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Cell 1 Regional Coastal Monitoring Programme
Bathymetric and Sea Bed Characterisation Survey

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Final Report

October 2010

Contents

Appendices

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Abbreviations and Acronyms

Acronym / Abbreviation	Definition
BGS	British Geological Survey
BS	British Standards
CD	Chart Datum
CEFAS	Centre for Environment, Fisheries and Aquaculture Sciences
MHWN	Mean High Water Neaps
OD (or ODN)	Ordnance Datum (or Ordnance Datum Newlyn)
SMP2	Shoreline Management Plan 2

Glossary of Terms

Term	Definition
Beach nourishment	Artificial process of replenishing a beach with material from another source.
Berm crest	Ridge of sand or gravel deposited by wave action on the shore just above the normal high water mark.
Breaker zone	Area in the sea where the waves break.
Coastal squeeze	The reduction in habitat area which can arise if the natural landward migration of a habitat under sea level rise is prevented by the fixing of the high water mark, e.g. a sea wall.
Downdrift	Direction of alongshore movement of beach materials.
Ebb-tide	The falling tide, part of the tidal cycle between high water and the next low water.
Fetch	Length of water over which a given wind has blown that determines the size of the waves produced.
Flood-tide	Rising tide, part of the tidal cycle between low water and the next high water.
Foreshore	Zone between the high water and low water marks, also known as the inter-tidal zone.
Geomorphology	The branch of physical geography/geology which deals with the form of the Earth, the general configuration of its surface, the distribution of the land, water, etc.
Groyne	Shore protection structure built perpendicular to the shore; designed to trap sediment.
Mean High Water (MHW)	The average of all high waters observed over a sufficiently long period.
Mean Low Water (MLW)	The average of all low waters observed over a sufficiently long period.
Mean Sea Level (MSL)	Average height of the sea surface over a 19-year period.
Offshore zone	Extends from the low water mark to a water depth of about 15 m and is permanently covered with water.
Storm surge	A rise in the sea surface on an open coast, resulting from a storm.
Swell	Waves that have travelled out of the area in which they were generated.
Tidal prism	The volume of water within the estuary between the level of high and low tide, typically taken for mean spring tides.
Tide	Periodic rising and falling of large bodies of water resulting from the gravitational attraction of the moon and sun acting on the rotating earth.
Topography	Configuration of a surface including its relief and the position of its natural and man-made features.
Transgression	The landward movement of the shoreline in response to a rise in relative sea level.
Updrift	Direction opposite to the predominant movement of longshore transport.
Wave direction	Direction from which a wave approaches.
Wave refraction	Process by which the direction of approach of a wave changes as it moves into shallow water.

Preamble

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

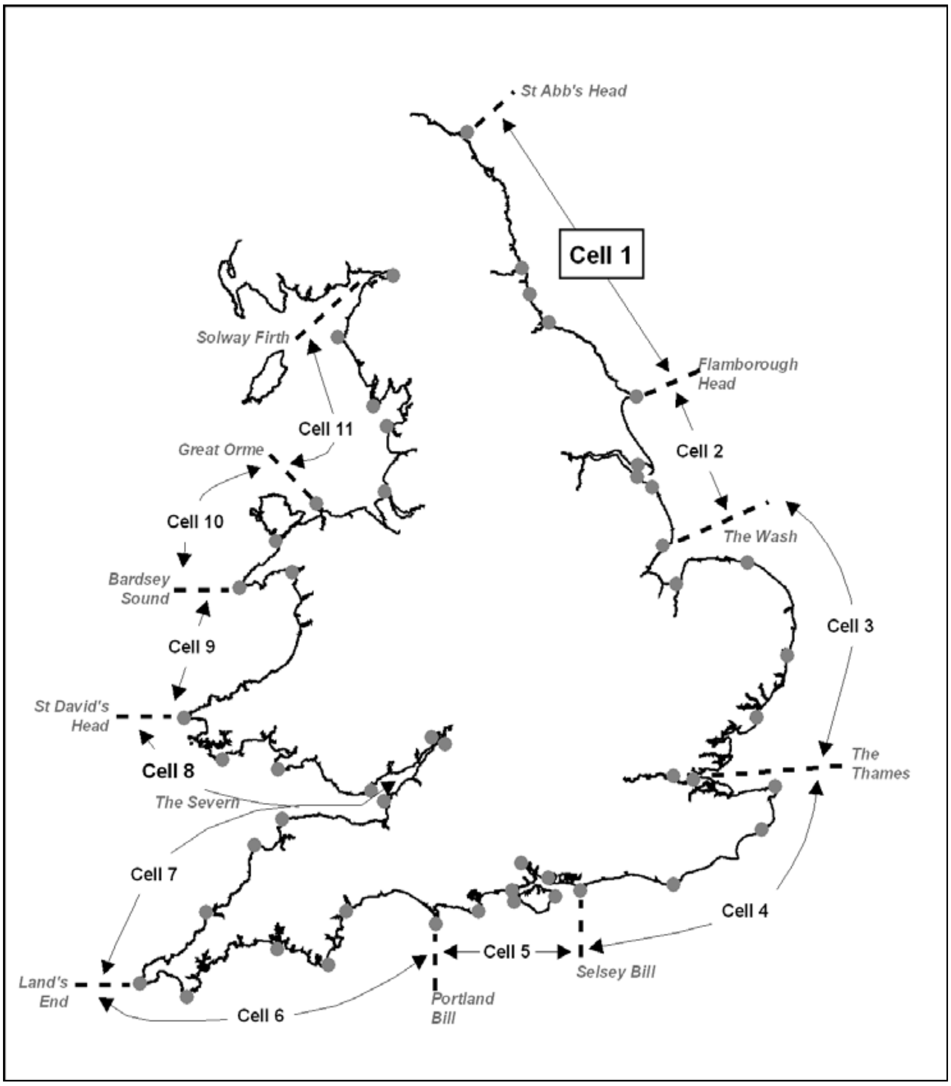


Figure 1 - Sediment Cells in England and Wales

The 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 data collection, analysis and reporting is being undertaken as a partnership between 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
- walk-over surveys

The present report covers the **Bathymetric and Sea Bed Characterisation Survey 2010** and provides details of these surveys and a summary of their main findings.

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, and aerial photography.

1. Introduction

1.1 Study Area

The main bathymetric and sea bed characterisations surveys were undertaken along a series of 15 shore-normal transect lines extending between the River Tyne (Tyne & Wear) and Filey Bay (North Yorkshire). The surveys were undertaken in response to specific issues raised in the Shoreline Management Plan 2 (SMP2) covering this frontage and are located as follows:

- Herd Sands, South Shields (South Tyneside);
- South Bents, Whitburn Bay (Sunderland);
- Salterfen Rocks (Sunderland);
- Blast Beach (near Noses Point, County Durham);
- Hartlepool North Sands (Hartlepool Borough);
- Saltburn-by-the-Sea (Redcar & Cleveland Borough);
- Skinningrove (Redcar & Cleveland Borough);
- Runswick Bay (Scarborough Borough);
- Sandsend (Scarborough Borough);
- Whitby Sands (Scarborough Borough);
- Robin Hood's Bay (Scarborough Borough);
- Scarborough North Bay (Scarborough Borough);
- Scarborough South Bay (Scarborough Borough);
- Cayton Bay (Scarborough Borough);
- Filey Bay (Scarborough Borough).

The locations of these transects are shown in Figure 2.

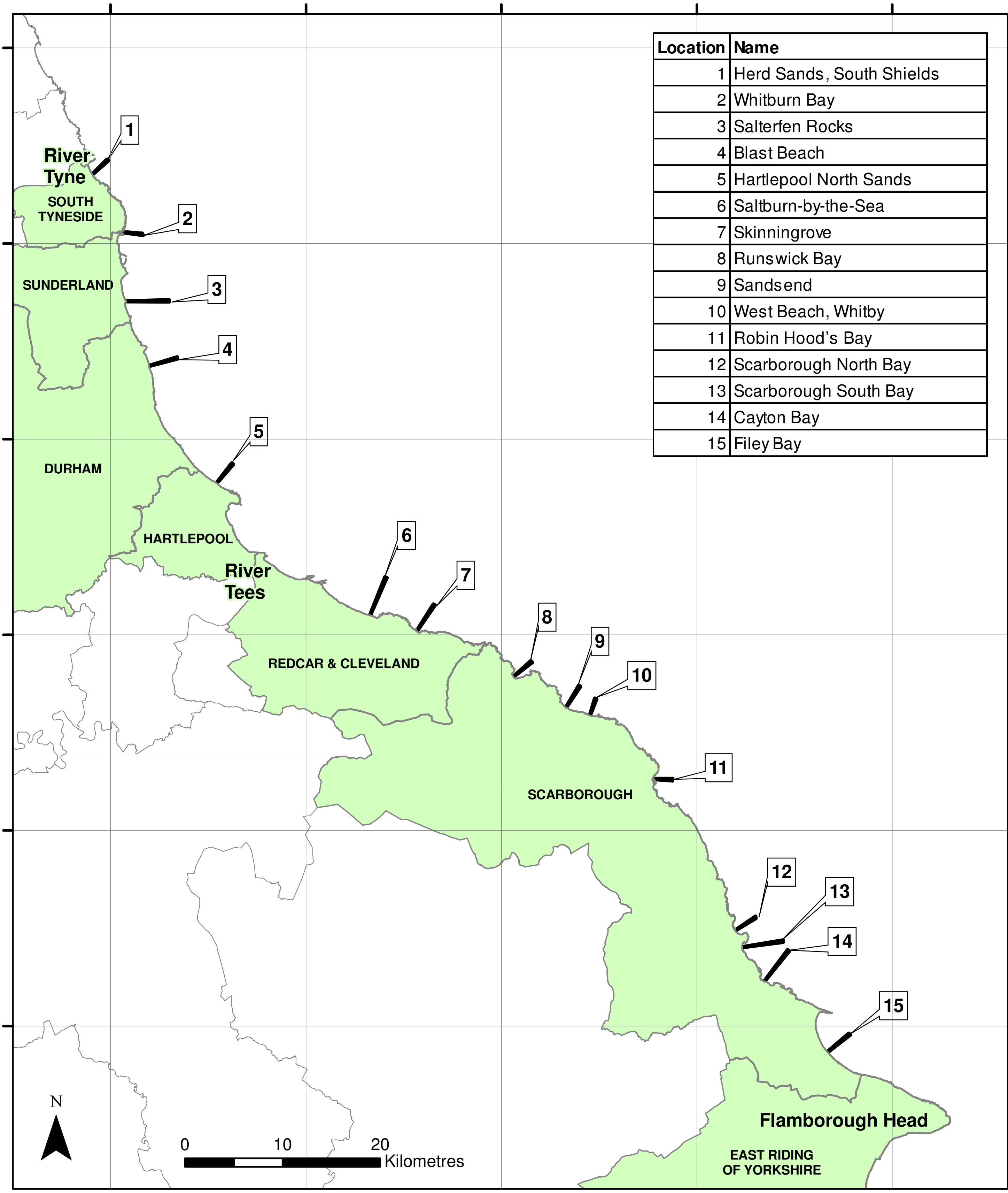
1.2 Methodology

The bathymetric surveys were undertaken using a dedicated swathe bathymetry survey vessel extending from the line of mean high water neap tides (MHWN) seawards nominally to the 20mCD sea bed contour. The surveying was carried out in compliance with the principles of the Environment Agency's *National Standard Contract and Specification for Surveying Services*. Further details of the bathymetric and sea bed surveys are provided in Appendix A.

Along each swathe bathymetry survey transect line sea bed sediment grab samples were also taken nominally at 1km intervals. These were subjected to particle size analysis for industry-standard parameters such as particle size, skewness, sorting and kurtosis, carried out in compliance with BS1377 and CEFAS (2002) *Guidelines for the Conduct of Benthic Studies at Aggregate Dredging Sites*. Resulting data were used to inform sediment characterisation of the sea bed. Further details of the particle size analysis are provided in Appendix B.

At this stage in the monitoring programme it is only possible to consider whether the scope and extent of the survey is likely to address the specific issues associated with each survey location. Following subsequent surveys, at suggested 5-yearly or 10-yearly intervals, the findings can be reassessed to identify changes in sea bed elevation and/or sediment character.

As the survey vessel was tracking between the main survey transect locations, ancillary survey data was also collected at a lesser resolution along nominally the 20mCD sea bed contour, running along the coast, to provided added value from the surveys.



Location	Name
1	Herd Sands, South Shields
2	Whitburn Bay
3	Salterfen Rocks
4	Blast Beach
5	Hartlepool North Sands
6	Saltburn-by-the-Sea
7	Skinningrove
8	Runswick Bay
9	Sandsend
10	West Beach, Whitby
11	Robin Hood's Bay
12	Scarborough North Bay
13	Scarborough South Bay
14	Cayton Bay
15	Filey Bay

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3 Bathymetric Survey Location

Figure 2
Bathymetric Survey Locations

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Project: Cell One Seabed Characterisation Study

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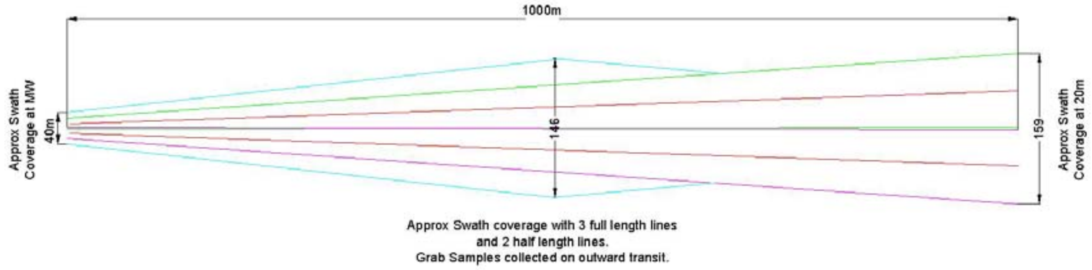
2. Survey Overview

The surveys were undertaken by Aspect Land & Hydrographic Surveys between 5th February 2010 and 17th June 2010. Particularly hard winter months at the start of 2010 severely hampered the initial progress of the operations, with strong and predominantly easterly winds preventing data gathering efforts from progressing as originally planned. However, all data were subsequently successfully collected to the specified levels of accuracy and extent of coverage.

The centreline was surveyed to full length from the 20m contour to the shallowest possible depth. Two further full length lines were then surveyed, either side of this centreline.



Bathymetric data was processed using Hypack, Fledermaus and McCarthy Taylor LSS software. Where it was found that there was a gap between the previously collected topographic survey data and the bathymetric data, further topographic surveys were carried out in order to ensure that there was an overlap with work carried out under that separate contract.

Once the bathymetry data was gathered the sea bed samples were then taken on the outward transit when the sea state allowed. Sea bed samples were retained for analysis at the University of Stirling's laboratory.

Data from the bathymetric surveys were supplied as full resolution x, y, z and as gridded data formats, with levels reduced to OSGB Ordnance Datum, Newlyn. Pixel resolution is 1m for the main survey and 5m for the ancillary survey areas and the vertical accuracy of the data is no worse than ±0.35m.

3. Survey Results

Results presented in Figures 3.1 to 3.15 provide a factual description of the 2010 survey that can be considered as a baseline against which future surveys can be assessed. The data is presented as a series of figures, one for each transect, comprises the following information:

- Multibeam bathymetry, with contours at 2 m intervals, also showing the location of sea bed grab samples.

- Geomorphological interpretation of the bathymetry data, including location of key sea bed features (boulders/depression) and information on the alignment of sandy bedforms and bedrock structure. The grab samples are presented as pie charts showing percentage breakdown of different particle sizes, using the Wentworth Scale). BGS 1:250,000-scale sea bed sediment data is also provided. This data is displayed using the Folk Scale.

- A long section through the bathymetry is also provided. This data has a greatly exaggerated vertical axis and highlights the key morphological units along the surveyed transects.

3.1 Herd Sands, South Shields

3.1.1 Background

Herd Sands, known locally as Sandhaven, comprises a sandy foreshore that is backed by sand 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, however, recognises that in the longer-term sea level rise will put increasing pressure on this frontage as the dunes will tend to be constrained in their natural tendency to migrate landwards by the presence of the promenade and fixed assets.

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.

3.1.2 Survey Findings

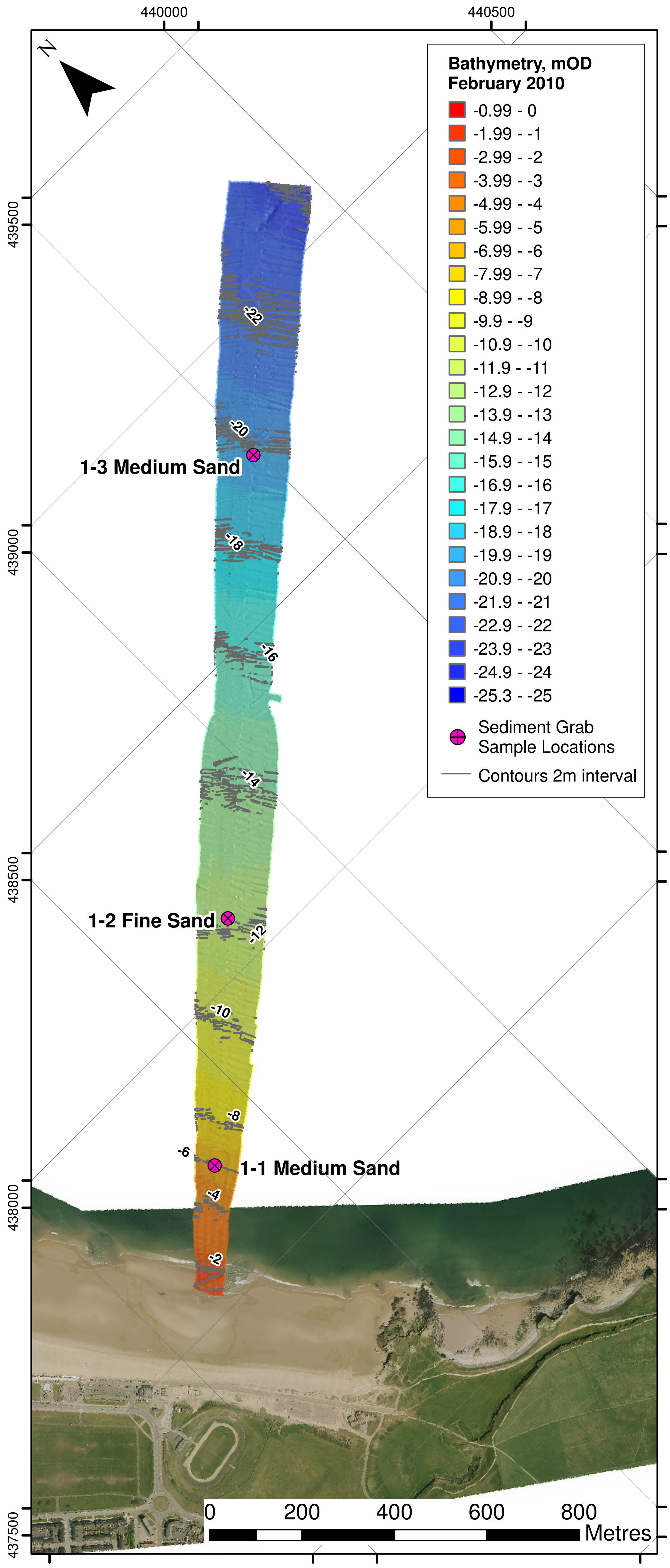
The bathymetric survey at Herd Sands extends approximately 2.4km offshore to a depth of –24mOD. According to the BGS data, the survey area is predominantly underlain by mudstone and gypsum, with a small area of underlying sandstone. The bathymetry, sea bed samples and BGS sea bed sediment data for Herd Sands are displayed in Figure 3.1.

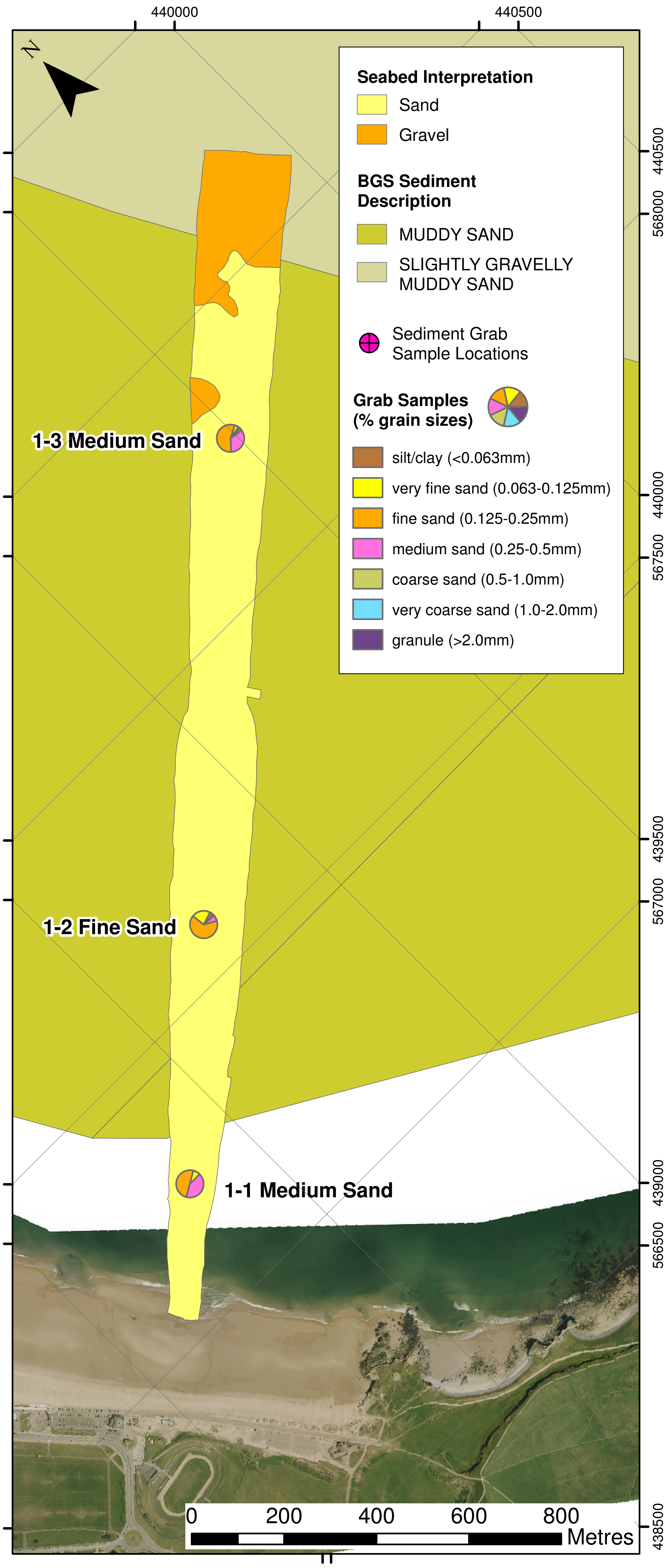
The interpretative mapping and long profile for Herd Sands suggest the this area of sea bed is fairly homogeneous, being composed mainly of fine to medium sand, although at the seaward end of the profile the sediment composition changes to become slightly more gravelly. The area containing the greatest proportion of fine sand, with also some very fine sand present, tends to occur in the area of the transect underlain by sandstone.

After dipping relatively steeply to around -8mOD the sea bed then adopts a shallower gradient to shelve more gently towards the offshore zone.

3.1.3 Review of Objectives

At this stage in the monitoring programme it is only possible to consider whether the scope and extent of the survey is likely to address the issues raised, particularly with respect to any results as to the nature of the sea bed. Following subsequent surveys the finding would be reviewed where the monitoring is picking up information relevant to the management issues.





