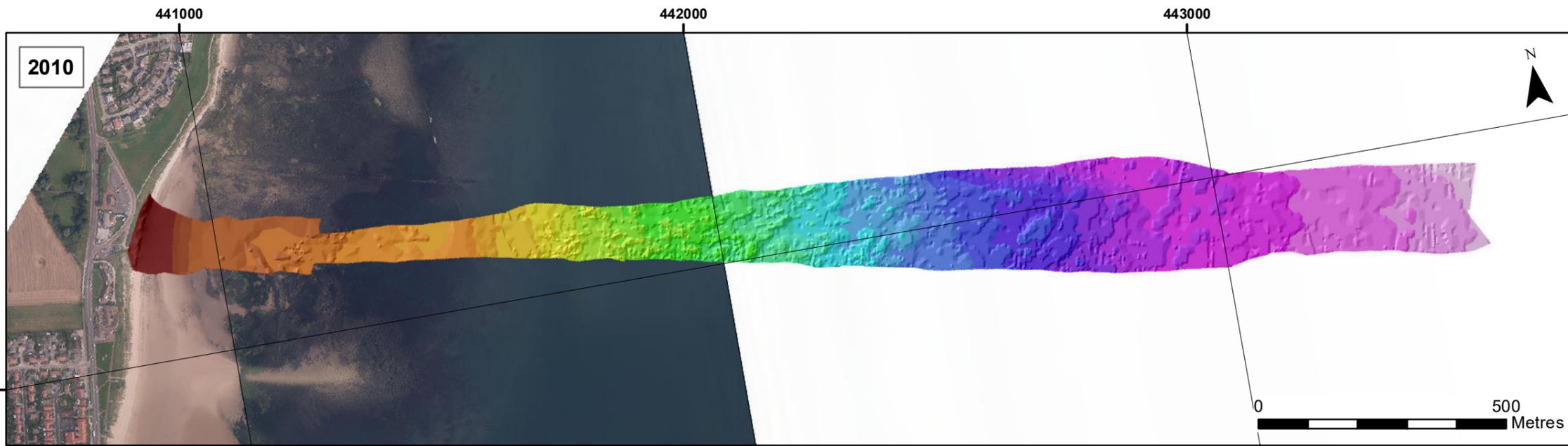
BATHYMETRY SURVEYS

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Legend

Bathymetry (mOD)

- 0.001 - 5
- 0.99 - 0
- 1.99 - -1
- 2.99 - -2
- 3.99 - -3
- 4.99 - -4
- 5.99 - -5
- 6.99 - -6
- 7.99 - -7
- 8.99 - -8
- 9.9 - -9
- 10.9 - -10
- 11.9 - -11
- 12.9 - -12
- 13.9 - -13
- 14.9 - -14
- 15.9 - -15
- 16.9 - -16
- 17.9 - -17
- 18.9 - -18
- 19.9 - -19
- 20.9 - -20
- 21.9 - -21
- 22.9 - -22
- 23.9 - -23
- 24.9 - -24
- 25.3 - -25

Client:
North East Coastal Group

Project:
Cell 1 Regional Coastal Monitoring Programme

Figure 4.4a

SOUTH BENTS

**South Tyneside
Council Frontage**

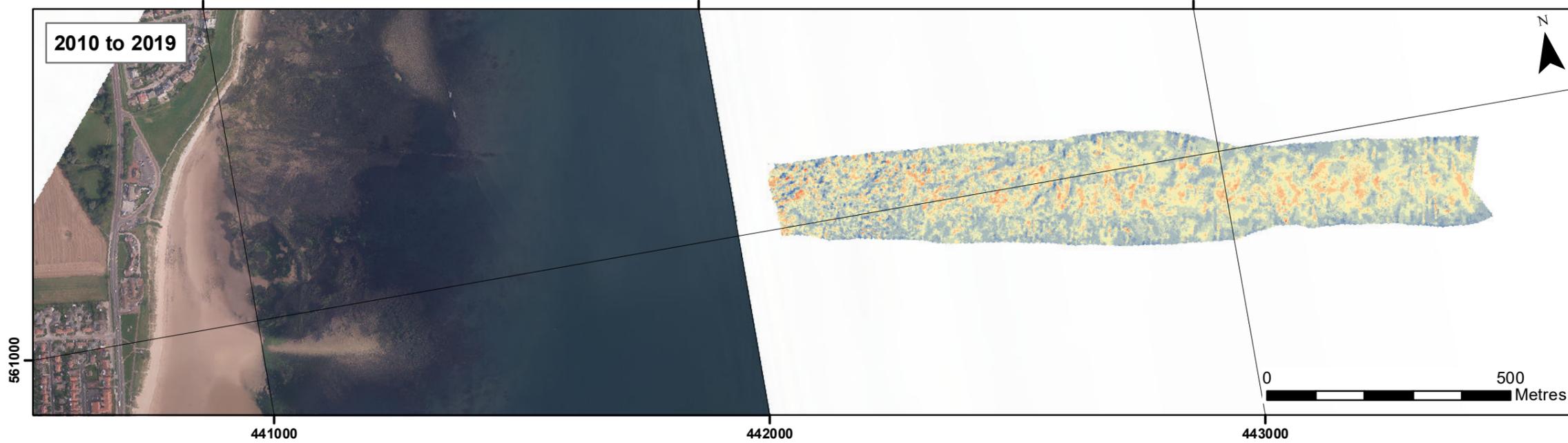
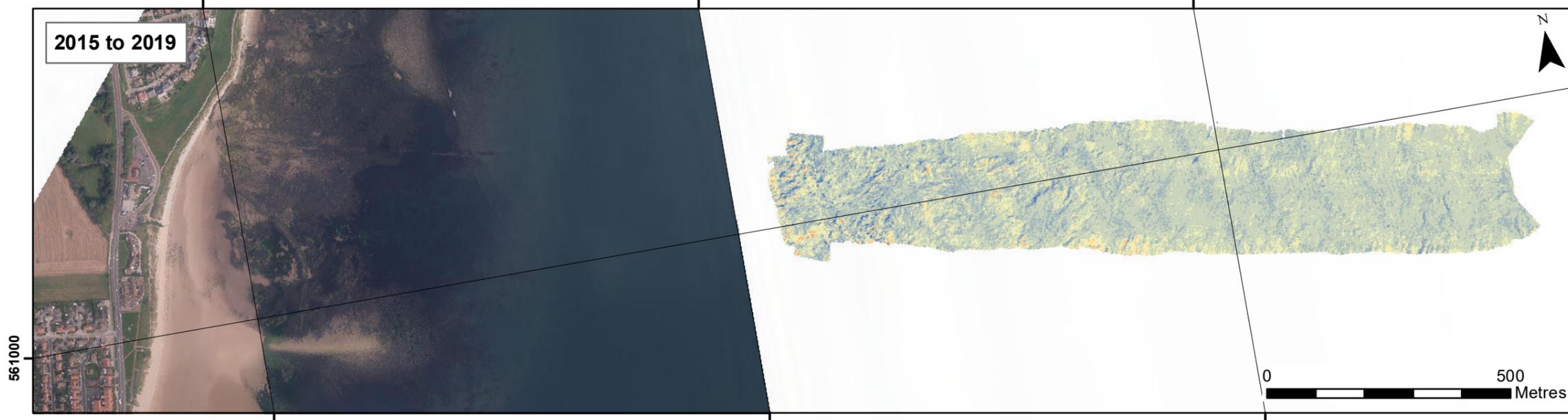
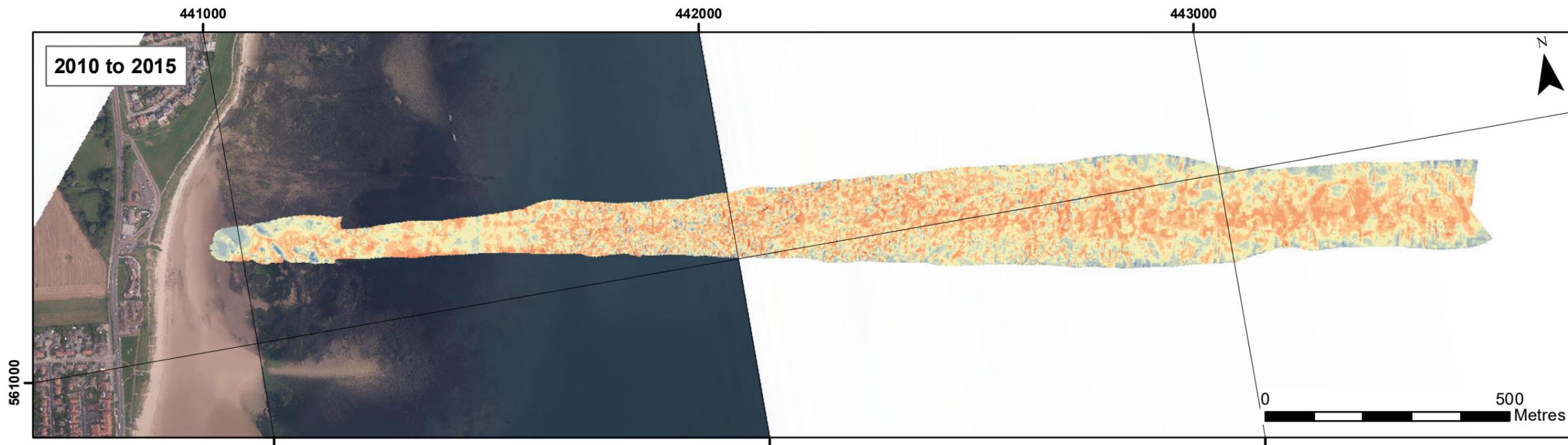
BATHYMETRY SURVEYS

Photography courtesy of the North East Coastal Observatory.
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Legend

Change in depths (mOD) between bathymetric surveys

> 1.0	Gain
0.751 - 1	
0.501 - 0.75	
0.251 - 0.5	
0.101 - 0.25	
0.001 - 0.1	Change +/- 0.1m
-0.099 - 0	
-0.249 - -0.1	Loss
-0.499 - -0.25	
-0.749 - -0.5	
-0.99 - -0.75	
< -1	

Client:
North East Coastal Group

Project:
Cell 1 Regional Coastal Monitoring Programme

Figure 4.4b

SOUTH BENTS

South Tyneside Council Frontage

BATHYMETRY ANALYSIS

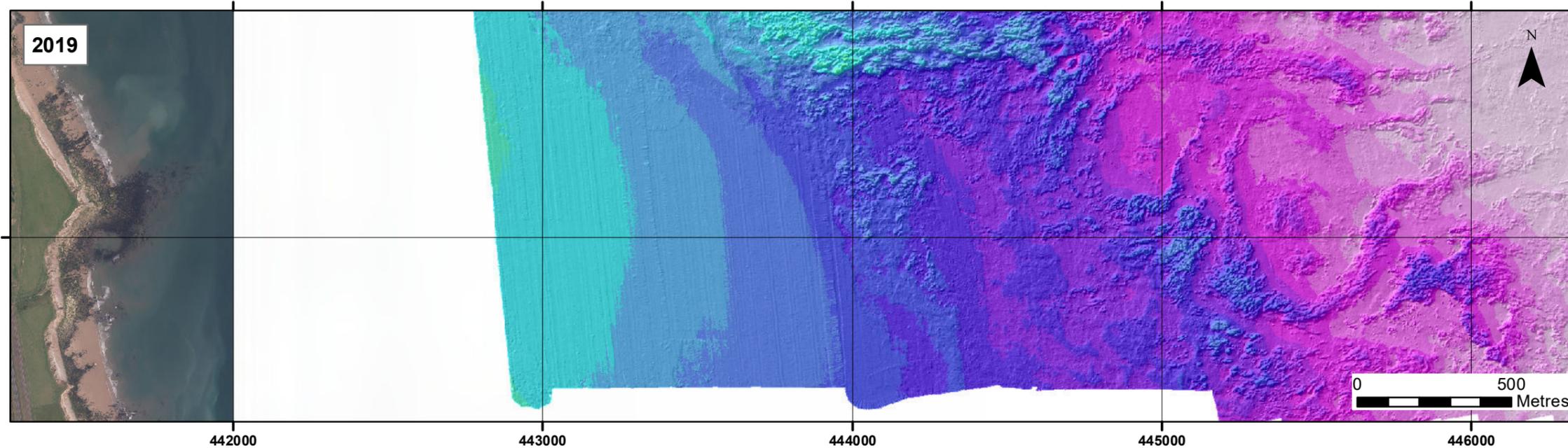
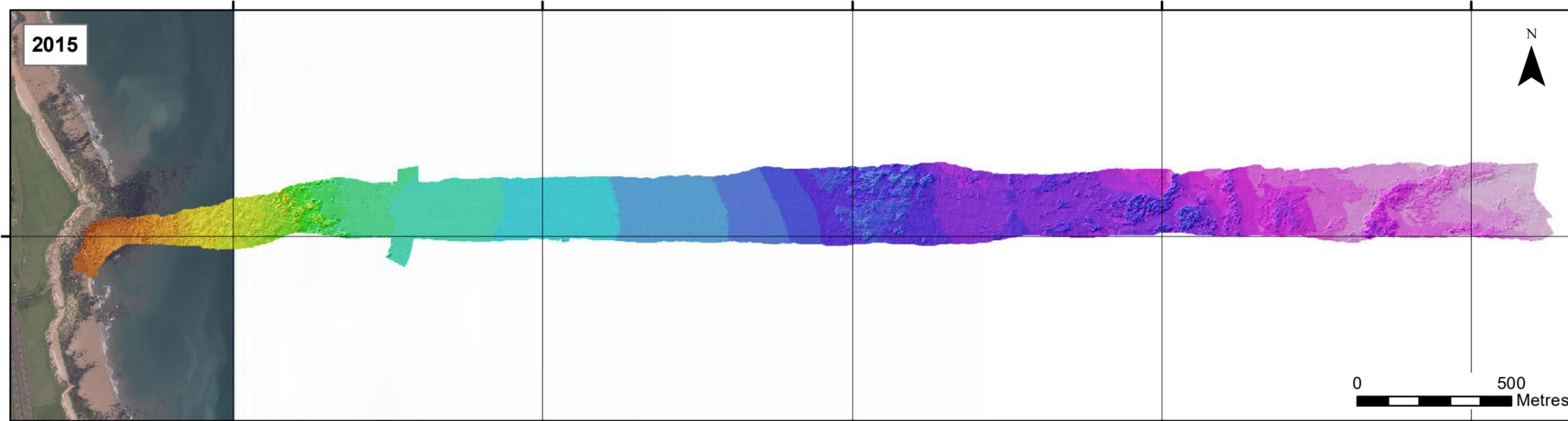
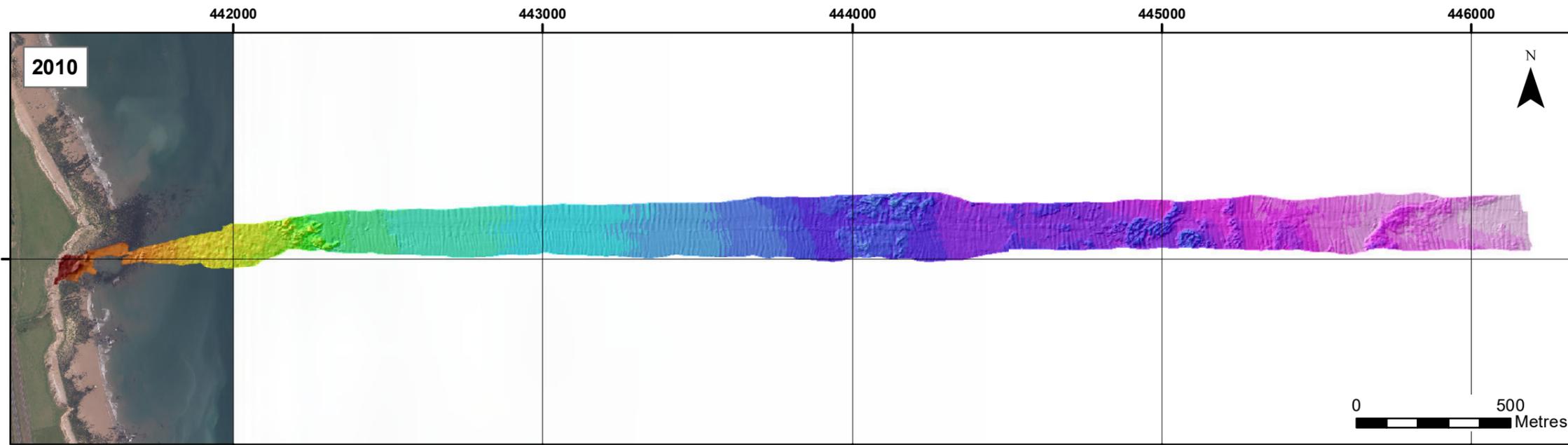
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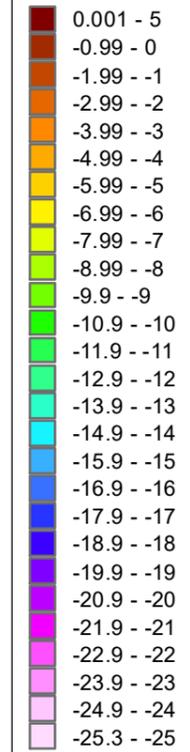


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Legend

Bathymetry (mOD)



Client:
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Project:
Cell 1 Regional Coastal Monitoring Programme

Figure 4.5a
SALTERFEN ROCKS
Sunderland City
Council Frontage
BATHYMETRY SURVEYS

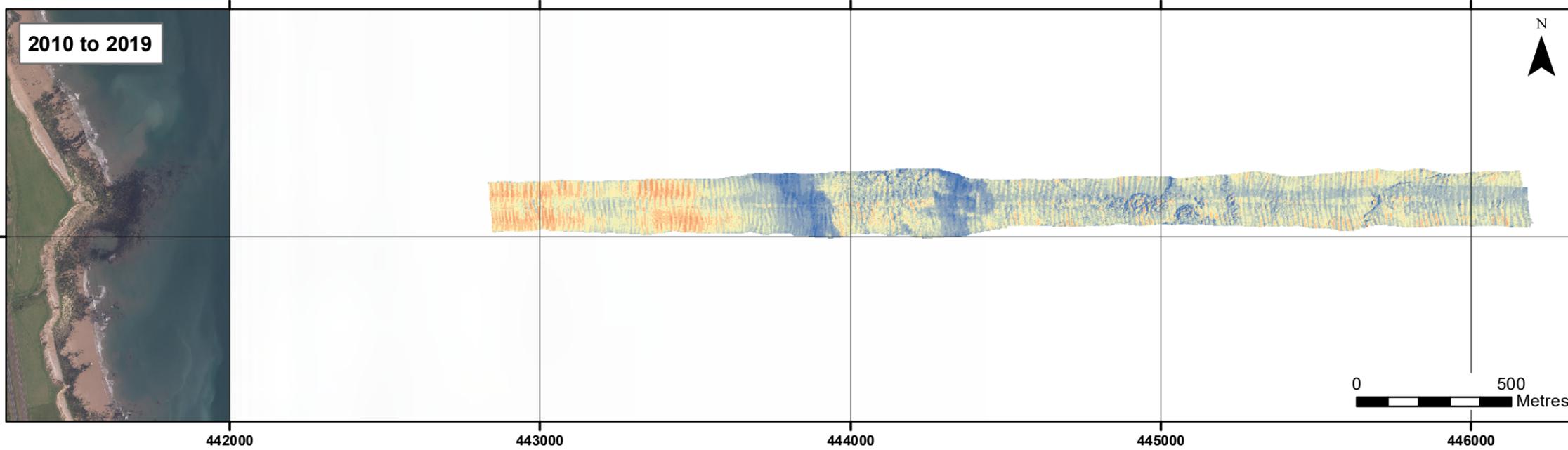
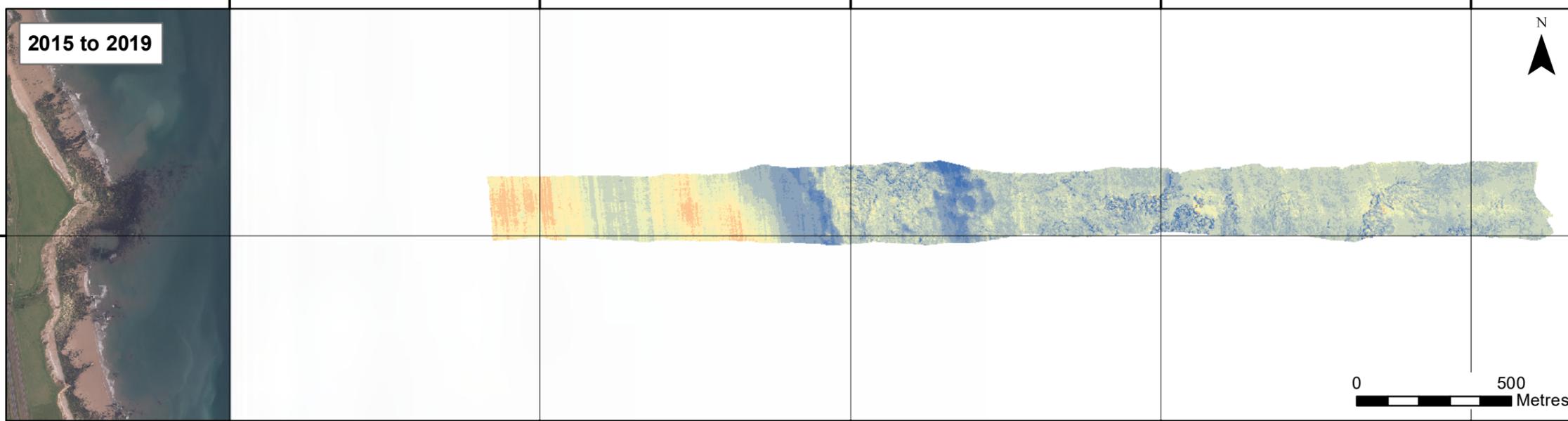
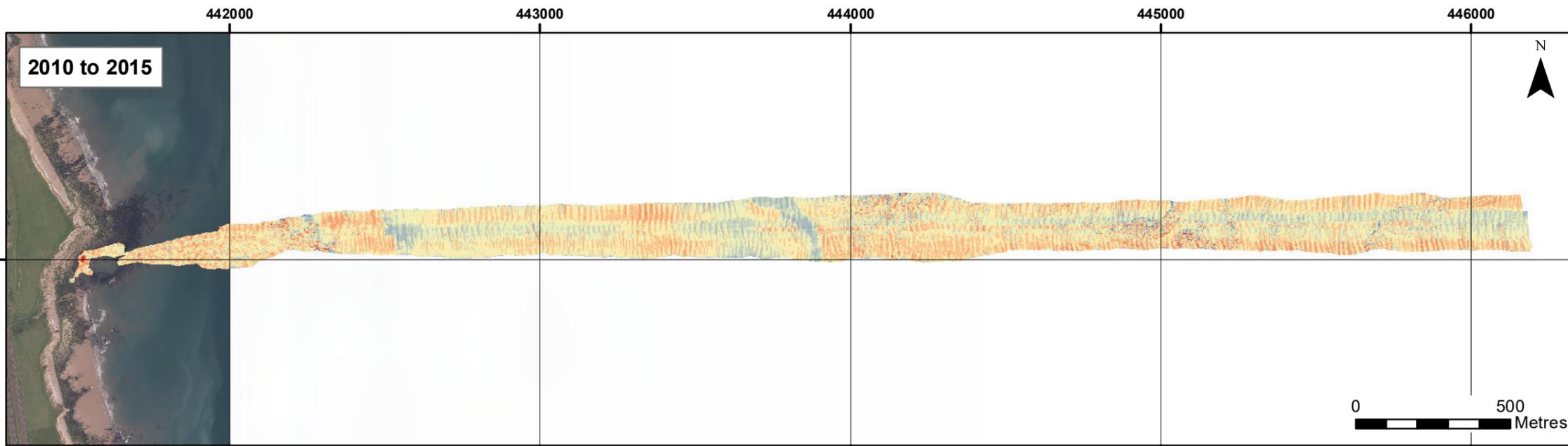
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Legend

Change in depths (mOD) between bathymetric surveys

> 1.0	Gain
0.751 - 1	
0.501 - 0.75	
0.251 - 0.5	
0.101 - 0.25	
0.001 - 0.1	Change +/- 0.1m
-0.099 - 0	
-0.249 - -0.1	
-0.499 - -0.25	
-0.749 - -0.5	
-0.99 - -0.75	Loss
< -1	

Client:
North East Coastal Group

Project:
Cell 1 Regional Coastal Monitoring Programme

Figure 4.5b

SALTERFEN ROCKS

Sunderland City Council Frontage

BATHYMETRY ANALYSIS

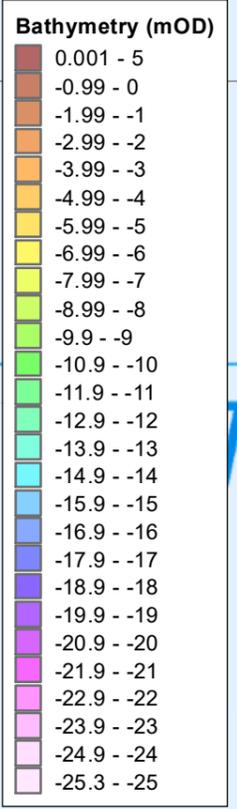
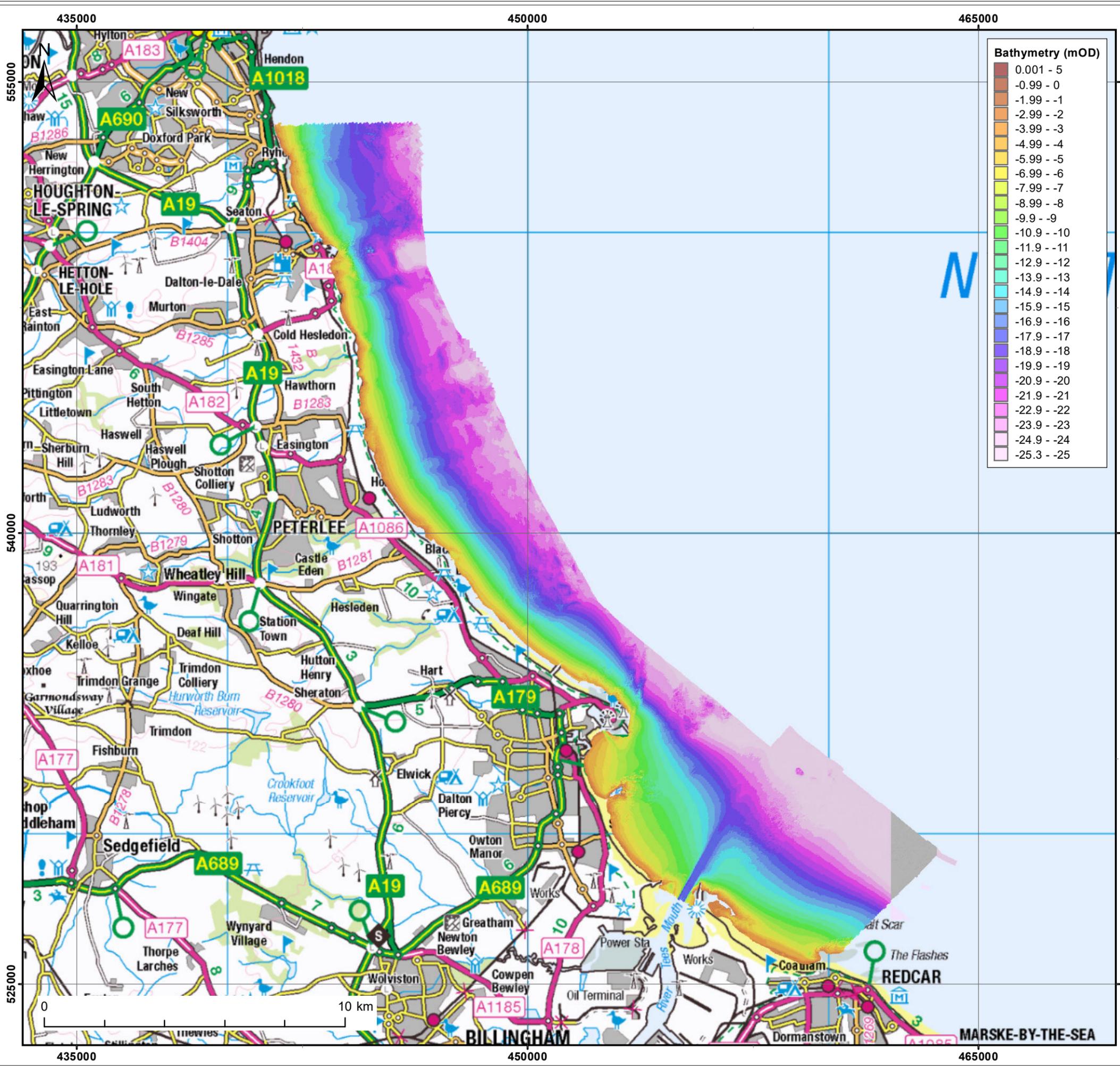
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Client:	Project:
North East Coastal Group	Cell 1 Regional Coastal Monitoring Programme

Title:
General overview of bathymetry between Sunderland and Redcar

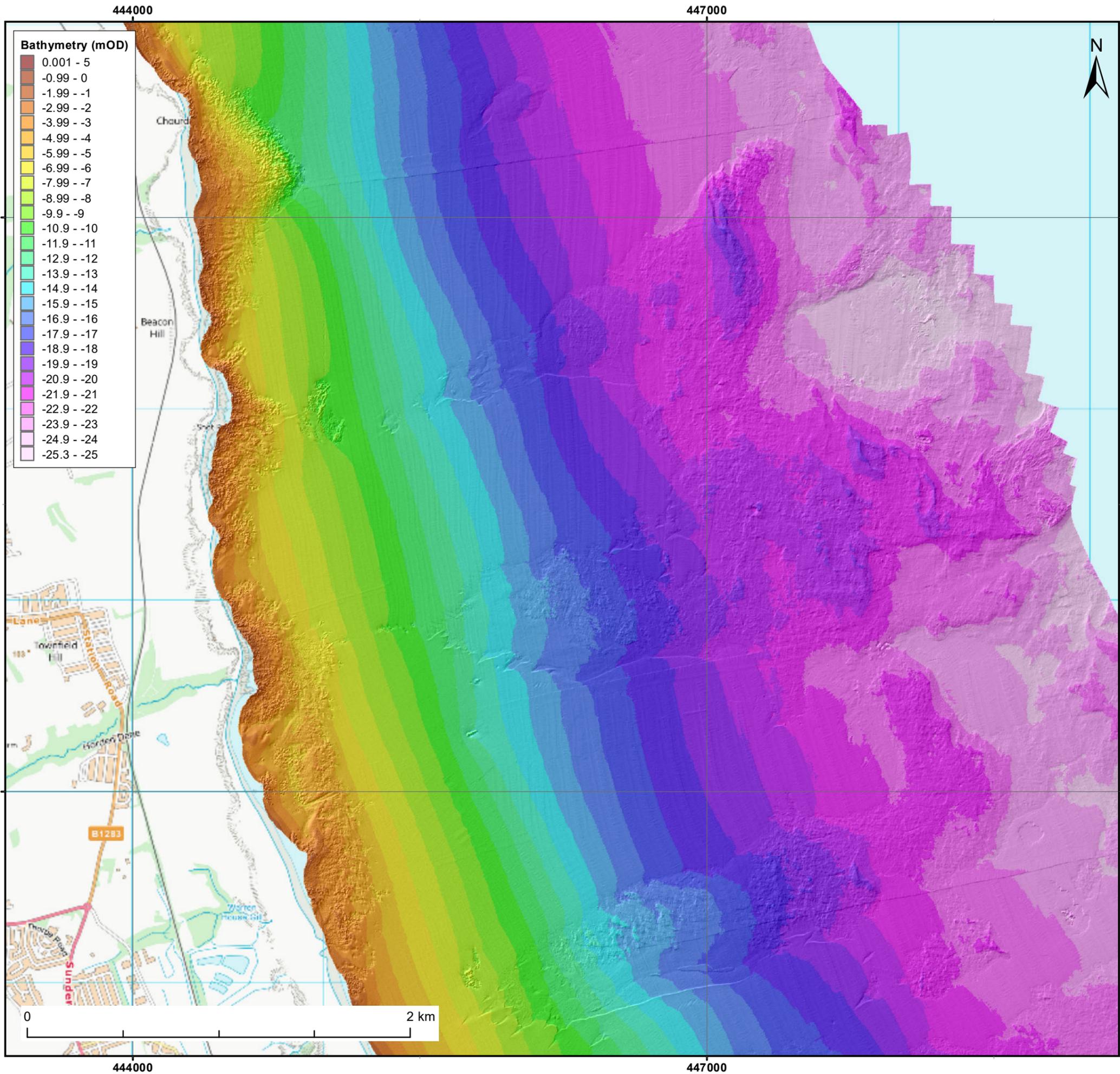
Figure: 5.1

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Client:	Project:
North East Coastal Group	Cell 1 Regional Coastal Monitoring Programme