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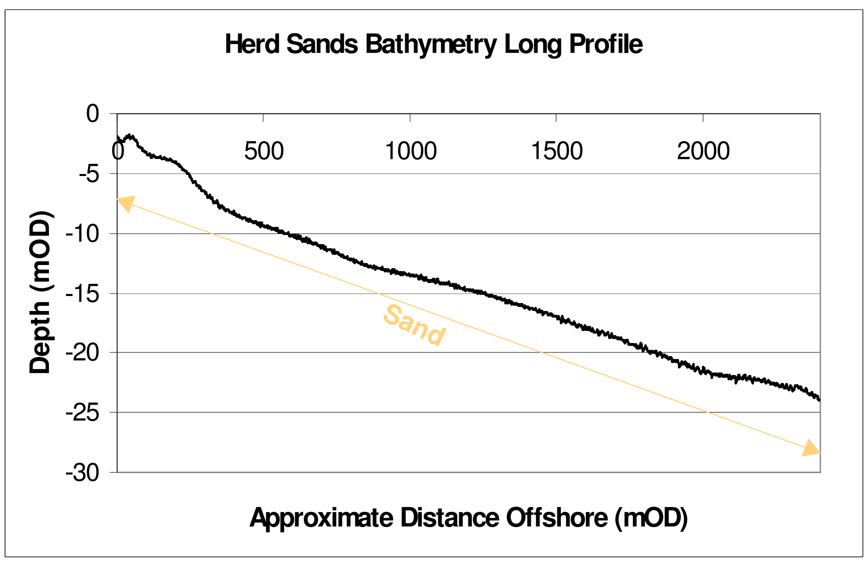

Figure 3.1
Herd Sands
Bathymetry & Interpretation

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Project: Cell One Seabed Characterisation Study

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3.2 South Bents, Whitburn Bay

3.2.1 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 estuary.

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.

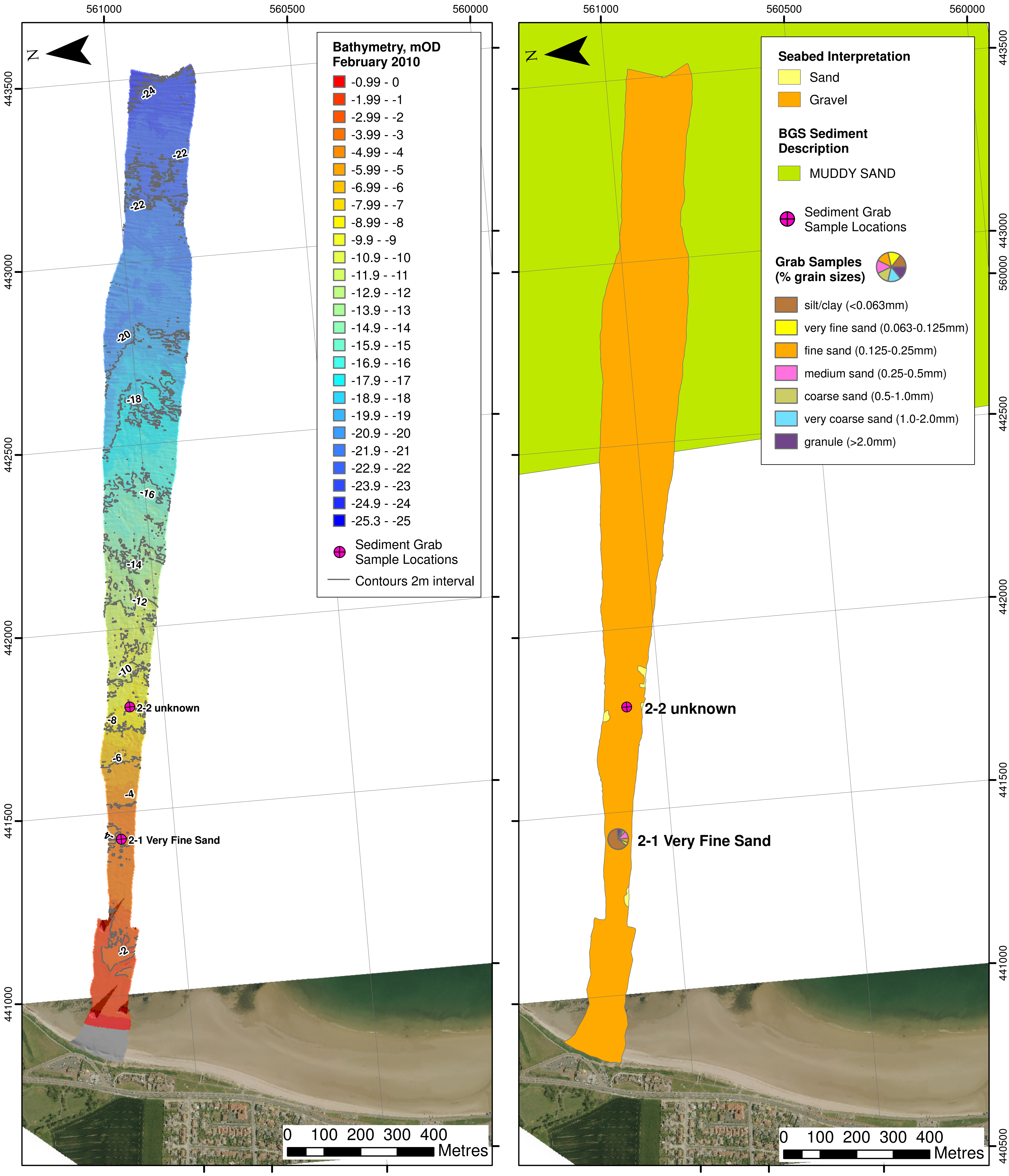
3.2.2 Survey Findings

The bathymetric survey at Whitburn Bay extends approximately 2.7km offshore to a depth of –24mOD. According to the BGS data, the survey area is predominantly underlain by mudstone and gypsum. The bathymetry, sea bed samples and BGS sea bed sediment data for Herd Sands are displayed in Figure 3.2.

The interpretative mapping and long profile for Whitburn Bay suggest the this area of sea bed is relatively homogeneous, being composed of hard rock with some areas of coarser sedimentary fractions. Grab sampling along much of the length returned no sediment samples, indicating that bedrock was encountered, although at the landward end a pocket of fine material was encountered.

3.2.3 Review of Objectives

At this stage in the monitoring programme it is only possible to consider whether the scope and extent of the survey is likely to address the issues raised, particularly with respect to any results as to the nature of the sea bed. Following subsequent surveys the finding would be reviewed where the monitoring is picking up information relevant to the management issues.



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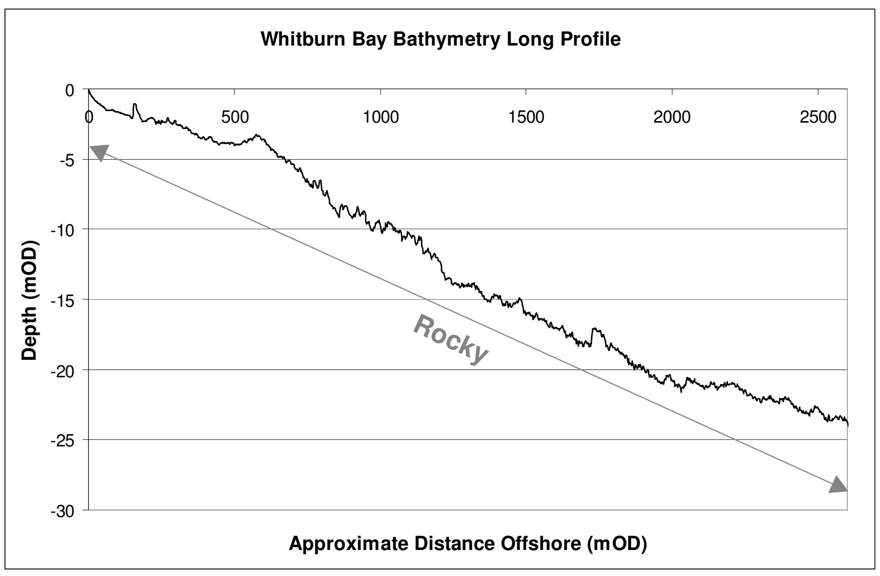

Figure 3.2
Whitburn Bay
Bathymetry & Interpretation

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3.3 Salterfen Rocks

3.3.1 Background

Saltafen Rocks, together with other rock stacks and rocky foreshore outcrops, exerts a key control on the evolution of the coastline between Hendon and Ryhope. The resilience of Saltafen Rocks to erosion has a significant bearing on projected assessments of future shoreline position, and hence whether, or when, assets such as road and railway line would be lost to erosion.

The purpose of this transect is to monitor the sea bed changes offshore of Salterfen which could have an influence on its stability and resilience to erosion, which in turn has a significant bearing on evolution of a wider section of coastline.

3.3.2 Survey Findings

The bathymetric survey at Saltafen Rocks extends approximately 4.7km offshore to a depth of –25mOD. According to the BGS data, the survey area is predominantly underlain by mudstone and gypsum. The bathymetry, sea bed samples and BGS sea bed sediment data for Saltafen Rocks are displayed in Figure 3.3.

The interpretative mapping and long profile for Saltafen Rocks suggest that this area of sea bed is divided into three distinct zones.

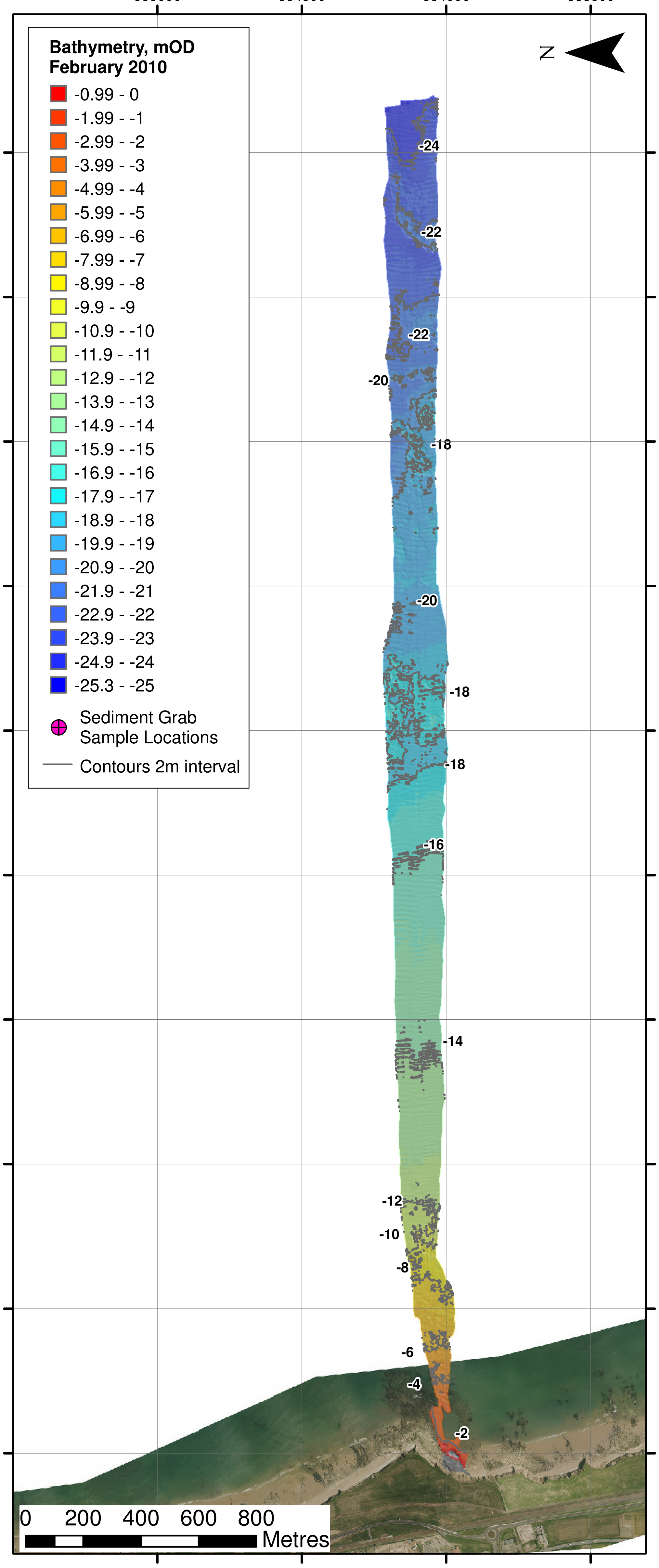
- Along the landward sections of the transect, to an offshore chainage of around 600m, bedrock is exposed on the foreshore, with pockets of predominantly very fine material (very fine sand, silts and clays) trapped between outcropping rocks.

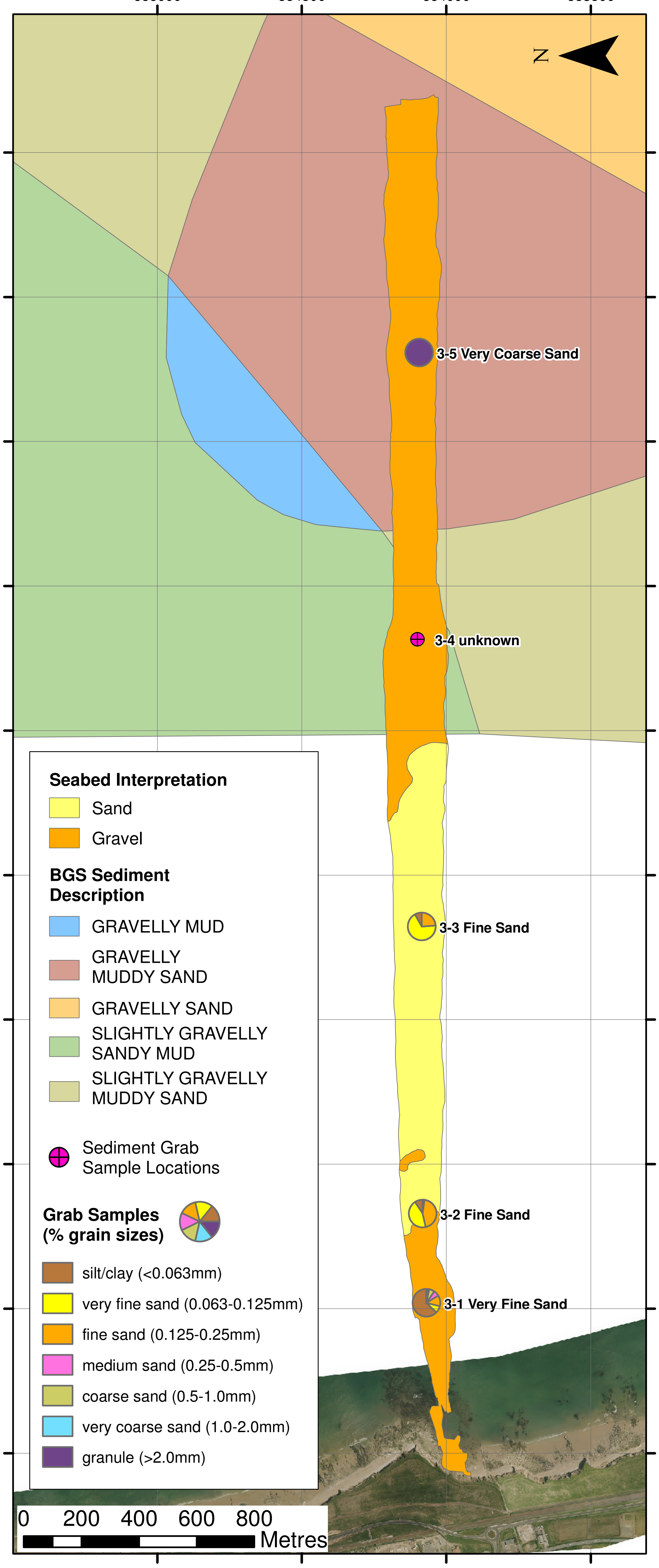
- The central section of the transect, between chainages of around 600m to 2.3km, is more characterised by fine to very fine sand covering the bedrock as a more continuous veneer.

- The seaward section of the transect, from around 2.3km to 4.7km is again characterised by exposed bedrock, but now with predominantly coarser material (almost exclusively granular material greater than 2mm in diameter) occasionally trapped between outcrops.

3.3.3 Review of Objectives

At this stage in the monitoring programme it is only possible to consider whether the scope and extent of the survey is likely to address the issues raised, particularly with respect to any results as to the nature of the sea bed. Following subsequent surveys the finding would be reviewed where the monitoring is picking up information relevant to the management issues.





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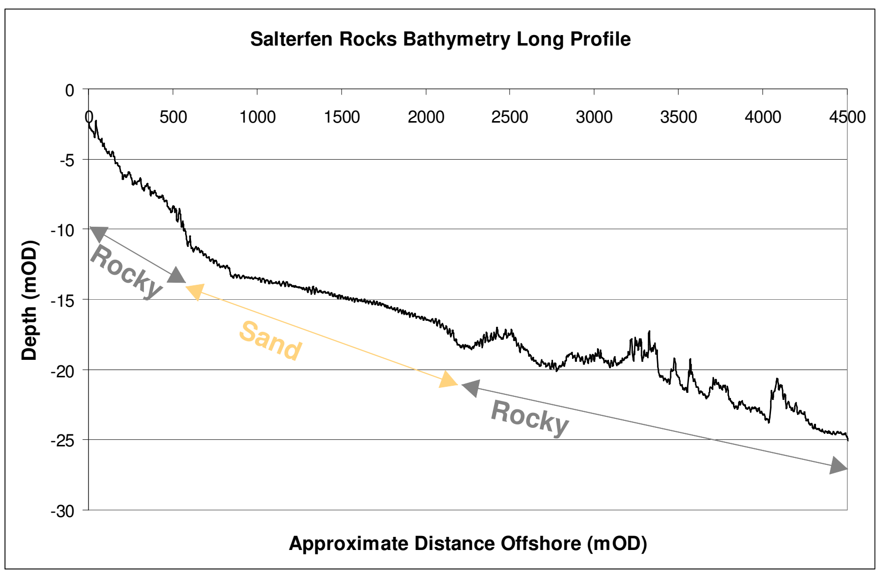

Figure 3.3
Salterfen Rocks Bathymetry & Interpretation

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3.4 Blast Beach

3.4.1 Background

Blast Beach is characterised by a relatively wide foreshore composed of colliery spoil which presently protects the stable backing cliffs. The SMP2 identifies that with sea level rise, material is likely to be eroded from the spoil beach and in the longer term could trigger recession of the cliffs.

The purpose of this transect is to observe for trends in the sea bed that could lead to accelerated erosion of the spoil beach material.

3.4.2 Survey Findings

The bathymetric survey at Blast Beach extends approximately 3.5km offshore to a depth of –24mOD. According to the BGS data, the survey area is predominantly underlain by mudstone and gypsum. The bathymetry, sea bed samples and BGS sea bed sediment data for Blast Beach are displayed in Figure 3.4.

The interpretative mapping and long profile for Blast Beach suggest that this area of sea bed is characterised by two distinct zones:

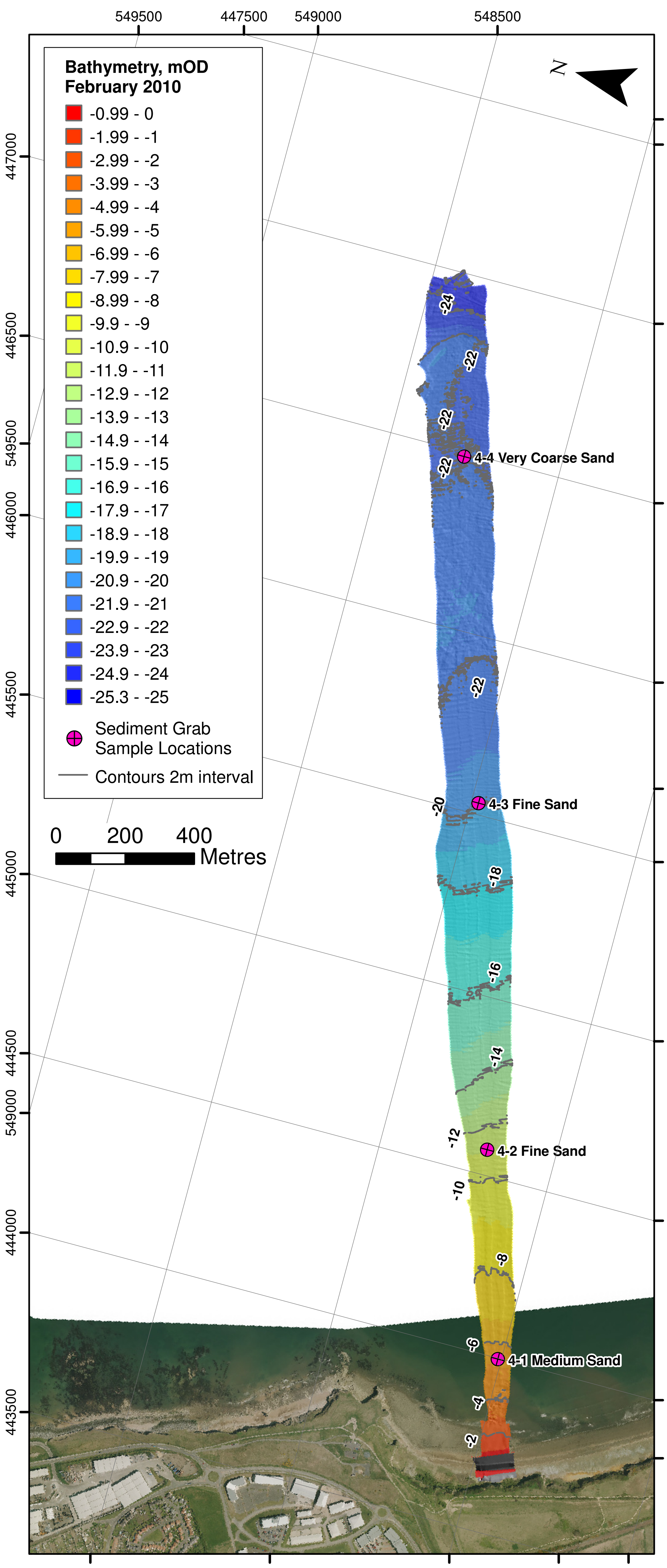
- The landward section (to a chainage of about 2.4km) is characterised by sand of varying grades with two isolated patches of gravel. This may be representative of some of the colliery waste that has fed the beaches in this location.

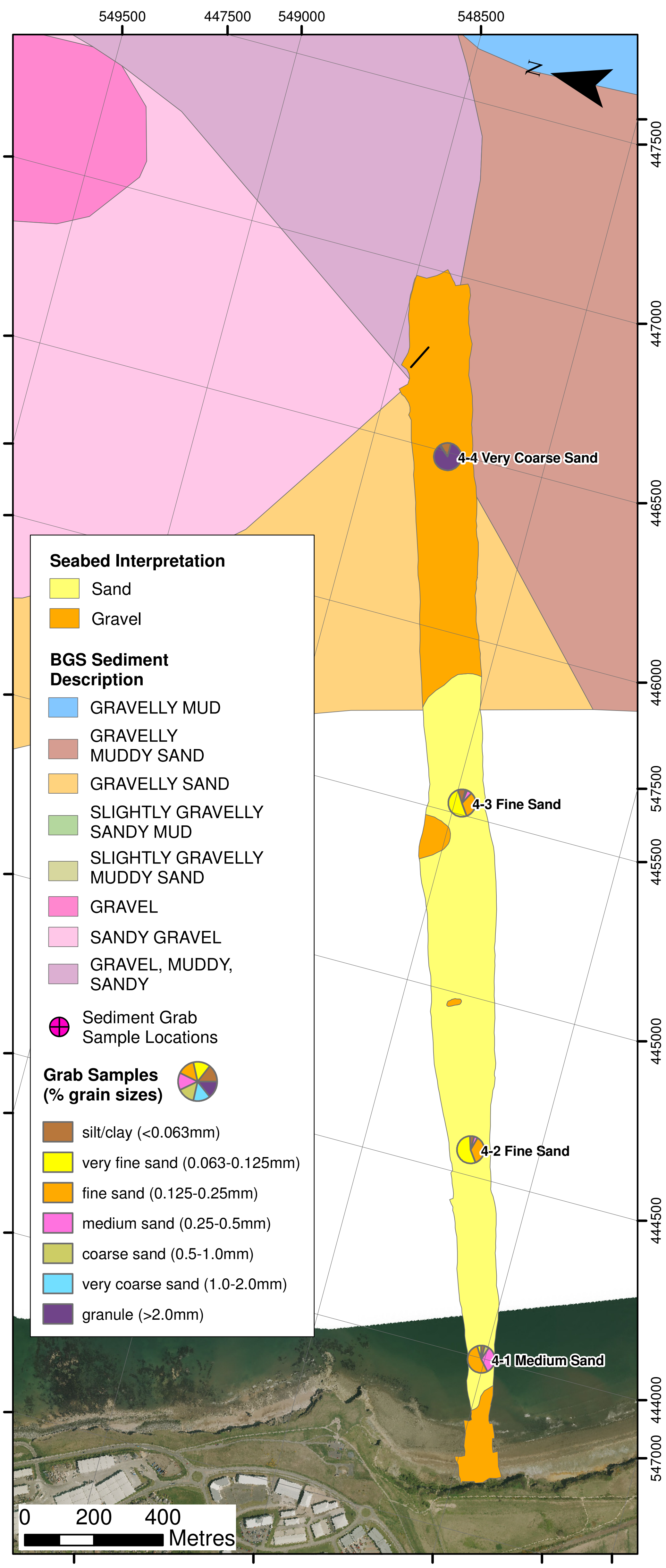
- The seaward section is more typically composed of gravel.

The sea bed gradient changes to generally become flatter offshore of the zone where there is this distinct change in sediment character.

3.4.3 Review of Objectives

At this stage in the monitoring programme it is only possible to consider whether the scope and extent of the survey is likely to address the issues raised, particularly with respect to any results as to the nature of the sea bed. Following subsequent surveys the finding would be reviewed where the monitoring is picking up information relevant to the management issues.





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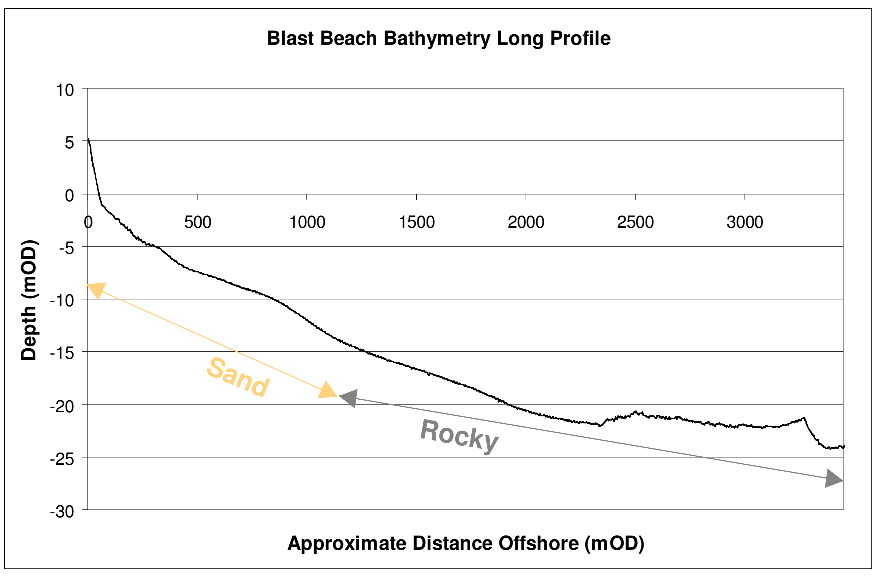

Figure 3.4
Blast Beach Bathymetry & Interpretation

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3.5 Hartlepool North Sands

3.5.1 Background

Hartlepool North Sands comprises a wide sandy beach backed by dunes, with various industrial works (some now disused), warehousing, residential development and a cemetery on the backing land.

The SMP2 identifies that with projected 50 and 100 year erosion lines would result in loss of dune, loss of land and loss of regeneration opportunity on presently derelict land. There are 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 purpose 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 coastline.

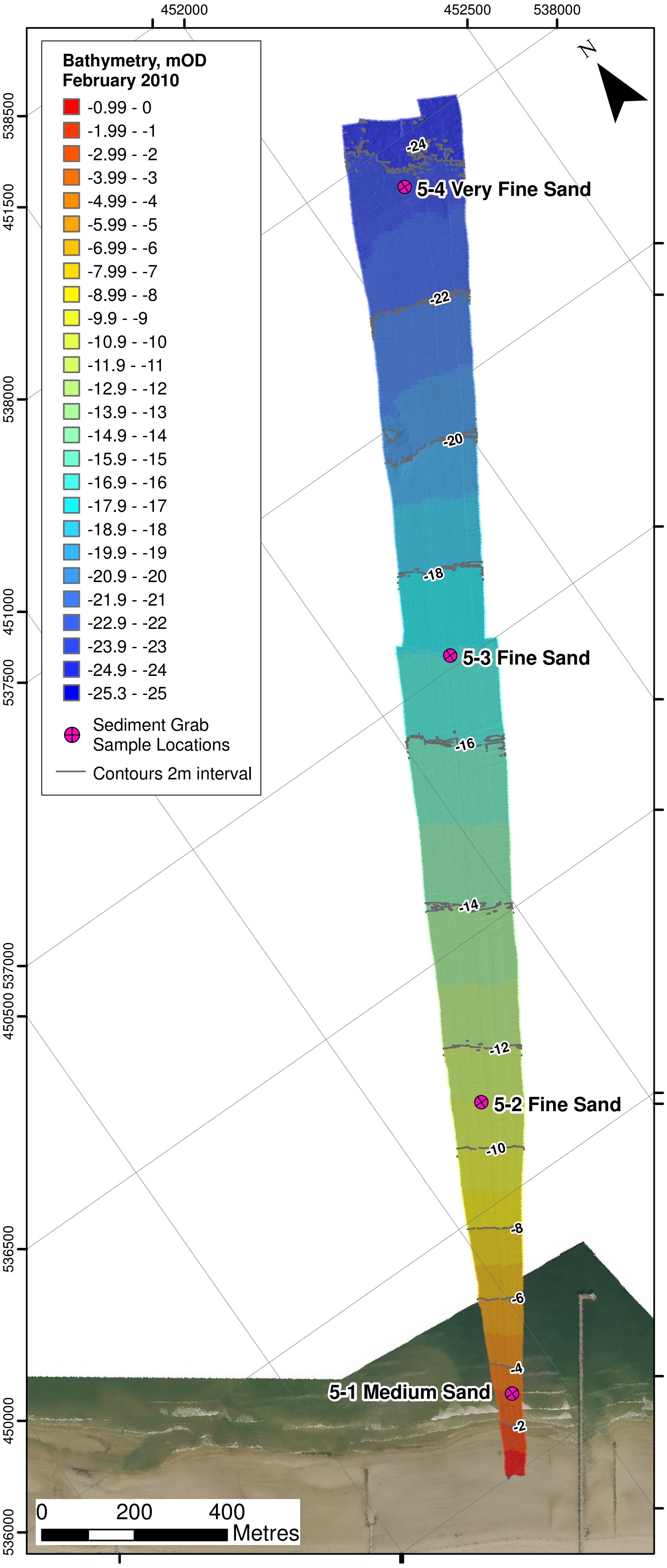
3.5.2 Survey Findings

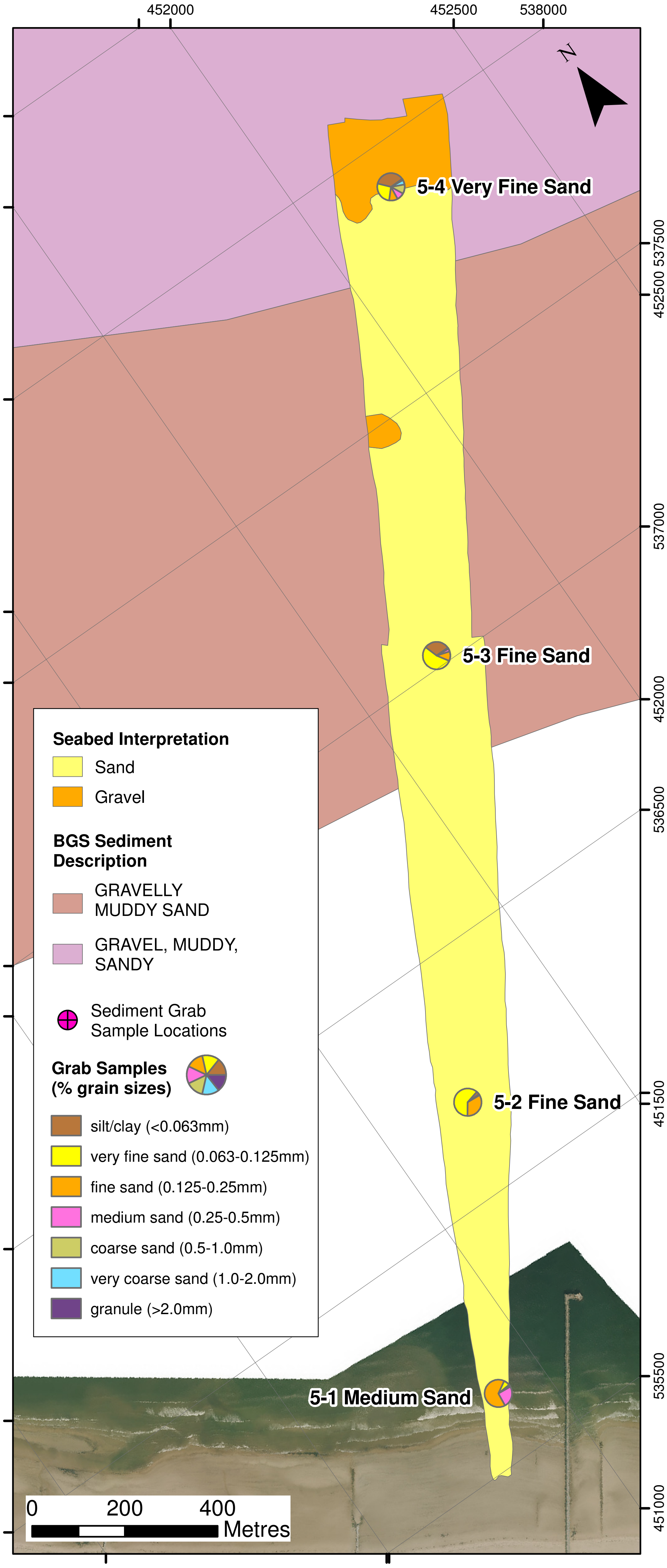
The bathymetric survey at Hartlepool North extends approximately 2.9km offshore to a depth of –25mOD. According to the BGS data, the survey area is predominantly underlain by mudstone and gypsum. The bathymetry, sea bed samples and BGS sea bed sediment data for Hartlepool North are displayed in Figure 3.5.

The interpretative mapping and long profile for Hartlepool North suggest that this area of sea bed is homogeneous to a depth of around 23mOD, being composed typically of sands of varying grades, mostly very fine or fine. Whilst the sea bed gradient does not change significantly, the sediment composition seaward of around 23mOD changes to become more gravely further offshore.

3.5.3 Review of Objectives

At this stage in the monitoring programme it is only possible to consider whether the scope and extent of the survey is likely to address the issues raised, particularly with respect to any results as to the nature of the sea bed. Following subsequent surveys the finding would be reviewed where the monitoring is picking up information relevant to the management issues.





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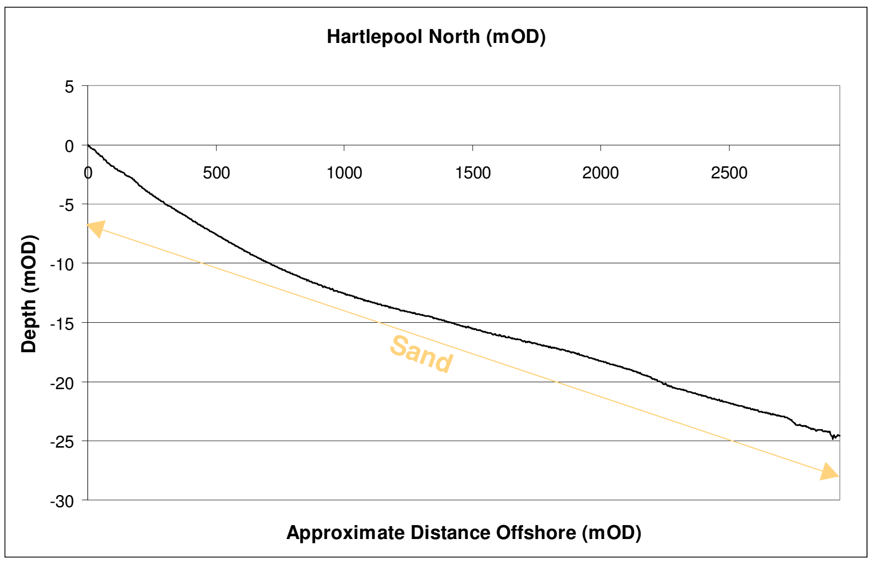

Figure 3.5
Hartlepool North Bathymetry & Interpretation

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3.6 Saltburn-by-the-Sea

3.6.1 Background

The SMP2 identifies that a significant area of Saltburn 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 purpose of this transect is to better understand the interactions between the beach and sea bed to ensure that coastal defences are appropriate.

3.6.2 Survey Findings

The bathymetric survey extends 4 km offshore where the sea bed reaches a depth of -25mOD. The BGS data shows the area is underlain by Jurassic limestone and mudstone of the Lias Group. The bathymetry and sea bed samples, together with existing BGS data on sea bed sediments, are shown in Figure 3.6.

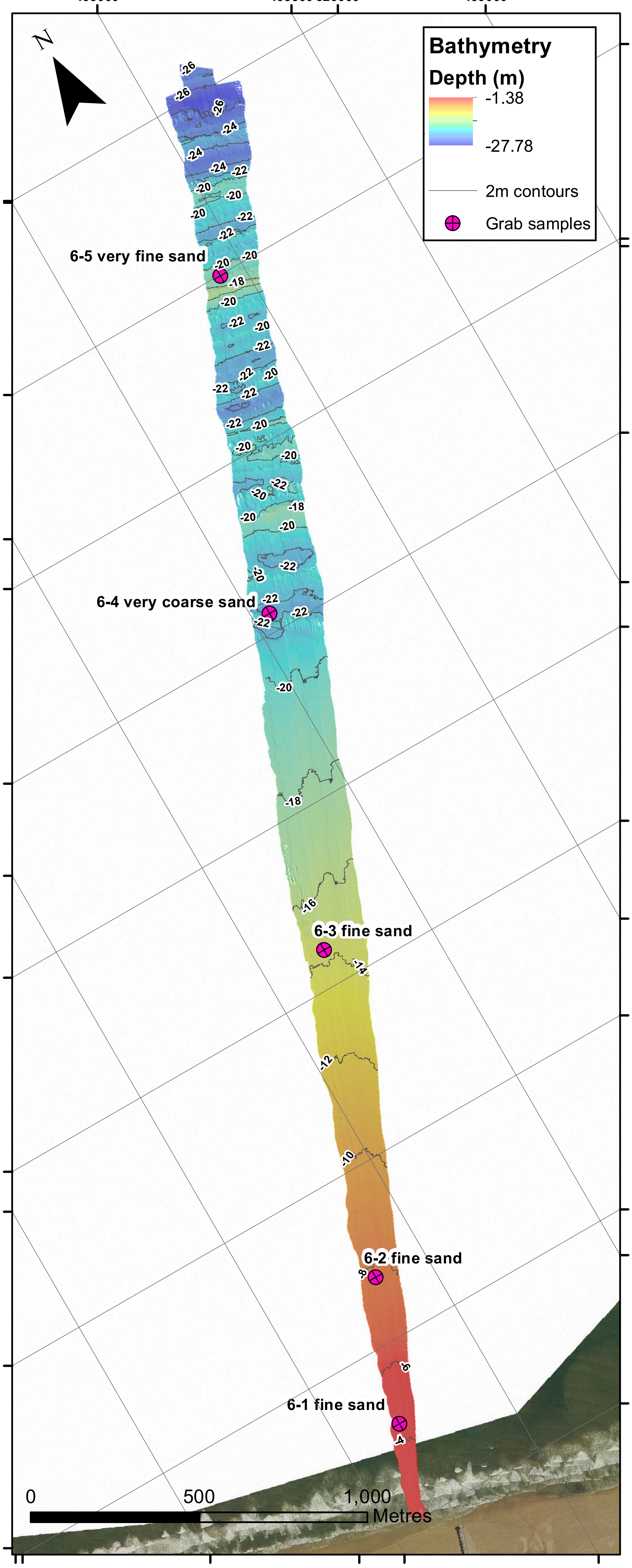
Sea bed mapping and a characteristic profile drawn through the data show the sea bed can be separated into two zones:

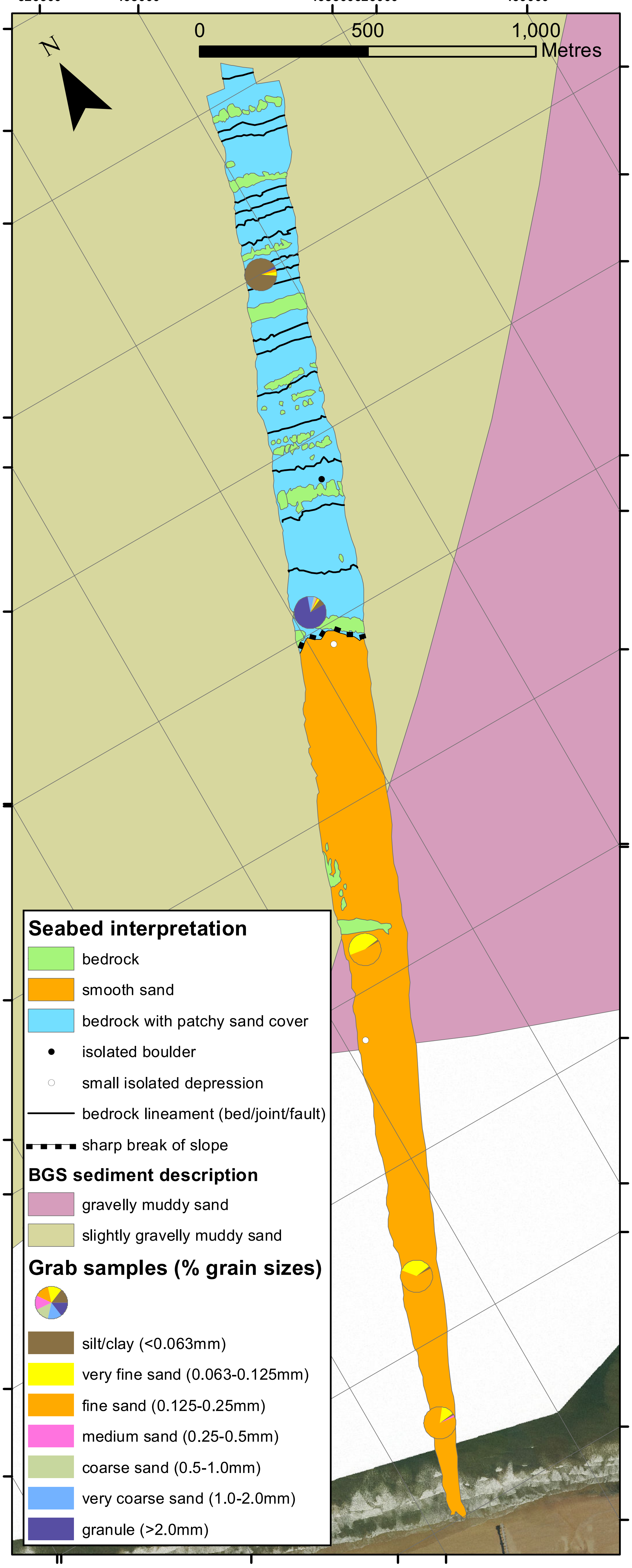
- a nearshore zone that extends to 2.5 km from the coast to 20 m depth, which is sandy and smooth, with a mean gradient of 0.4 degrees. This zone is generally featureless, with occasional small outcrops of rock and no bedforms can be discerned. The sea bed samples in this zone show fine sand, while BGS sea bed sediment mapping shows gravelly muddy sand in the nearshore area becoming slightly gravelly muddy sand further offshore.

- an offshore zone that extends from 2.5 km to 4 km offshore, characterised by a rugged sea bed with a mean gradient of 0.1 degrees. Bedrock crops out throughout the zone with clear evidence for gently dipping strata with a strike of ENE – WSW. The outcrop shows outcrop forms ranging from distinct saw-toothed dip and scarp slopes to isolated bedrock ‘reefs’ with *in situ* rock and detached boulders. This variation probably reflects changes in rock strength. Sea bed sediments in this zone are located in bedrock hollows and samples ranging from very coarse sand to very fine sand were recovered. BGS sea bed sediment mapping shows slightly gravelly muddy sand throughout the area, and does not recognise any bedrock outcrop. This difference probably reflects the low resolution of the BGS data.

3.6.3 Review of Objectives

At this stage in the monitoring programme it is only possible to consider whether the scope and extent of the survey is likely to address the issues raised, particularly with respect to any results as to the nature of the sea bed. Following subsequent surveys the finding would be reviewed where the monitoring is picking up information relevant to the management issues.





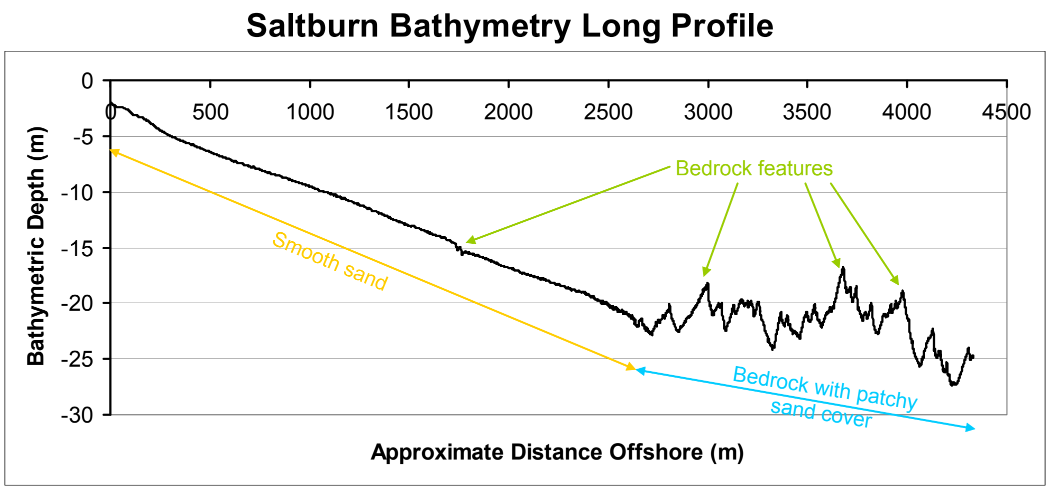


Figure 3.6
Saltburn-by-the-Sea Bathymetry & Interpretation

Client: Scarborough Borough Council

Project: Cell 1 Seabed Characterisation Study

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GIS Filename: Saltburn.mxd

3.7 Skinningrove

3.7.1 Background

The village of Skinningrove rests on a low till platform with a stream running to the southern and eastern sides of the village. The basic concrete block wall which protects the village has been enhanced through the construction of a rock fishtail groyne to the eastern side of the beck. The SMP2 has identified that this structure has encouraged significant build up of material along the foreshore.

The purpose of this transect is to better understand the interactions between the sediments along the sea bed and the shoreline, and how they are influenced by the coastal defence structures, especially the rock fish tail groyne.

3.7.2 Survey Findings

The bathymetric survey for Skinningrove extends approximately 3.6km offshore to a depth of 26mOD. According to the BGS data, this area is underlain by Jurassic limestones and mudstones of the Lias Group. The bathymetry, sea bed samples and BGS sea bed sediment data are displayed in Figure 3.7.