Title:
Bathymetry offshore from Easington

Figure: 5.2

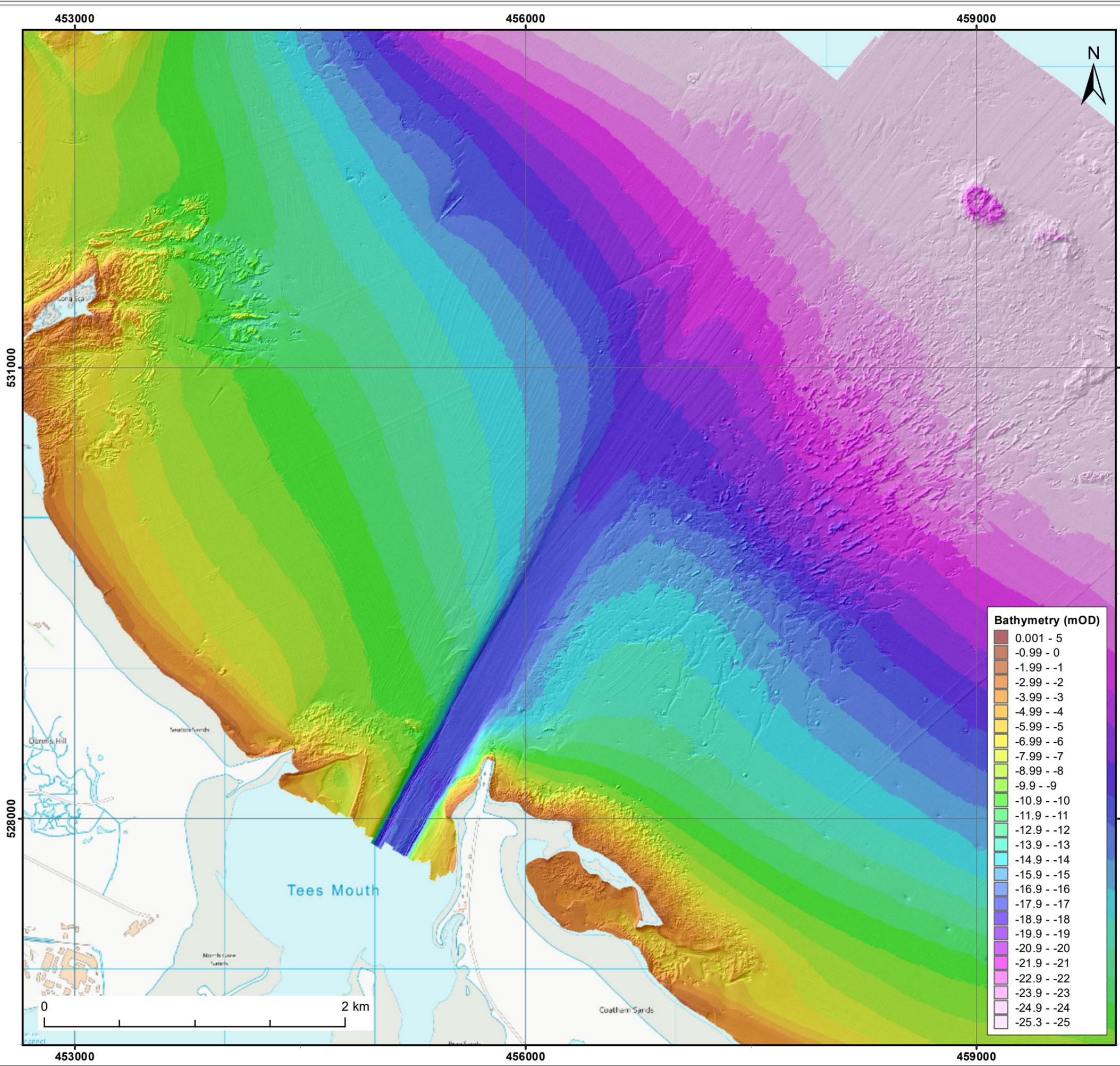
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Title:
Bathymetry of the Tees Estuary dredged channel

Figure: 5.3

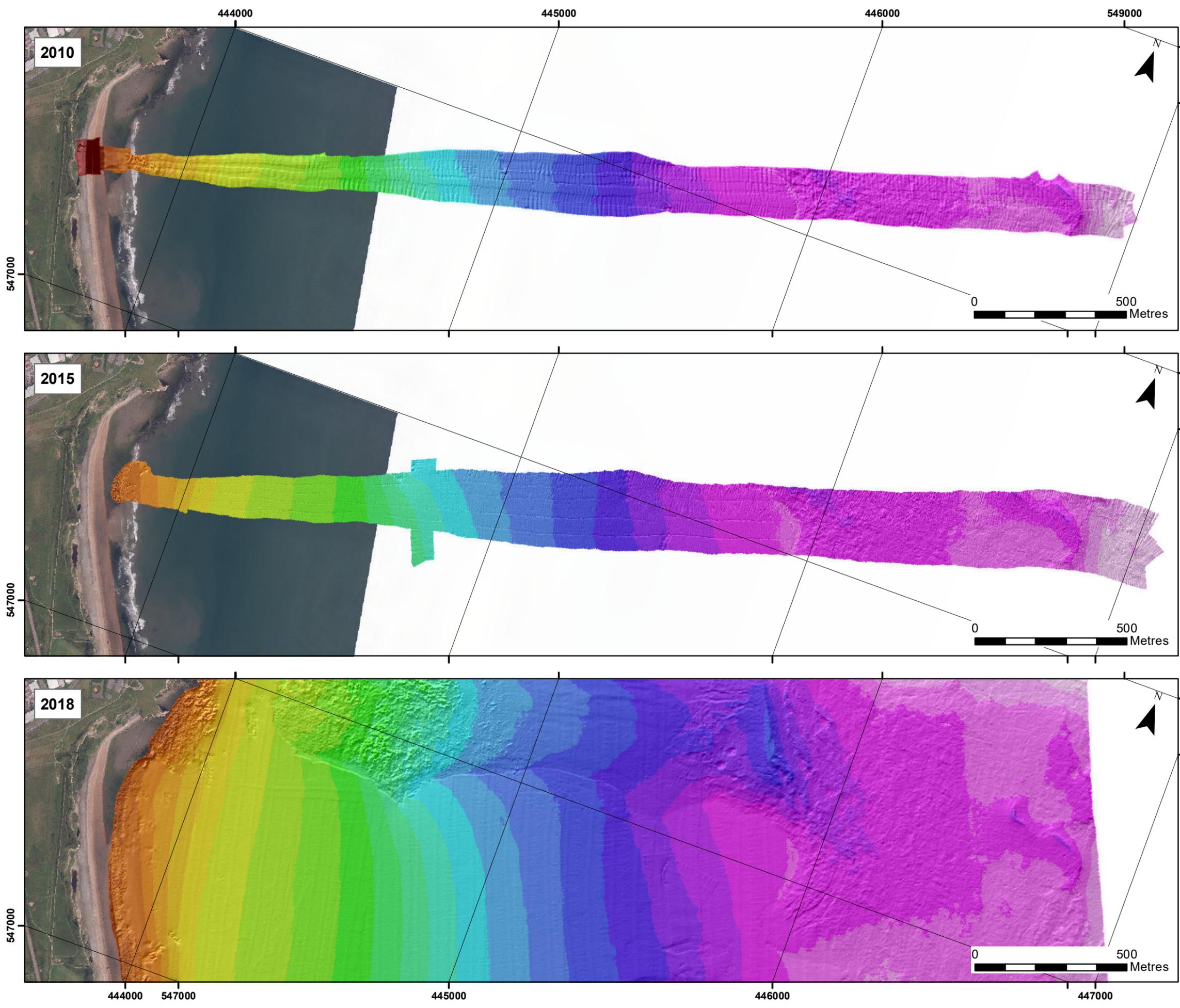
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Legend

Bathymetry (mOD)

0.001 - 5
-0.99 - 0
-1.99 - -1
-2.99 - -2
-3.99 - -3
-4.99 - -4
-5.99 - -5
-6.99 - -6
-7.99 - -7
-8.99 - -8
-9.9 - -9
-10.9 - -10
-11.9 - -11
-12.9 - -12
-13.9 - -13
-14.9 - -14
-15.9 - -15
-16.9 - -16
-17.9 - -17
-18.9 - -18
-19.9 - -19
-20.9 - -20
-21.9 - -21
-22.9 - -22
-23.9 - -23
-24.9 - -24
-25.3 - -25

Client:
North East Coastal Group

Project:
Cell 1 Regional Coastal Monitoring Programme

Figure 5.4a

BLAST BEACH

Durham County Council Frontage

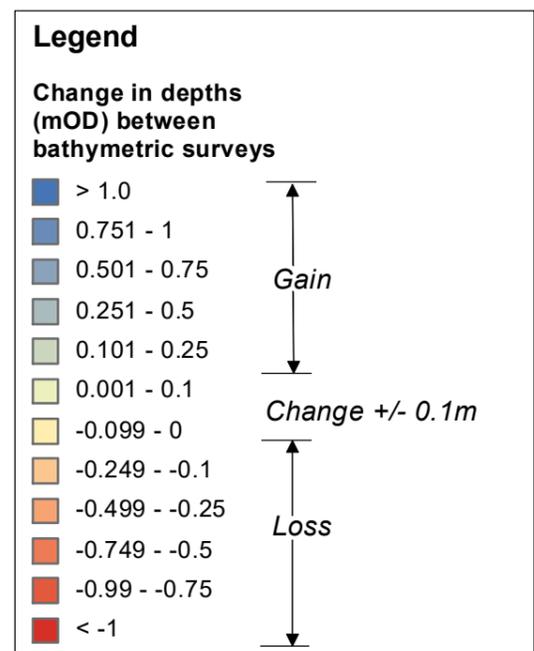
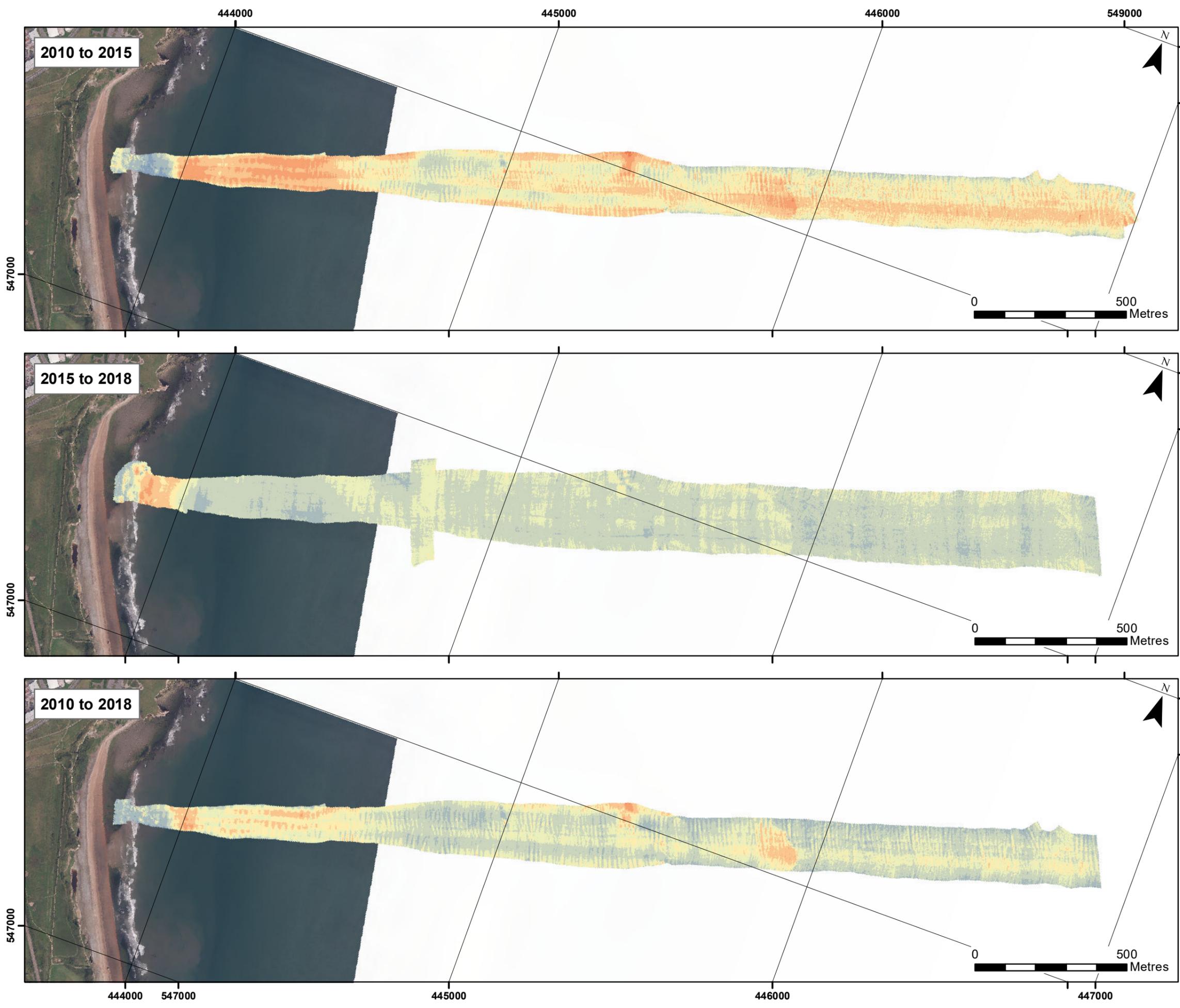
BATHYMETRY SURVEYS

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Project:
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Figure 5.4b

BLAST BEACH

Durham County Council Frontage

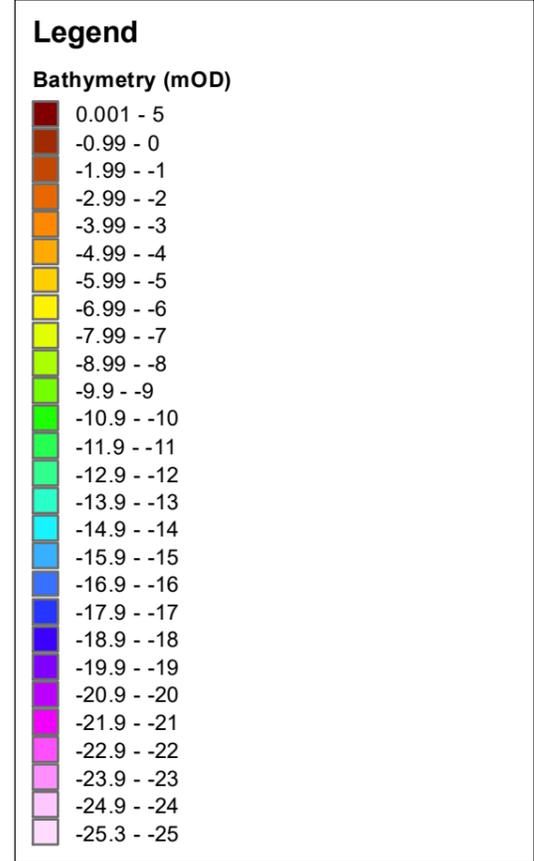
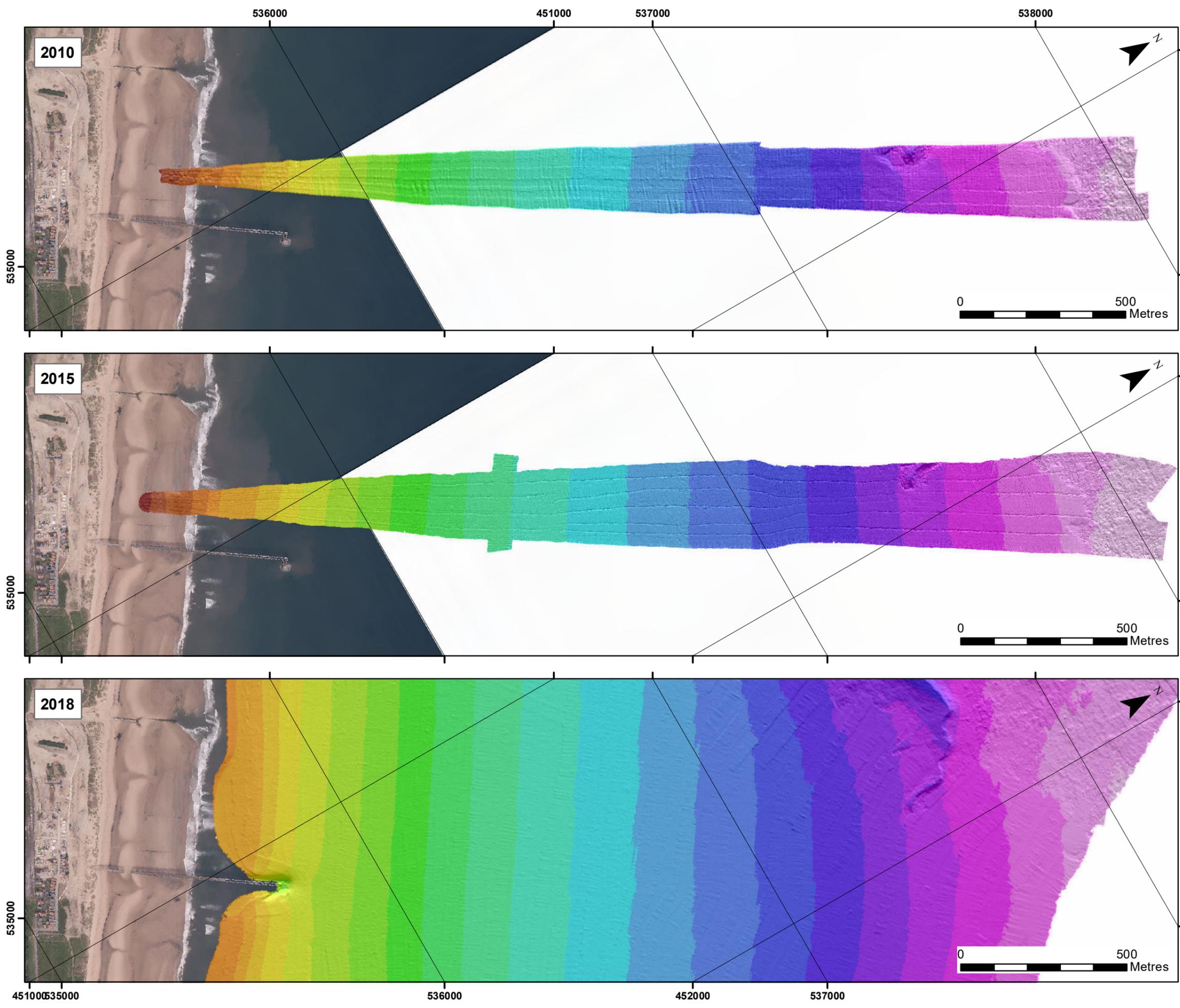
BATHYMETRY ANALYSIS

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Client:
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Project:
Cell 1 Regional Coastal Monitoring Programme

Figure 5.5a

**HARTLEPOOL
NORTH SANDS**

**Hartlepool Borough
Council Frontage**

BATHYMETRY SURVEYS

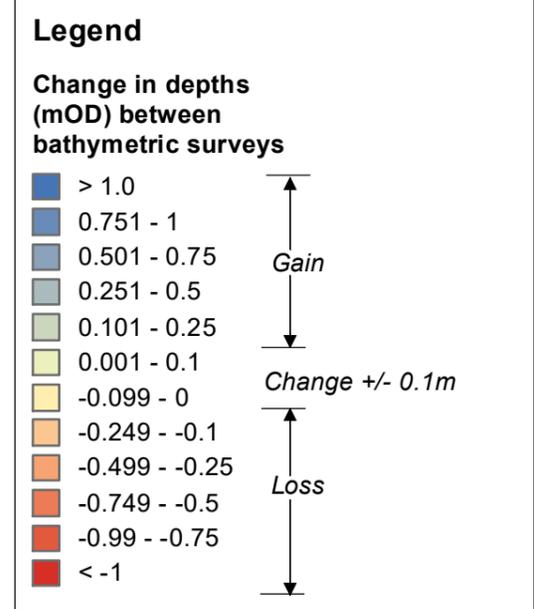
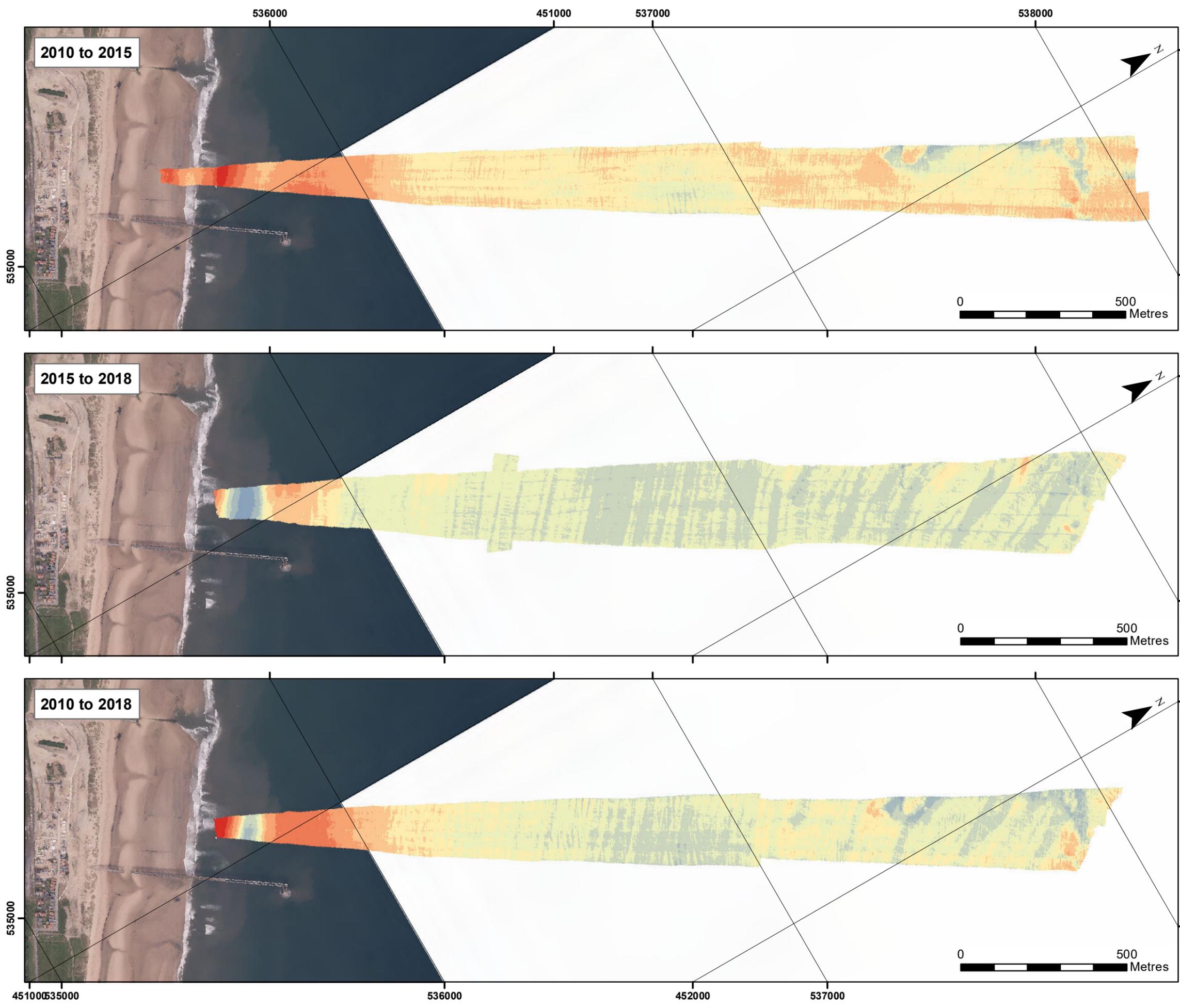
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Figure 5.5b

**HARTLEPOOL
NORTH SANDS**

**Hartlepool Borough
Council Frontage**

BATHYMETRY ANALYSIS

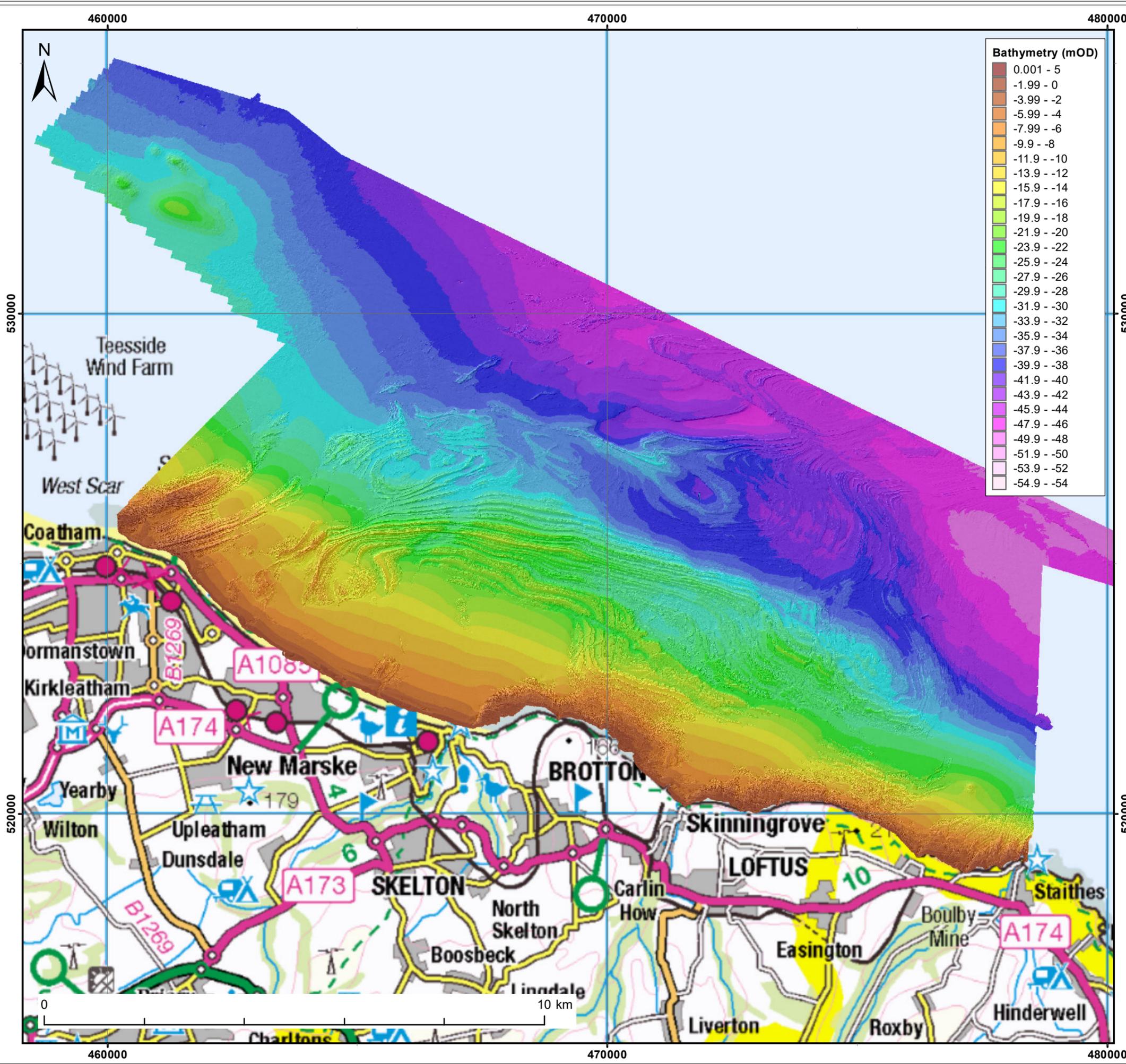
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Client:	Project:
North East Coastal Group	Cell 1 Regional Coastal Monitoring Programme

Title:
 General overview of bathymetry between Redcar and Staithes

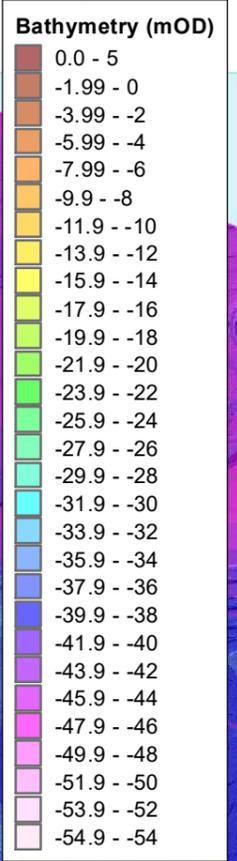
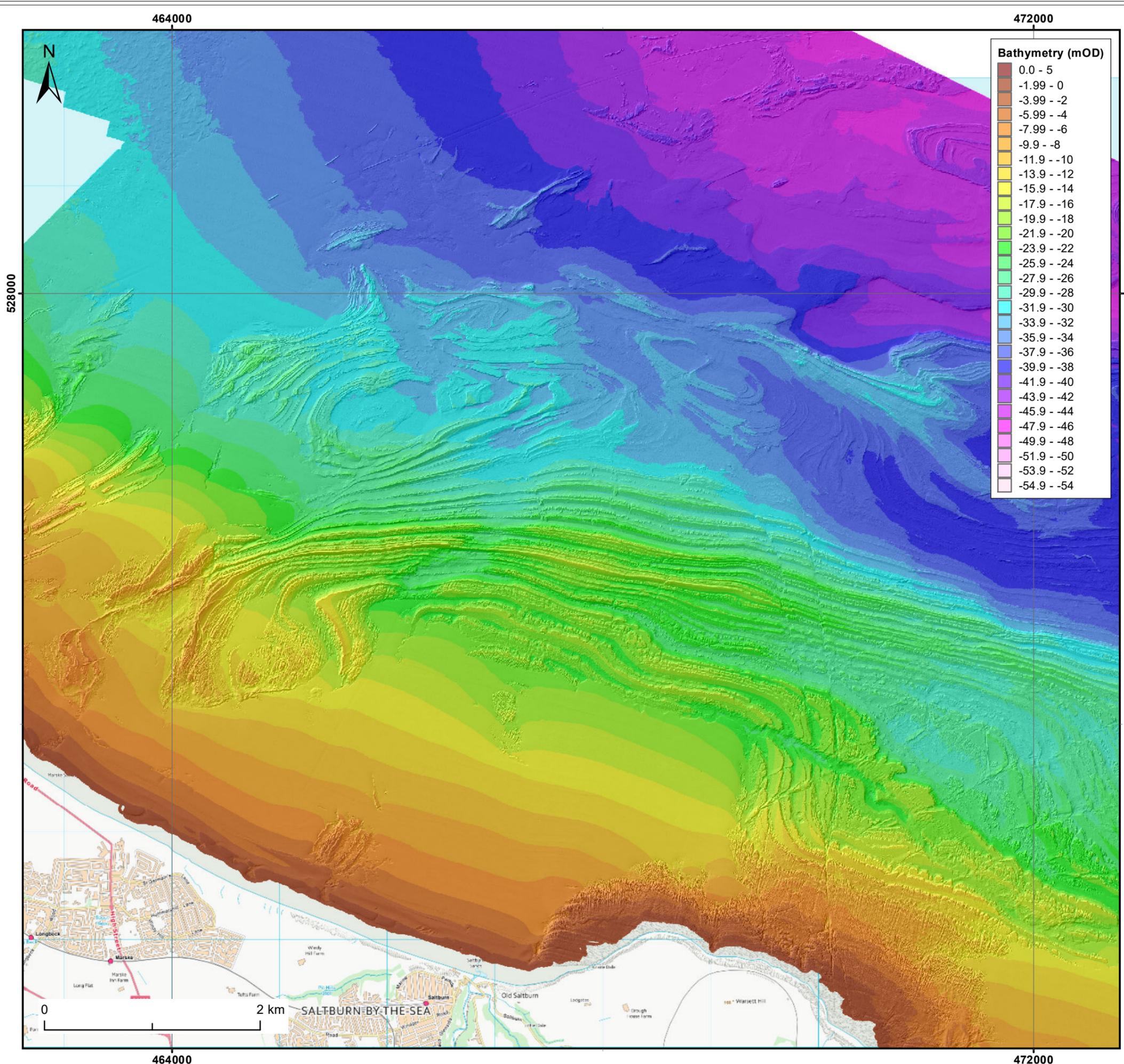
Figure: 6.1