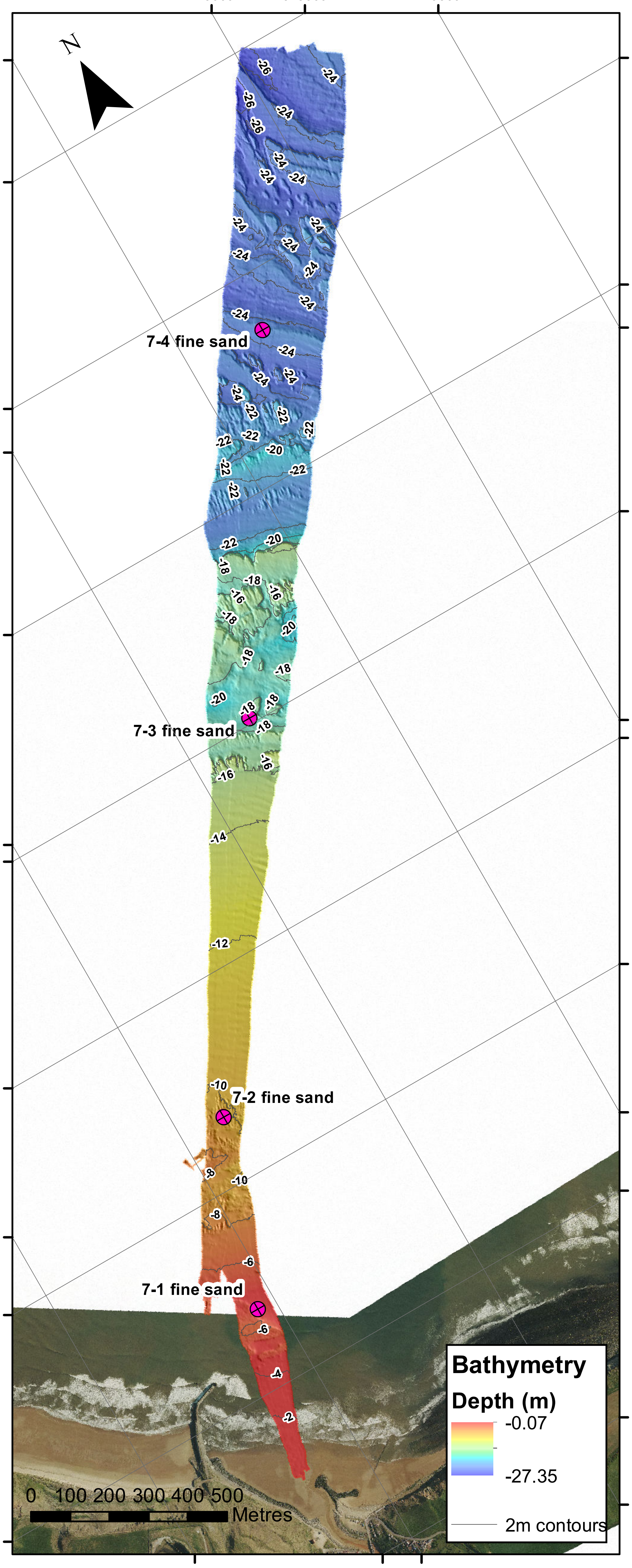
The sea bed mapping and long profile of this section of bathymetry indicate the area is characterised by two key zones:

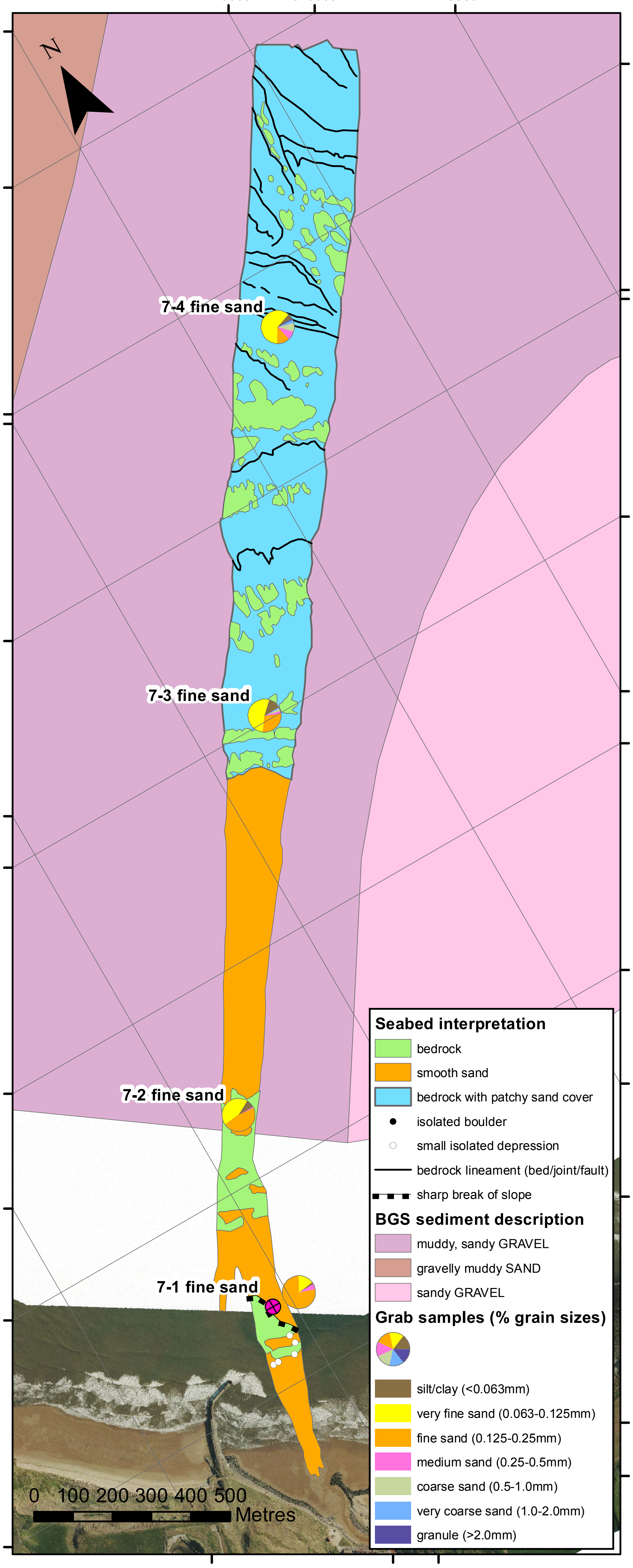
- A nearshore zone which is predominantly sandy and smooth but which is interspersed with areas of bedrock. The bedrock has a rough and uneven surface with no clear bedding or jointing. The zone extends to c. 1.8 km offshore and has a mean slope angle of 0.3 degrees. It is largely featureless with the exception of some small isolated depressions in the surface of the sand, which may be bedforms or scour hollows. The two grab samples in this zone recovered fine sand. Sea bed mapping indicates bedrock and sand in the area samples. The BGS sediment data indicates muddy sandy gravel.

- An offshore zone which extends from 1.8 km to 3.6 km offshore and is characterised by outcrops of bedrock with a patchy cover of smooth sand that have accumulated in bedrock hollows. The bedrock outcrops include isolated linear ‘reefs’ and more distinct saw-tooth dip and scarp slopes caused by marine erosion. Bedding and jointing or faulting is clearly visible and shows a complex pattern with beds striking from WNW to ESE to WSW to ENE and joints/faults aligned NNW to SSE. .The two grab samples within this zone both recovered fine sand that lies in hollows between the rock outcrops. BGS sediment mapping indicates muddy sandy gravel in this area, and does not show any bedrock outcrops. This difference may reflect the coarse resolution of the BGS data.

3.7.3 Review of Objectives

At this stage in the monitoring programme it is only possible to consider whether the scope and extent of the survey is likely to address the issues raised, particularly with respect to any results as to the nature of the sea bed. Following subsequent surveys the finding would be reviewed where the monitoring is picking up information relevant to the management issues.





Skinningrove Bathymetry Long Profile

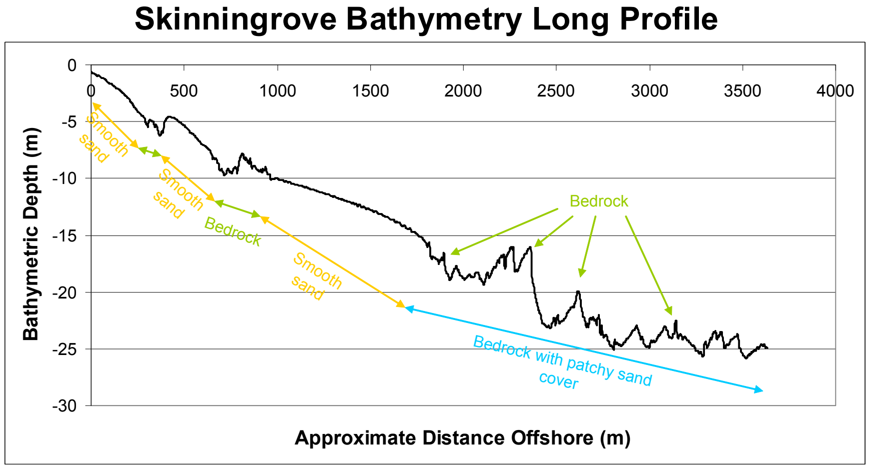


Figure 3.7 Skinningrove Bathymetry & Interpretation

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Project: Cell 1 Seabed Characterisation Study

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3.8 Runswick Bay

3.8.1 Background

Runswick Bay is formed between the headlands of Caldron Cliff and Kettleness and comprises a quite deeply indented sandy bay backed mostly by cliffs but also with steep till coastal slopes.

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 recommends the urgent need for works as detailed in the strategy.

The purpose 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.

3.8.2 Survey Findings

The bathymetric survey for Runswick Bay extends approximately 2.4 km offshore to a depth of 25mOD. According to the BGS data, this area is underlain by Jurassic limestones and mudstones of the Lias Group. The bathymetry, sea bed samples and BGS sea bed sediment data are displayed in Figure 3.8.

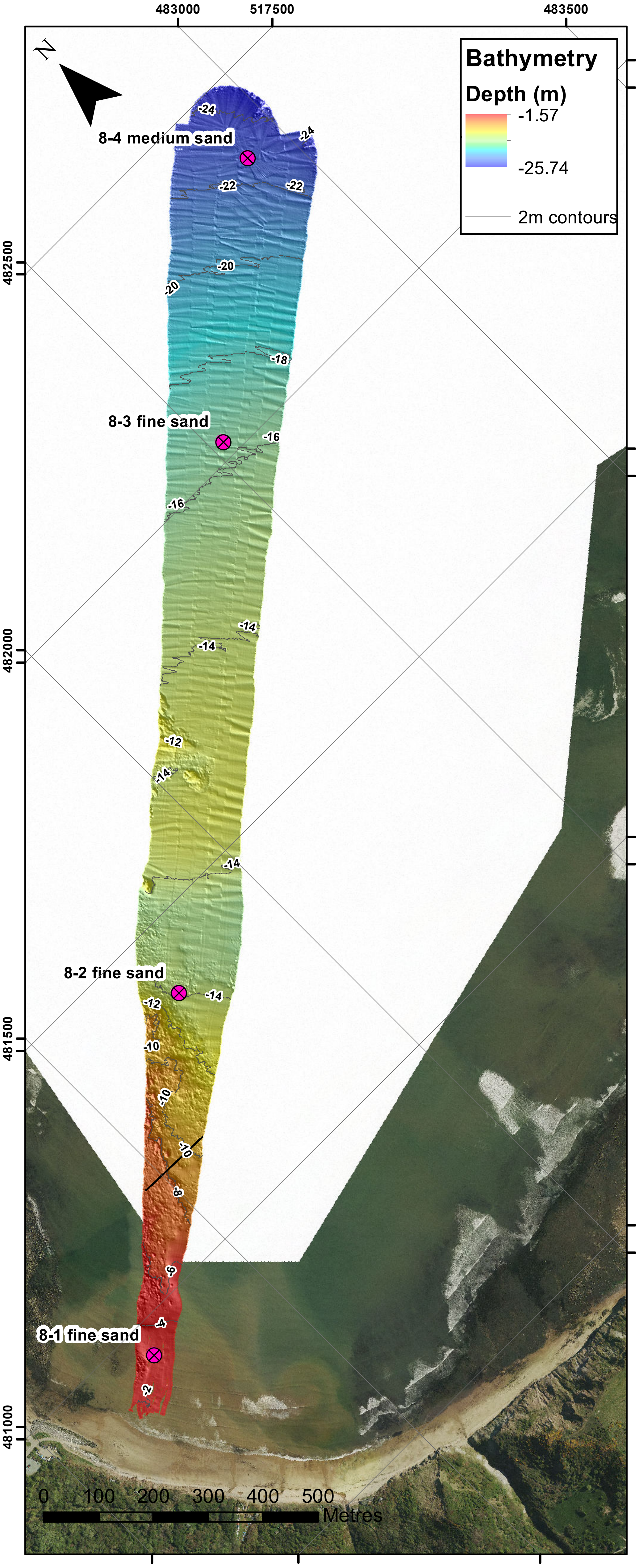
The sea bed bathymetry, mapping and long profile for Runswick Bay indicate that the area can be categorised into two main zones:

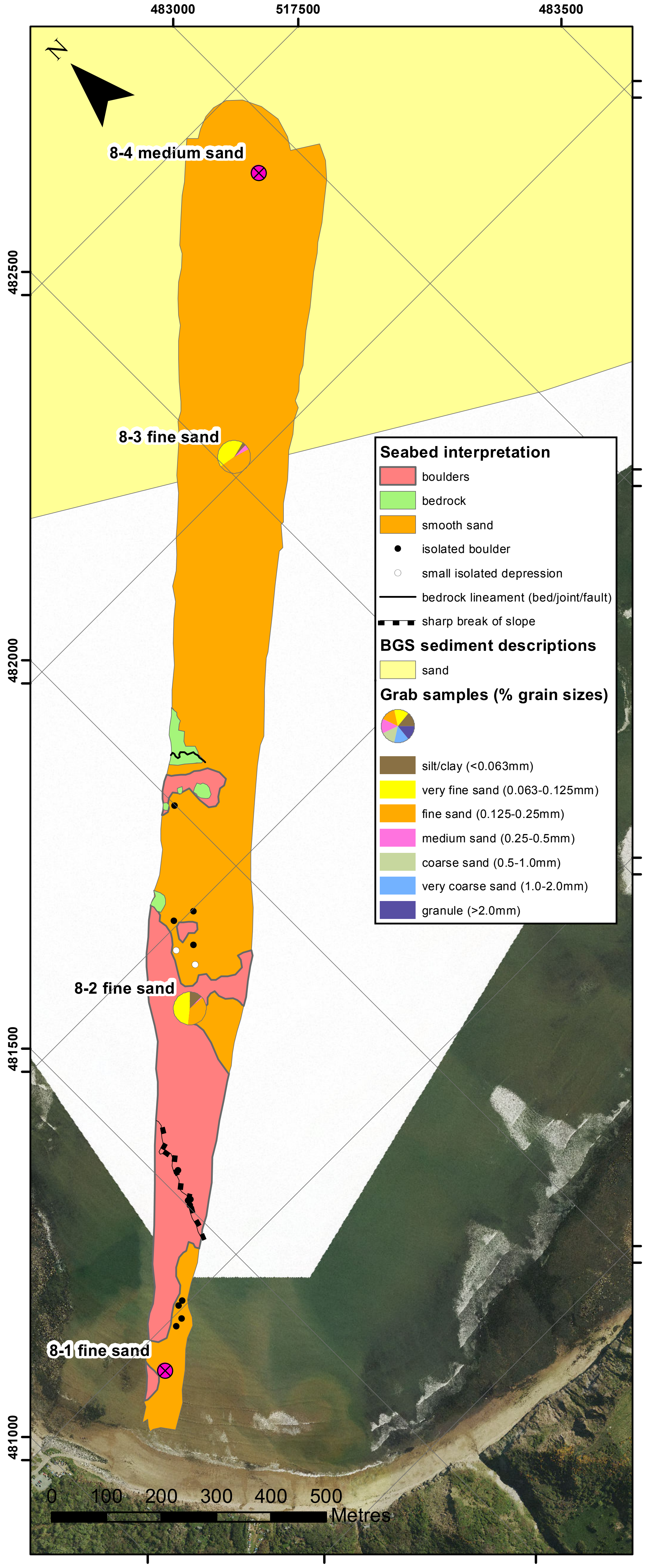
- A nearshore zone that extends to a depth of around -12 mOD, slopes at about 0.6 degrees, and which is characterised by a rugged boulder-strewn sea bed with smaller patches of smooth sand. The boulder zone is characterised by a marked 1.5 m step down from -7.5 mOD to -9 mOD at around 500 m offshore. The step is aligned NNE – SSW and may represent a fault offset not recognised in BGS mapping, or, more likely, an engineered feature such as a buried cable. Grab samples within this zone indicate a sea bed composed of fine to medium sands. The BGS data does not cover this nearshore area.

- Further offshore, the sea bed is characterised by smooth sand with occasional rocky outcrops and boulders, particularly in the shallower part. The long profile suggests the area has a convex form, with slope angles of under 0.5 degrees. Sea bed samples in this area recovered fine to medium sands. The BGS sediment mapping also indicates sand. The morphology on the surface of the sand shown in the bathymetry data is evenly spaced and defined by individual survey swathes. It is thought to relate to subtle error in the data and not representative of bedforms.

3.8.3 Review of Objectives

At this stage in the monitoring programme it is only possible to consider whether the scope and extent of the survey is likely to address the issues raised, particularly with respect to any results as to the nature of the sea bed. Following subsequent surveys the finding would be reviewed where the monitoring is picking up information relevant to the management issues.





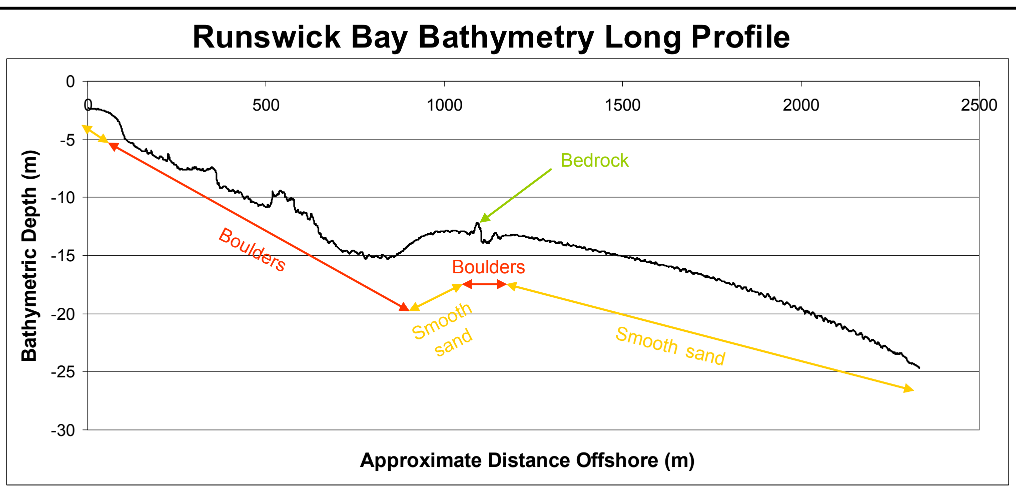


Figure 3.8
Runswick Bay Bathymetry & Interpretation

Client: Scarborough Borough Council

Project: Cell 1 Seabed Characterisation Study

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GIS Filename: Runswick Bay.mxd

3.9 Sandsend

3.9.1 Background

The coast road at Sandsend is under some pressure from erosion and the SMP2 recommends a policy of managed realignment of the road in the medium and longer-term epochs, supported by further investigations of options for achieving this.

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

3.9.2 Survey Findings

The bathymetric survey for Sandsend extends approximately 2.7km offshore to a depth of 24mOD. According to the BGS data, this area is underlain by Jurassic limestones and mudstones of the Lias Group. The bathymetry, sea bed samples and BGS sea bed sediment data are displayed in Figure 3.9.

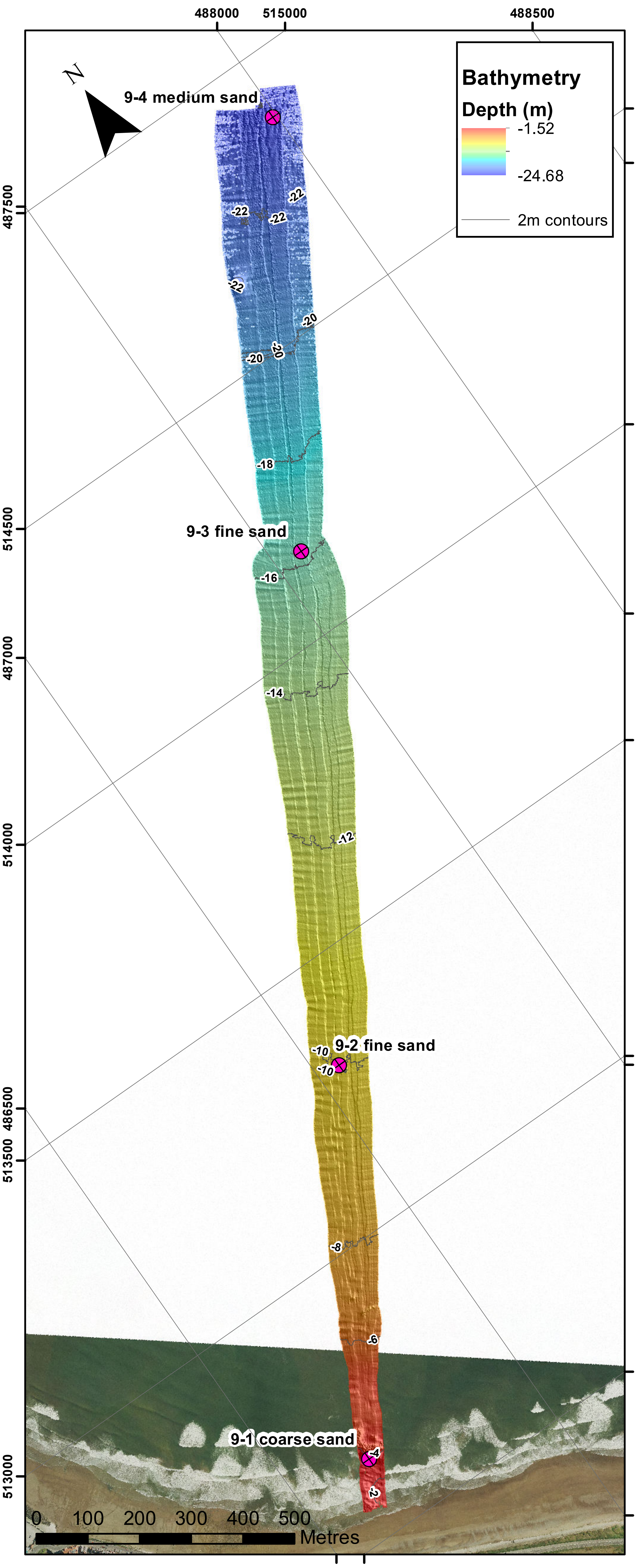
The sea bed interpretation mapping and long profile for the Sandsend bathymetry indicate that this area is characterised by two main zones, as follows:

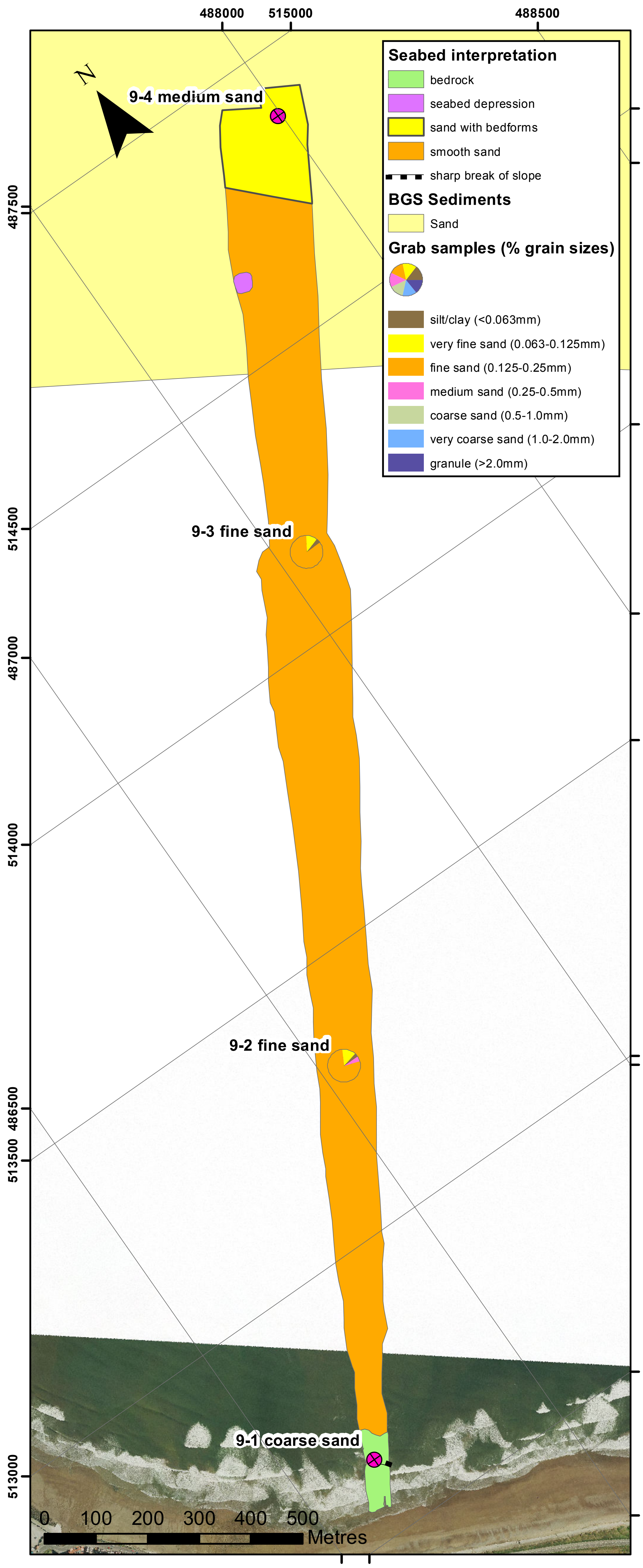
- A small nearshore zone which extends about 150 m offshore to a depth of about -4.7 mOD and has a mean gradient of 0.8 degrees. This area comprises bedrock of boulders at sea bed with a sharp drop in elevation of c. 2m at 90m offshore. Grab samples recovered coarse sand. There is no BGS data in this nearshore area.