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Co-ordinate system: British National Grid

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Title:
Bathymetry offshore from Saltburn-by-the-Sea

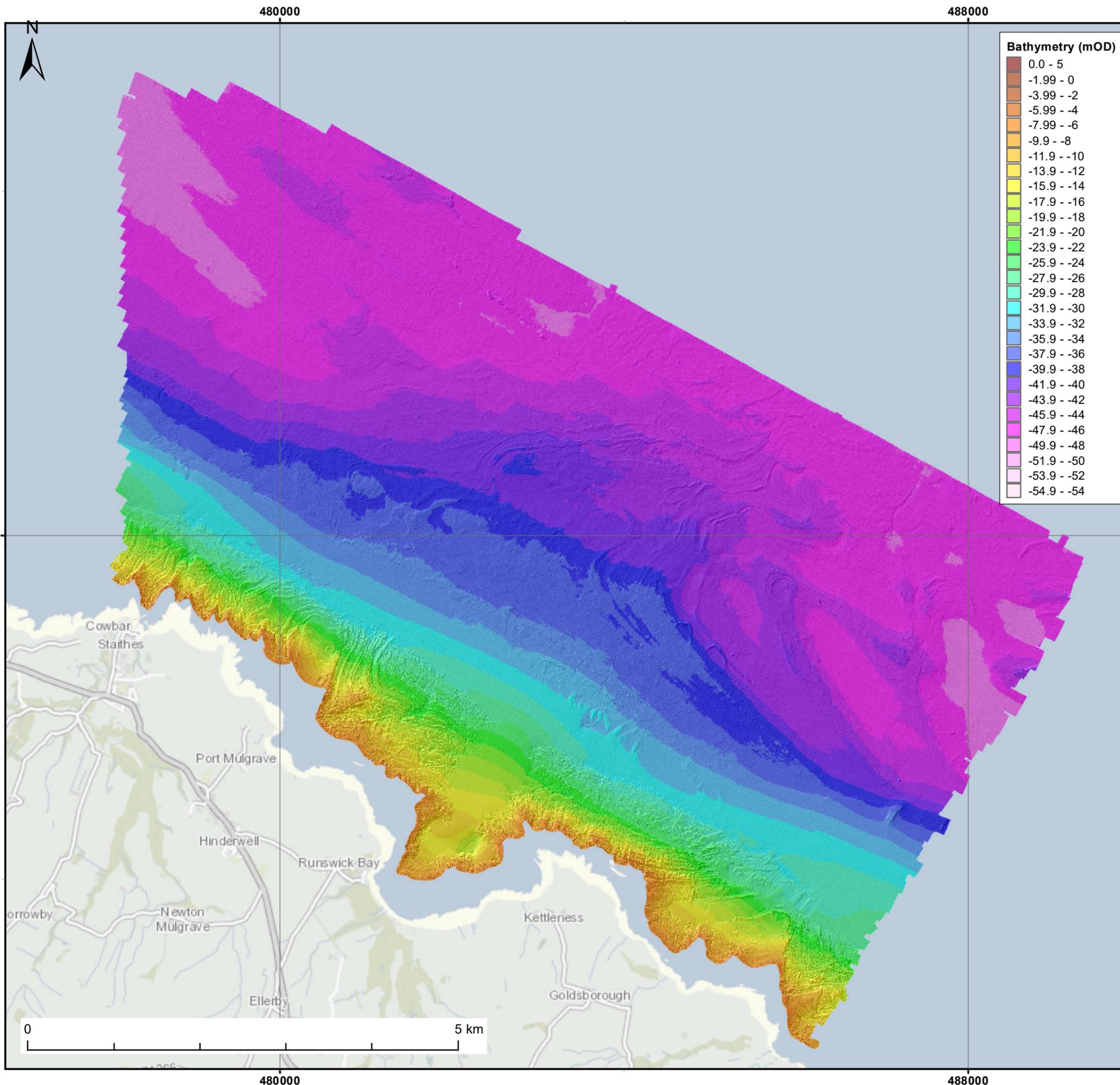
Figure: 6.2

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Title:
General overview of bathymetry offshore from Runswick Bay

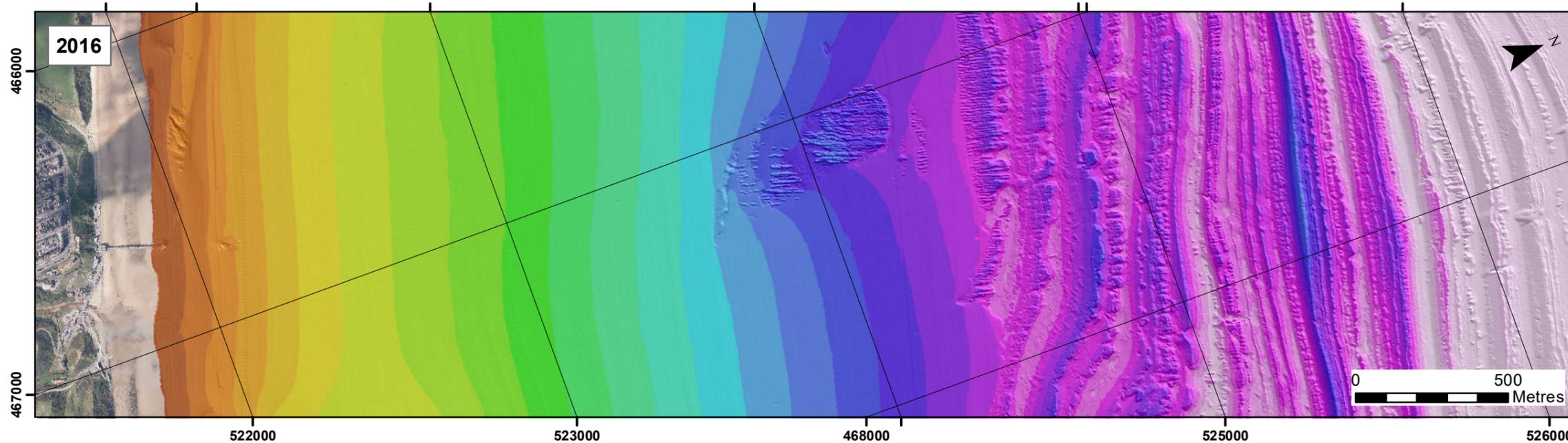
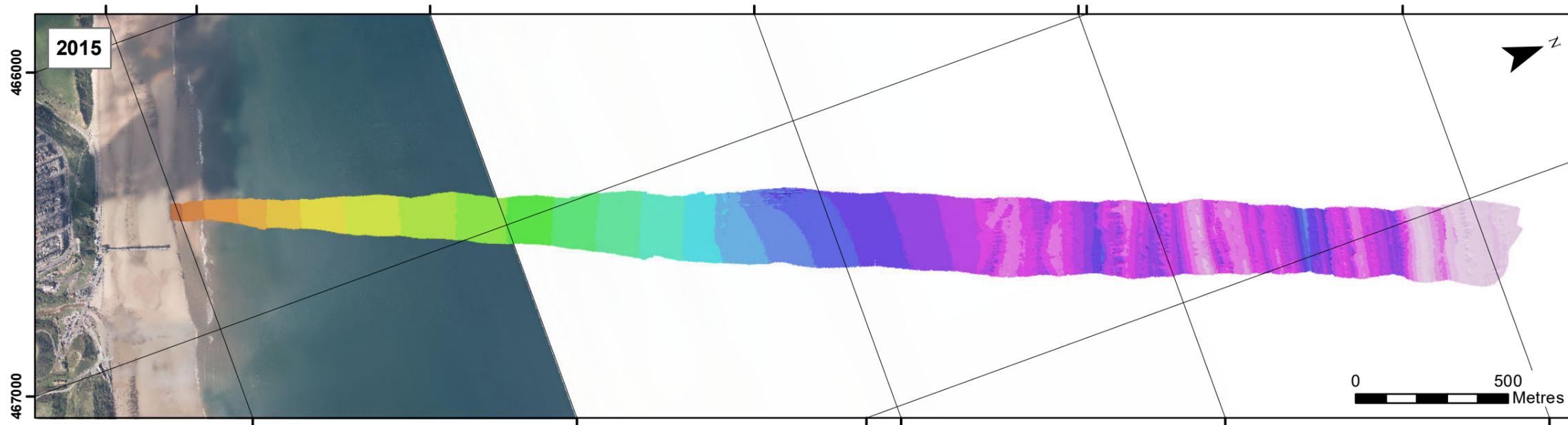
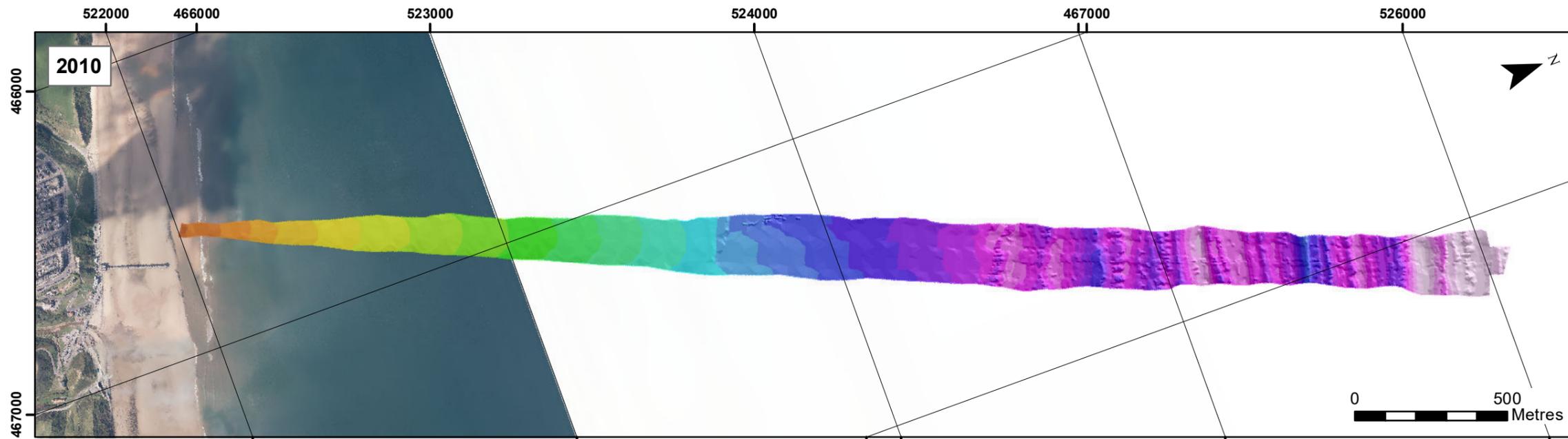
Figure: 6.3

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Legend

Bathymetry (mOD)

- 0.001 - 5
- 0.99 - 0
- 1.99 - -1
- 2.99 - -2
- 3.99 - -3
- 4.99 - -4
- 5.99 - -5
- 6.99 - -6
- 7.99 - -7
- 8.99 - -8
- 9.9 - -9
- 10.9 - -10
- 11.9 - -11
- 12.9 - -12
- 13.9 - -13
- 14.9 - -14
- 15.9 - -15
- 16.9 - -16
- 17.9 - -17
- 18.9 - -18
- 19.9 - -19
- 20.9 - -20
- 21.9 - -21
- 22.9 - -22
- 23.9 - -23
- 24.9 - -24
- 25.3 - -25

Client:
North East Coastal Group

Project:
Cell 1 Regional Coastal Monitoring Programme

Figure 6.4a

SALTBURN SANDS

**Redcar and Cleveland
Borough Council Frontage**

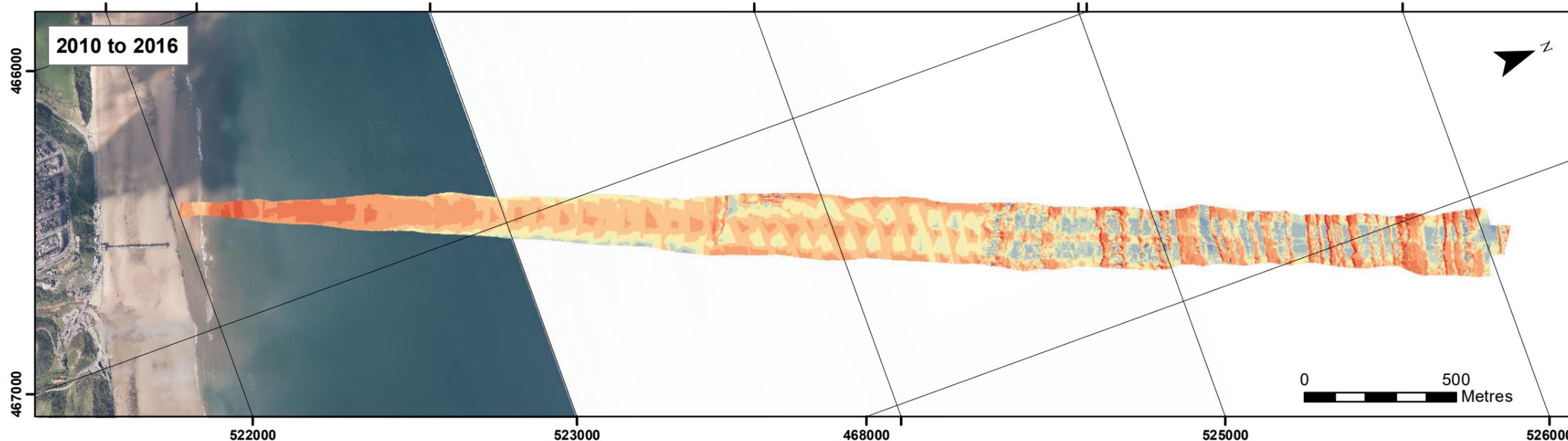
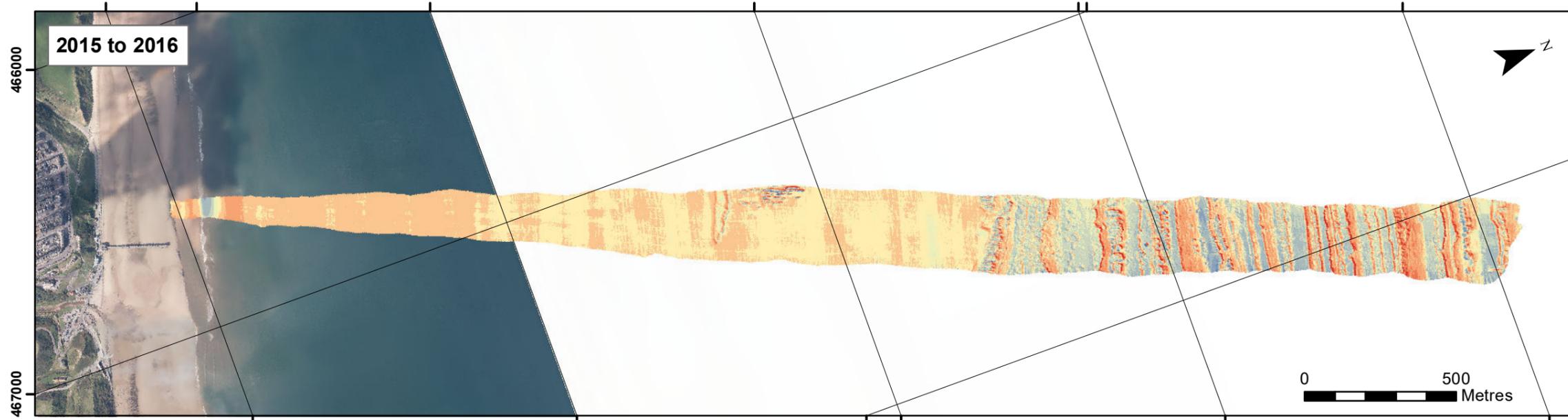
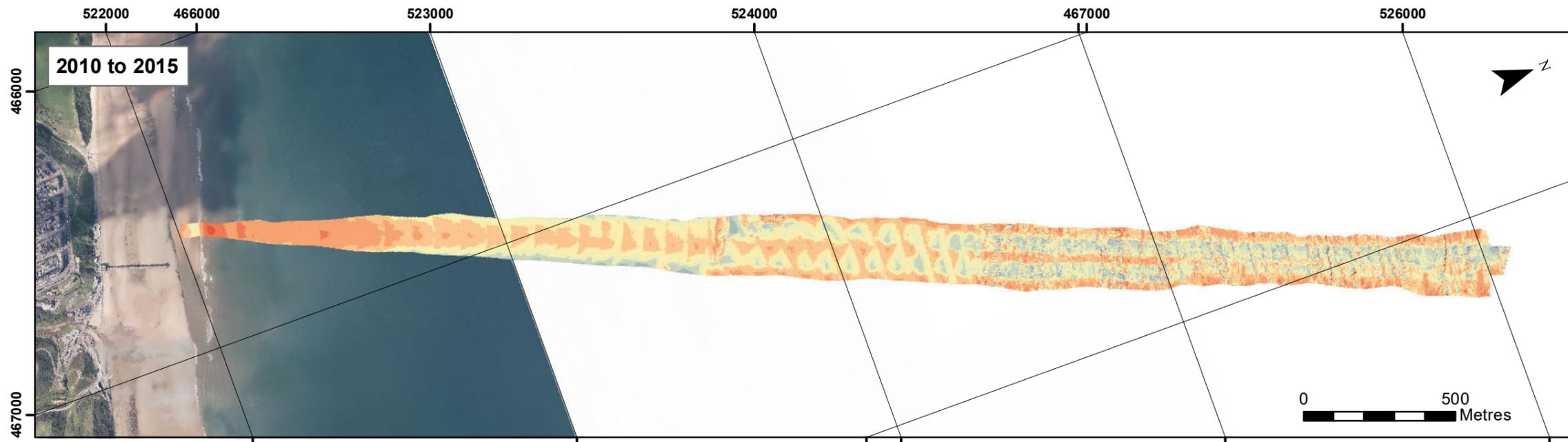
BATHYMETRY SURVEYS

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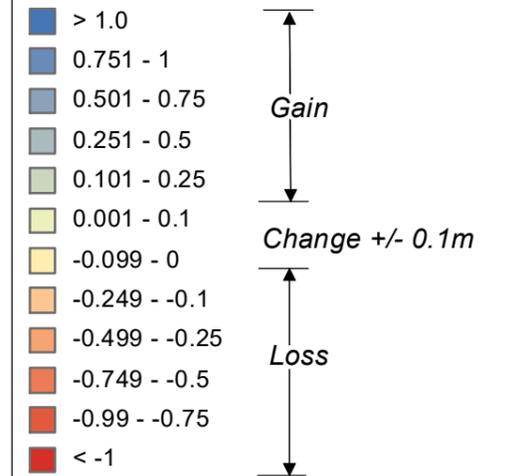
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Legend

Change in depths (mOD) between bathymetric surveys



Client:
North East Coastal Group

Project:
Cell 1 Regional Coastal Monitoring Programme

Figure 6.4b

SALTBURN SANDS

**Redcar and Cleveland
Borough Council Frontage**

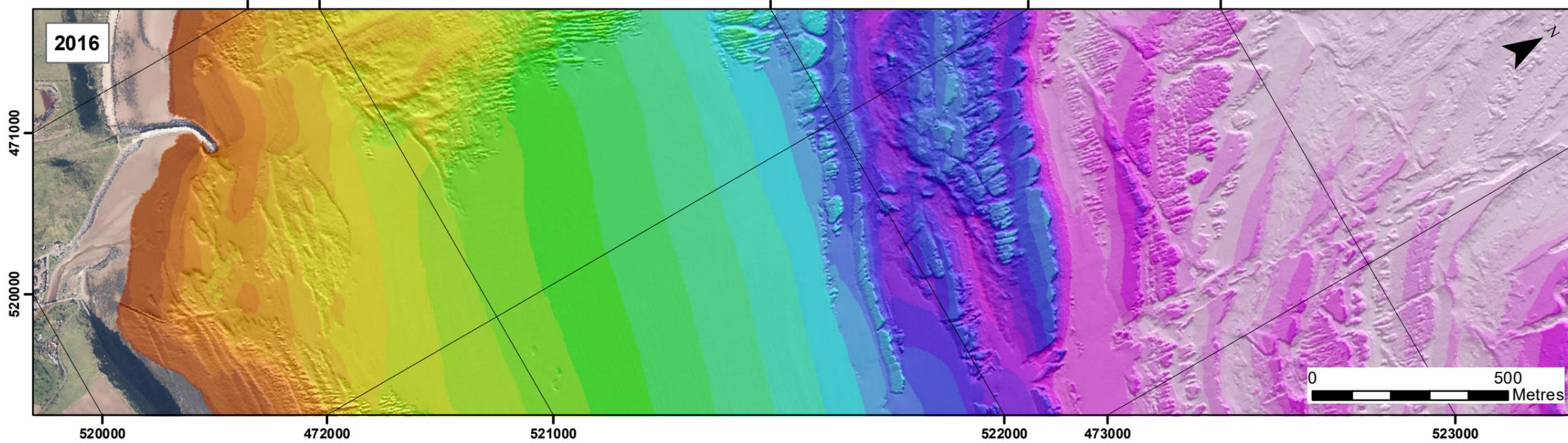
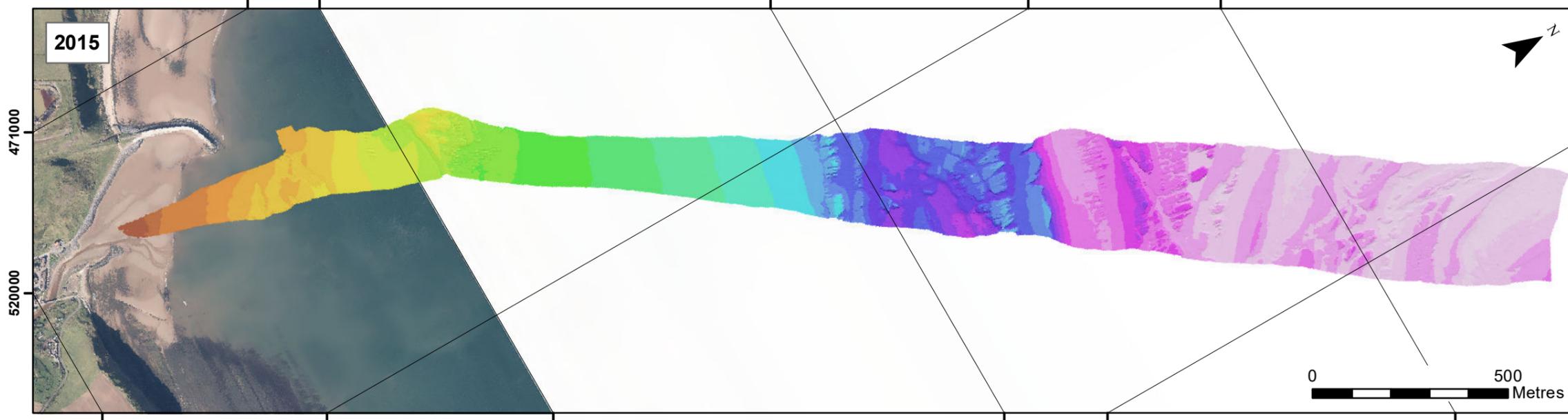
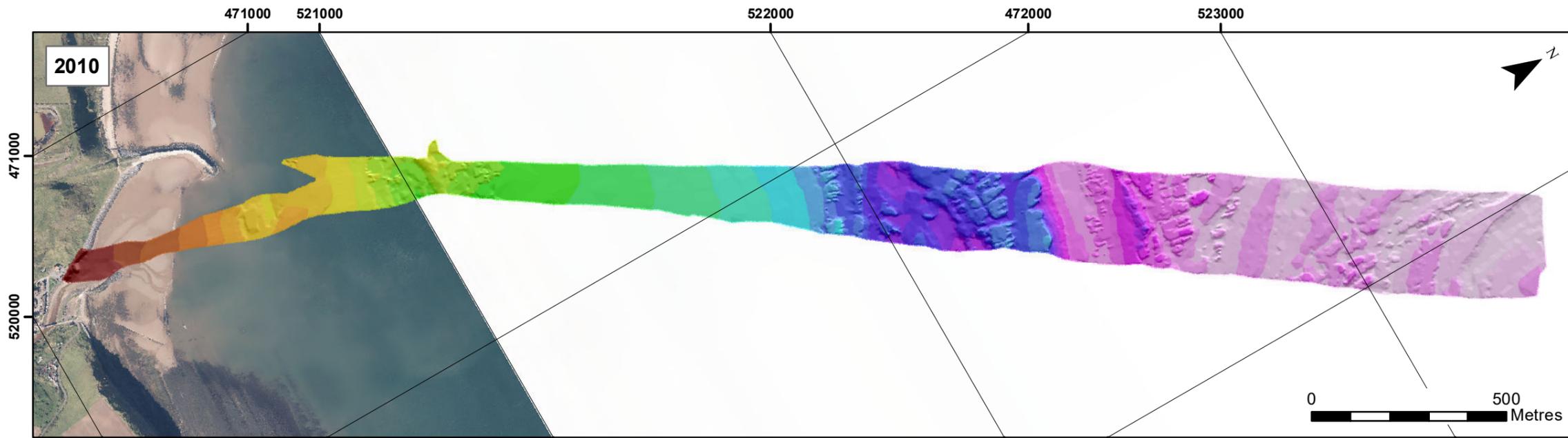
BATHYMETRY ANALYSIS

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Legend

Bathymetry (mOD)

- 0.001 - 5
- 0.99 - 0
- 1.99 - -1
- 2.99 - -2
- 3.99 - -3
- 4.99 - -4
- 5.99 - -5
- 6.99 - -6
- 7.99 - -7
- 8.99 - -8
- 9.9 - -9
- 10.9 - -10
- 11.9 - -11
- 12.9 - -12
- 13.9 - -13
- 14.9 - -14
- 15.9 - -15
- 16.9 - -16
- 17.9 - -17
- 18.9 - -18
- 19.9 - -19
- 20.9 - -20
- 21.9 - -21
- 22.9 - -22
- 23.9 - -23
- 24.9 - -24
- 25.3 - -25

Client:
North East Coastal Group

Project:
Cell 1 Regional Coastal Monitoring Programme

Figure 6.5a

SKINNINGROVE

**Redcar and Cleveland
Borough Council Frontage**

BATHYMETRY SURVEYS

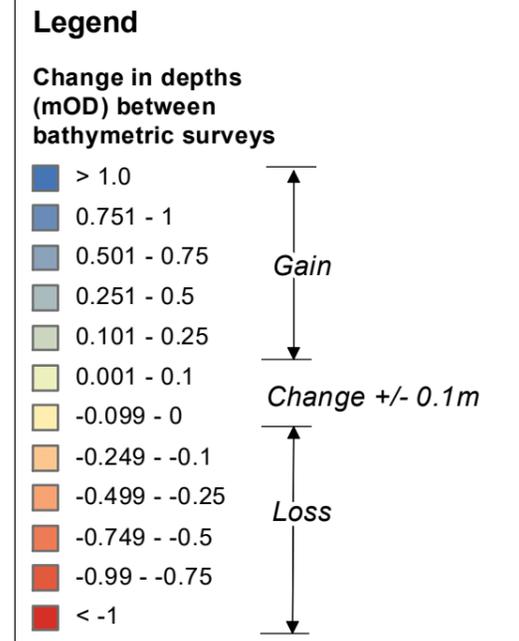
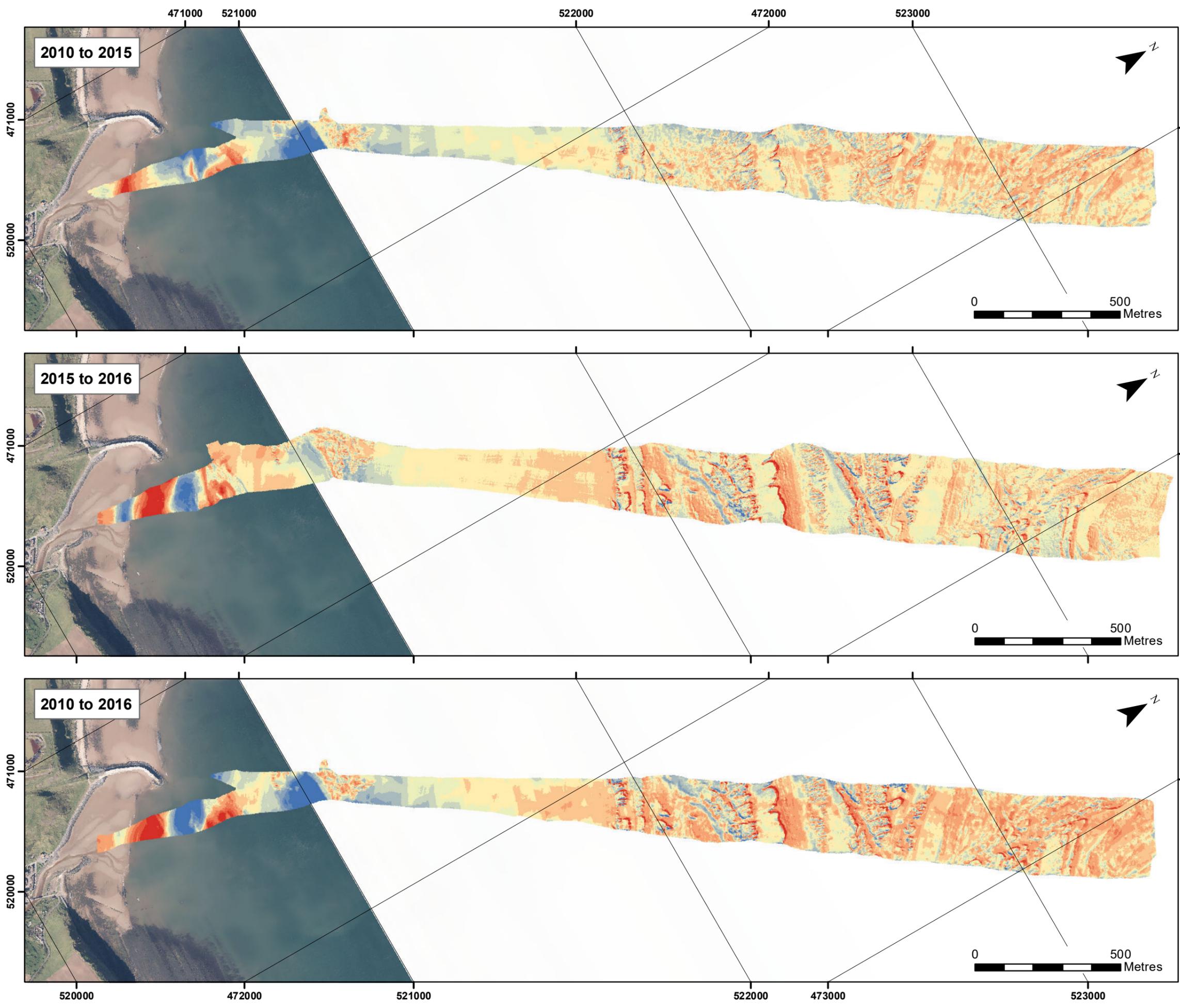
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Client:
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Project:
Cell 1 Regional Coastal Monitoring Programme

Figure 6.5b

SKINNINGROVE

Redcar and Cleveland Borough Council Frontage

BATHYMETRY ANALYSIS

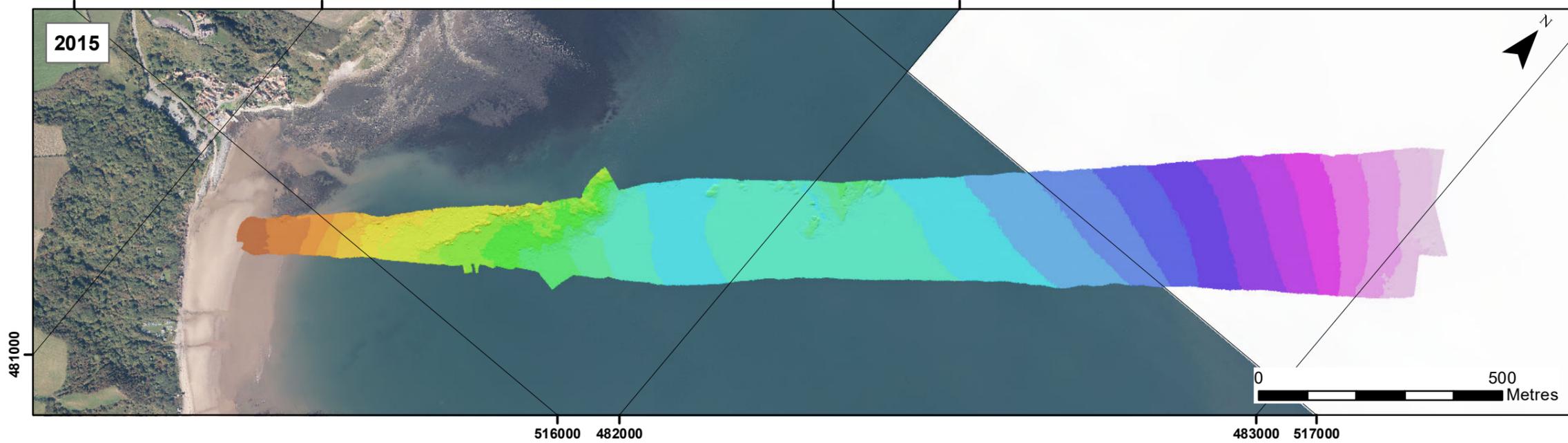
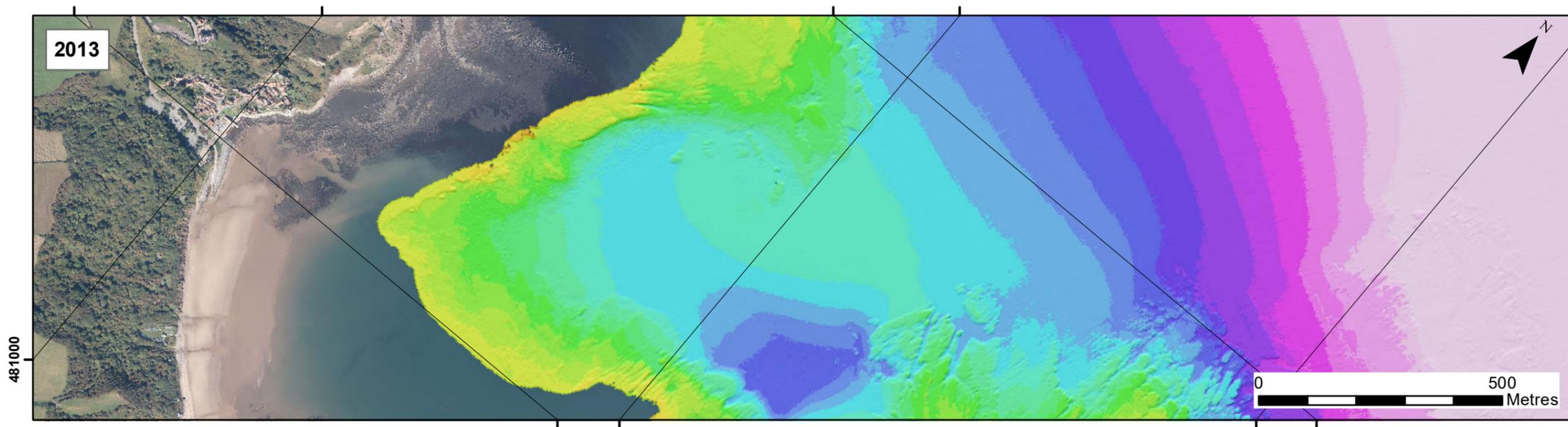
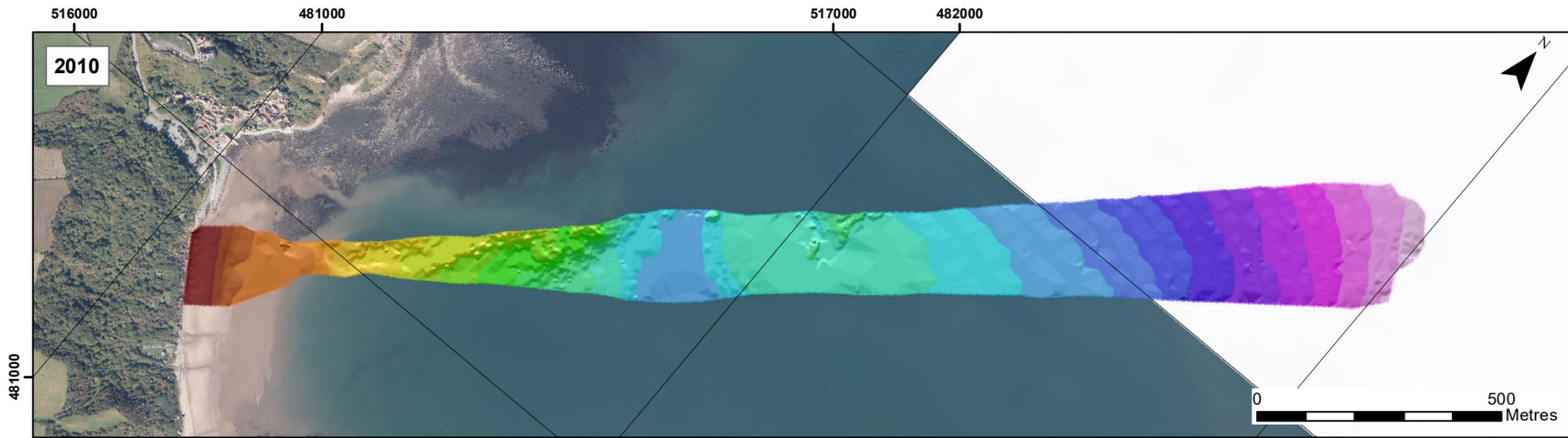
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Legend

Bathymetry (mOD)

0.001 - 5
-0.99 - 0
-1.99 - -1
-2.99 - -2
-3.99 - -3
-4.99 - -4
-5.99 - -5
-6.99 - -6
-7.99 - -7
-8.99 - -8
-9.9 - -9
-10.9 - -10
-11.9 - -11
-12.9 - -12
-13.9 - -13
-14.9 - -14
-15.9 - -15
-16.9 - -16
-17.9 - -17
-18.9 - -18
-19.9 - -19
-20.9 - -20
-21.9 - -21
-22.9 - -22
-23.9 - -23
-24.9 - -24
-25.3 - -25

Client:
North East Coastal Group

Project:
Cell 1 Regional Coastal Monitoring Programme

Figure 6.6a

RUNSWICK BAY

Scarborough Borough Council Frontage

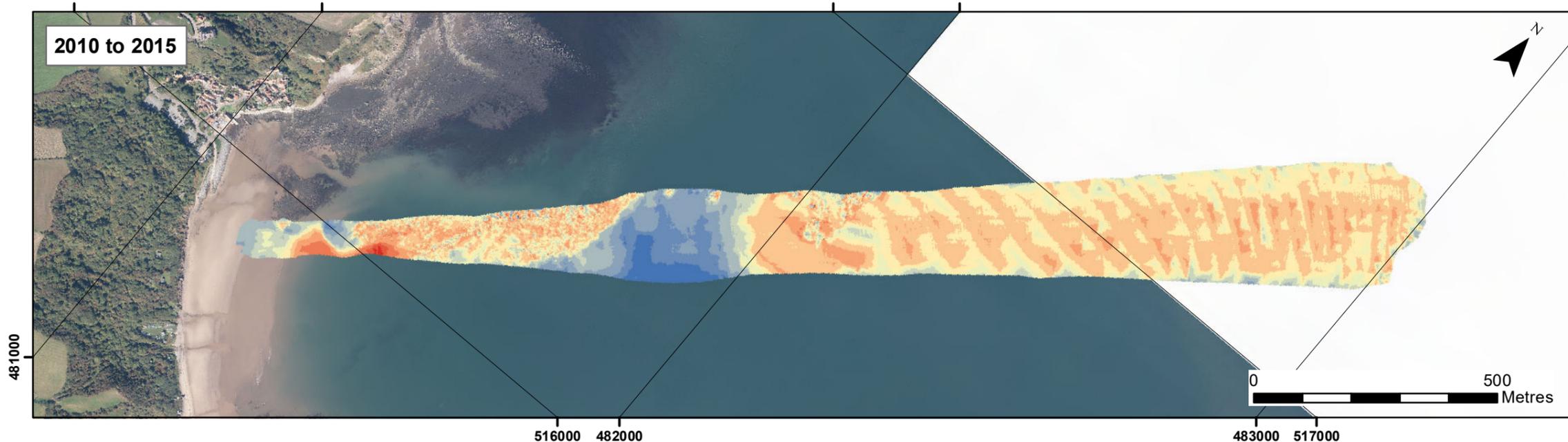
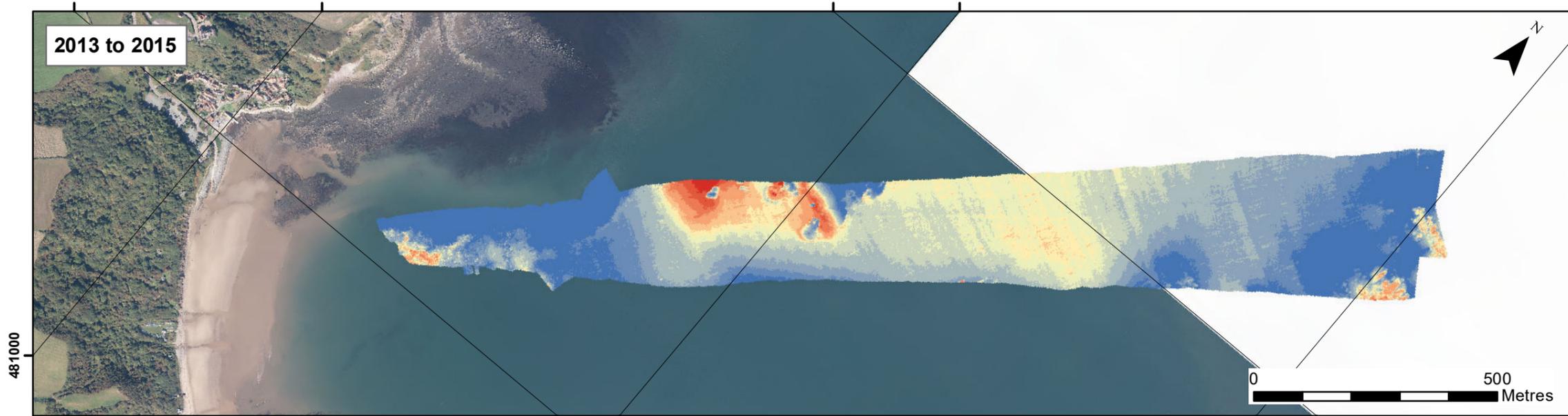
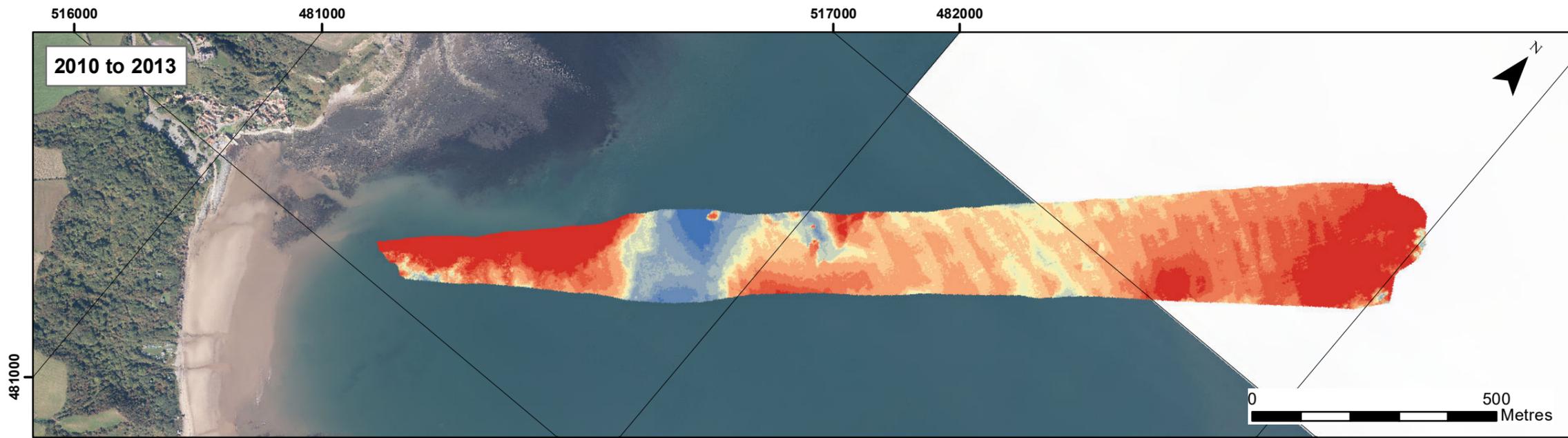
BATHYMETRY SURVEYS

Photography courtesy of the North East Coastal Observatory.
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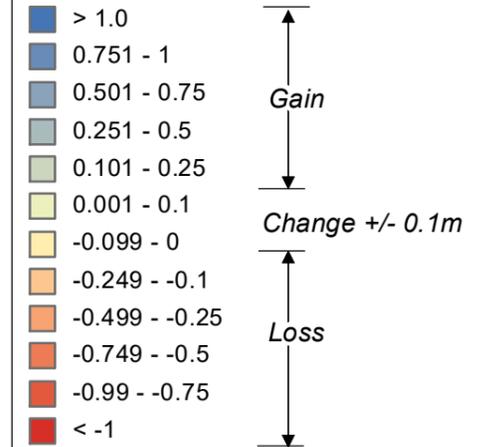
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Legend

Change in depths (mOD) between bathymetric surveys



Client:
North East Coastal Group

Project:
Cell 1 Regional Coastal Monitoring Programme

Figure 6.6b

RUNSWICK BAY

**Scarborough Borough
Council Frontage**

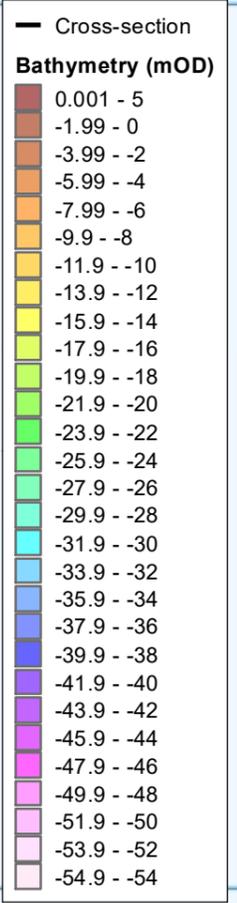
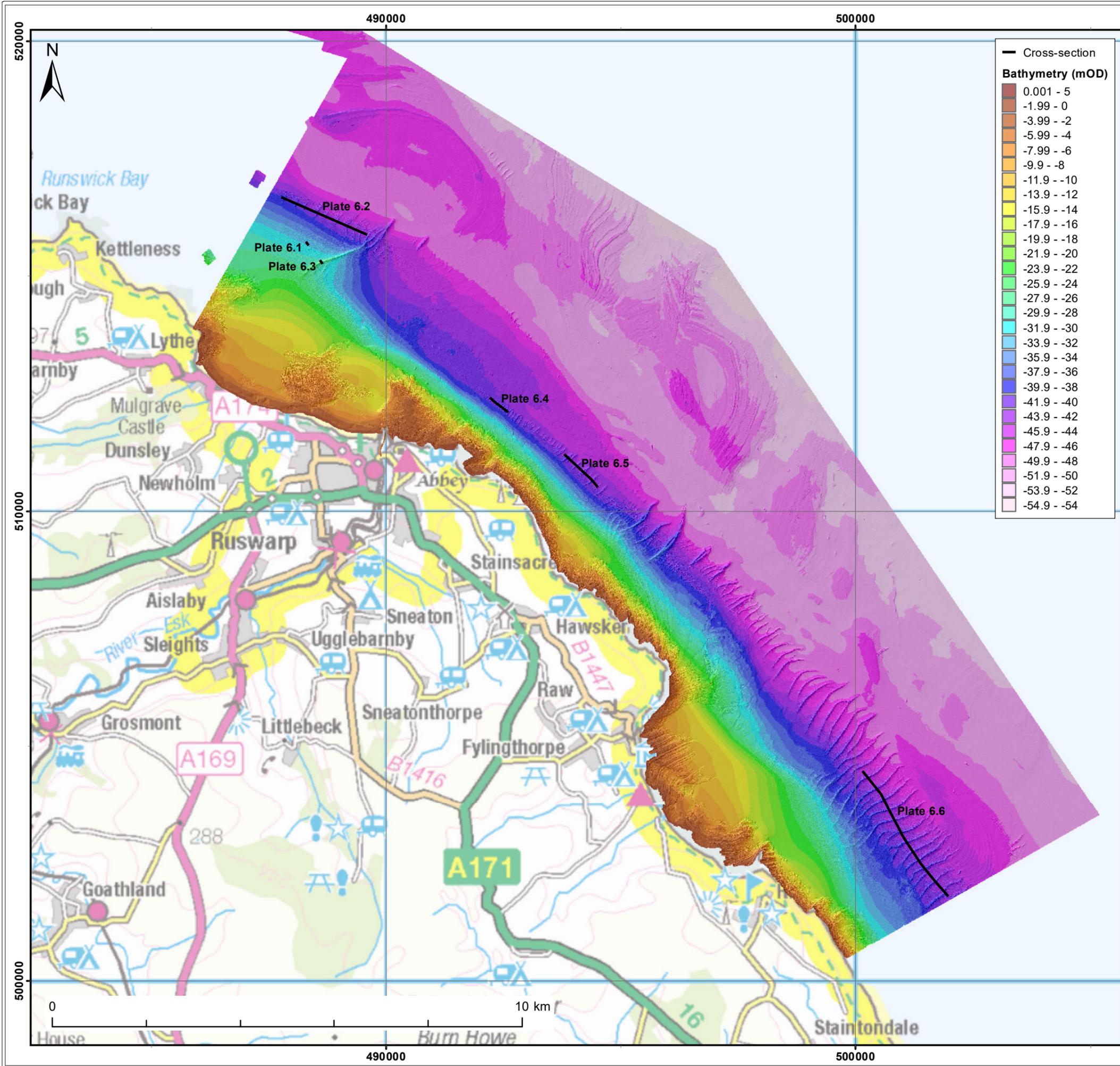
BATHYMETRY ANALYSIS

Photography courtesy of the North East Coastal Observatory.
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Client:	Project:
North East Coastal Group	Cell 1 Regional Coastal Monitoring Programme

Title:
General overview of bathymetry between Runswick Bay and Robin Hood's Bay

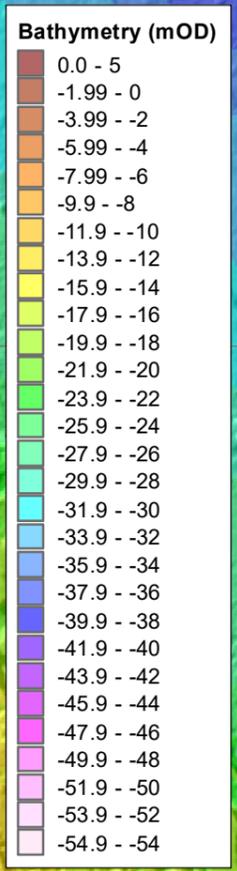
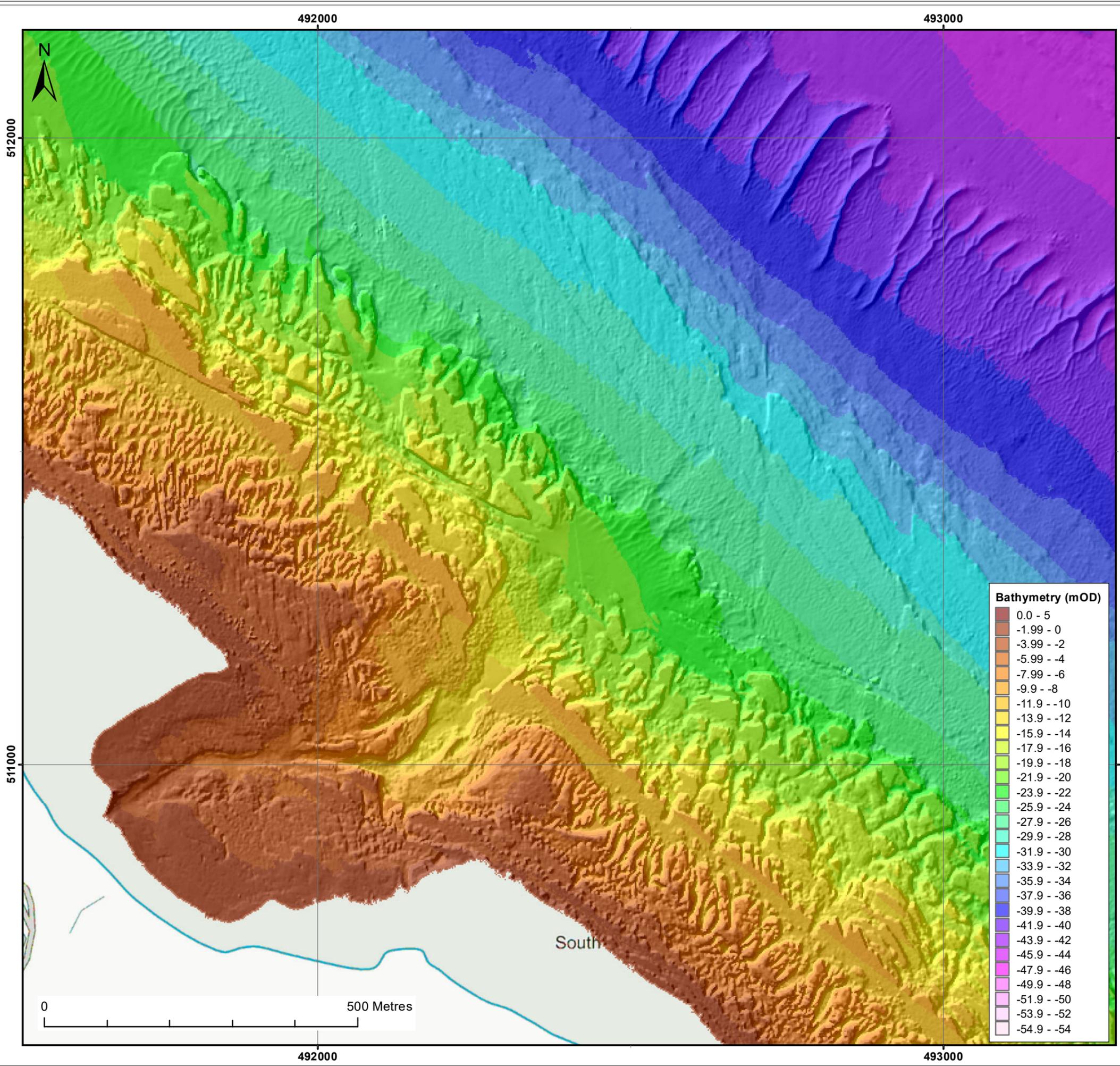
Figure: 7.1

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
0	09/06/2022	TC	DB	A3	1:80,000

Co-ordinate system: British National Grid



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Title:

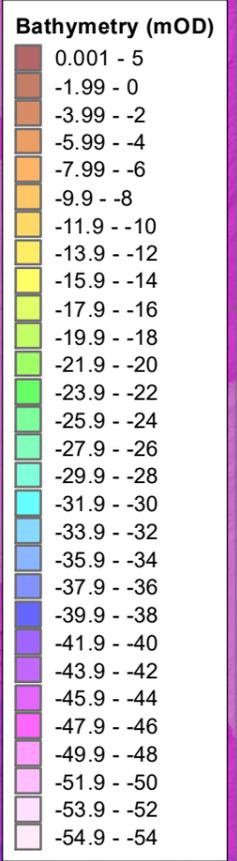
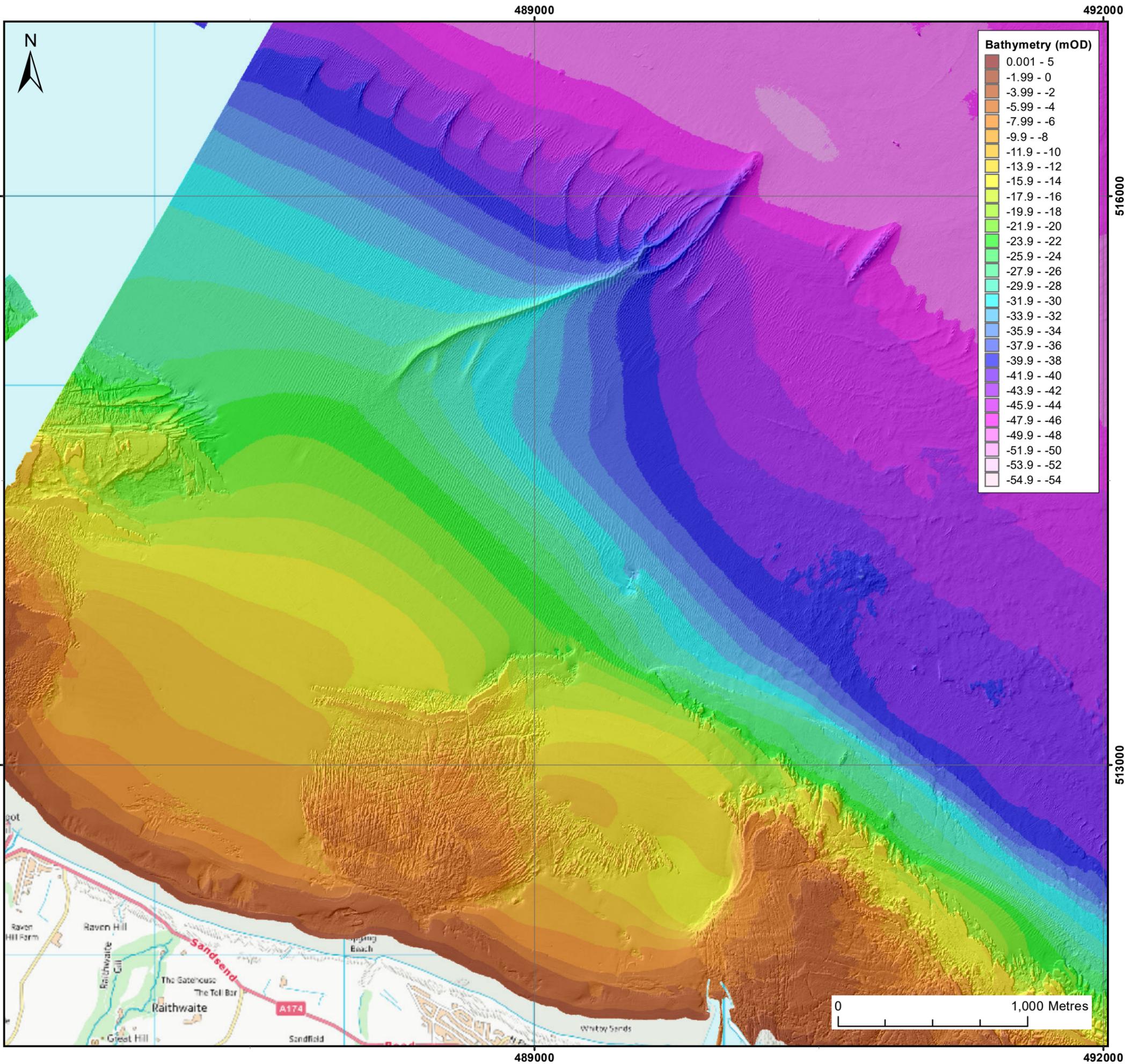
Bathymetry of antecedent river channel at Saltwick Bay

Figure: 7.2

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
0	09/06/2022	TC	DB	A3	1:6,000

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Title: Bathymetry of sand sea bed covered in ripples, sand waves and a sand ridge offshore from Sandsend

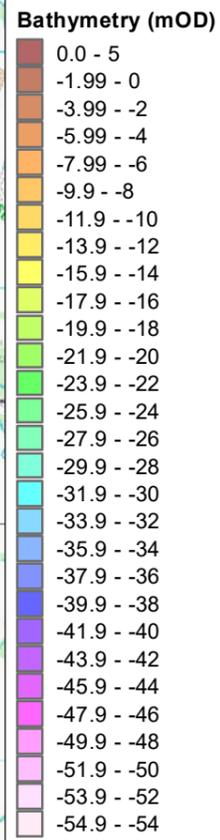
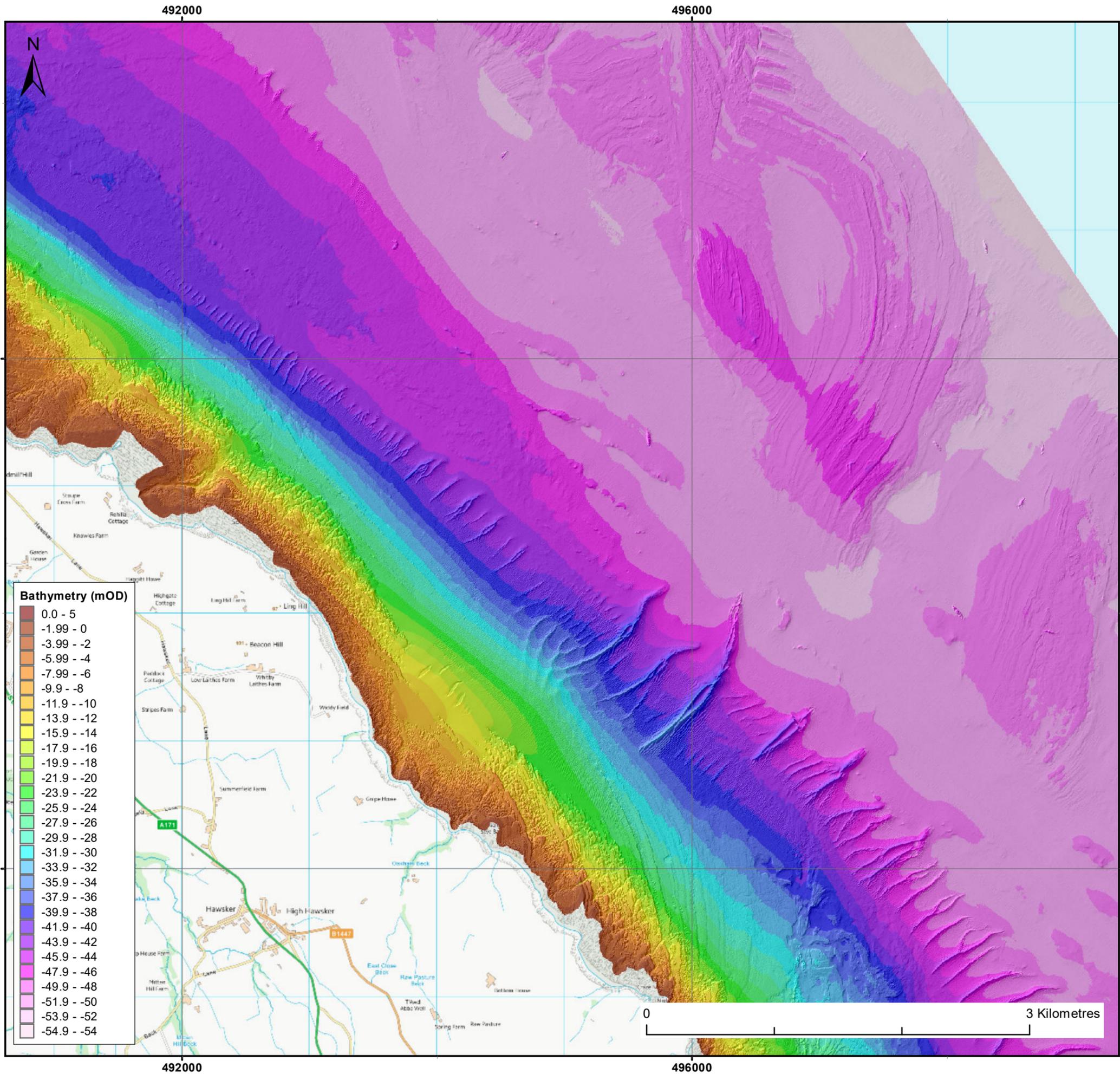
Figure: 7.3