- An offshore zone which covers the majority of the survey area. This zone is generally smooth and sandy, with a mean gradient of 0.4 degrees. A localised area of linear, NE - SW trending bedforms is seen in the area deeper than -22mOD. The remaining area has no clear bedforms, and is featureless apart from an isolated sea bed depression about 2.3km offshore. This feature is roughly circular with a diameter of c.35m and a depth below the surrounding sea bed of c.0.8m.The interpretation of this feature is uncertain. The grab samples from this zone indicate a sea bed of fine sand to medium sand. The BGS sediment classification is sand.

3.9.3 Review of Objectives

At this stage in the monitoring programme it is only possible to consider whether the scope and extent of the survey is likely to address the issues raised, particularly with respect to any results as to the nature of the sea bed. Following subsequent surveys the finding would be reviewed where the monitoring is picking up information relevant to the management issues.





Sandsend Bathymetry Long Profile

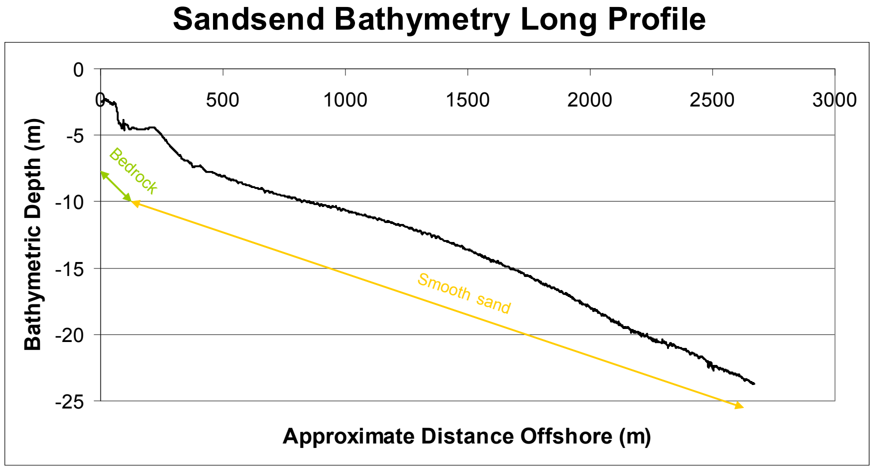


Figure 3.9
Sandsend Bathymetry & Interpretation

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Project: Cell 1 Seabed Characterisation Study

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GIS Filename: Sandsend.mxd

3.10 Whitby Sands

3.10.1 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 easterly drifting sediments and help retain the beach. The SMP2 identifies that there is some 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.

3.10.2 Survey Findings

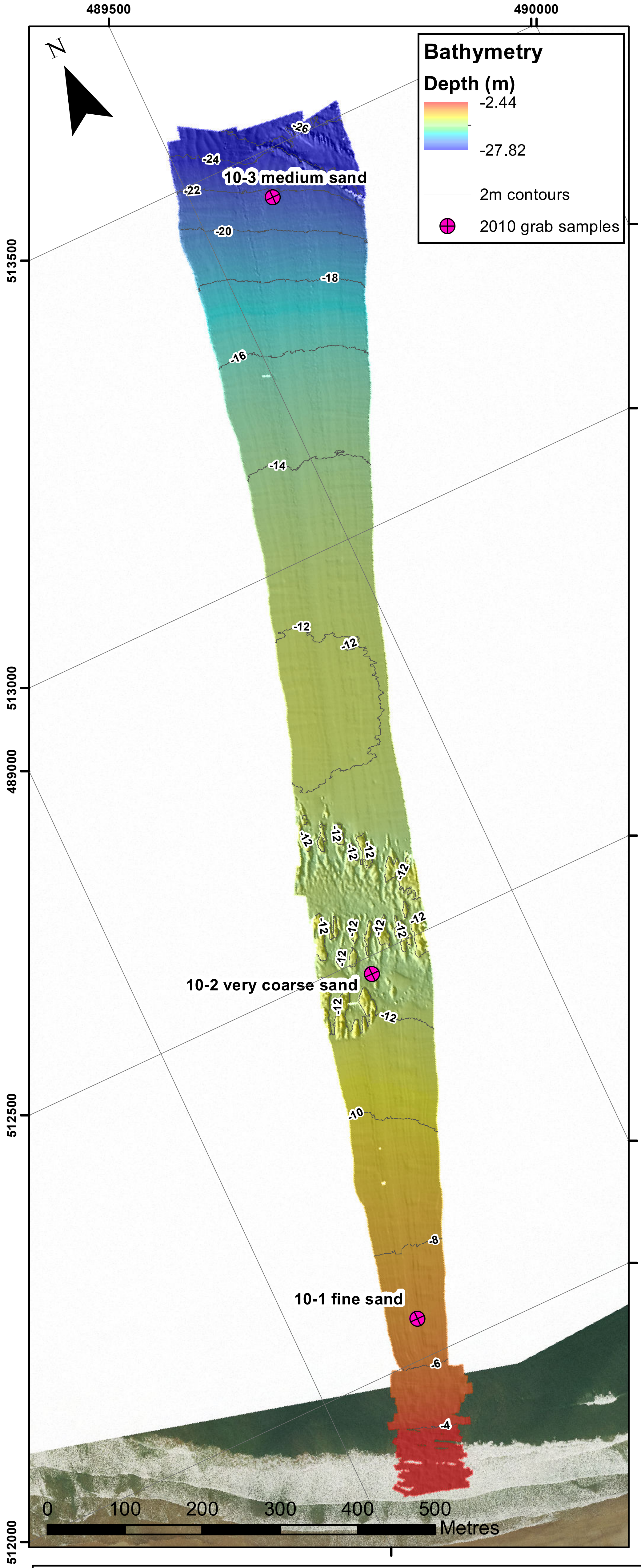
The bathymetric survey for Whitby West Beach extends approximately 1.7km offshore to a depth of 26mOD. BGS data indicates this area is underlain by Jurassic limestones and mudstones of the Lias Group. The bathymetry, sea bed samples and BGS sea bed sediment data are displayed in Figure 3.10.

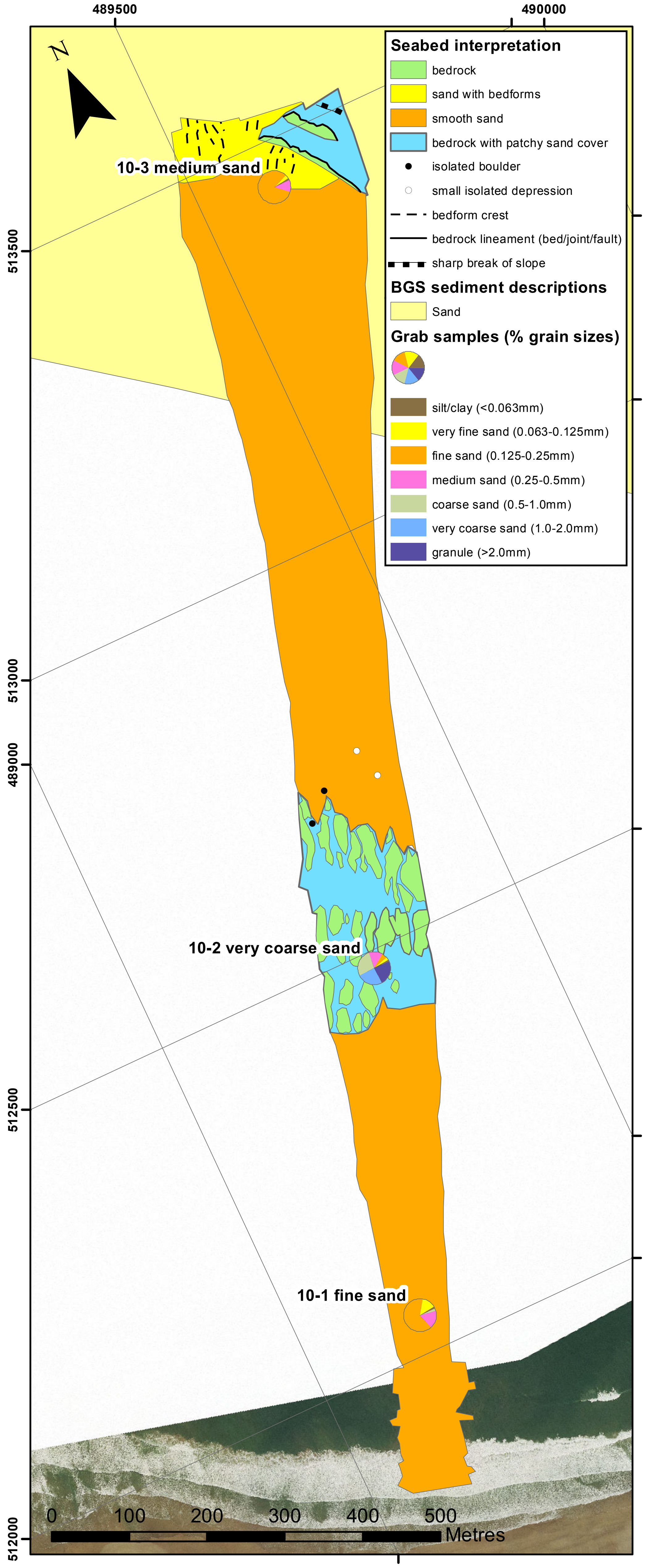
The interpretative mapping and long profile graph for Whitby West Beach indicates the sea bed can be categorised into five types:

- The nearshore area, to a depth of -12mOD, comprises smooth, featureless sea bed, with a mean gradient of 1 degree. A grab sample proved fine sand. Bedforms are not observed; the observed sea bed patterns relate to data joins between individual survey swathes.
- From around 600 m or 850 m offshore, the sea bed is characterised by an outcrop of uneven rock pinnacles with intervening smooth sand with a depth range of -13.5mOD to -10.5mOD. The individual rocky pinnacles have significant relief, and rise up to 2.5m above the intervening sandy areas. They are aligned in a NNE-SSW direction, range in length from c.5 m to c.75 m and are typically 10 to 15 m wide. A grab sample from this area recovered very course sand.
- The sea bed from 850 m to 1.6 km offshore reaches a depth of -22mOD and is similar to the nearshore zone, being smooth and featureless. The long profile indicates this area of sea bed has a distinct convex morphology, suggesting it is a sand bank.
- From 1.6 to 1.7 km offshore in the western half of the survey area, the sandy sea bed is characterised by bedforms. The features are slightly sinuous, aligned NNE-SSW, typically spaced 10 to 15 m apart and up to 60 m in length. Grab samples in the vicinity show of medium sand. BGS sea bed sediment data indicates sand.
- From 1.6 to 1.7 km offshore in the eastern half of the survey area, an area of bedrock with patchy sand cover is observed. The outcrop is observed at a depth of -22mOD to -28mOD and beds with a strike of NW-SE are seen. This rocky outcrop is not identified in the BGS sediment mapping.

3.10.3 Review of Objectives

At this stage in the monitoring programme it is only possible to consider whether the scope and extent of the survey is likely to address the issues raised, particularly with respect to any results as to the nature of the sea bed. Following subsequent surveys the finding would be reviewed where the monitoring is picking up information relevant to the management issues.





Whitby West Beach Bathymetry Long Profile

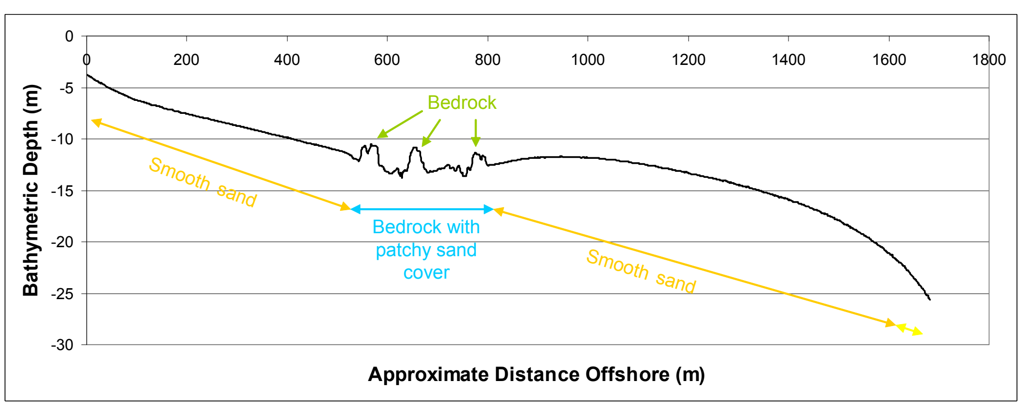


Figure 3.10
Whitby West Beach Bathymetry & Interpretation

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Project: Cell 1 Seabed Characterisation Study

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3.11 Robin Hood's Bay

3.11.1 Background

Robin Hood's Bay comprises exposed rock scar, with occasional sand beaches at the toe, backed by cliffs. 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 landsliding 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.

3.11.2 Survey Findings

The bathymetric survey for Robin Hood's Bay extends approximately 1.8km offshore to a depth of -27mOD. The BGS data indicates nearshore bedrock is Jurassic limestones and mudstones of the Lias Group, while further offshore the area is underlain by a downthrown block of younger Jurassic sandstones and mudstones of the West Sole Group. The normal fault that delineates the boundary between the two rock units is not visible at sea bed. The bathymetry, sea bed samples and BGS sea bed sediment data for Robin Hoods Bay are displayed in Figure 3.11.

The interpretative mapping and long profile graph for Robin Hood's Bay suggest that this area of sea bed is characterised by three key zones:

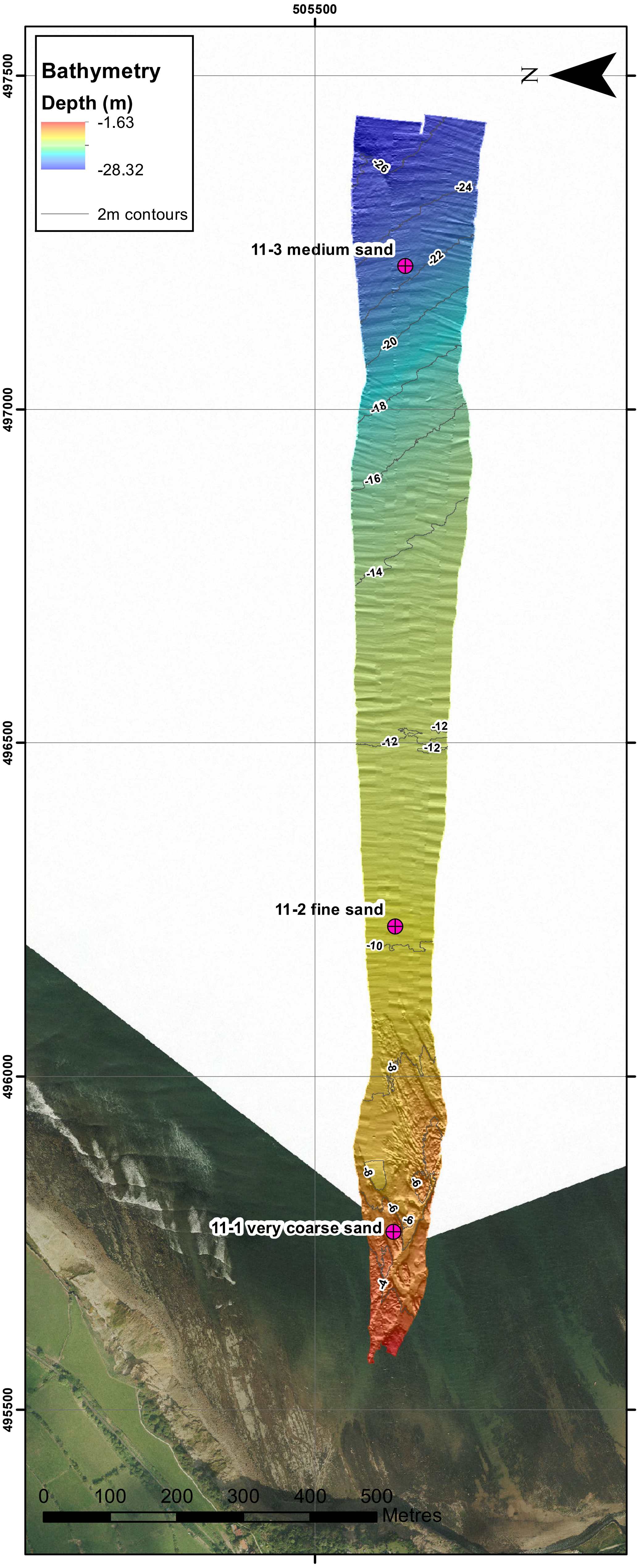
- A nearshore zone to a depth of c. -8mOD where the bedrock crops out at sea bed and there is an intermittent cover of sand. Bedding is clearly visible and trends NE to SE, which accords with the regional pattern evident in the aerial photograph. The bedrock also shows a series of faults which trend ESE – WSW and can be traced over the foreshore in the aerial photograph. Due to the bedding and faulting of the rock, the sea bed form in this zone is complicated, with sharp breaks of slope, occasional boulders and linear sand-filled depressions between outcrops of bedding. Grab sample data collected within this zone suggests a sea bed composed of very coarse sand. The BGS sediment data does not extend close enough to the shoreline to cover this zone.

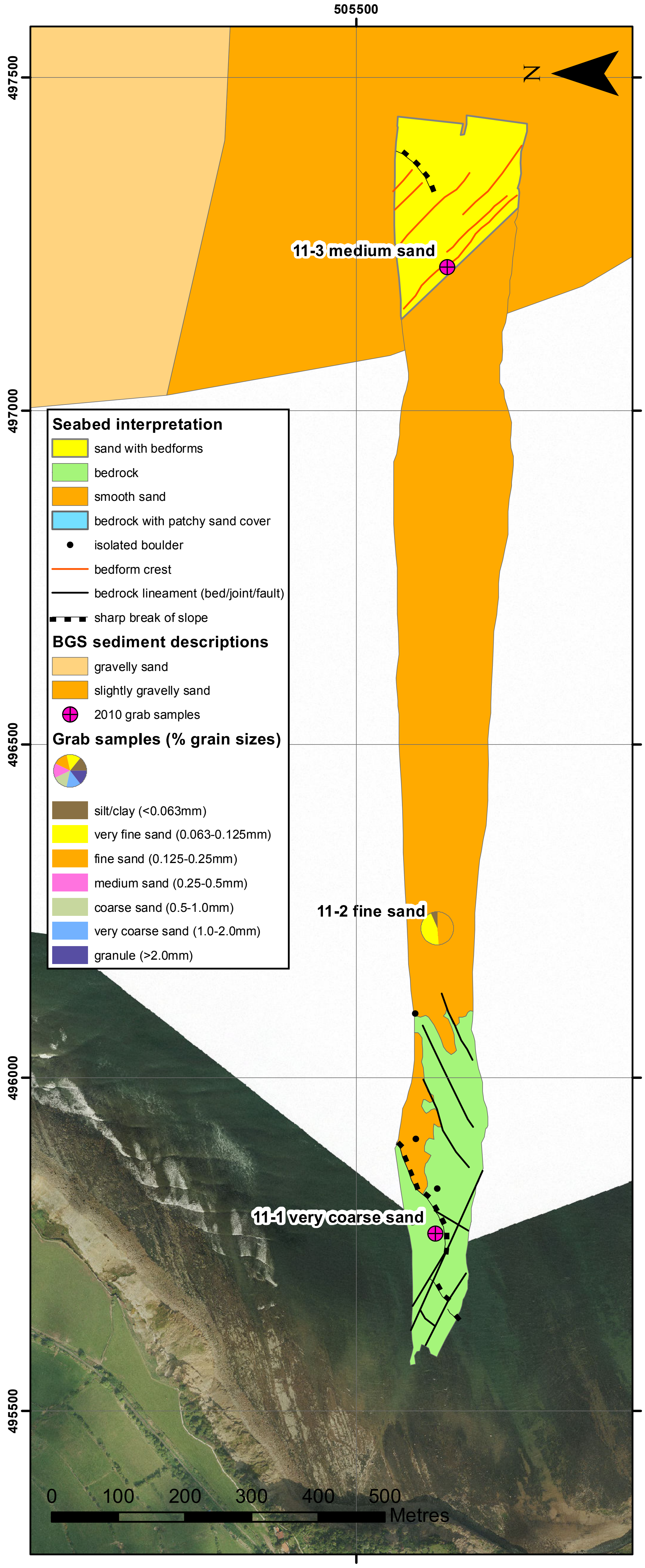
- Beyond the outcrop of bedrock, to a depth of c. -22mOD, the sea bed is smooth and featureless. Grab samples indicate fine to medium sand. The long profile indicates that this zone has a convex form, suggesting it represents a sand bank.

- The deepest section of sea bed, from -22 to -27mOD, is characterised by subtle linear bedforms that are spaced 10 to 40m apart and aligned NW – SE. A sharp break of slope cuts through the bedforms at right angles. It is unclear whether this feature represents a bedform or some expression of the subjacent bedrock geology. A grab sample taken within this zone shows medium sand. BGS sediment descriptions in this area show slightly gravelly sand

3.11.3 Review of Objectives

At this stage in the monitoring programme it is only possible to consider whether the scope and extent of the survey is likely to address the issues raised, particularly with respect to any results as to the nature of the sea bed. Following subsequent surveys the finding would be reviewed where the monitoring is picking up information relevant to the management issues.





Robin Hoods Bay Bathymetry Long Profile

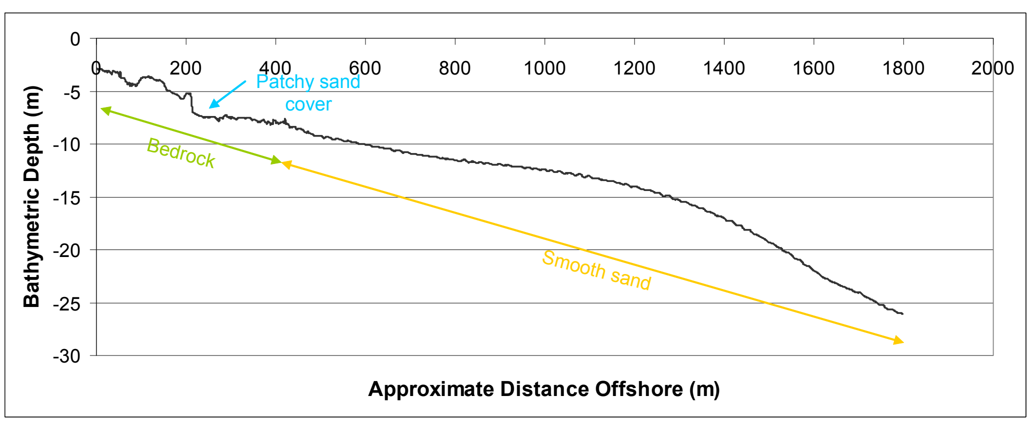


Figure 3.11
Robin Hoods Bay Bathymetry & Interpretation

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Project: Cell 1 Seabed Characterisation Study

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3.12 Scarborough North Bay

3.12.1 Background

Scarborough North Bay comprises a sandy beach backed by coastal defences which protect a promenade, residential properties and amenity assets. The SMP2 identifies that there are complex wave patterns in the bay which could influence shoreline behaviour and that the condition of coastal defences is in need of 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 as recommended by the recent Strategy review.