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
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Co-ordinate system: British National Grid



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Title:
Bathymetry of sea bed offshore from Stainsacre

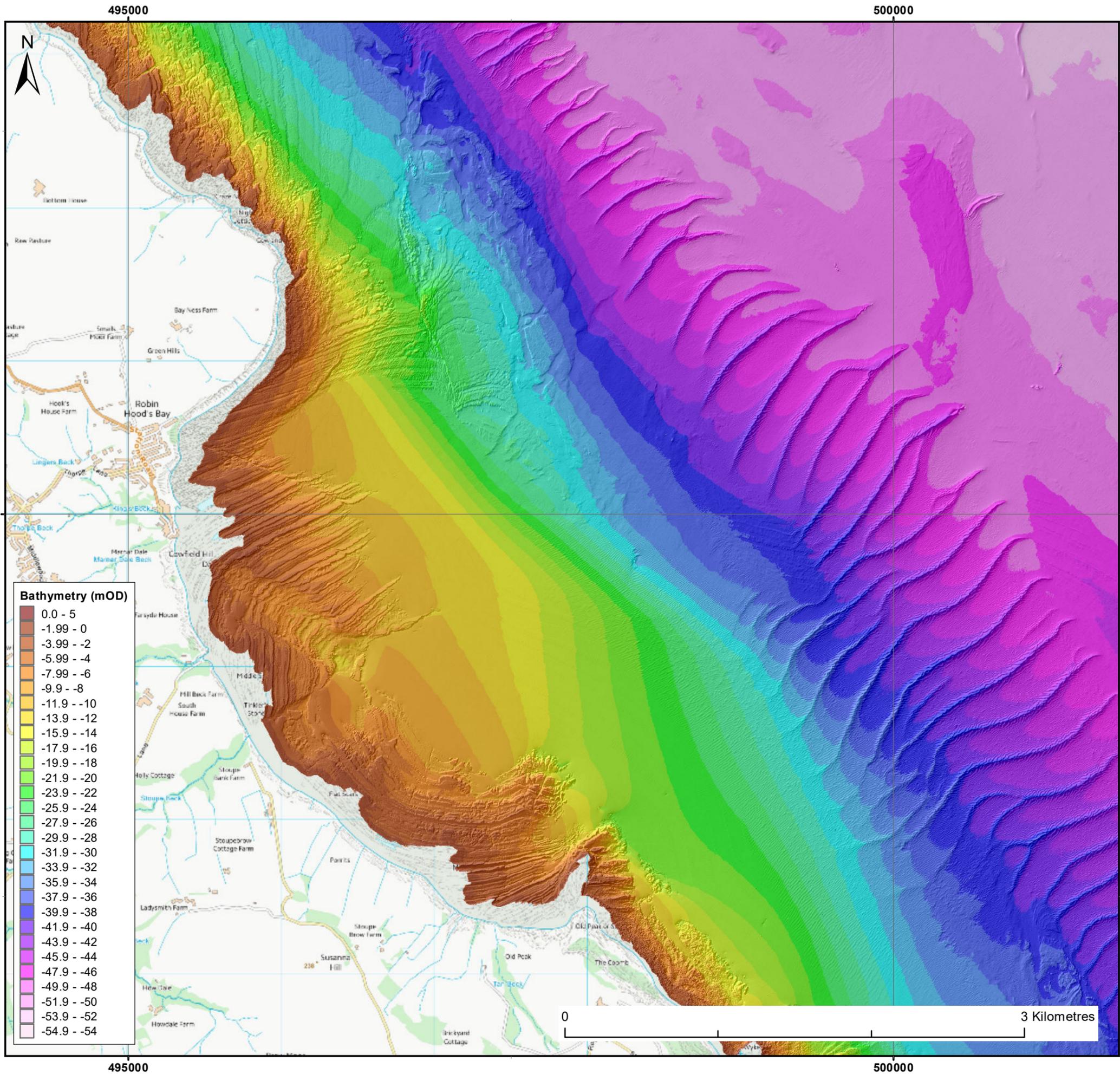
Figure: 7.4

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
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Co-ordinate system: British National Grid



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Title:

Bathymetry of sea bed offshore from Robin Hood's Bay

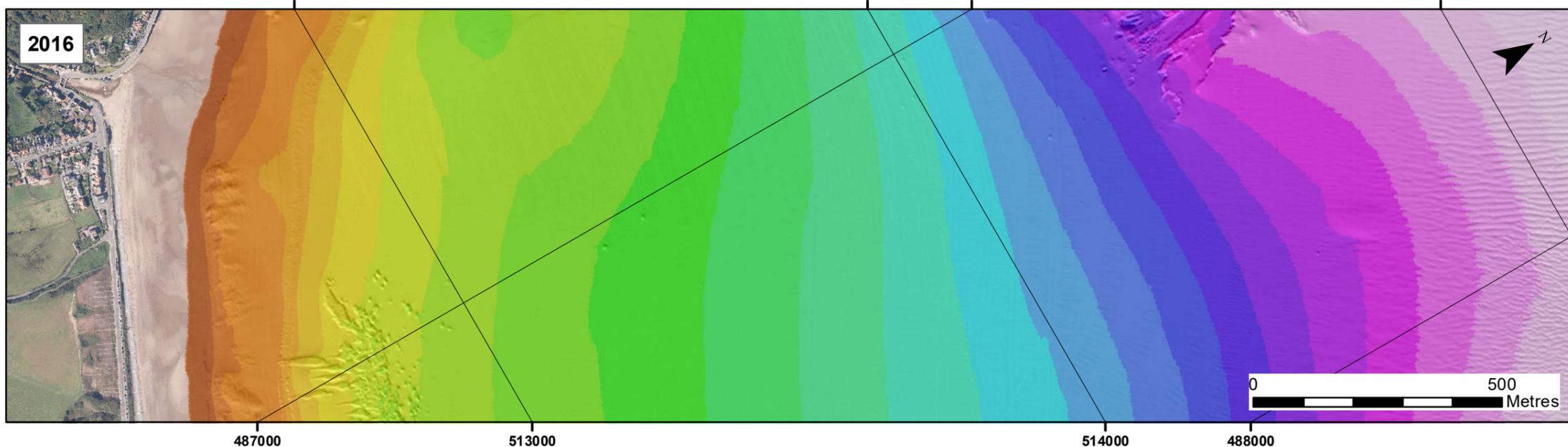
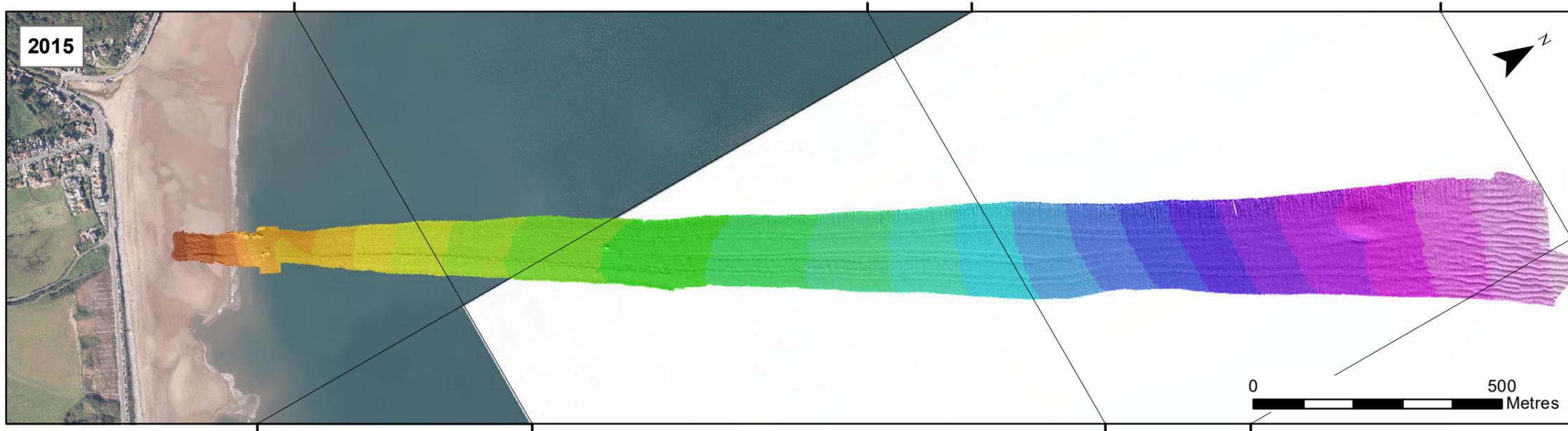
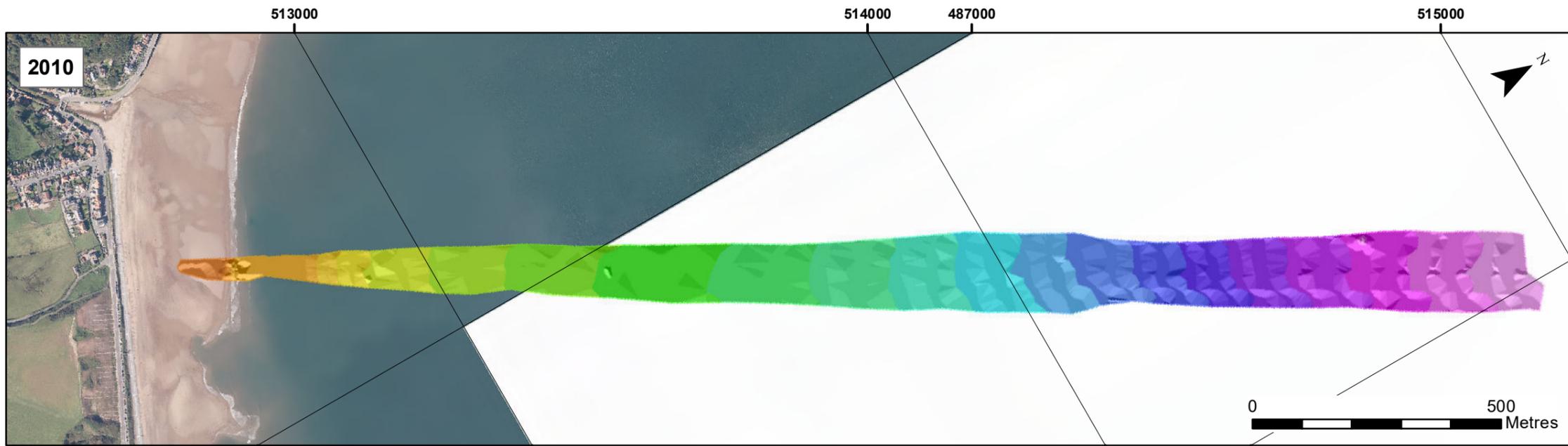
Figure: 7.5

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
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Legend

Bathymetry (mOD)

- 0.001 - 5
- 0.99 - 0
- 1.99 - -1
- 2.99 - -2
- 3.99 - -3
- 4.99 - -4
- 5.99 - -5
- 6.99 - -6
- 7.99 - -7
- 8.99 - -8
- 9.9 - -9
- 10.9 - -10
- 11.9 - -11
- 12.9 - -12
- 13.9 - -13
- 14.9 - -14
- 15.9 - -15
- 16.9 - -16
- 17.9 - -17
- 18.9 - -18
- 19.9 - -19
- 20.9 - -20
- 21.9 - -21
- 22.9 - -22
- 23.9 - -23
- 24.9 - -24
- 25.3 - -25

Client:
North East Coastal Group

Project:
Cell 1 Regional Coastal Monitoring Programme

Figure 7.6a

SANDESEND

**Scarborough Borough
Council Frontage**

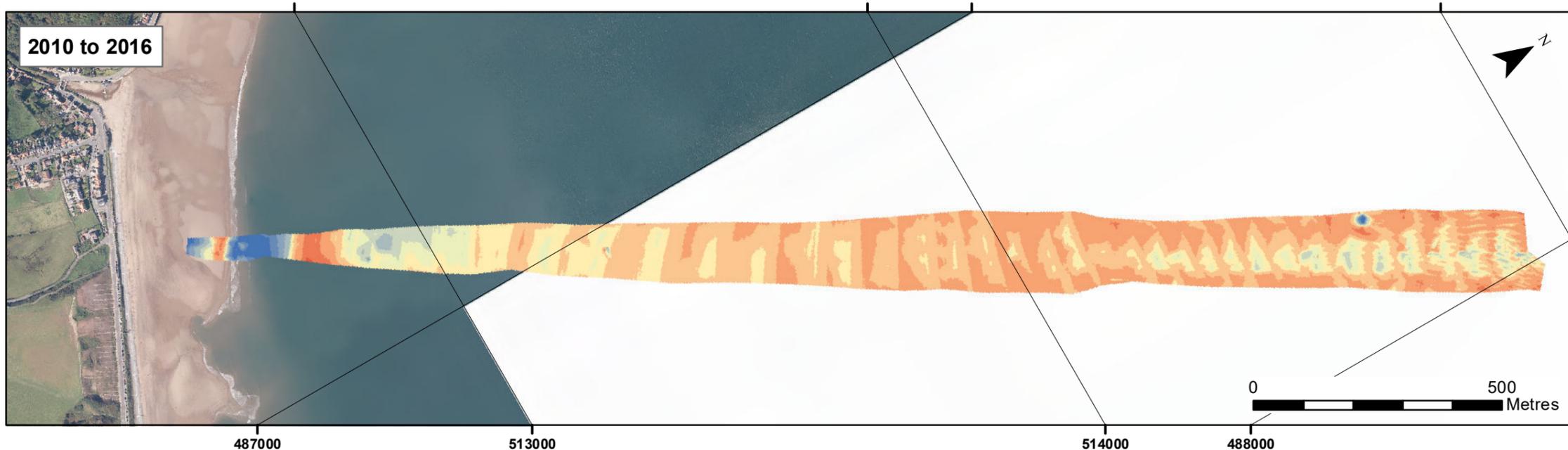
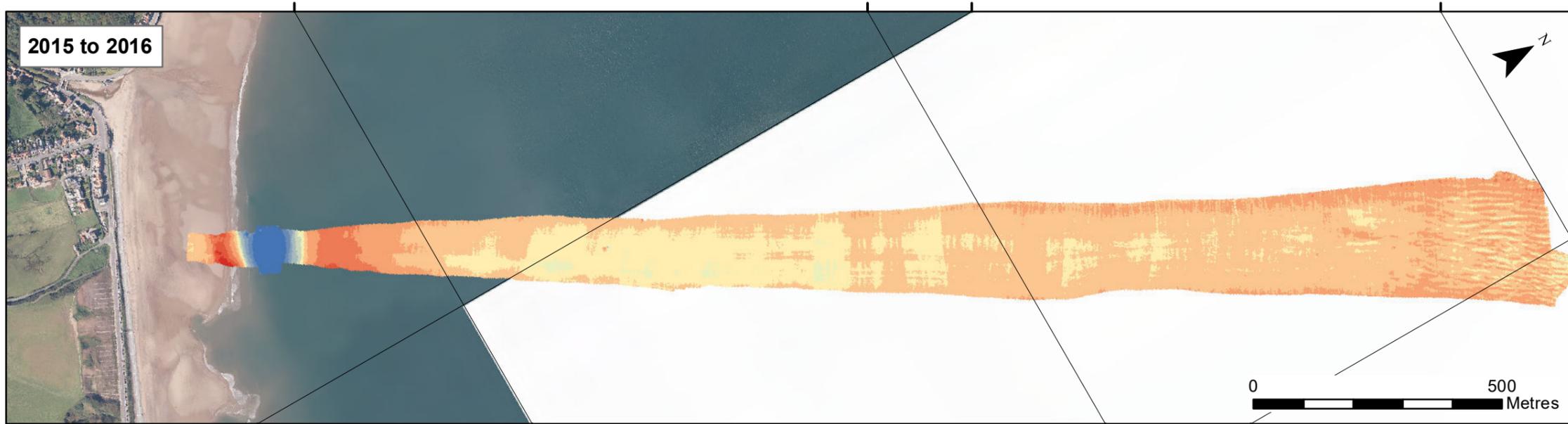
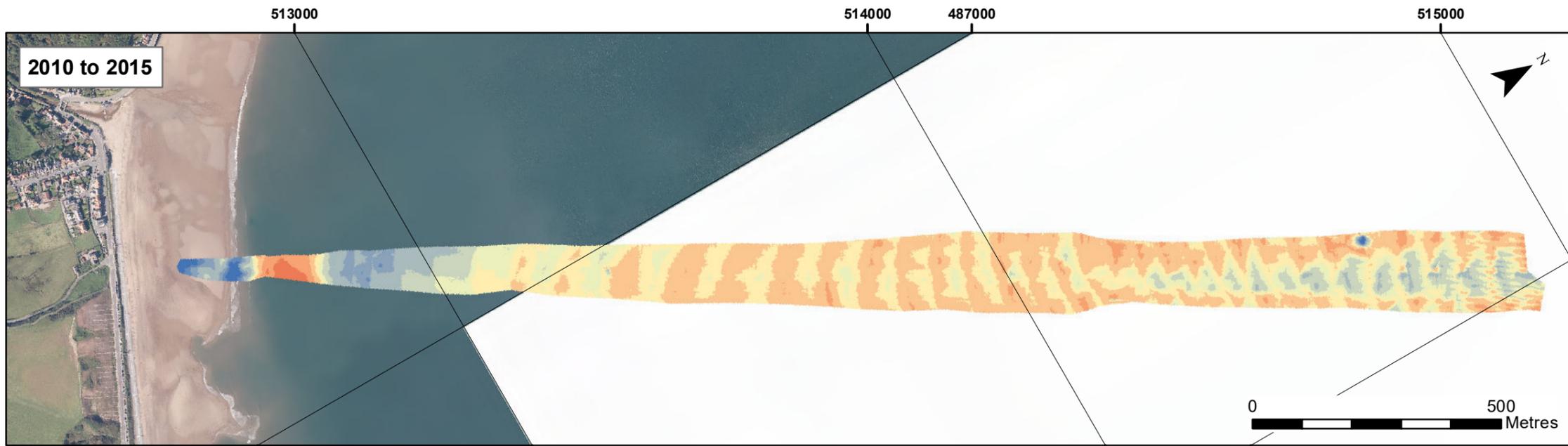
BATHYMETRY ANALYSIS

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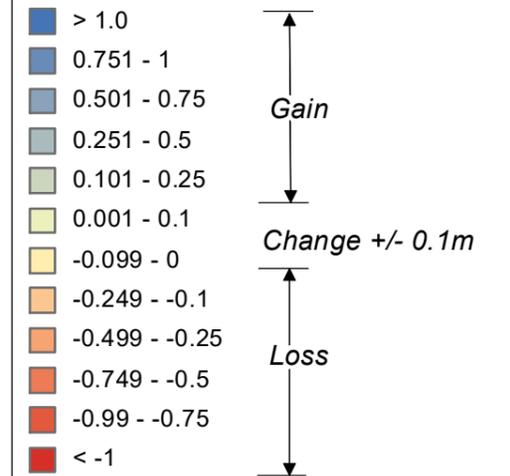
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Legend

Change in depths (mOD) between bathymetric surveys



Client:
North East Coastal Group

Project:
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Figure 7.6b

SANDESEND

**Scarborough Borough
Council Frontage**

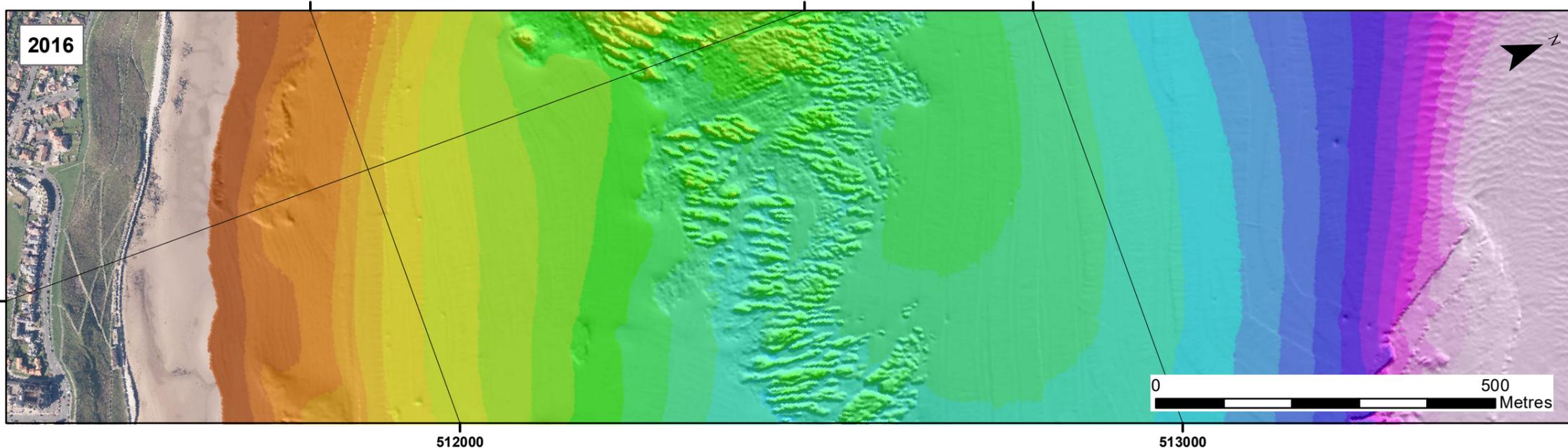
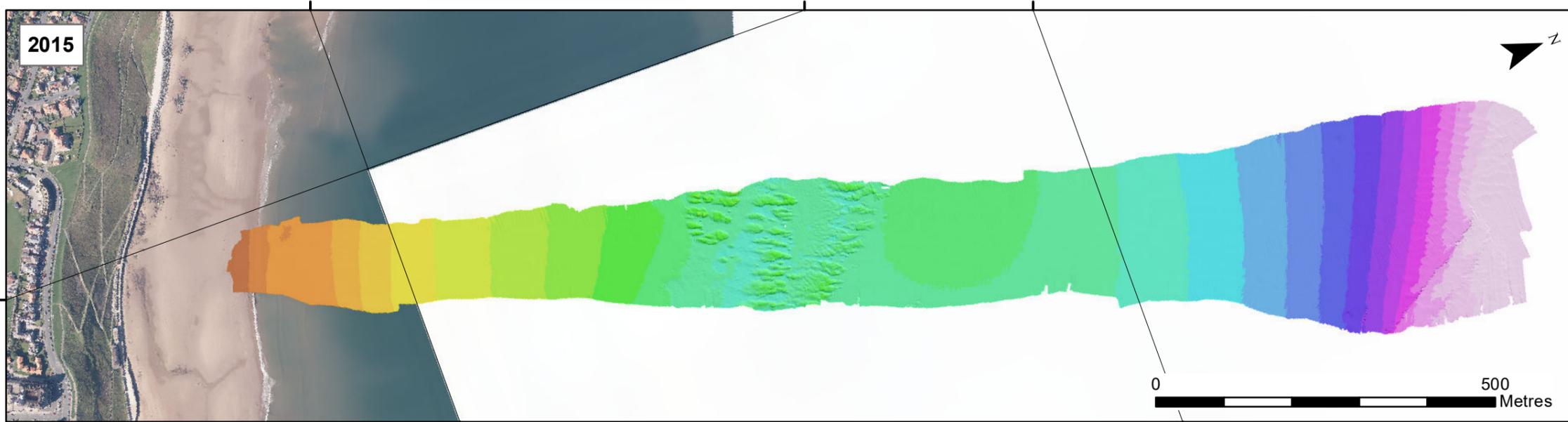
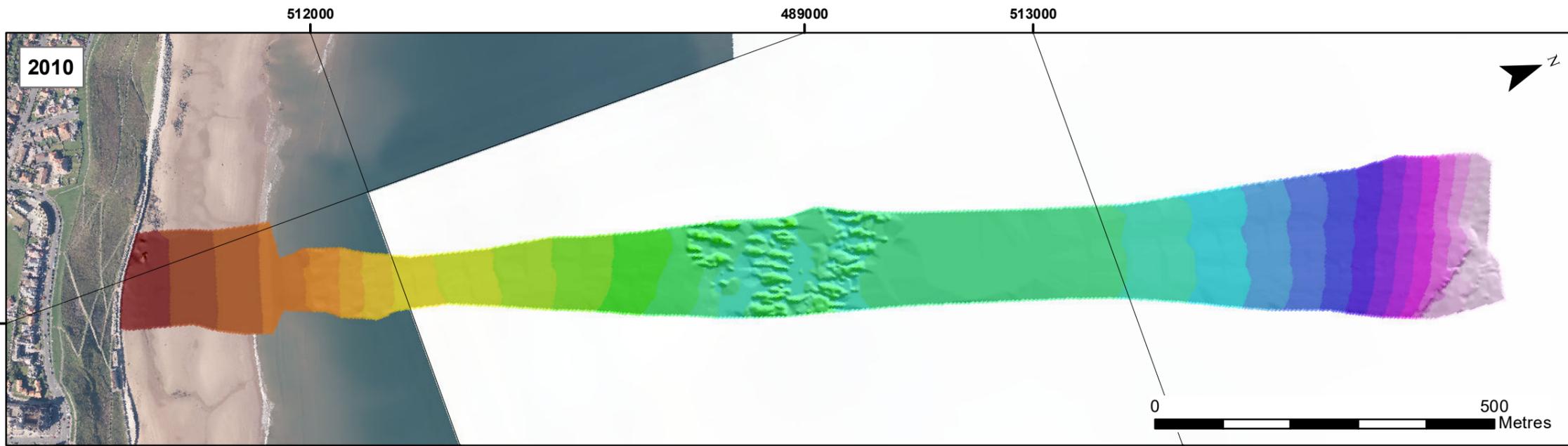
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Legend

Bathymetry (mOD)

- 0.001 - 5
- 0.99 - 0
- 1.99 - -1
- 2.99 - -2
- 3.99 - -3
- 4.99 - -4
- 5.99 - -5
- 6.99 - -6
- 7.99 - -7
- 8.99 - -8
- 9.9 - -9
- 10.9 - -10
- 11.9 - -11
- 12.9 - -12
- 13.9 - -13
- 14.9 - -14
- 15.9 - -15
- 16.9 - -16
- 17.9 - -17
- 18.9 - -18
- 19.9 - -19
- 20.9 - -20
- 21.9 - -21
- 22.9 - -22
- 23.9 - -23
- 24.9 - -24
- 25.3 - -25

Client:
North East Coastal Group

Project:
Cell 1 Regional Coastal Monitoring Programme

Figure 7.7a

WHITBY

**Scarborough Borough
Council Frontage**

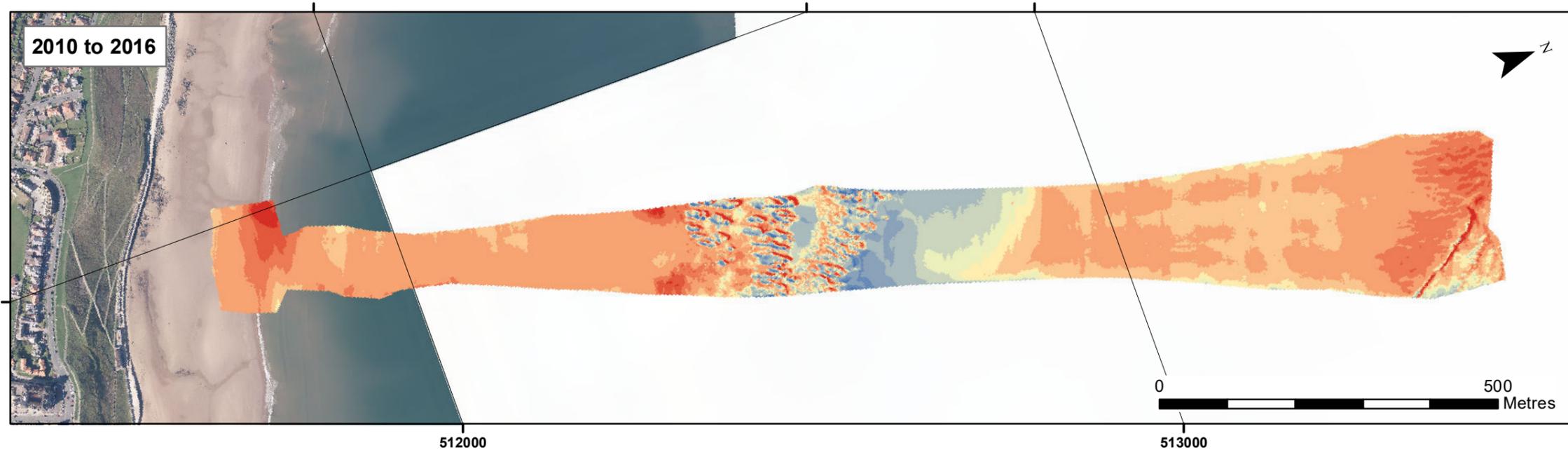
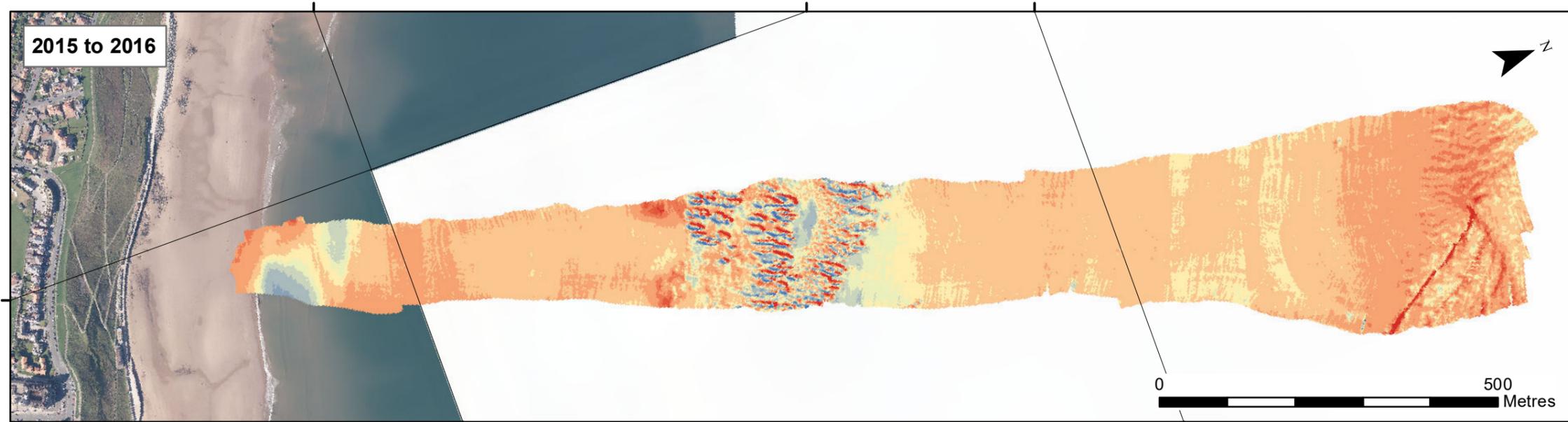
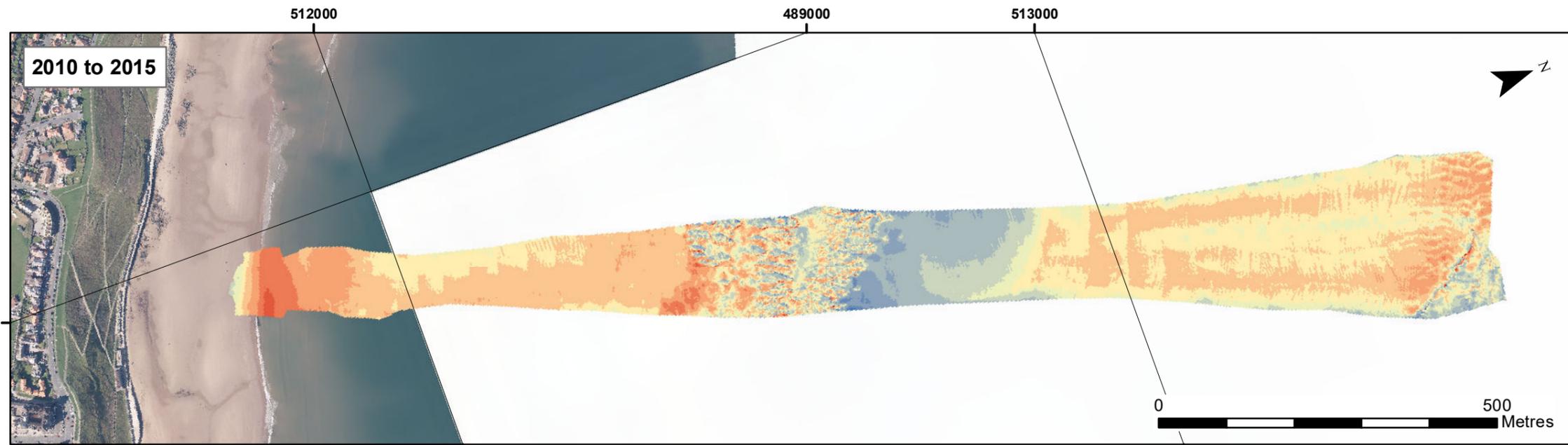
BATHYMETRY SURVEYS