3.12.2 Survey Findings

The bathymetric survey for Scarborough North Bay extends approximately 2.8km offshore to a depth of -25mOD. According to the BGS data, the survey area is underlain by Jurassic sandstones and mudstones of the West Sole Group. The bathymetry, sea bed samples and BGS sea bed sediment data for Scarborough North Bay are displayed in Figure 3.12.

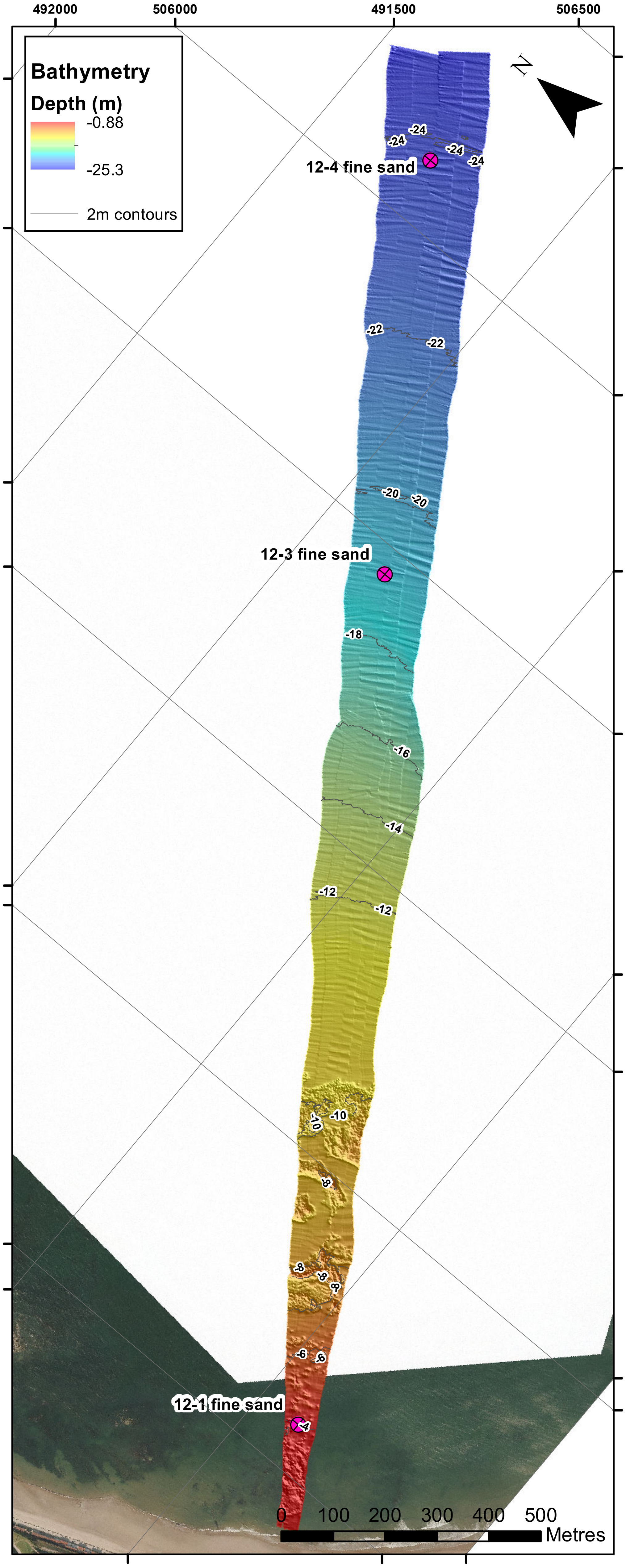
The interpretive mapping and long profile graph for Scarborough North Bay suggest that this area of sea bed is broadly characterised by two different sea bed types:

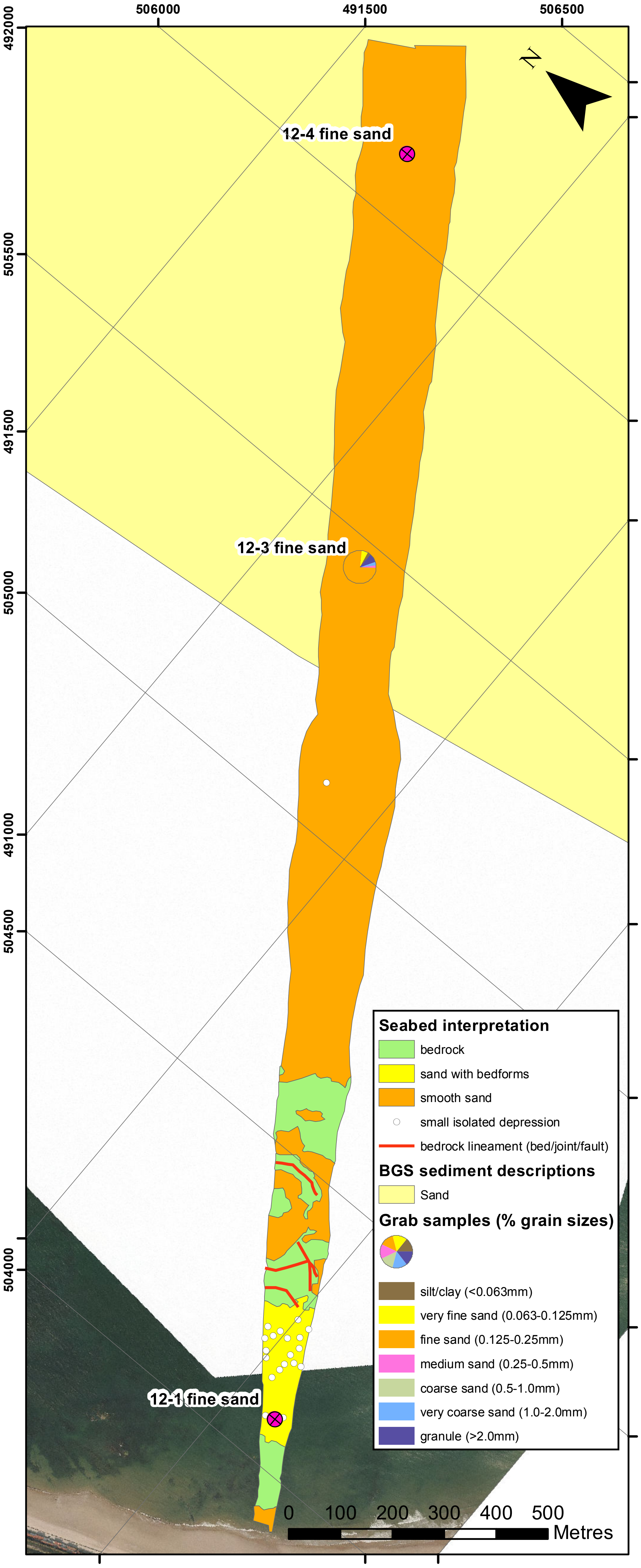
- A complex nearshore zone, which extends c. 900 m to a depth of c. -11mOD at an average gradient of 0.5 degrees. This zone is extremely variable, and comprises areas of patchy smooth sand over rough bedrock to c. -3mOD, pitted sand from -3 to -7mOD and bedrock with clear bedding from -7 to -11mOD. The area of sand and bedrock nearest the shoreline is featureless, and indicative of a thin cover of sand over outcrops of bedrock or boulders. The area of pitted sea bed is characterised by numerous small and shallow (typically 0.6m deep and 10m diameter) depressions in the sea bed. The bases of the depressions are rough, and appear to be bedrock. The features probably represent an area of thin cover of sand over uneven bedrock. A grab sample from this location proved fine sand. The area of bedrock further offshore has clear bedding, including a curved ridge, which trends approximately north to south, which stands proud of the surrounding sea bed by over 1.5m.

- Further offshore, in deeper waters, the sea bed is smooth and sandy. This area lacks bedforms or other sea bed features. The grab samples within this zone indicate that the sea bed is composed of fine sands. This is in agreement with BGS sediment description of sand. The long profile from this zone is convex, particularly between 1 and 2 km offshore, which probably represents a large sand bank.

3.2.4 Review of Objectives

At this stage in the monitoring programme it is only possible to consider whether the scope and extent of the survey is likely to address the issues raised, particularly with respect to any results as to the nature of the sea bed. Following subsequent surveys the finding would be reviewed where the monitoring is picking up information relevant to the management issues.





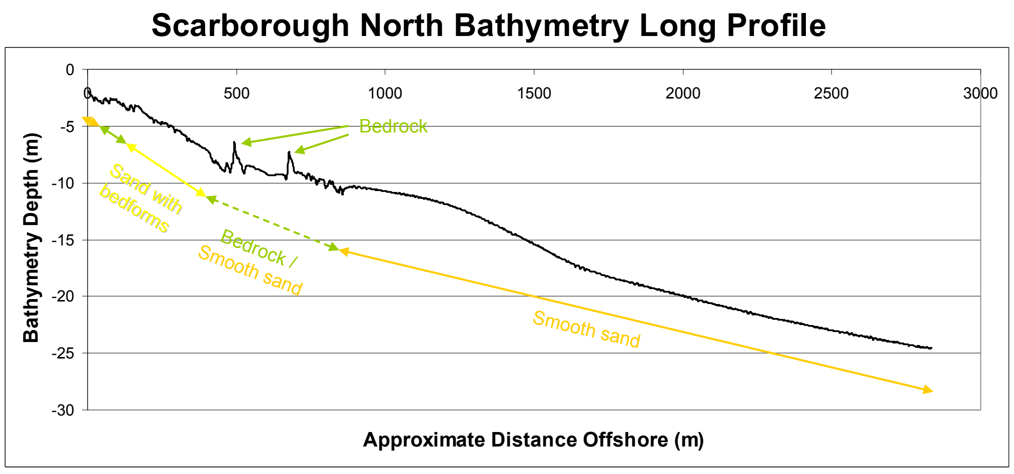


Figure 3.12 Scarborough North Bathymetry & Interpretation

Client: Scarborough Borough Council

Project: Cell 1 Seabed Characterisation Study

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Checked by:	PRF	Date:	Sept 2010
Approved by:	NP	Date:	Sept 2010

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GIS Filename: Scarborough North.mxd

3.13 Scarborough South Bay

3.13.1 Background

Scarborough South Bay comprises a sandy beach merging into a rocky foreshore platform in the south, backed by coastal defences which protect a promenade, commercial and residential properties, and amenity assets. The SMP2 identifies that there are complex sediment patterns in the bay and that the condition of coastal defences is in need of improvement. The recent Strategy update identifies a programme of capital works for South 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 as recommended by the recent Strategy review.

3.13.2 Survey Findings

The bathymetric survey for Scarborough South Bay extends approximately 4.6 km offshore to a depth of -24mOD. BGS data indicates the survey area is underlain by Jurassic sandstones and mudstones of the West Sole Group. The bathymetry, sea bed samples and BGS sea bed sediment data for Scarborough South Bay are displayed in Figure 3.13.

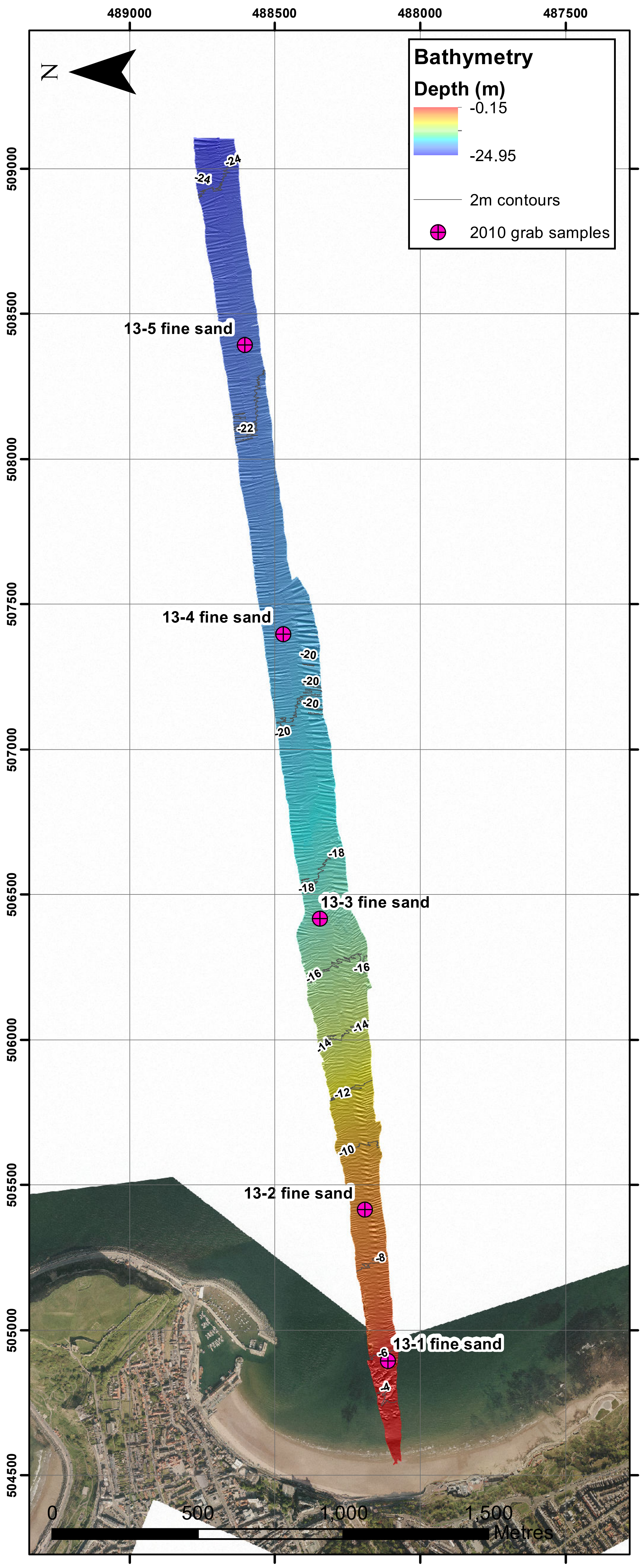
The interpretative mapping and long profile graph for Scarborough South Bay suggest that this area of sea bed is broadly characterised by two different sea bed types:

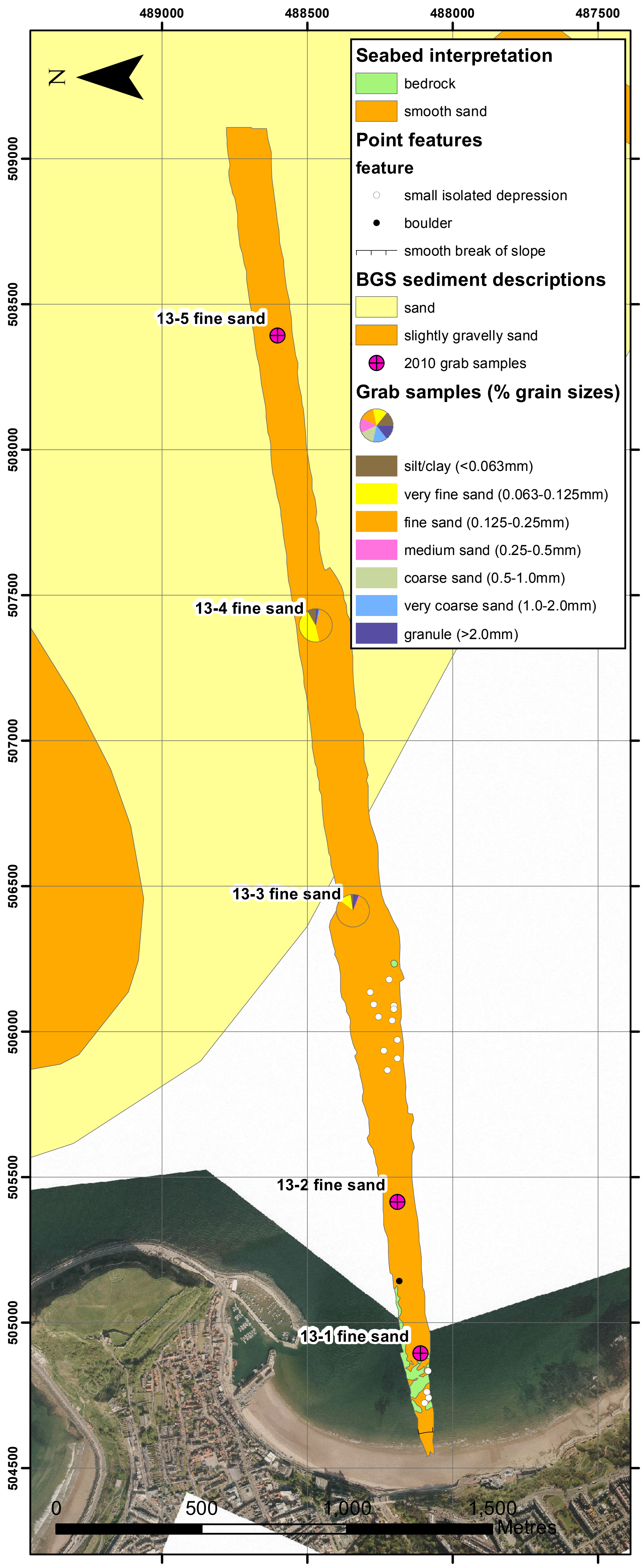
- The nearshore part of the survey area is characterised by outcrops of rough, uneven bedrock that stands proud of the surrounding sandy sea bed by around 1.5 m. Of note is a break of slope at about 80 m offshore, where the sea bed slopes flattens out from an angle of 1.6 to 0.3 degrees The aerial photography in this region also illustrates that the sea bed to a depth of around -6mOD is characterised by rocky ‘reefs’. No grab samples were obtained within these areas, and the BGS sediment data does not extend this far towards the shore, but the aerial photography shows the sea bed is composed of sandy sediments.

- The majority of the survey area, deeper than -6mOD, is characterised by smooth sand with an average gradient of around 0.3 degrees. The area is largely featureless, but does include an area of small isolated depressions from 1.3 to 1.7 km offshore. The long profile indicates the area of depressions is coincident with a convex area of sea bed interpreted as a sand bar. The grab samples indicate fine sands. The BGS sediment description for this area is sand.

3.13.3 Review of Objectives

At this stage in the monitoring programme it is only possible to consider whether the scope and extent of the survey is likely to address the issues raised, particularly with respect to any results as to the nature of the sea bed. Following subsequent surveys the finding would be reviewed where the monitoring is picking up information relevant to the management issues.





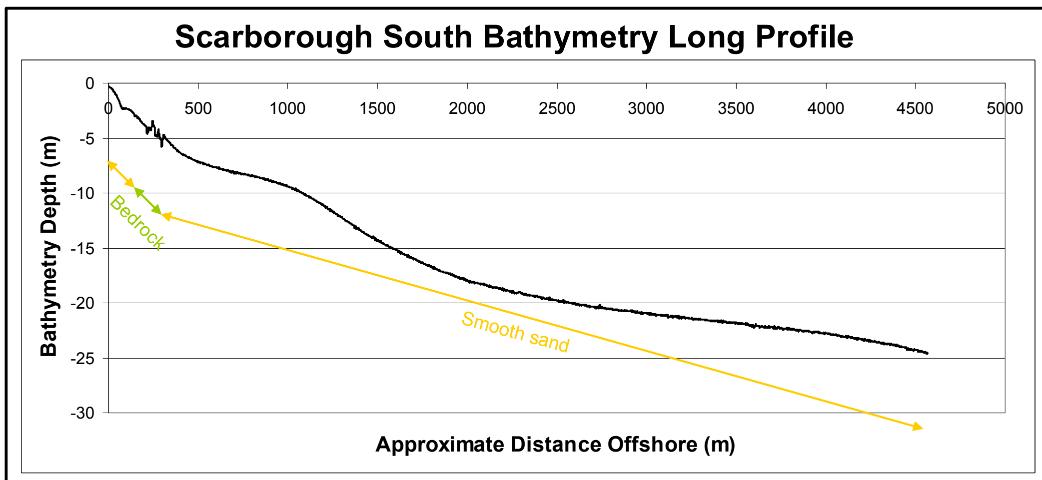


Figure 3.13 Scarborough South Bathymetry & Interpretation

Client: Scarborough Borough Council

Project: Cell 1 Seabed Characterisation Study

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GIS Filename: Scarborough South.mxd

3.14 Cayton Bay

3.14.1 Background

Cayton Bay is strongly influenced in its plan form by the presence of Osgodby/Knipe Point and in its behaviour by the geological composition. Properties have already been lost to cliff recession through landsliding at Knipe Point, and other properties and the coast road remain at risk from landsliding. The SMP2 largely recommends a policy of No Active Intervention, but with further investigations into the likelihood of landsliding, particularly along Knipe Point and Tenants' Cliff, to provide realistic estimates of timescales in which residents can make plans for evacuation.

The purpose of this transect is to inform understanding of the interactions between the shoreline and sea bed, so as to better inform assessments of the likelihood of slope failures.

3.14.2 Survey Findings

The bathymetric survey for Cayton Bay extends approximately 4.2km offshore to a depth of -23mOD. According to the BGS data, the survey area is underlain by Jurassic sandstones and mudstones of the West Sole Group. The bathymetry, sea bed samples and BGS sea bed sediment data for Cayton Bay are displayed in Figure 3.14.