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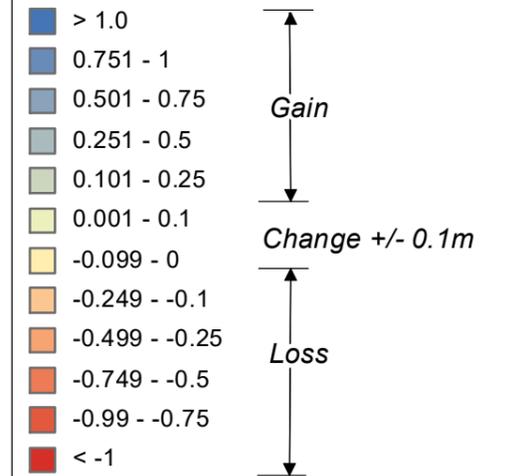
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Legend

Change in depths (mOD) between bathymetric surveys



Client:
North East Coastal Group

Project:
Cell 1 Regional Coastal Monitoring Programme

Figure 7.7b

WHITBY

**Scarborough Borough
Council Frontage**

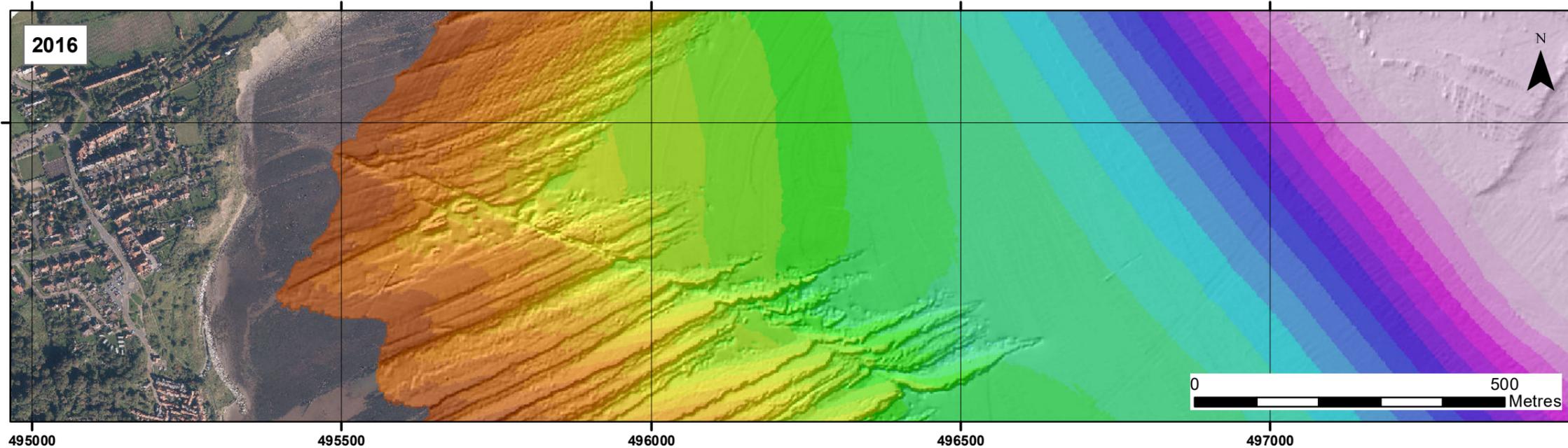
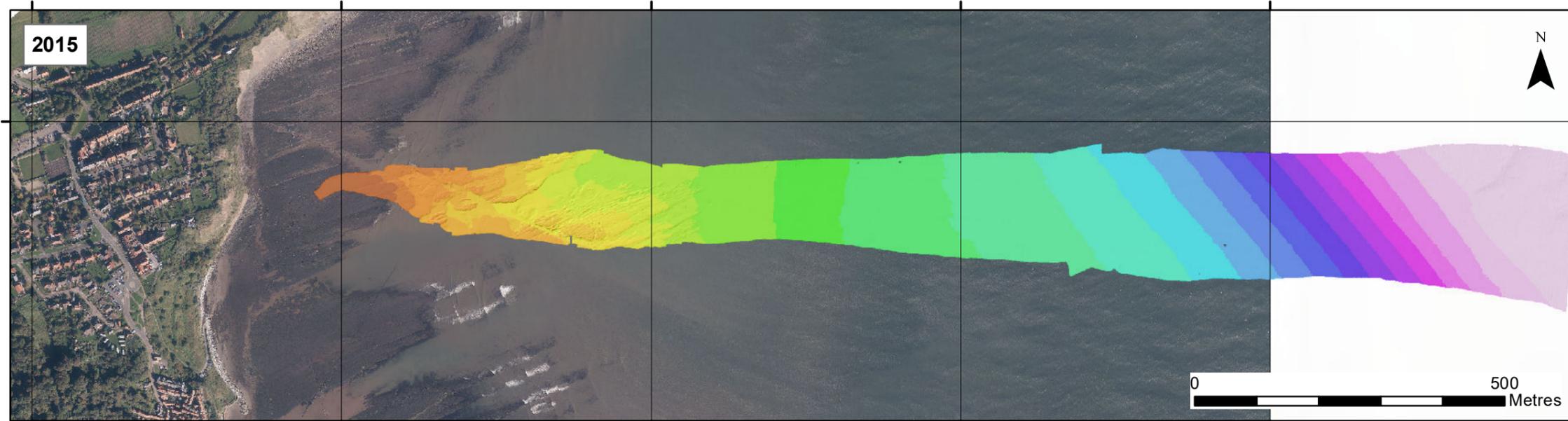
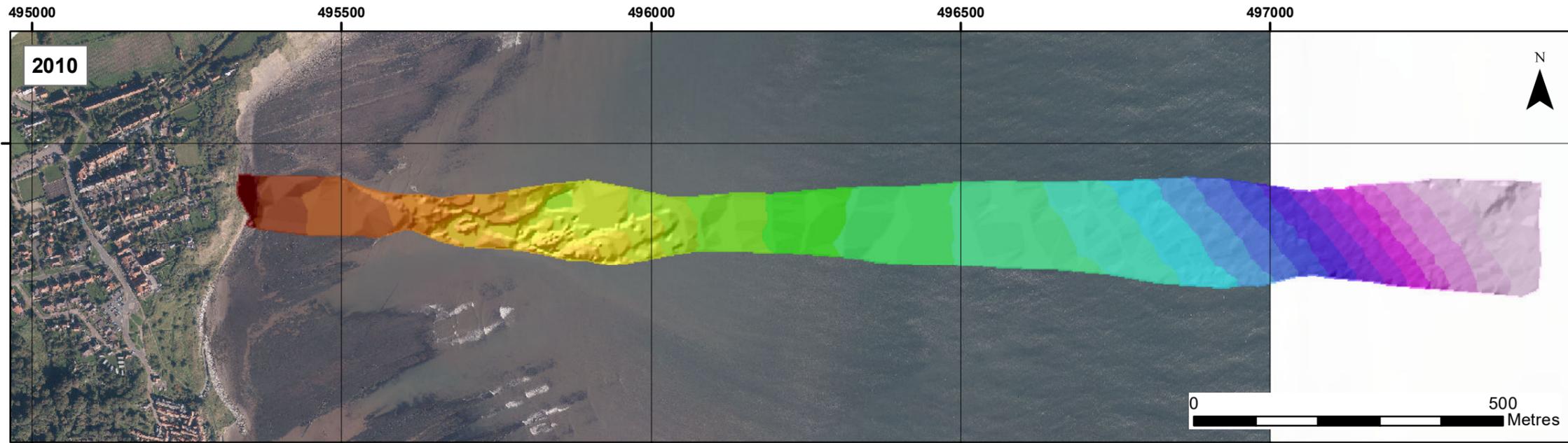
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Legend

Bathymetry (mOD)

- 0.001 - 5
- 0.99 - 0
- 1.99 - -1
- 2.99 - -2
- 3.99 - -3
- 4.99 - -4
- 5.99 - -5
- 6.99 - -6
- 7.99 - -7
- 8.99 - -8
- 9.9 - -9
- 10.9 - -10
- 11.9 - -11
- 12.9 - -12
- 13.9 - -13
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- 15.9 - -15
- 16.9 - -16
- 17.9 - -17
- 18.9 - -18
- 19.9 - -19
- 20.9 - -20
- 21.9 - -21
- 22.9 - -22
- 23.9 - -23
- 24.9 - -24
- 25.3 - -25

Client:
North East Coastal Group

Project:
Cell 1 Regional Coastal Monitoring Programme

Figure 7.8a

ROBIN HOOD'S BAY

**Scarborough Borough
Council Frontage**

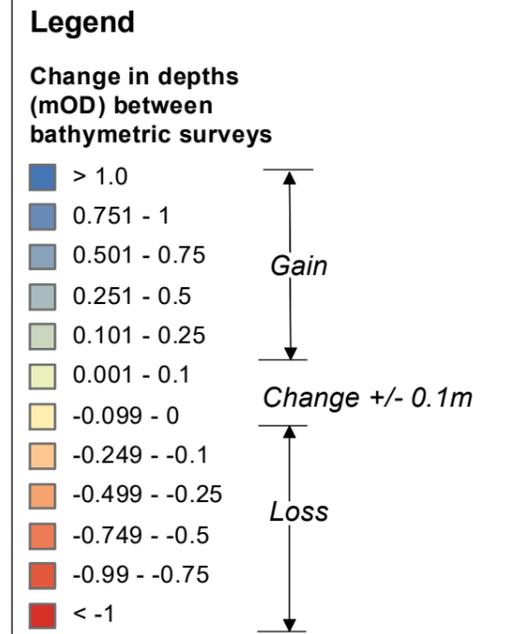
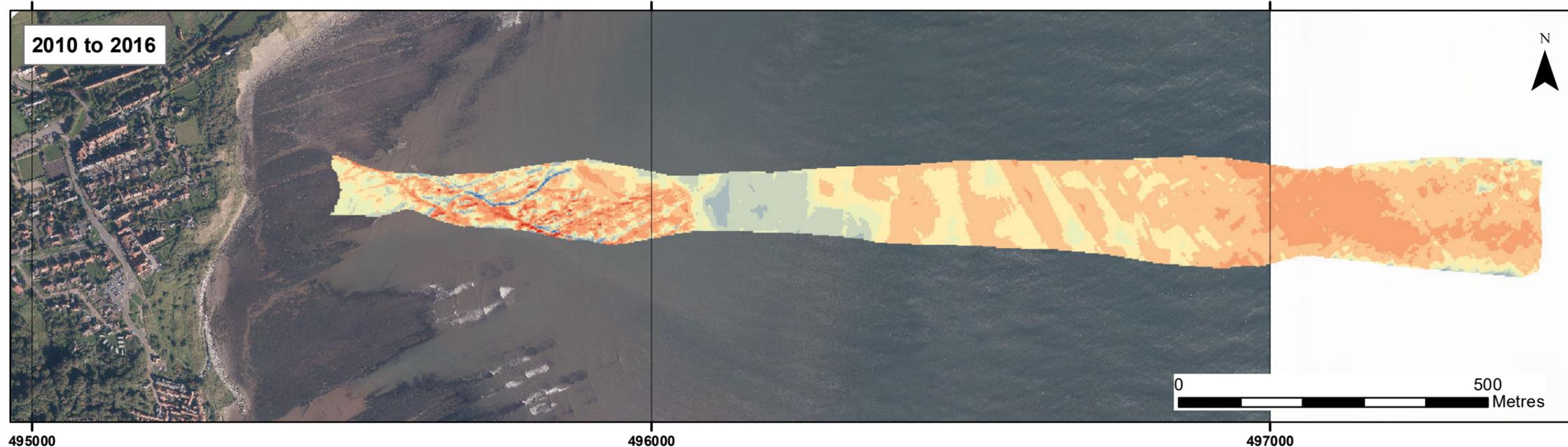
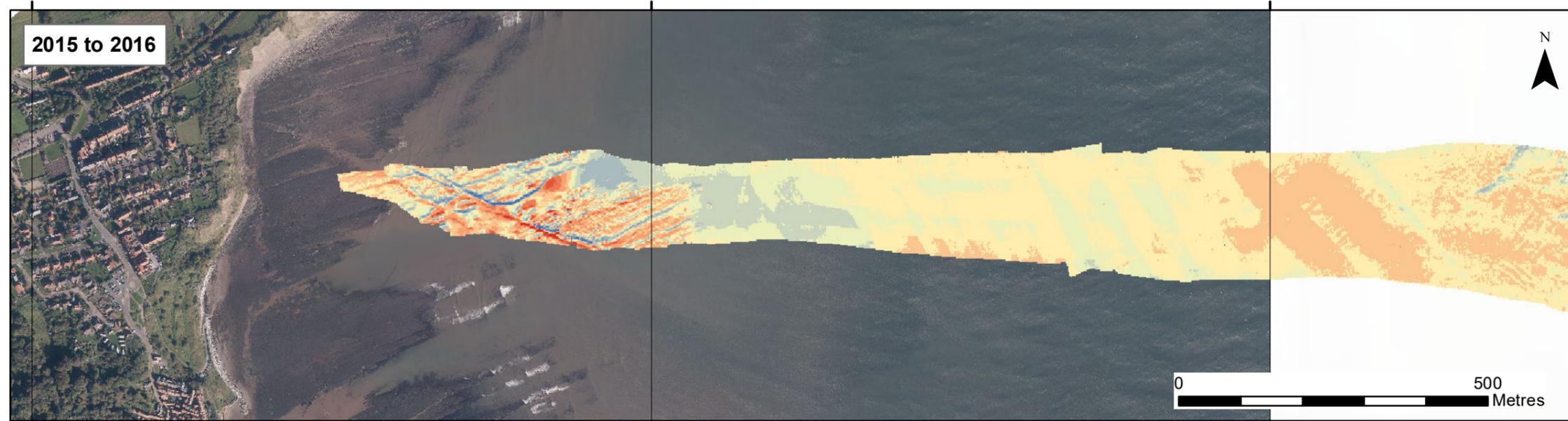
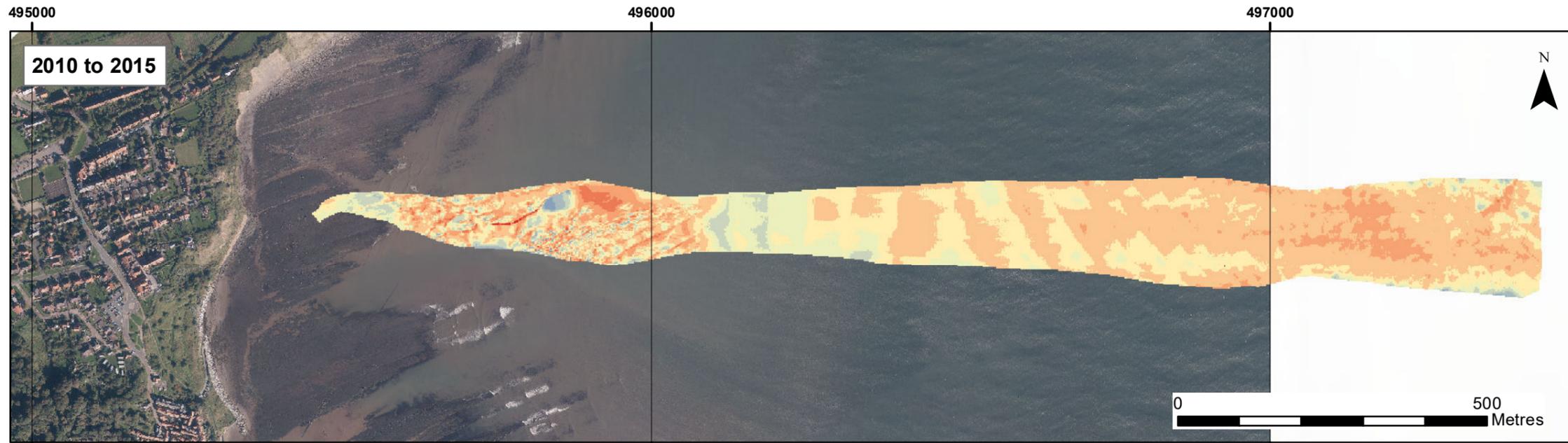
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Client:
North East Coastal Group

Project:
Cell 1 Regional Coastal Monitoring Programme

Figure 7.8b

ROBIN HOOD'S BAY

Scarborough Borough Council Frontage

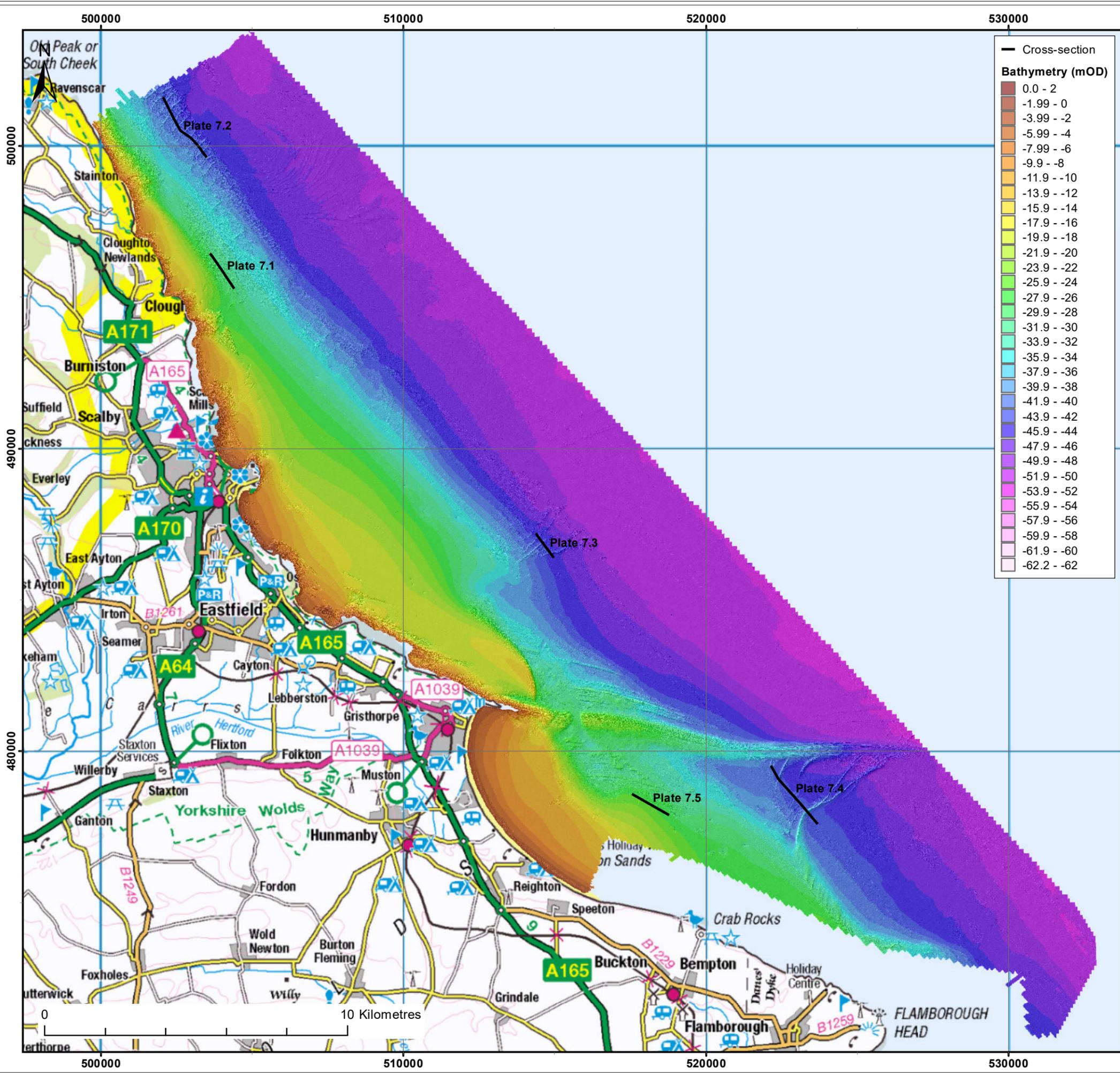
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Client:	Project:
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Title:
General overview of bathymetry between Robin Hood's Bay and Flamborough Head

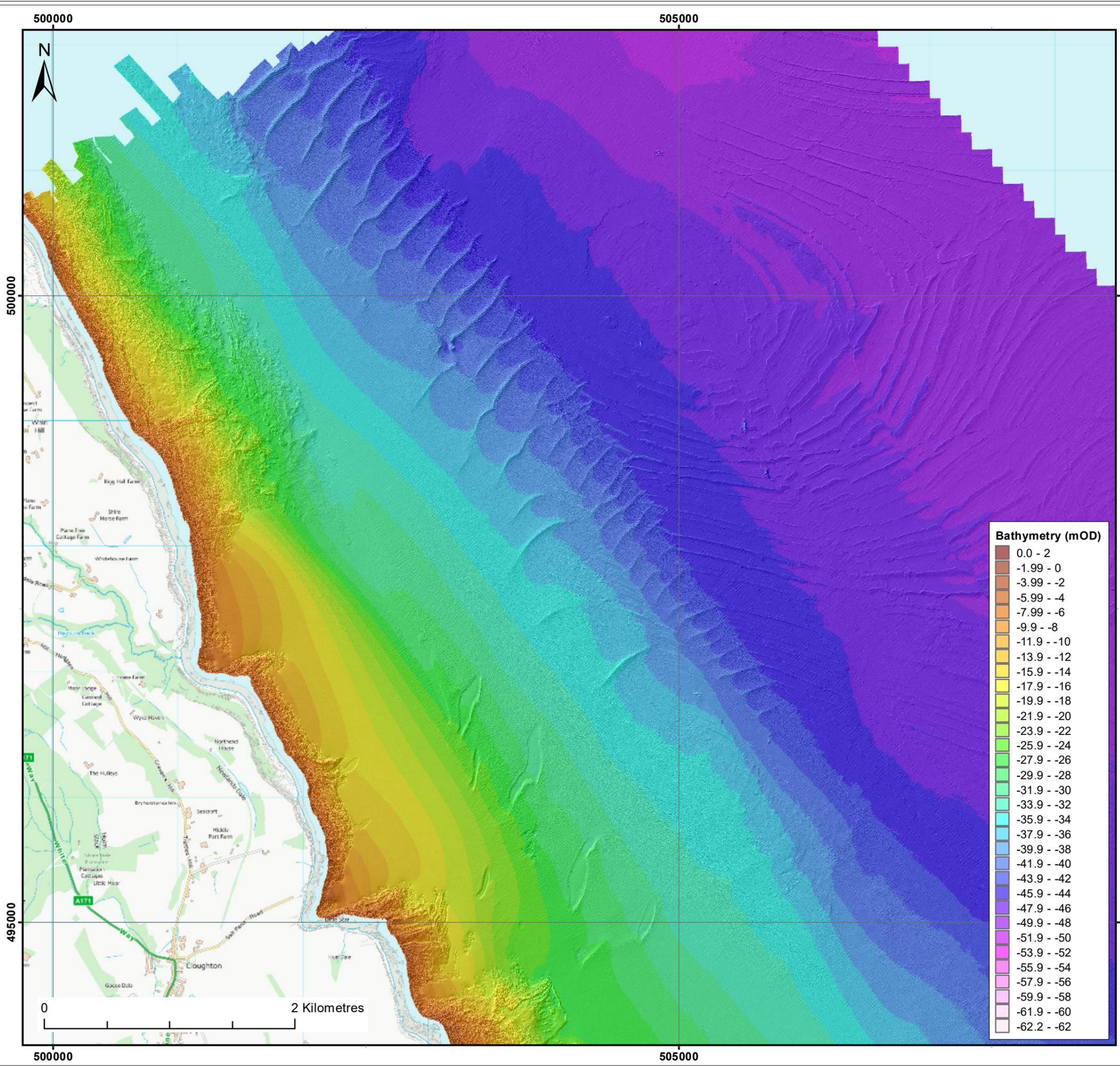
Figure: 8.1

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
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Enhancing Society Together



Bathymetry (mOD)

0.0 - 2
-1.99 - 0
-3.99 - -2
-5.99 - -4
-7.99 - -6
-9.9 - -8
-11.9 - -10
-13.9 - -12
-15.9 - -14
-17.9 - -16
-19.9 - -18
-21.9 - -20
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-53.9 - -52
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-57.9 - -56
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-62.2 - -62



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Title:
Bathymetry of sea bed offshore of Ravenscar to Cloughton

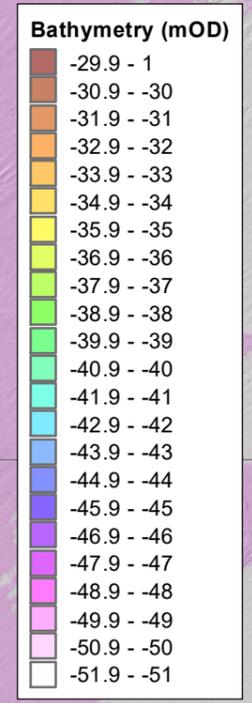
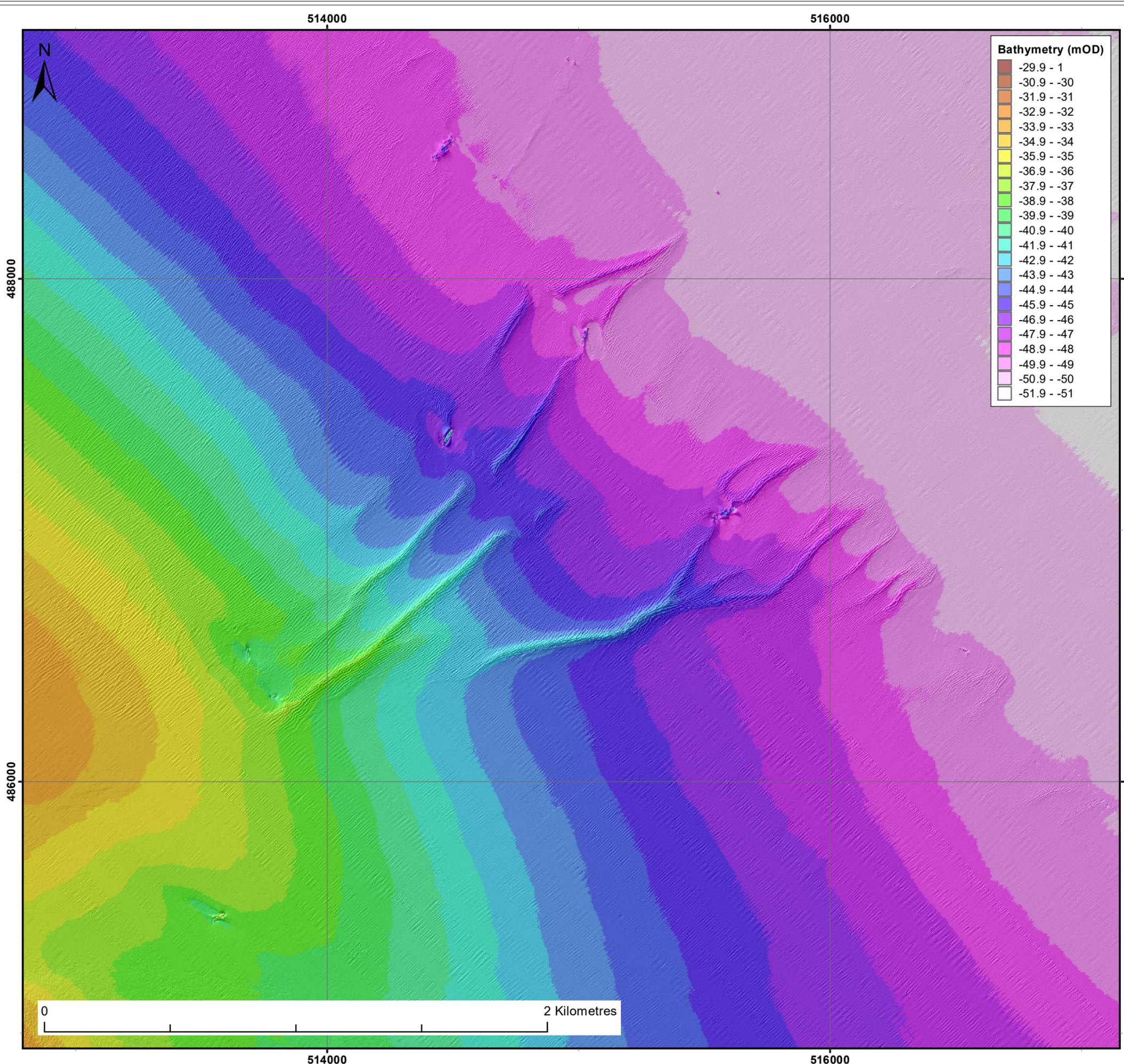
Figure: 8.2

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Co-ordinate system: British National Grid



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Client: North East Coastal Group	Project: Cell 1 Regional Coastal Monitoring Programme
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Title:
Bedforms offshore from Gristhorpe