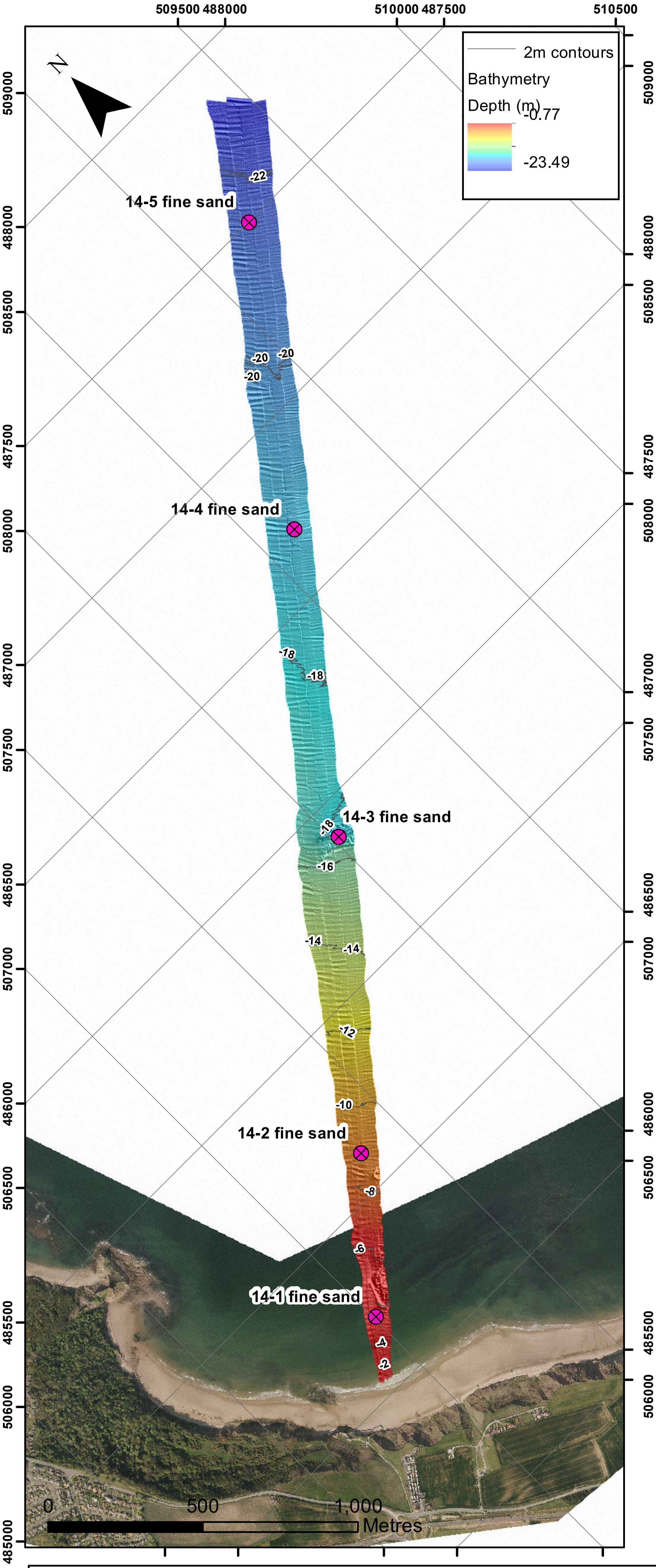
The interpretative mapping and long profile graph for Cayton Bay suggest that this area of sea bed is broadly characterised by two different sea bed types:

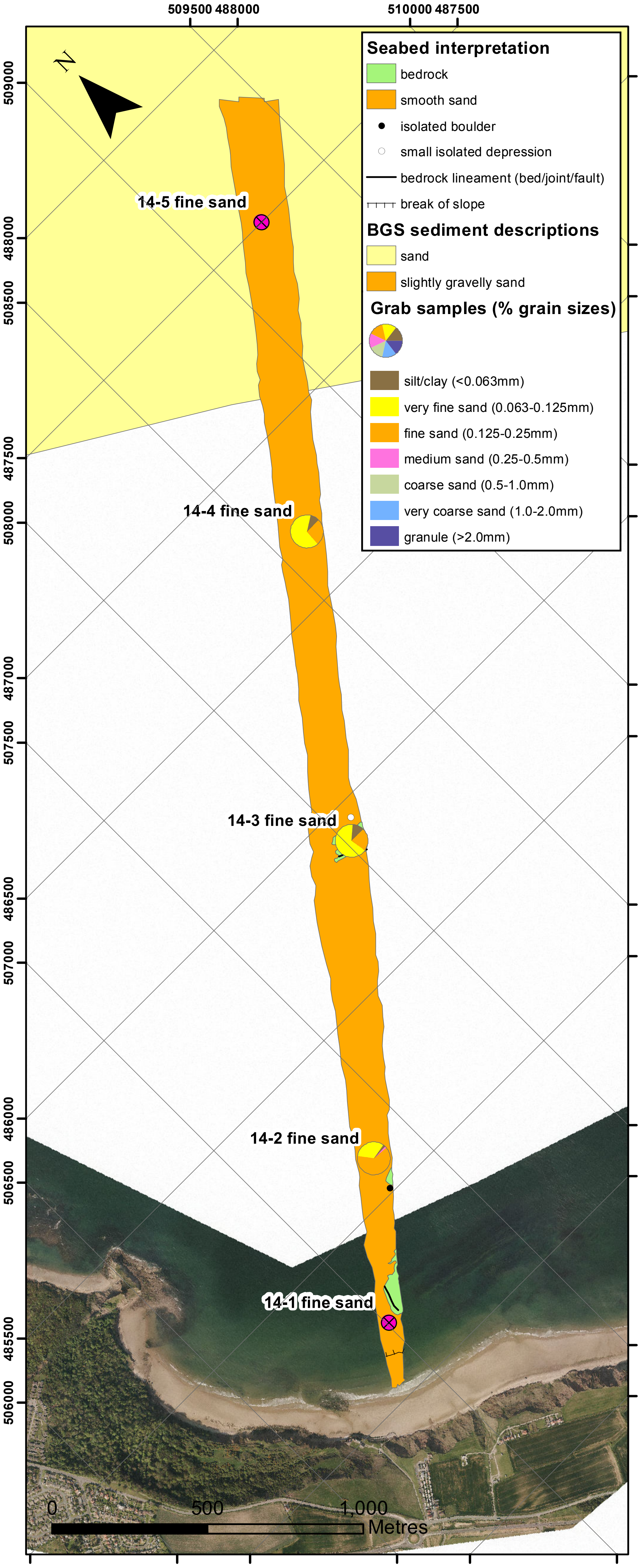
- A nearshore zone of sea bed with a gradient of around 0.5 degrees that extends offshore by c.1.8 km to a depth of c. -17mOD. This area of sea bed is predominantly smooth, but is punctuated by occasional rocky outcrops and occasional isolated boulders. In one location, the bedrock outcrops form a linear ridge which is identified is around 90 m long, 30 m wide and rises about 1.5 m above the surrounding seafloor. A sharp slope break, c. 110 m from the start of the survey, probably relates to a migrating sand bar that is approaching the base of the beach. The sea bed grab samples indicate fine sands. No evidence for toe heave associated with the recent landslide reactivation was observed.

- Further offshore, at depths greater than -17mOD, the sea bed is smooth and featureless, and has a mean gradient of 0.1 degree. Grab samples indicate fine sand. The BGS sediment description is sand.

3.14.3 Review of Objectives

At this stage in the monitoring programme it is only possible to consider whether the scope and extent of the survey is likely to address the issues raised, particularly with respect to any results as to the nature of the sea bed. Following subsequent surveys the finding would be reviewed where the monitoring is picking up information relevant to the management issues.





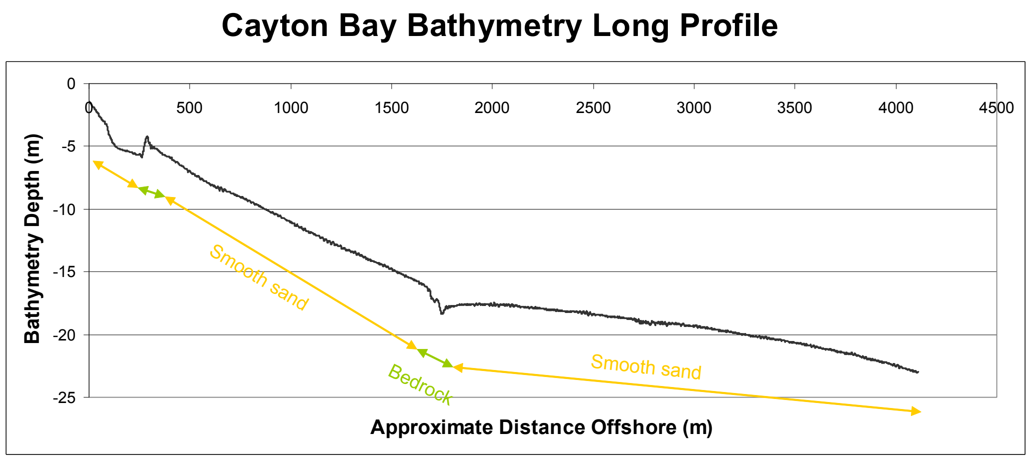


Figure 3.14
Cayton Bay Bathymetry & Interpretation

Client: Scarborough Borough Council

Project: Cell 1 Seabed Characterisation Study

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GIS Filename: Cayton Bay.mxd

3.15 Filey Bay

3.15.1 Background

Filey Bay extends between the headland of Filey Brigg and the village of Speeton near Flamborough Head and comprises sandy beaches backed by till or clay cliffs of varying behaviour. There are settlements at Filey, Flat Cliff, Hunmanby Gap and Reighton Gap, and large holiday villages at Primrose Valley and Reighton Sands, all of which are locally 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, but providing defences over the 100 year lifetime of the plan was considered unsustainable. However, the SMP2 recommends that monitoring is undertaken to assist people in planning for the eventual loss of property.

This 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.

3.15.2 Survey Findings

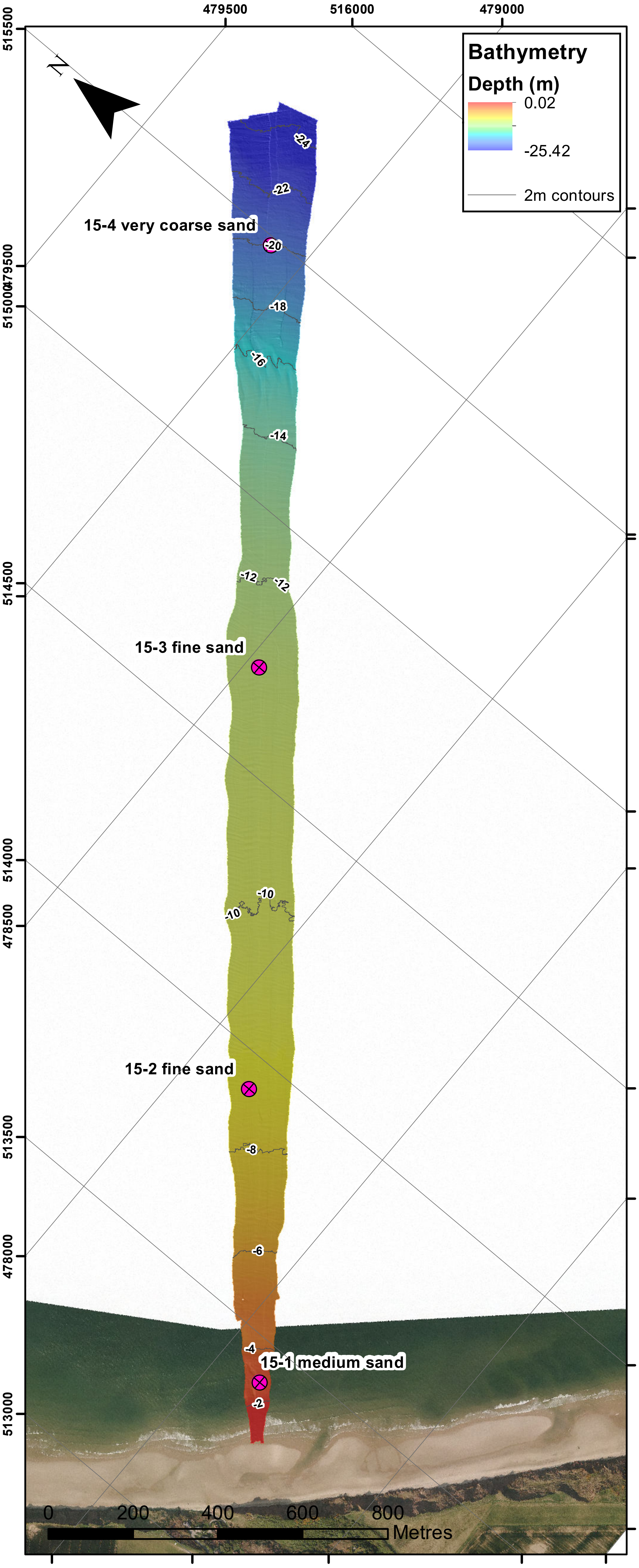
The bathymetric survey for Filey Bay extends approximately 3.1km offshore to a depth of 24m OD. According to the BGS data, the survey area is underlain by Jurassic sandstones and mudstones of the West Sole Group. The bathymetry, sea bed samples and BGS sea bed sediment data for Cayton Bay are displayed in Figure 3.15.

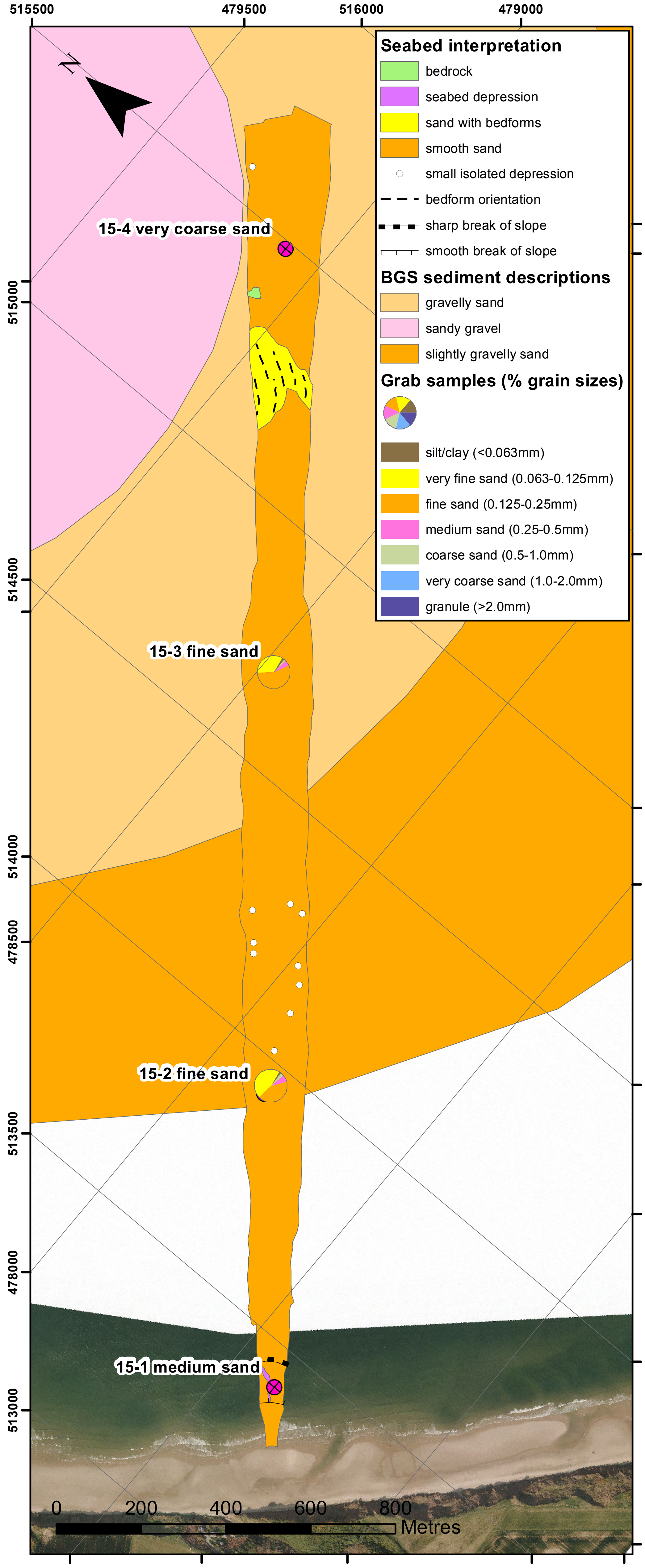
The interpretative mapping and long profile graph for Filey Bay suggest that this area of sea bed is broadly characterised by two main sea bed types, as well as an isolated bedrock outcrop and some small, linear sea bed depressions. The sea bed morphology is as follows:

- An extensive zone of smooth sandy sea bed with covers the majority of the survey area. Bedforms are not obvious in the bathymetry map, but the long profile indicates features that are interpreted as bars with wavelengths of around 2km (crest at c. 2km offshore) and 100 m (a series of forms in the nearshore 500m). A number of small isolated depressions which lie between 860m and 1300m offshore are coincident with the landward face of the large sand bar. The seaward face of the bar (c. 2.4 to 2.6km offshore) has an average gradient of 1 degree, and is characterised by bedforms which aligned NE-SW with a typical dimensions of 60 - 80m long, 25m wide and 0.5m deep. The area of smaller sandbars, at the nearshore end of the survey, is associated with a series of slope breaks and depressions, all of which are formed in sand. Cross reference to the aerial imagery suggests these forms are associated with sand bars and beach ridge and runnel systems. At about 2.7km offshore, there is a small area of bedrock, identifiable as it is slightly raised in elevation (0.3m) and has a rougher texture than the surrounding sand.

3.15.3 Review of Objectives

At this stage in the monitoring programme it is only possible to consider whether the scope and extent of the survey is likely to address the issues raised, particularly with respect to any results as to the nature of the sea bed. Following subsequent surveys the finding would be reviewed where the monitoring is picking up information relevant to the management issues.





Filey Bay Bathymetry Long Profile

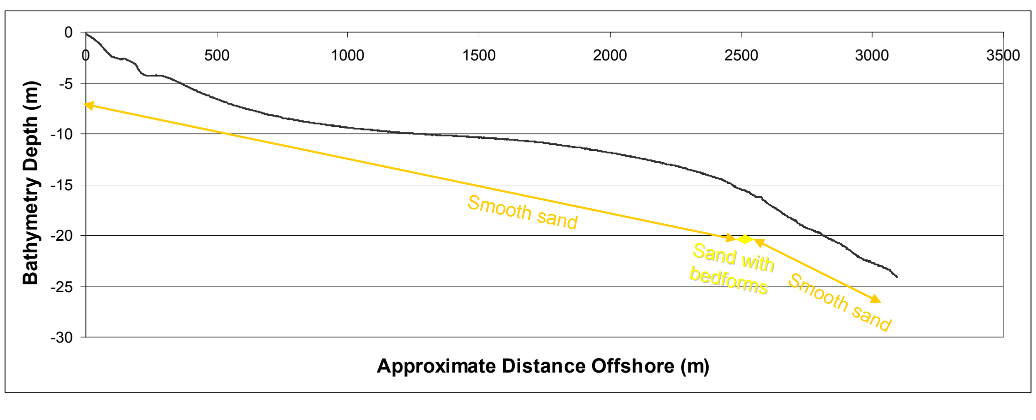


Figure 3.15 Filey Bay Bathymetry & Interpretation

Client: Scarborough Borough Council

Project: Cell 1 Seabed Characterisation Study

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GIS Filename: Filey Bay.mxd

4. Comparison with Previous Assessment

The 2010 survey represents a baseline survey against which future repeat surveys can be compared. The high resolution of the data means subtle changes in sea bed morphology should be detectible following re-survey. The grab samples are indicative of a single sample location only, but cross reference to the interpreted multibeam data shows particle size data is likely to be representative of larger areas.

Included in our assessment is a comparison of the sea bed characterisation with respect to BGS sea bed mapping purchased for purposes of this report. The newly captured sediment characterisation data is broadly consistent with the BGS data, however there are differences. In particular bedrock outcrops are not identified in BGS mapping and there is some subtle difference is sediment size. Both of these issues are likely to be related to the coarser scale of the BGS data. The comparison therefore concludes that the BGS data is appropriate for regional-scale assessments of sea bed sediments, whilst the newly surveyed data provides more detailed information specific to the areas covered.

5. Problems Encountered and Uncertainty in Analysis

The overall accuracy of the survey data appears to be very good and no major problems or uncertainties were encountered during the analysis.

6. Conclusions and Recommended Actions

Broadly speaking, it is apparent that the sea bed character is relatively homogenous along Herd Sands, Whitburn Bay, Salterfen Rocks, Blast Beach and Hartlepool North, but becomes more complex in the vicinity of Seaburn and remains so further south.

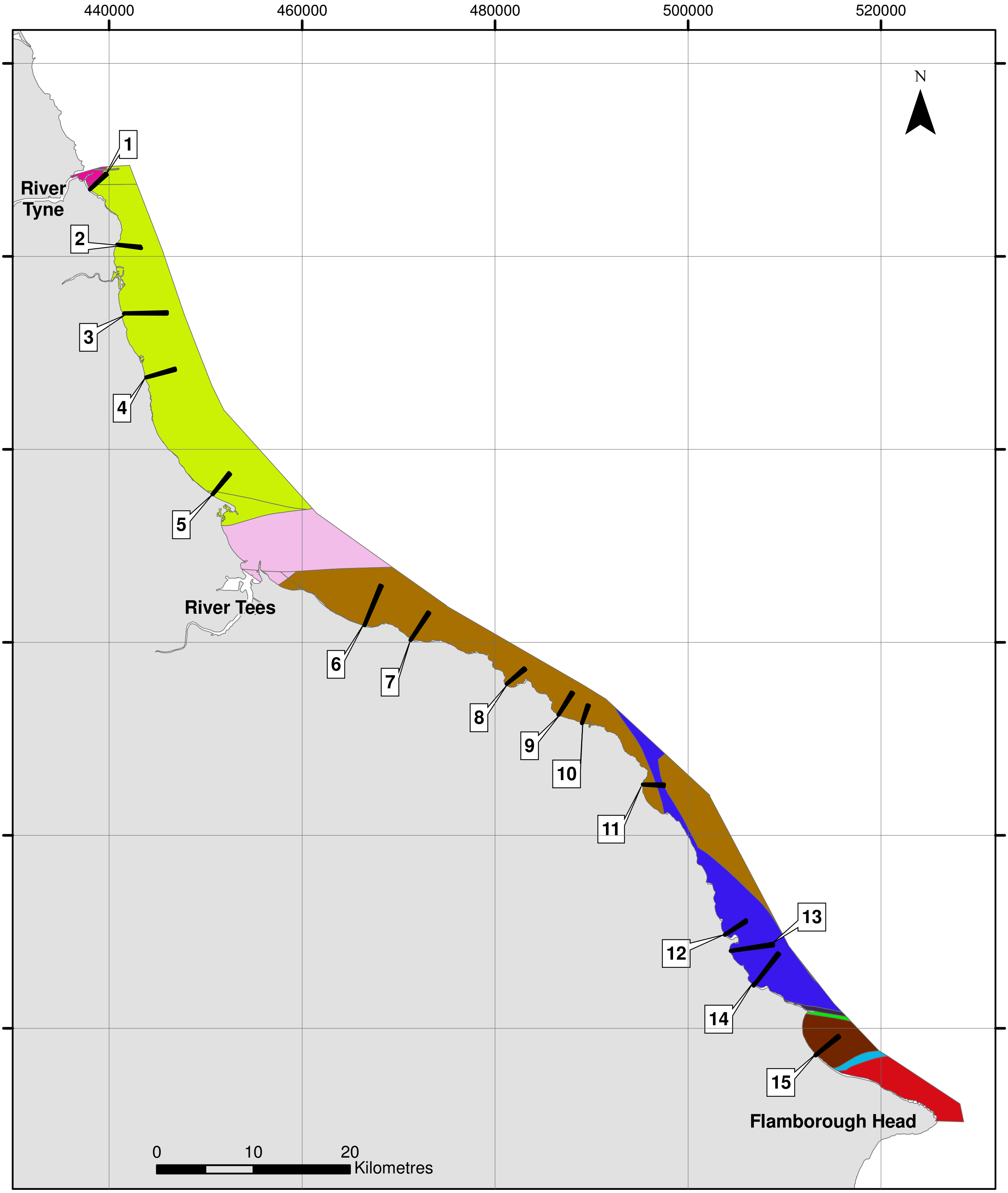
This pattern is also replicated in the behaviour of the sea cliffs along this frontage and this characteristic behaviour is dominated by the nature of the underlying geology (shown in Figure 4), which notably differs north and south of Saltburn. This shows the importance of geology in governing the behaviour of the north east coastline and should be remembered in management approaches.

As data from the 2010 bathymetric and sea bed characterisation surveys represents a 'baseline', its true value will be fully realised when a future repeat survey is undertaken, enabling changes in sea bed level, form or sediment character to be identified.

During future surveys it is therefore imperative that particular care should be given to ensure re-survey locations are identical to those covered in the 2010 survey.
Future analysis of repeat surveys should comprise assessment of:

- change in elevation, to highlight any patterns of erosion/sedimentation
- change in morphological character to highlight the nature of the sea bed process regime (for example any migration of bedforms, change in pattern of exposure of sand and rock, etc.)
- change in sediment type, to indicate the nature of materials moving in the coastal system.

It is suggested that the intervals of future surveys should be on 5-yearly or 10-yearly cycles (depending on what funding allocations allow) and ideally the data collection should be synchronised with beach profile or beach topographic surveys to ensure a continuous survey from the upper foreshore to the 20m sea bed contour.



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Solid Geology

- CHALK GROUP
- COAL MEASURES GROUP
- CORALLIAN GROUP
- CROMER KNOLL GROUP
- KIMMERIDGE CLAY FORMATION
- LIAS GROUP
- OXFORD CLAY FORMATION
- PERMIAN ROCKS (UNDIFFERENTIATED)
- TRIASSIC ROCKS (UNDIFFERENTIATED)
- UNNAMED IGNEOUS INTRUSION, CARBONIFEROUS TO PERMIAN
- WEST SOLE GROUP

3 Bathymetric Survey Location

Figure 4
Regional Solid Gology of the Sea Bed

Client: Scarborough Borough Council

Project: Cell One Seabed Characterisation Study

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Checked by:	NC	Date:	Oct 2010
Approved by:	NC	Date:	Oct 2010

GIS Filename: Figure4_Regional_Solid_Gology.mxd

Appendices

Appendix A

Bathymetric and Sea Bed Characterisation Survey Report

Aspect Land & Hydrographic Surveys
Chartered Surveyors

Aspect Land & Hydrographic Surveys

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SCARBOROUGH BOROUGH COUNCIL

CELL 1 COASTAL MONITORING

BATHYMETRIC AND SEABED CHARACTERISATION SURVEYS

REPORT

A4534

27th August 2010

COMPILED: C D Thomson	
APPROVED: G J Campbell	

Scarborough Borough Council
Britain's most enterprising place 2008
Europe's most enterprising place 2008/2009

Client:

Scarborough Borough Council
Town Hall
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Scarborough
YO11 2HG

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CONTENTS

1. Introduction

On the instructions of Scarborough Borough Council multibeam bathymetric and seabed characterisation surveys were conducted throughout cell 1 of the regional coastal monitoring project. Cell 1 encompasses the area from the Scottish Borders to Flamborough Head. On the occasion of these surveys 15 transects were undertaken as follows:

- Herd Sands, South Shields (Tyne & Wear)
- Whitburn Bay (Tyne & Wear)
- Salterfen Rocks (Tyne & Wear)
- Blast Beach (near Noses Point, County Durham)
- Hartlepool North Sands (Hartlepool Borough)
- Saltburn-by-the-Sea (Redcar & Cleveland Borough)
- Skinningrove (Redcar & Cleveland Borough)
- Runswick Bay (Scarborough Borough)
- Sandsend (Scarborough Borough)
- West Beach, Whitby (Scarborough Borough)
- Robin Hood's Bay (Scarborough Borough)
- Scarborough North Bay (Scarborough Borough)
- Scarborough South Bay (Scarborough Borough)
- Cayton Bay (Scarborough Borough)
- Filey Bay (Scarborough Borough)

In addition to these 15 transects, transit lines were undertaken along the 20m contour to join these transects.