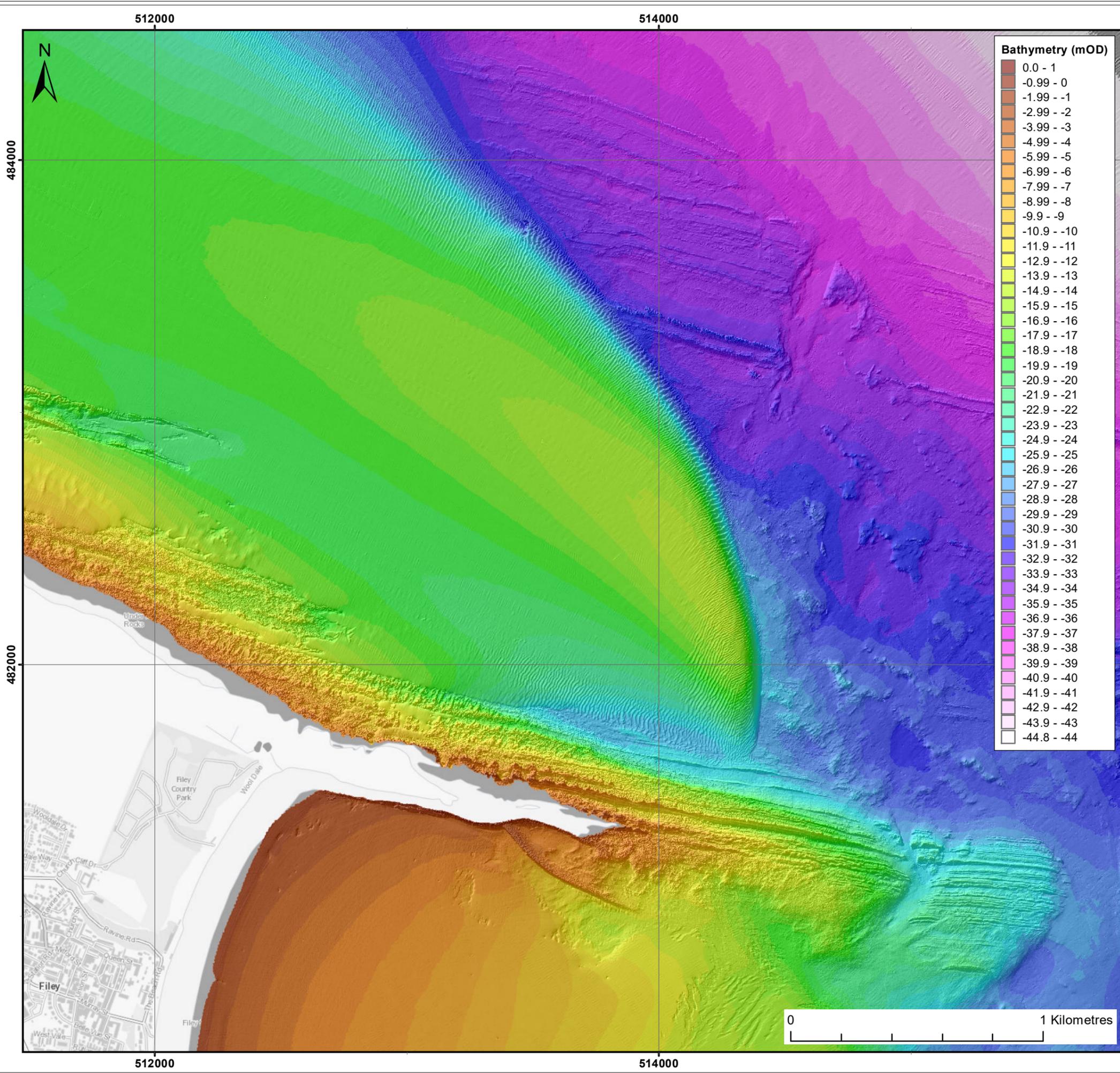
Figure: 8.3

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
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Co-ordinate system: British National Grid



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Title:
Sand bank feature immediately north of Filey Brigg

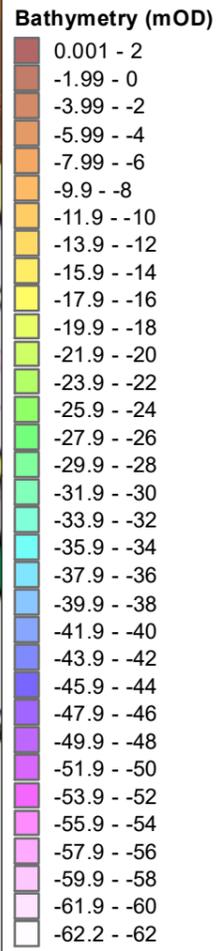
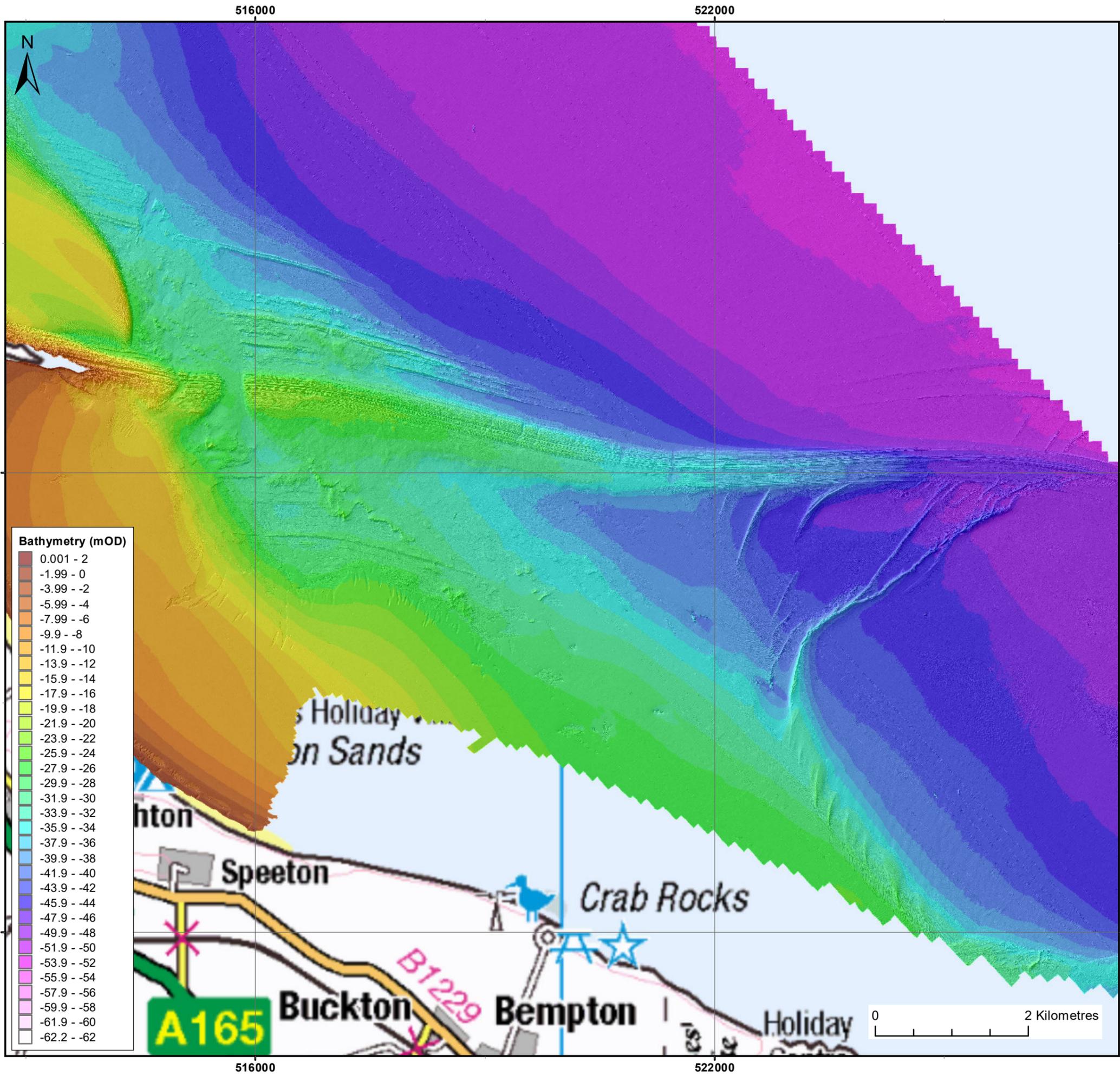
Figure: 8.4

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Title:
Bathymetry of sea bed offshore from Filey Brigg and Filey Bay

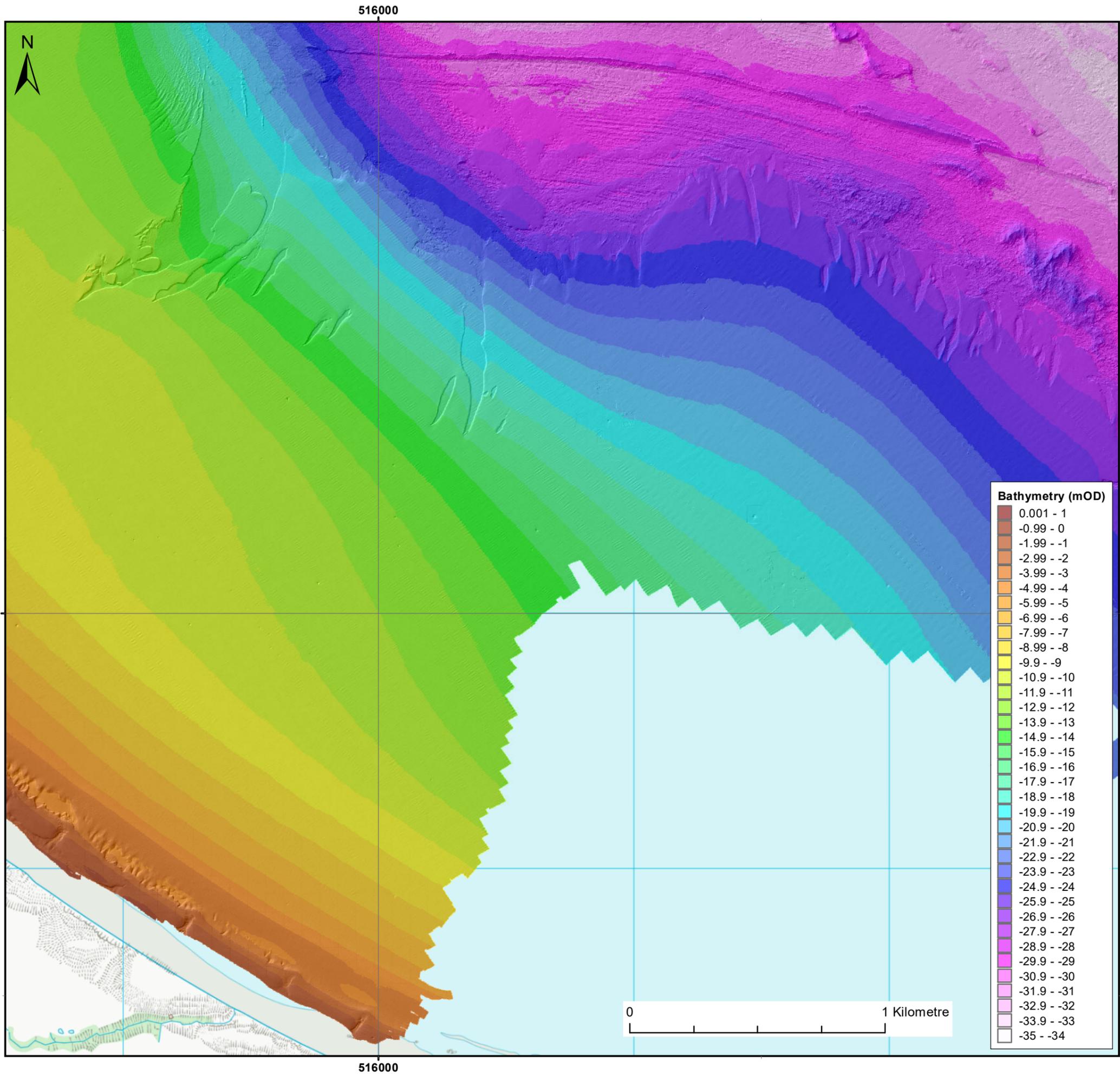
Figure: 8.5

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Title:
Bathymetry of sea bed offshore from Reighton to Speeton (Filey Bay)

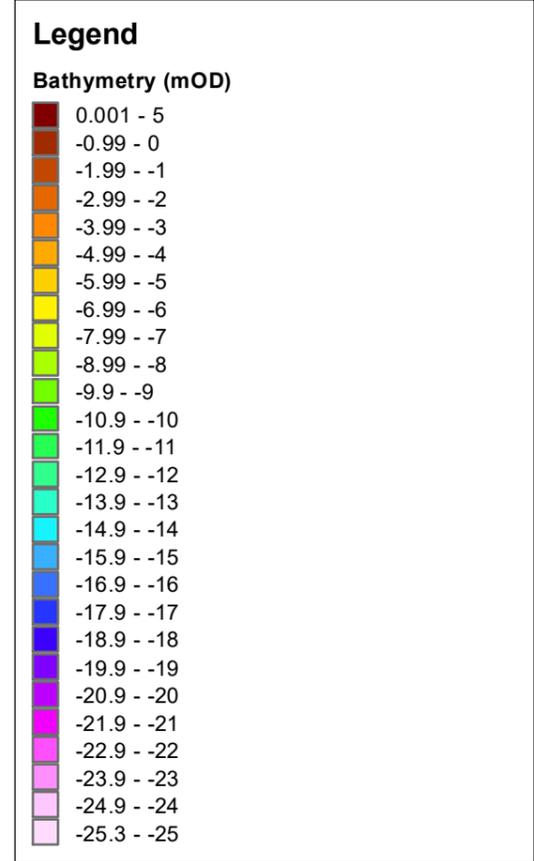
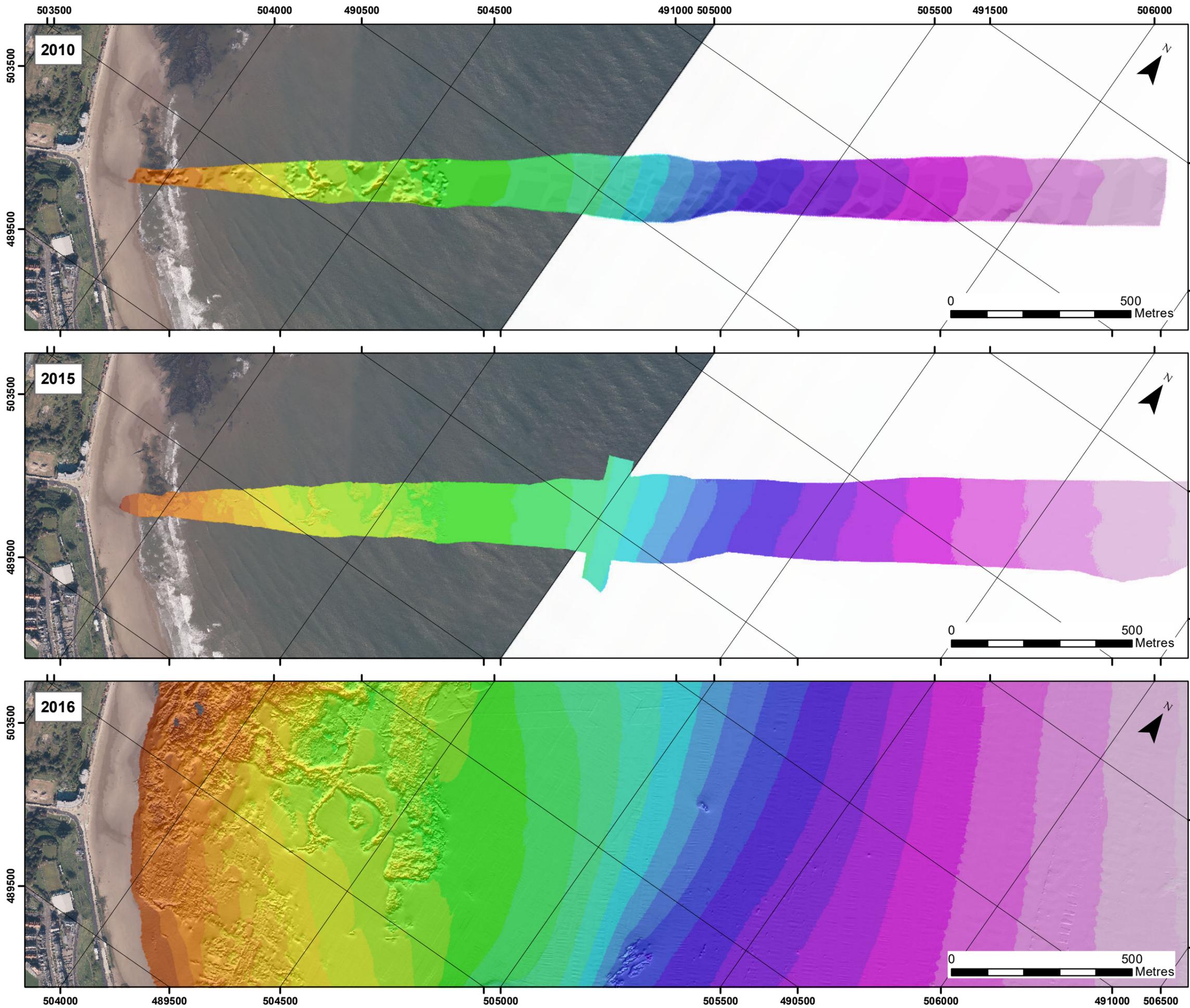
Figure: 8.6

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
0	09/06/2022	TC	DB	A3	1:15,000

Co-ordinate system: British National Grid



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Client:
North East Coastal Group

Project:
Cell 1 Regional Coastal Monitoring Programme

Figure 8.7a

SCARBOROUGH NORTH BAY

Scarborough Borough Council Frontage

BATHYMETRY SURVEYS

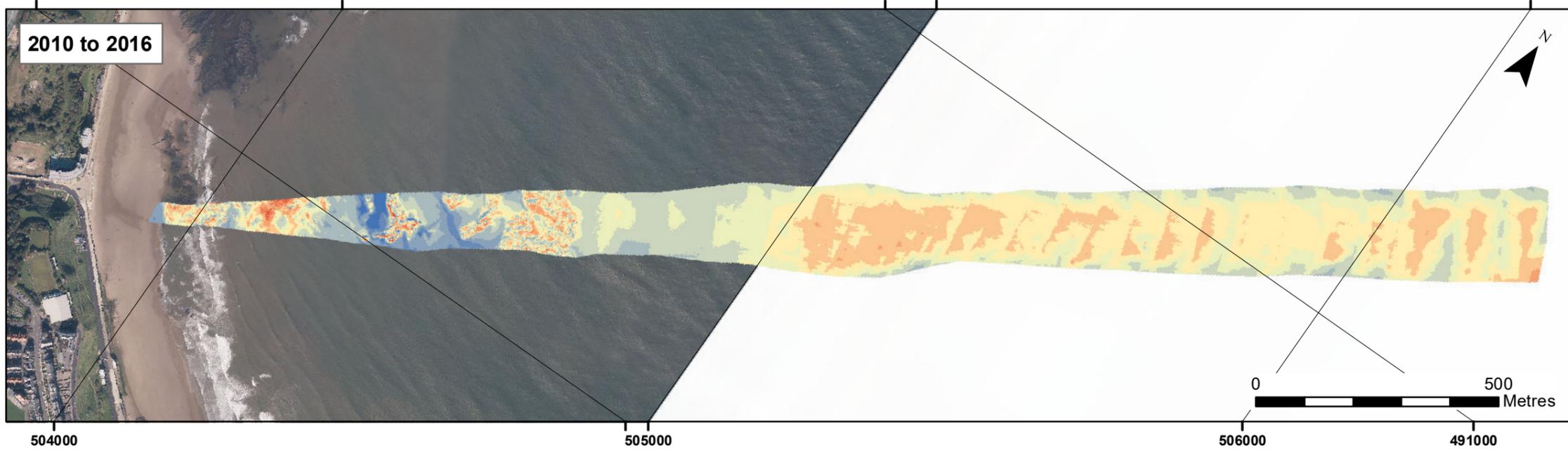
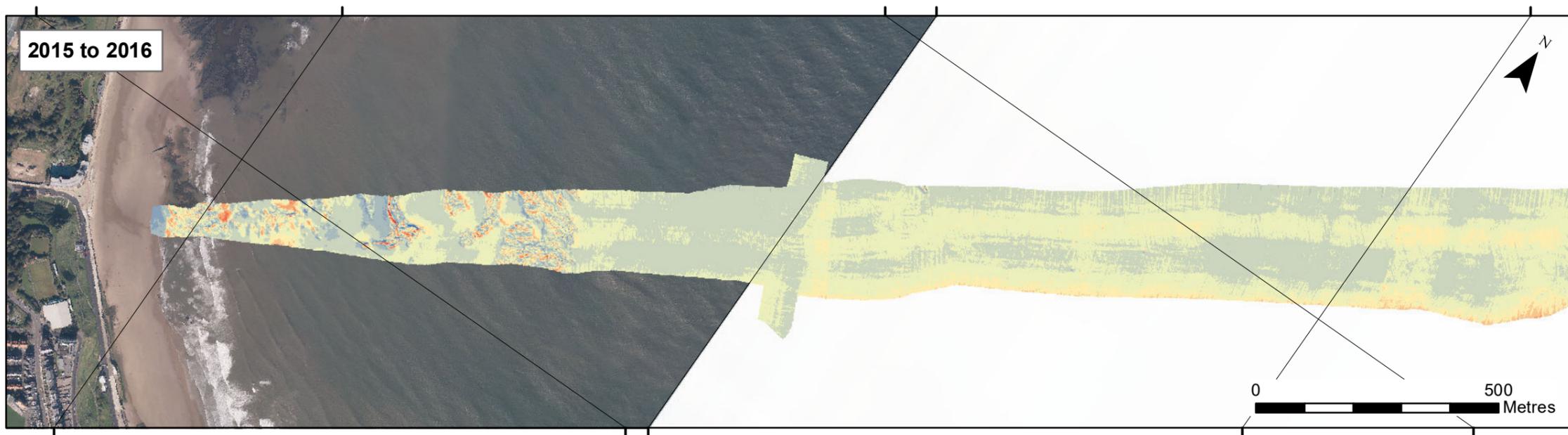
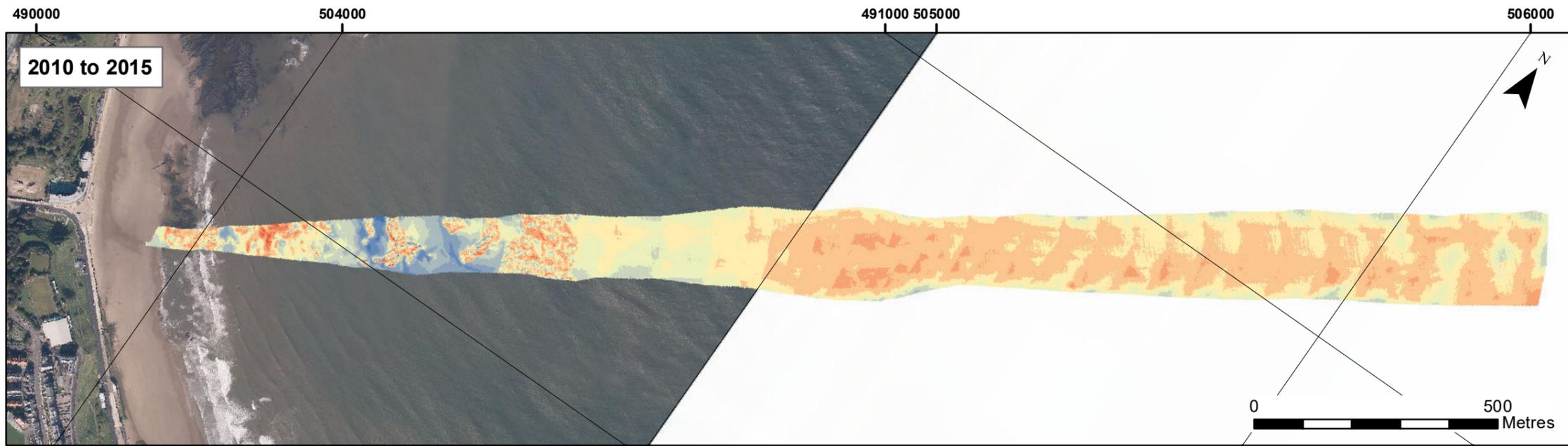
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Legend

Change in depths (mOD) between bathymetric surveys

> 1.0	<i>Gain</i> <i>Change +/- 0.1m</i> <i>Loss</i>
0.751 - 1	
0.501 - 0.75	
0.251 - 0.5	
0.101 - 0.25	
0.001 - 0.1	
-0.099 - 0	
-0.249 - -0.1	
-0.499 - -0.25	
-0.749 - -0.5	
-0.99 - -0.75	
< -1	

Client:
North East Coastal Group

Project:
Cell 1 Regional Coastal Monitoring Programme

Figure 8.7b

SCARBOROUGH NORTH BAY

Scarborough Borough Council Frontage

BATHYMETRY ANALYSIS

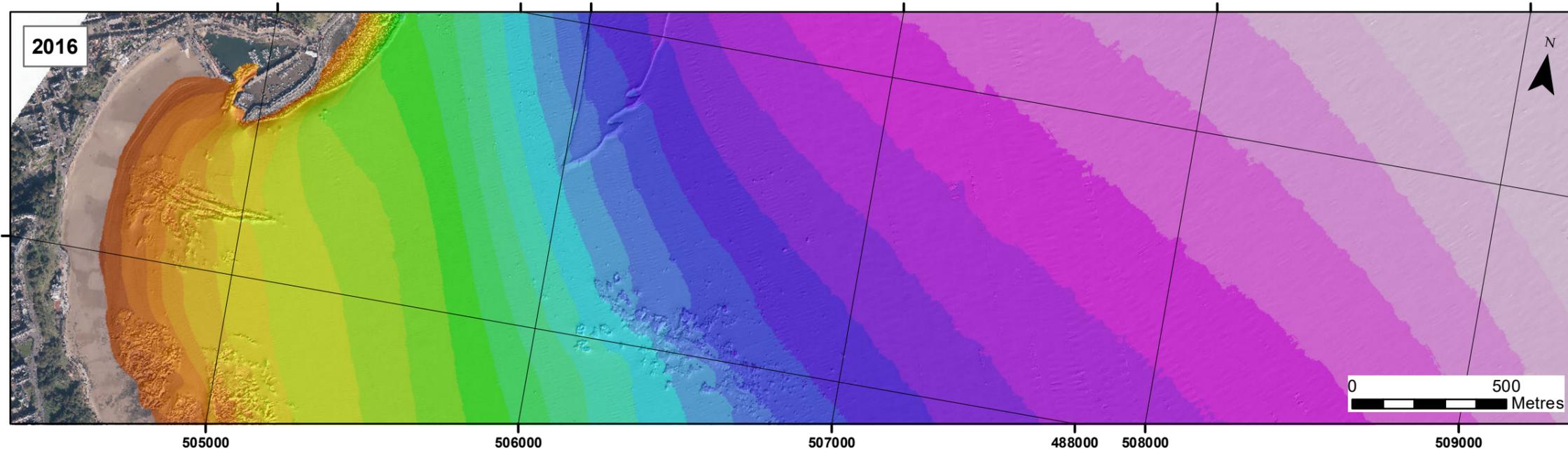
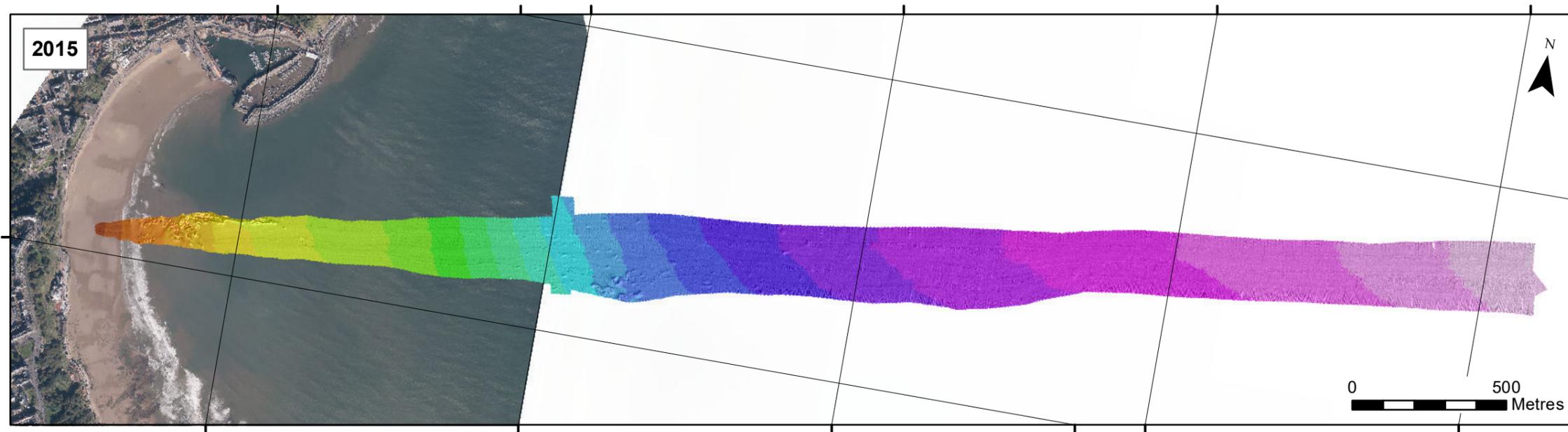
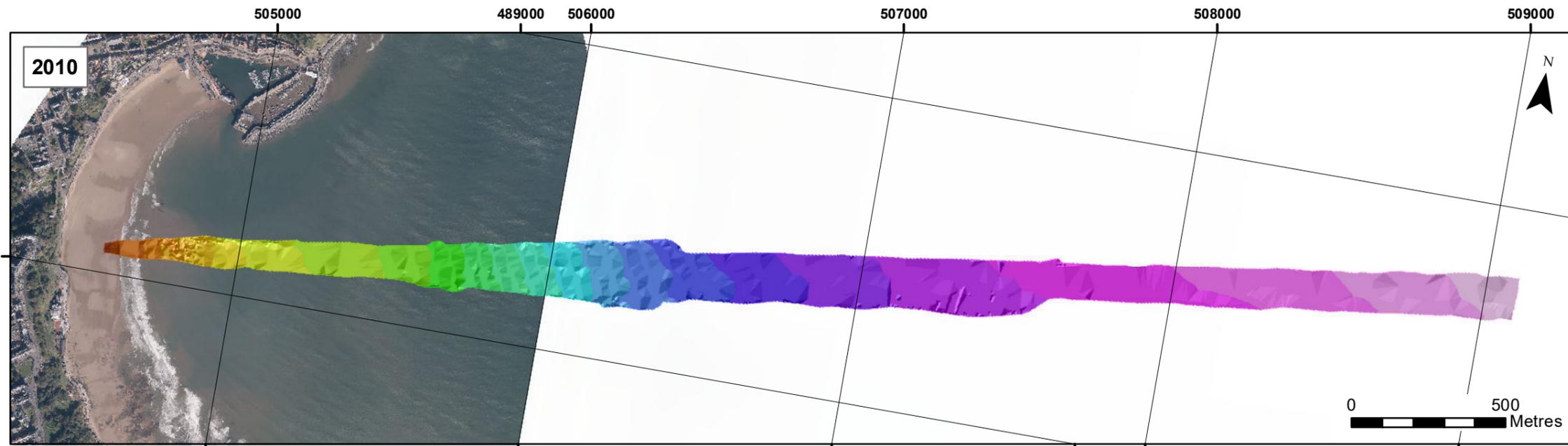
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Legend

Bathymetry (mOD)

- 0.001 - 5
- 0.99 - 0
- 1.99 - -1
- 2.99 - -2
- 3.99 - -3
- 4.99 - -4
- 5.99 - -5
- 6.99 - -6
- 7.99 - -7
- 8.99 - -8
- 9.9 - -9
- 10.9 - -10
- 11.9 - -11
- 12.9 - -12
- 13.9 - -13
- 14.9 - -14
- 15.9 - -15
- 16.9 - -16
- 17.9 - -17
- 18.9 - -18
- 19.9 - -19
- 20.9 - -20
- 21.9 - -21
- 22.9 - -22
- 23.9 - -23
- 24.9 - -24
- 25.3 - -25

Client:
North East Coastal Group

Project:
Cell 1 Regional Coastal Monitoring Programme

Figure 8.8a

**SCARBOROUGH
SOUTH BAY**

**Scarborough Borough
Council Frontage**

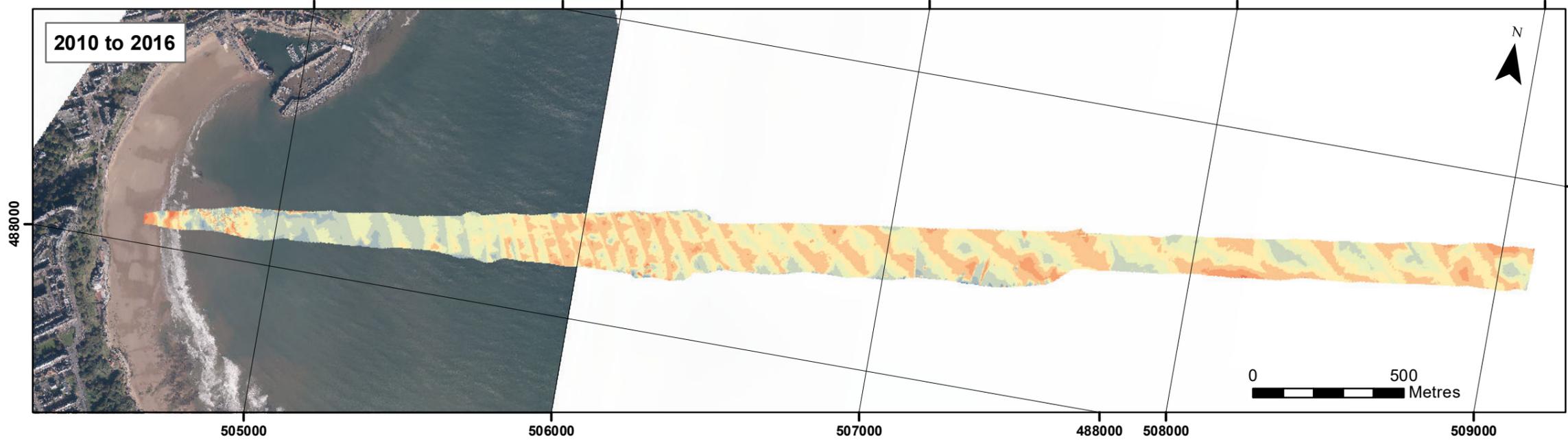
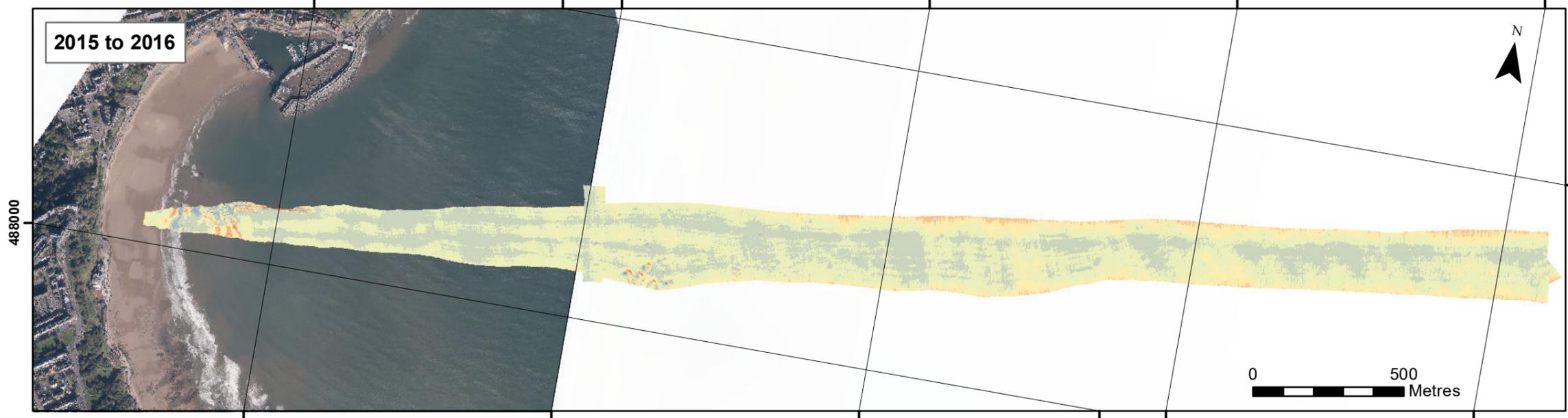
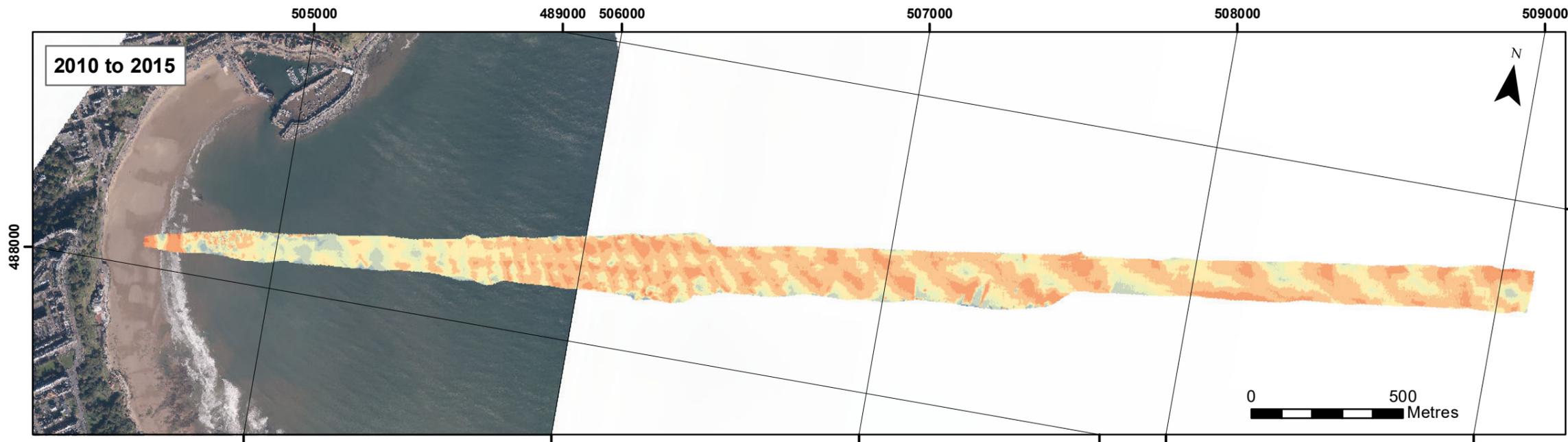
BATHYMETRY SURVEYS

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Legend

Change in depths (mOD) between bathymetric surveys

> 1.0	Gain
0.751 - 1	
0.501 - 0.75	
0.251 - 0.5	
0.101 - 0.25	
0.001 - 0.1	Change +/- 0.1m
-0.099 - 0	
-0.249 - -0.1	
-0.499 - -0.25	
-0.749 - -0.5	
-0.99 - -0.75	Loss
< -1	

Client:
North East Coastal Group

Project:
Cell 1 Regional Coastal Monitoring Programme

Figure 8.8b

SCARBOROUGH SOUTH BAY

Scarborough Borough Council Frontage

BATHYMETRY ANALYSIS

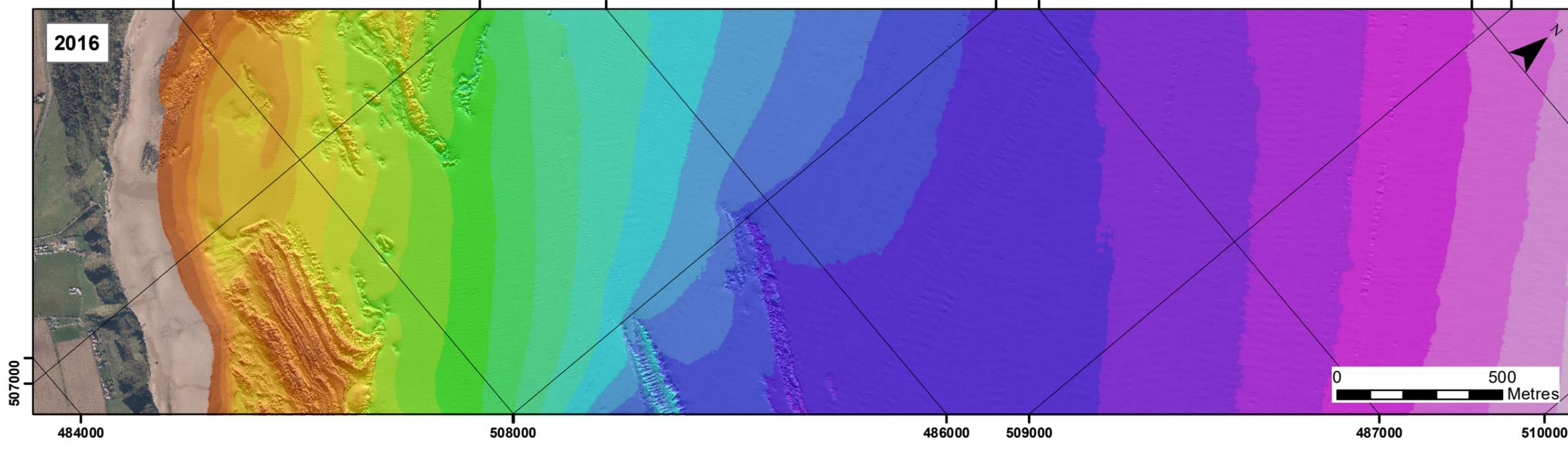
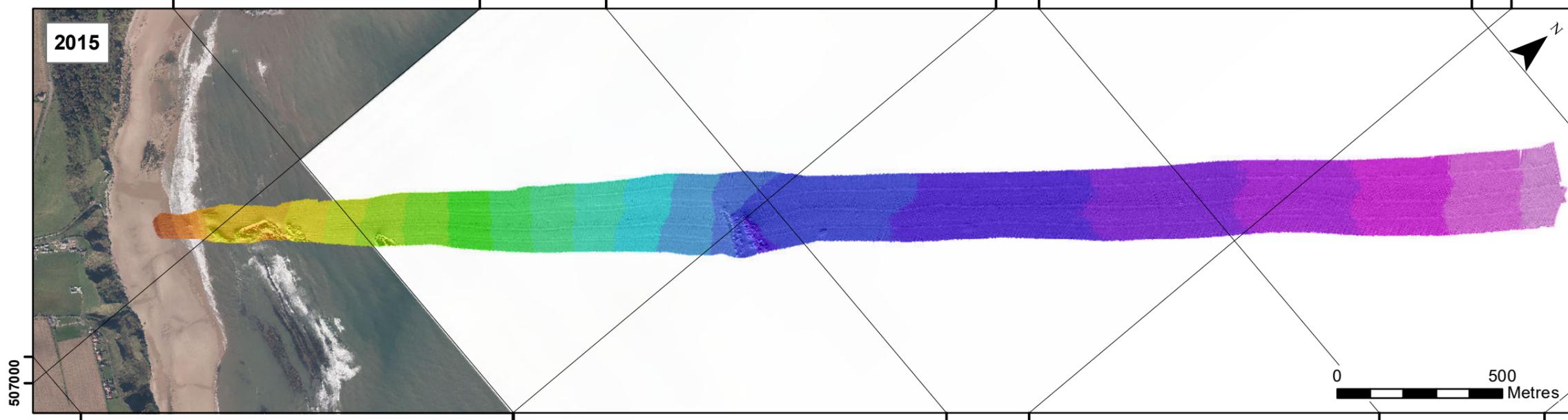
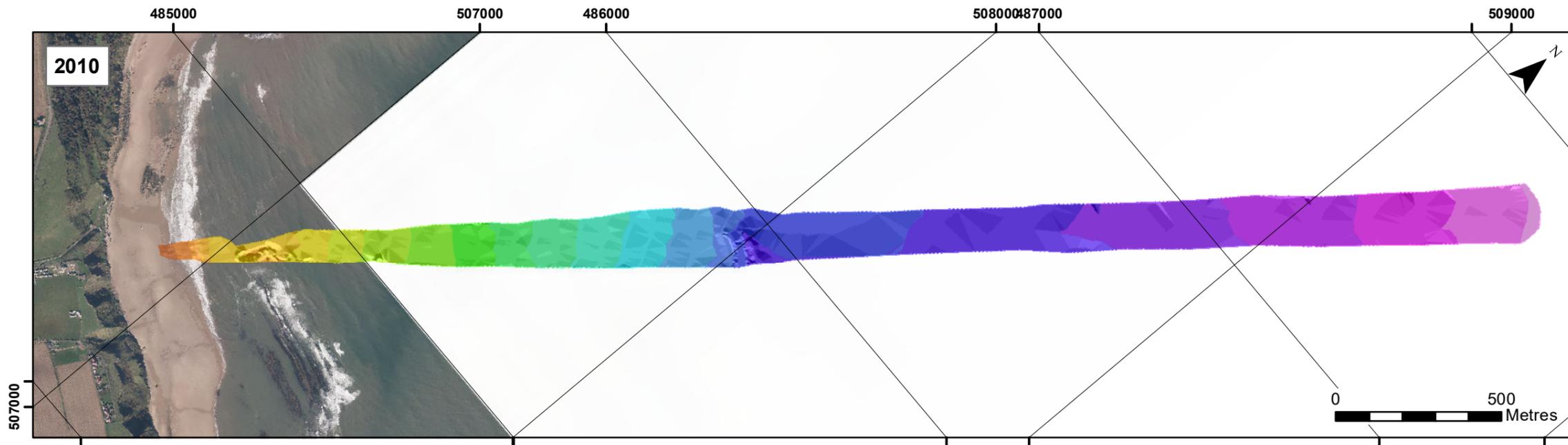
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Legend

Bathymetry (mOD)

0.001 - 5
-0.99 - 0
-1.99 - -1
-2.99 - -2
-3.99 - -3
-4.99 - -4
-5.99 - -5
-6.99 - -6
-7.99 - -7
-8.99 - -8
-9.9 - -9
-10.9 - -10
-11.9 - -11
-12.9 - -12
-13.9 - -13
-14.9 - -14
-15.9 - -15
-16.9 - -16
-17.9 - -17
-18.9 - -18
-19.9 - -19
-20.9 - -20
-21.9 - -21
-22.9 - -22
-23.9 - -23
-24.9 - -24
-25.3 - -25

Client:
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Project:
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Figure 8.9a

CAYTON BAY

Scarborough Borough Council Frontage

BATHYMETRY SURVEYS

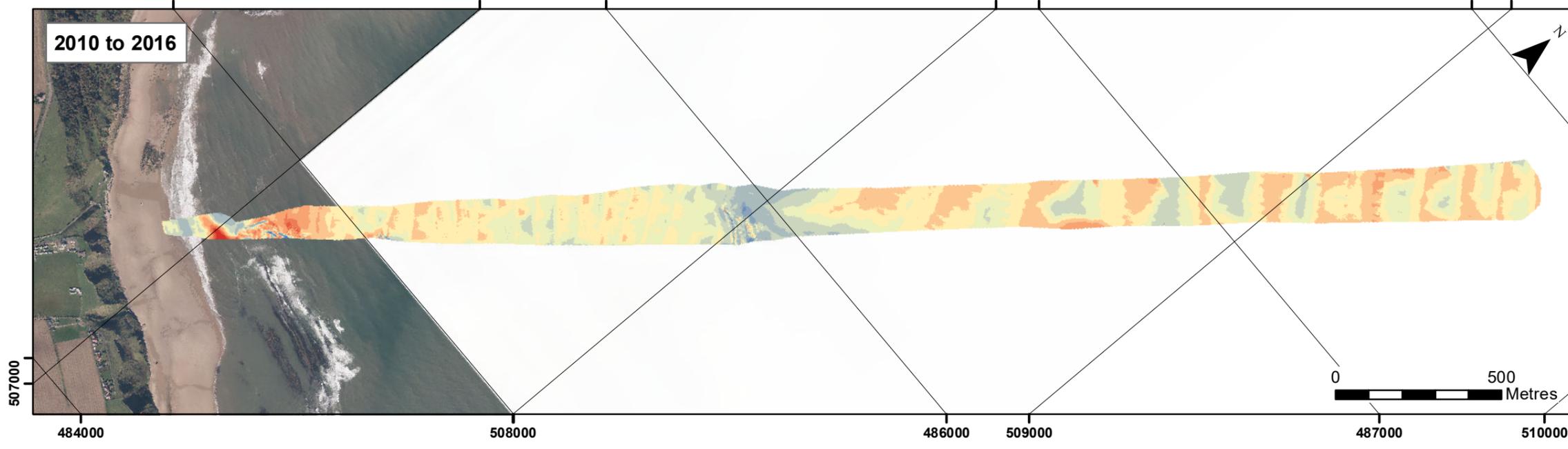
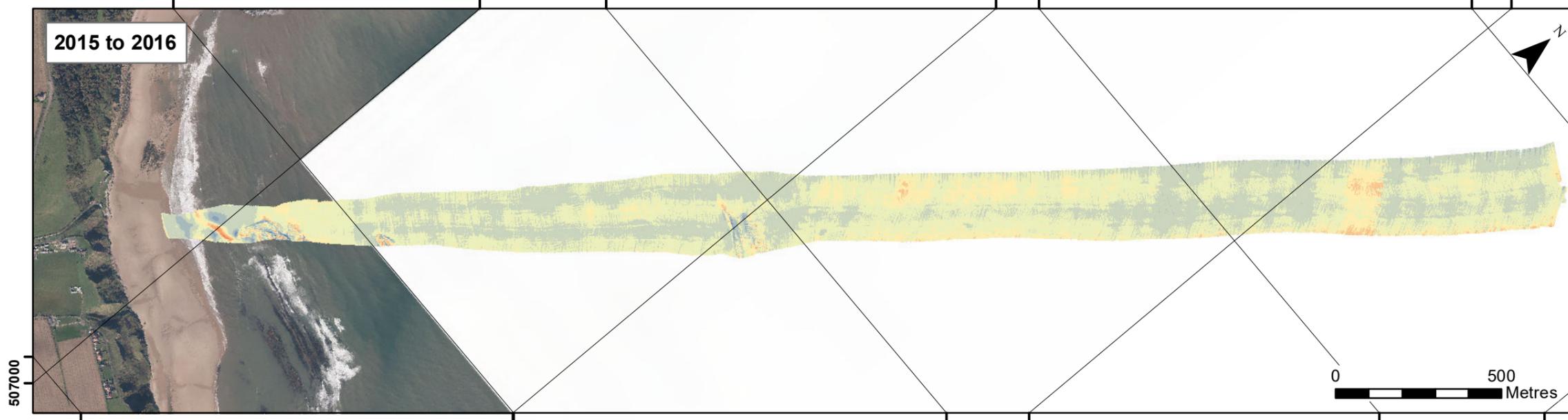
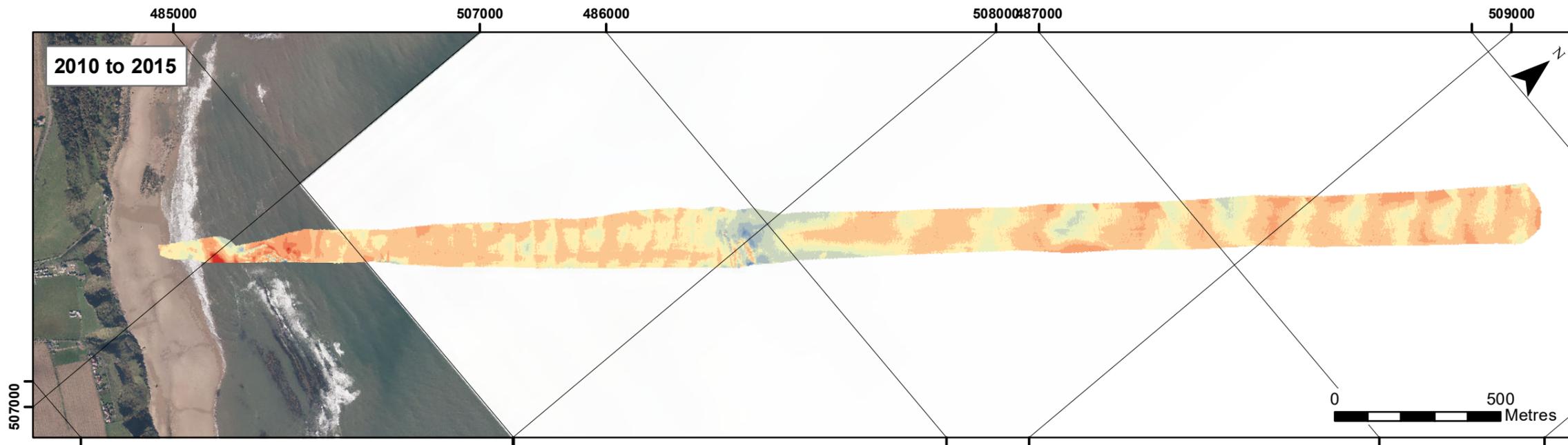
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Legend

Change in depths (mOD) between bathymetric surveys

> 1.0	Gain
0.751 - 1	
0.501 - 0.75	
0.251 - 0.5	
0.101 - 0.25	
0.001 - 0.1	Change +/- 0.1m
-0.099 - 0	
-0.249 - -0.1	
-0.499 - -0.25	
-0.749 - -0.5	
-0.99 - -0.75	Loss
< -1	

Client:
North East Coastal Group

Project:
Cell 1 Regional Coastal Monitoring Programme

Figure 8.9b

CAYTON BAY

Scarborough Borough Council Frontage

BATHYMETRY ANALYSIS

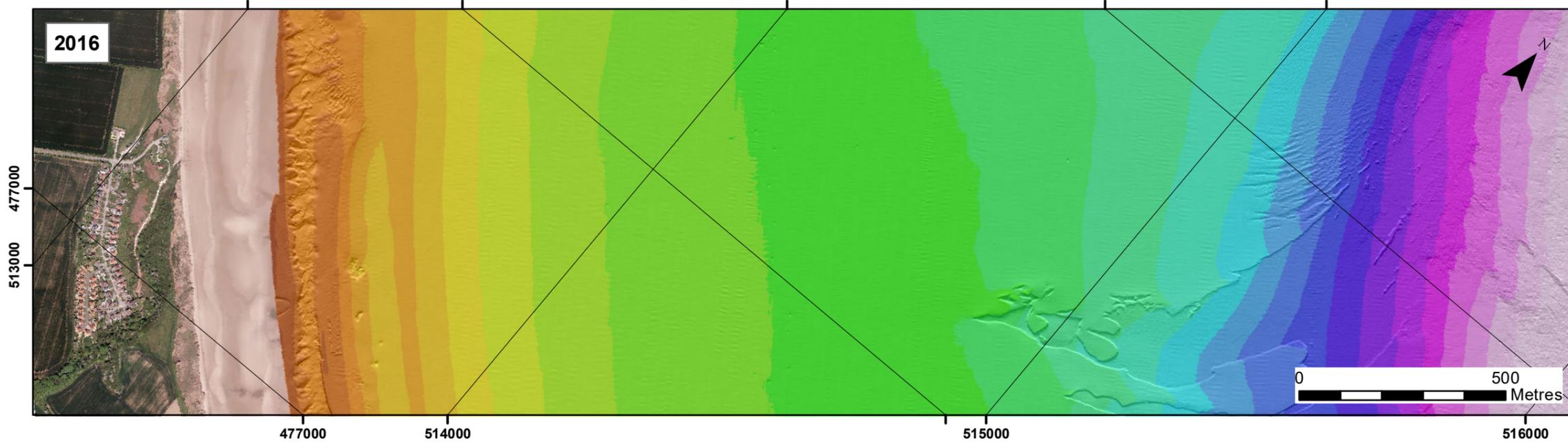
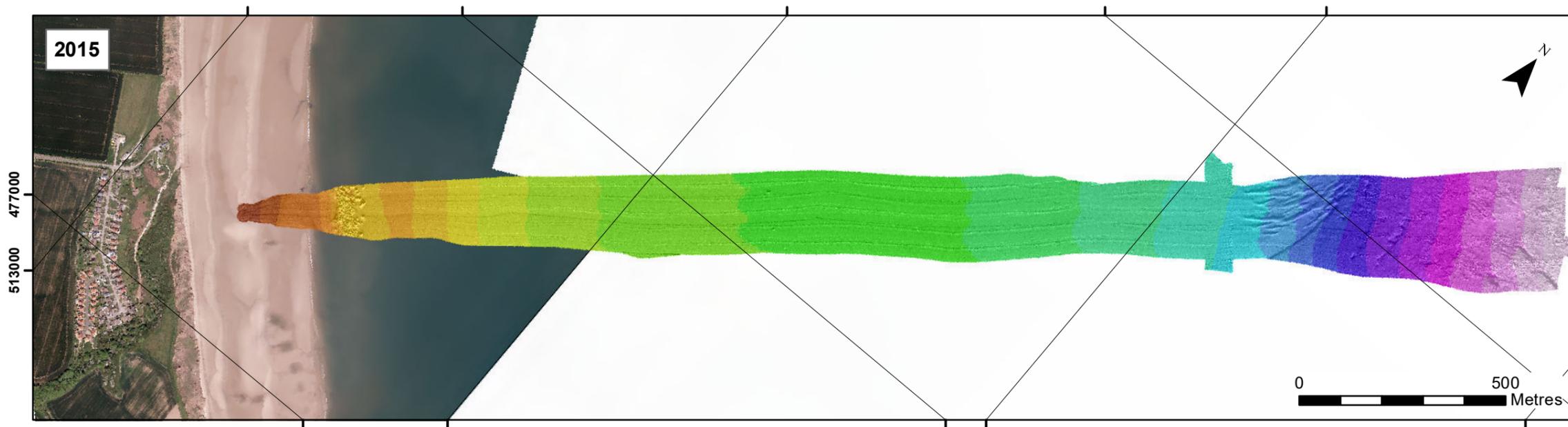
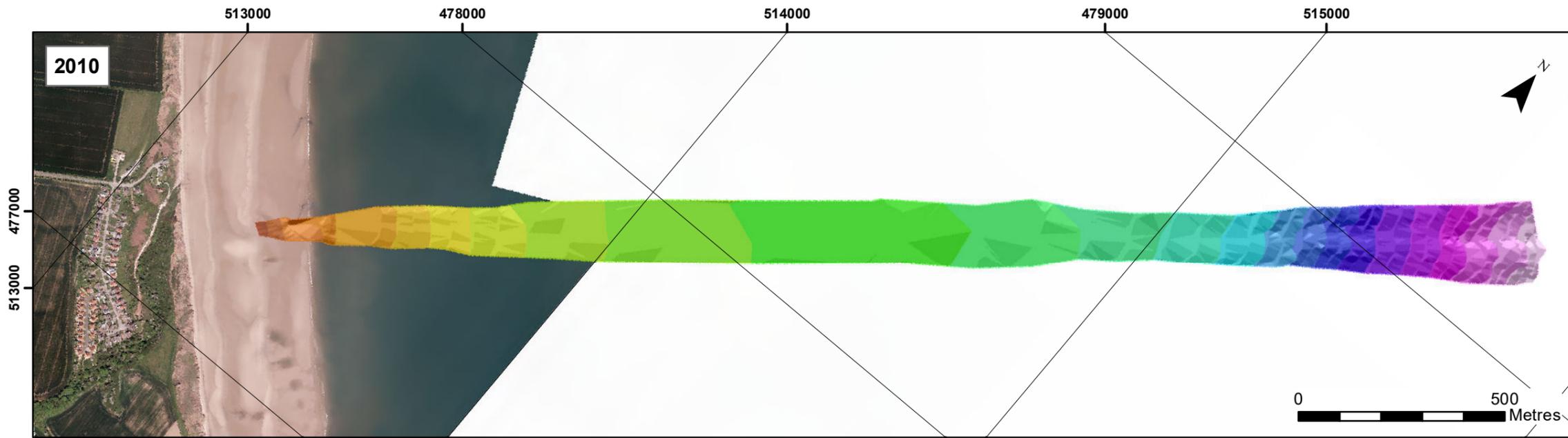
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Legend

Bathymetry (mOD)

0.001 - 5
-0.99 - 0
-1.99 - -1
-2.99 - -2
-3.99 - -3
-4.99 - -4
-5.99 - -5
-6.99 - -6
-7.99 - -7
-8.99 - -8
-9.9 - -9
-10.9 - -10
-11.9 - -11
-12.9 - -12
-13.9 - -13
-14.9 - -14
-15.9 - -15
-16.9 - -16
-17.9 - -17
-18.9 - -18
-19.9 - -19
-20.9 - -20
-21.9 - -21
-22.9 - -22
-23.9 - -23
-24.9 - -24
-25.3 - -25

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Figure 8.10a

FILEY BAY

Scarborough Borough Council Frontage

BATHYMETRY SURVEYS

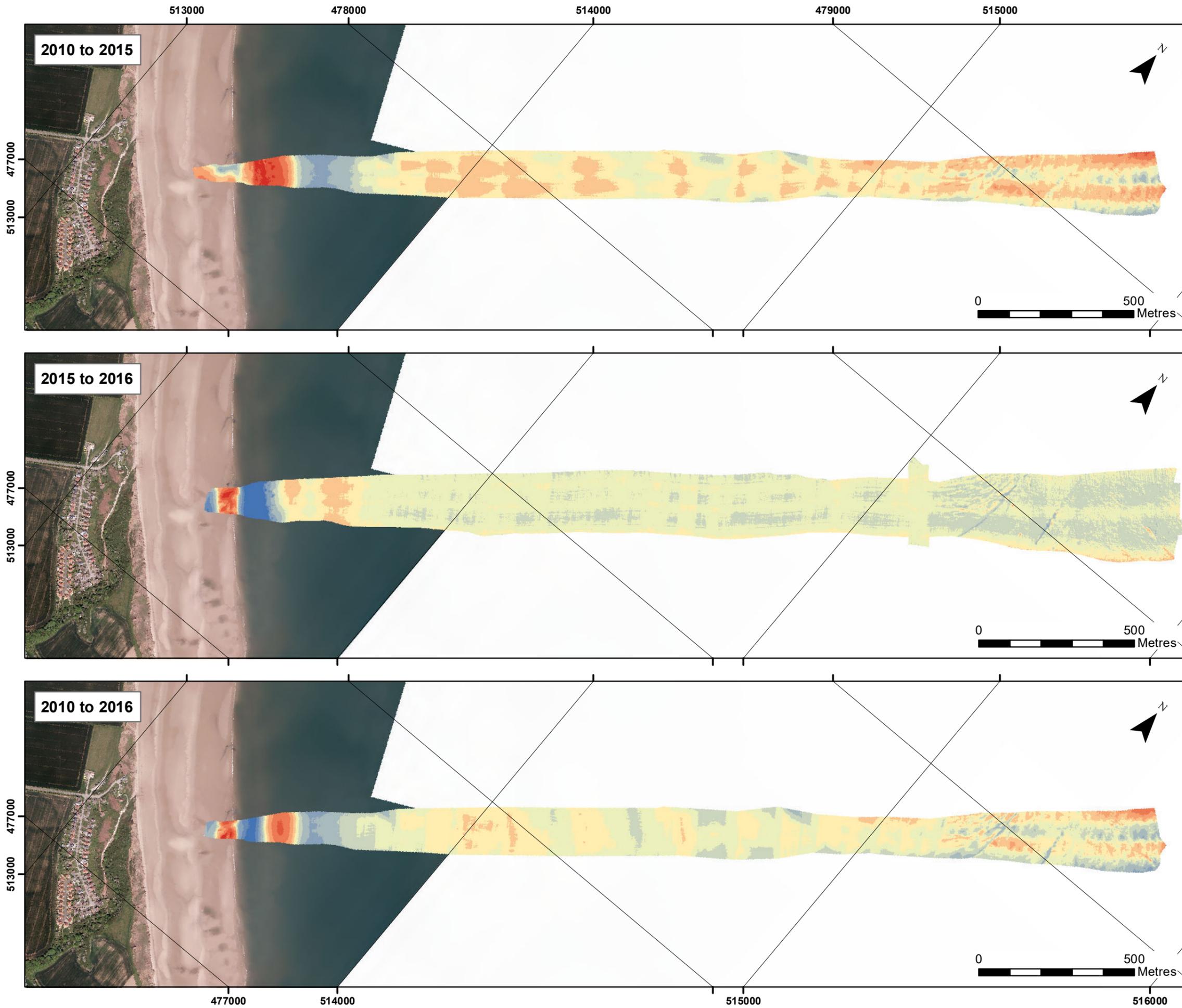
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Legend

Change in depths (mOD) between bathymetric surveys

> 1.0	Gain
0.751 - 1	
0.501 - 0.75	
0.251 - 0.5	
0.101 - 0.25	
0.001 - 0.1	Change +/- 0.1m
-0.099 - 0	
-0.249 - -0.1	
-0.499 - -0.25	
-0.749 - -0.5	
-0.99 - -0.75	Loss
< -1	

Client:
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Project:
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Figure 8.10b

FILEY BAY

Scarborough Borough Council Frontage

BATHYMETRY ANALYSIS

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