The geomorphology of this stretch of coast varies a great deal with some areas having gently sloping beaches while others are dominated by high, hard rock cliffs.

The data gathering on the project was commenced on 5th February 2010 and completed on 17th June 2010.

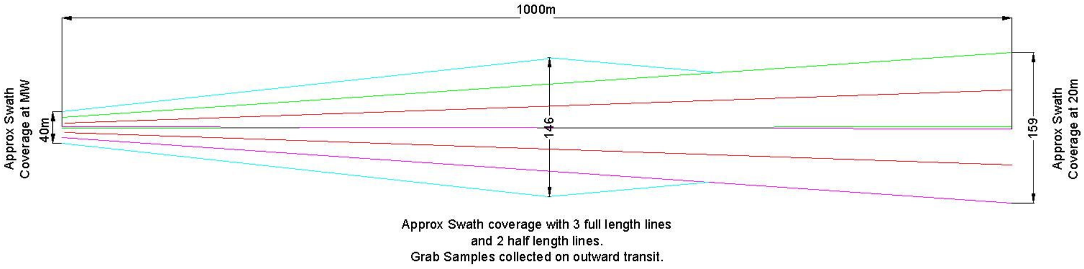
Particularly hard winter months at the start of 2010 severely hampered the progress of this project with strong and predominantly easterly winds preventing data gathering efforts from progressing as planned.

These easterly winds resulted in high easterly swells which precluded survey operations in the area. Initial attempts at carrying out our survey operations in the area in early February proved difficult with the survey vessel not able to operate in shallow enough water to allow an overlap between the topographic surveys and the hydrographic surveys. As a result a number of survey areas were re-visited at a later date when weather conditions allowed the shallow areas of the survey to be completed.

Details of the daily weather conditions throughout the period of the project are at Annex A.

Each transect was progressed broadly as follows:

The centreline was surveyed to full length from the 20m contour to the shallowest possible depth. Two further full length lines were then surveyed, either side of this centreline.



Swath Pattern Per Transect

On a number of occasions, either due to the height of tide when the main lines were being carried out or as a result of weather and sea conditions, survey in very shallow water was precluded. On these occasions the survey area was re-visited at a later date and the survey work in the shallow water areas completed. This resulted in all transects being fully surveyed as required by the specification.

Bathymetric data was processed using Hypack, Fledermaus and McCarthy Taylor LSS software. Where it was found that there was a gap between the previously collected topographic survey data and the bathymetric data, further topographic surveys were carried out in order to ensure that there was an overlap with work carried out under separate contract.

Once the bathymetry data was gathered the seabed samples were then taken on the outward transit when the sea state allowed. Seabed samples were retained for analysis at Stirling University's laboratory. Seabed samples were named from landward to seaward for each transect as below:

A4534_1_1 – The furthest inshore sample from transect 1.
A4534_1_3 – The furthest seaward sample from transect 1.

2. Daily Diary

Date	**Activity**
4 Feb 10	Mobilise Remote Sensor to Sunderland
5 Feb 10	Data Gathering Transect A4534_4_Blast Beach
6 Feb 10	Data Gathering Transect A4534_3_Salterfen Rocks
7 Feb 10	Data Gathering Transect A4534_3_Salterfen Rocks
7 Feb 10	Data Gathering Transect A4534_2_Whitburn Bay
8 Feb 10	Data Gathering Transect A4534_1_Herd Sands
14 Feb 10	De Mobilise Sunderland
15 Feb 10	Mobilise Whitby
16 Feb 10	Data Gathering Transect A4534_9_Sandsend
16 Feb 10	Data Gathering Transect A4534_10_Whitby West Beach
17 Feb 10	Data Gathering Transect A4534_11_Robin Hoods Bay
18 Feb 10	Data Gathering Transect A4534_8_Runswick Bay
18 Feb 10	De-Mobilise Whitby
12 Mar 10	Mobilise Hartlepool
17 Mar 10	Data Gathering Transect A4534_6_Saltburn Sands

17 Mar 10	Data Gathering Transect A4534_7_Skinningrove
18 Mar 10	Data Gathering Transect A4534_5_Hartlepool North Sands
19 Mar 10	Data Gathering Transect A4534_5_Hartlepool North Sands
20 Mar 10	De-Mobilise Hartlepool
4 May 10	Mobilise Sunderland
5 May 10	Data Gathering Transect A4534_1_Herd Sands
5 May 10	Data Gathering Transect A4534_2_Whitburn Bay
5 May 10	Data Gathering Transect A4534_4_Blast Beach
5 May 10	Data Gathering Transect A4534_3_Salterfen Rocks
6 May 10	De-Mobilise Sunderland
7 Jun 10	Mobilise Scarborough
8 Jun 10	Data Gathering Transect A4534_12_Scarborough North Bay
8 Jun 10	Data Gathering Transect A4534_13_Scarborough South Bay
9 Jun 10	Data Gathering Transect A4534_13_Scarborough South Bay
16 Jun 10	Data Gathering Transect A4534_13_Scarborough South Bay
16 Jun 10	Data Gathering Transect A4534_14_Cayton Bay
17 Jun 10	Data Gathering Transect A4534_15_Filey bay
17 Jun 10	De-Mobilise Scarborough
18 Jun – 27 Aug 10	Processing and Reporting

3. Survey Data – Bathymetric Survey

a. Results of the Survey – The results of the survey are rendered as follows:

- 1m gridded xyz files referred to OD(N).
- Full density xyz files referred to OD(N).
- 1:1000 scale AutoCAD dwg files showing the bathymetry of each transect overlain with zonal interpretation of the seabed geomorphology interpreted from grab samples and sonar backscatter interpretation. These are referred to OD(N).
- Tidal information files referred to OD.
- Multibeam Echosounder Generic Sensor Format (GSF) data to allow future interpretation of the data if required either for bathymetric or backscatter interpretation.

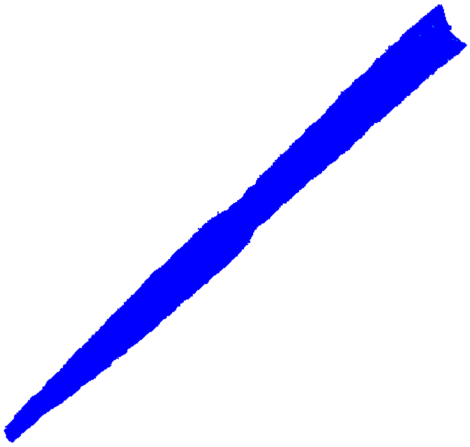
Each transect is individually detailed below with a brief description. Bathymetric data was processed in Hypack and quality assured in IVS3D Fledermaus software.

The interpretation of backscatter information in order to ascertain the seabed geomorphology from multibeam data was undertaken in IVS3D Fledermaus software.

This information has been included below for each transect with a graphic showing seabed type. The areas of seabed type have been delineated in the rendered AutoCAD drawings.

i. Herd Sands –

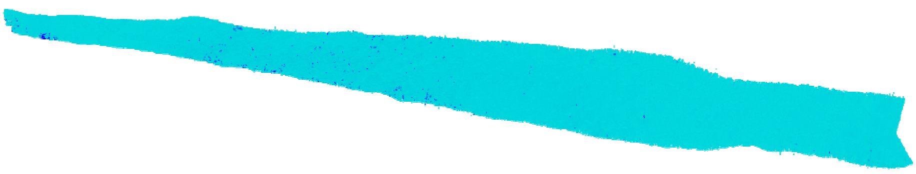
This transect is 2400m long on a bearing of 042° from the beach running broadly parallel to the entrance to the River Tyne breakwaters. The shallowest depth is 1.4m below OD and the maximum depth of 24.1m below OD. Chart Datum at the entrance to the River Tyne is 2.60m below OD. This therefore means that the seaward extent of the transect is 21.5m below CD and the landward extent 1.2m above CD.



The image to the left shows transect 1 seabed characterisation. The dark blue shading shows a degree of homogeneity over the transect. The seabed types here vary from predominantly medium sand in the inshore and offshore areas with more fine sand in the central area of the transect.

ii. Whitburn Bay –

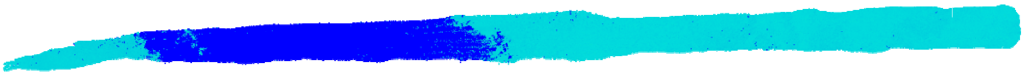
This transect is 2700m long on a bearing of 098° from the landing point ashore. The shallowest depth is 4.63m above OD and the maximum depth is 24.4m below OD. Due to the rugged nature of the seabed it was not navigationally safe to proceed sufficiently inshore to achieve an overlap with existing land survey and therefore some topographical survey was conducted on this transect to ensure continuity. Chart Datum at Sunderland is 2.72m below OD. This therefore means that the seaward extent of the transect is 21.7m below CD and the landward extent 7.35m above CD.



The image above shows transect 2 seabed characterisation. The light blue shading shows that the seabed types here are predominantly coarser sedimentary fractions with gravel being present and also areas of rocky seabed. Areas where samples were attempted but no sample returned after 3 attempts are marked as H for Hard on the AutoCAD drawings accompanying this report.

iii. Salterfen Rocks -

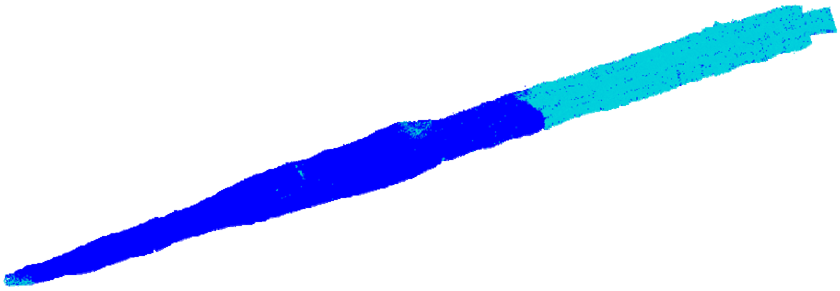
This transect is 4700m long on a bearing of 090° from the shore and with an inshore level of 2.96m above OD and a maximum depth of 25.3m below OD. Chart Datum at Sunderland is 2.72m below OD. This therefore means that the seaward extent of the transect is 22.6m below CD and the landward extent 5.68m above CD. As it was not possible to achieve a significant overlap with the bathymetric survey some topographic survey was conducted in order to ensure some tie in with any existing or future topographic surveys under separate contract.



The above image shows transect 3 seabed characterisation. The light blue shading shows areas of coarser sedimentary fractions with gravel and rock being present while the darker blue areas highlight areas which are finer sandy areas of seabed.

iv. Blast Beach -

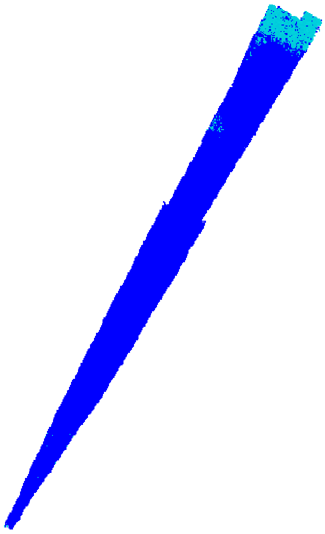
This transect is 3500m long on a bearing of 073° from the shore and with an inshore level 5.33m above OD and a maximum depth of 24.8m below OD. Chart Datum at Seaham is 2.70m below OD. This therefore means that the seaward extent of the transect is 22.1m below CD and the landward extent 8.03m above CD. Some topographic survey was carried out at the landward extent of this transect to ensure coverage between the bathymetric work and existing or future topographic work under separate contract.



The image above shows transect 4 seabed characterisation. The light blue shading shows areas of coarser sedimentary fractions in the offshore half of the transect where gravel is predominant. In most of the inshore section of the transect the seabed type is dominated by sand of varying grades with 2 isolated patches of gravel.

v. Hartlepool North Sands -

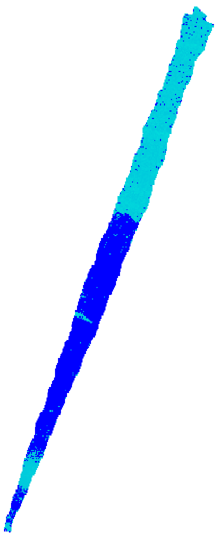
This transect is 2900m long on a bearing of 030° from the shore and with an inshore level 0.2m above OD and a maximum depth of 24.6m below OD. Chart Datum at Hartlepool is 2.70m below OD. This therefore means that the seaward extent of the transect is 21.9m below CD and the landward extent 2.9m above CD.



The image on the left shows transect 5 seabed characterisation. The light blue shading shows areas of coarser sedimentary fractions in the extreme offshore area of the transect where gravel is predominant. In the remainder of the transect the seabed type is dominated by sand of varying grades.

vi. Saltburn by the Sea -

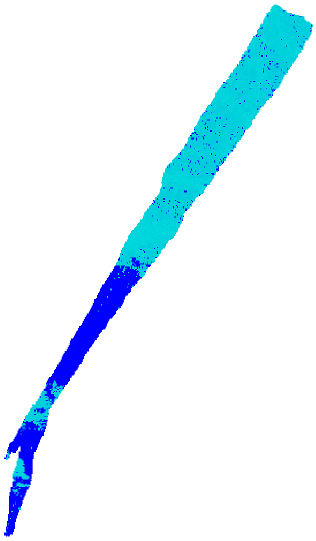
This transect is 4300m long on a bearing of 021° from the shore and with an inshore level 1.3m below OD and a maximum depth of 27.4m below OD. Chart Datum at the River Tees Entrance is 2.85m below OD. This therefore means that the seaward extent of the transect is 24.6m below CD and the landward extent 1.6m above CD.



The image on the left shows transect 6 seabed characterisation. The light blue shading shows areas of coarser sedimentary fractions in the offshore half of the transect and at the inshore end where gravel is predominant. In the remainder of the inshore section of the transect the seabed type is dominated by fine sand with some isolated patches of gravel.

vii. Skinningrove -

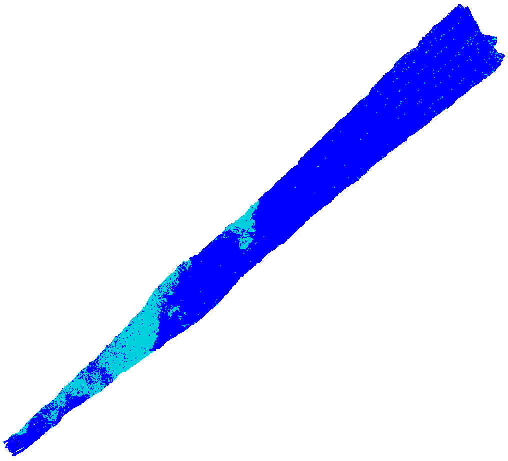
This transect is 3750m long on a bearing of 029° from the shore and with an inshore level of 5.90m above OD and a maximum depth of 26.6m below OD. Chart Datum at the River Tees Entrance is 2.85m below OD. This therefore means that the seaward extent of the transect is 23.8m below CD and the landward extent 8.8m above CD. Some topographic survey was undertaken on this transect to ensure an overlap between the bathymetric survey work and existing and future land surveys under separate contract.



The image on the left shows transect 7 seabed characterisation. The light blue shading shows areas of coarser sedimentary fractions such as gravel in the offshore portion. There are also gravel and rock patches at the inshore end of the transect which show clearly in the unevenness and rugged nature of the seabed in this area that is not characteristic of areas of sand. In the remainder of the inshore section of the transect the seabed type is dominated by fine sand with some isolated patches of gravel. Seabed grab samples in this transect do not show evidence of the harder gravel or rock seabed type that has been identified by the multibeam backscatter. This is considered to be due to the gravel or rock being too compact to be collected by the van veen grab used for this task.

viii. Runswick Bay -

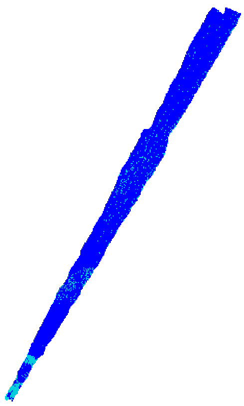
This transect is 2500m long on a bearing of 049° from the shore and with an inshore level of 3.23m above OD and a maximum depth of 25.6m below OD. Chart Datum at Whitby is 3.00m below OD. This therefore means that the seaward extent of the transect is 22.6m below CD and the landward extent 6.2m above CD. Some topographic survey was undertaken on this transect to ensure an overlap between the bathymetric survey work and existing and future land surveys under separate contract.



The image on the left shows transect 8 seabed characterisation. The dark blue shading shows areas of sand over most of the transect. At the inshore end there are bands of gravel and rock delineated by the lighter blue areas. In the remainder of the inshore section of the transect the seabed type is dominated by fine sand with some isolated patches of gravel.

ix. Sandsend -

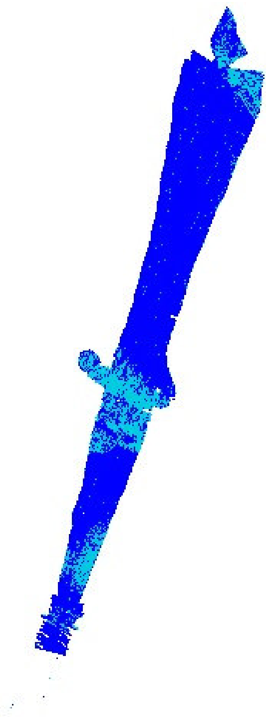
This transect is 2700m long on a bearing of 030° from the shore and with an inshore level of 1.6m below OD and a maximum depth of 24.2m below OD. Chart Datum at Whitby is 3.00m below OD. This therefore means that the seaward extent of the transect is 21.2m below CD and the landward extent 1.4m above CD.



The image on the left shows transect 9 seabed characterisation. The dark blue shading shows areas of sand over most of the transect. At the inshore end there are bands of gravel and rock delineated by the lighter blue areas.

x. Whitby, West Beach -

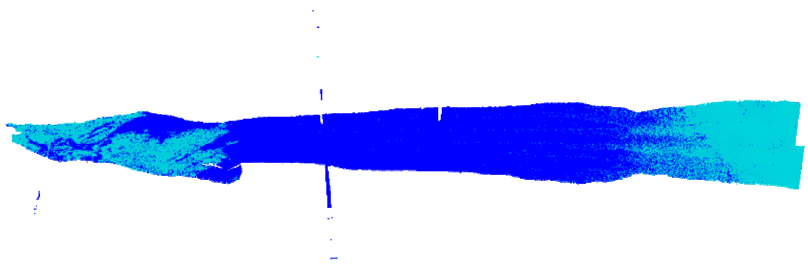
This transect is 2000m long on a bearing of 018° from the shore and with an inshore level of 2.94m above OD and a maximum depth of 27.4m below OD. Chart Datum at Whitby is 3.00m below OD. This therefore means that the seaward extent of the transect is 24.4m below CD and the landward extent 5.94m above CD. Some topographic survey was undertaken on this transect to ensure an overlap between the bathymetric survey work and existing and future land surveys under separate contract.



The image on the left shows transect 10 seabed characterisation. The dark blue shading shows areas of sand over most of the transect. At the extreme North East, in the middle and at the inshore end there are 3 bands of gravel / rock delineated by the lighter blue areas.

xi. Robin Hood's Bay -

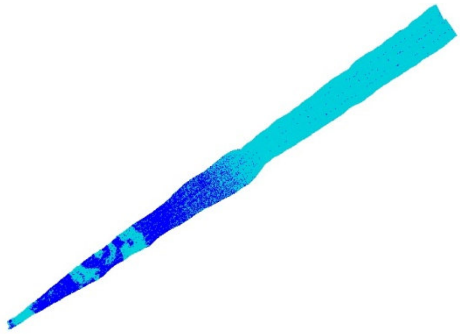
This transect is 2100m long on a bearing of 091° from the shore and with an inshore level of 4.18m above OD and a maximum depth of 28m below OD. Chart Datum at Whitby is 3.00m below OD. This therefore means that the seaward extent of the transect is 7.18m below CD and the landward extent 25.0m above CD. Some topographic survey was undertaken on this transect to ensure an overlap between the bathymetric survey work and existing and future land surveys under separate contract.



The image above shows transect 11 seabed characterisation. The dark blue central area in the graphic shows areas of sand while the lighter blue areas at the seaward and landward ends of the transect show areas of gravel and rock. These areas are also clear from the rugged nature of the seabed displayed in the bathymetric data.

xii. Scarborough North Bay -

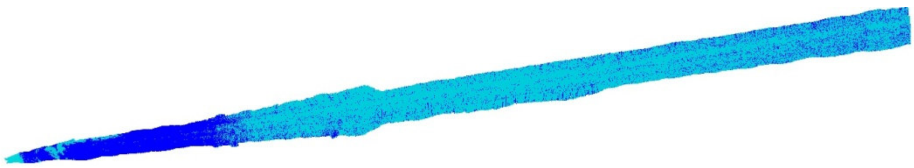
This transect is 2850m long on a bearing of 055° from the shore and with an inshore level of 0.8m below OD and a maximum depth of 25.2m below OD. Chart Datum at Scarborough is 3.25m below OD. This therefore means that the seaward extent of the transect is 21.95m below CD and the landward extent 2.45m above CD.



The image on the left shows transect 12 seabed characterisation. The light blue at the offshore half of the transect shows uneven areas of gravel deposits. These are again present in bands along with rocky ridges in the inner portion of the transect also. The remainder of the transect is made up of sandy sediment.

xiii. Scarborough South Bay -

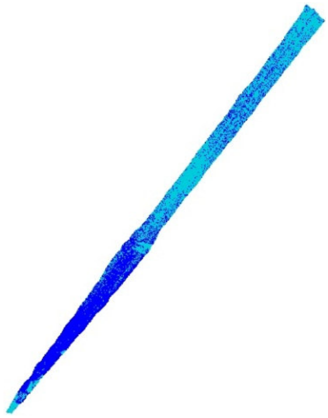
This transect is 4600m long on a bearing of 082° from the shore and with an inshore level of 0.2m below OD and a maximum depth of 24.7m below OD. Chart Datum at Scarborough is 3.25m below OD. This therefore means that the seaward extent of the transect is 21.45m below CD and the landward extent 3.05m above CD.



The image above shows transect 13 seabed characterisation. The majority of the transect is predominantly light blue which relates to a mainly gravelly seabed morphology. The seabed samples in these areas do not all display this gravel but it is considered that this is a result of the coarser sediment fractions in the area being too compacted or hard to be sampled effectively. The closer inshore areas in dark blue are sand before the near shore again is characterised as gravel.

xiv. Cayton Bay -

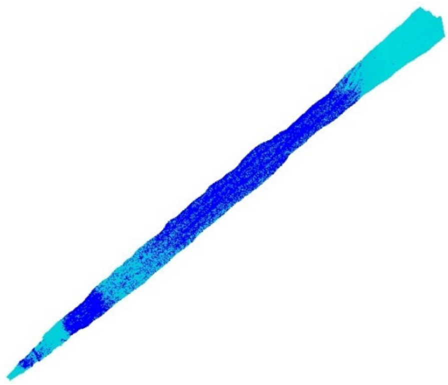
This transect is 4100m long on a bearing of 038° from the shore and with an inshore level of 0.7m below OD and a maximum depth of 23.3m below OD. Chart Datum at Scarborough is 3.25m below OD. This therefore means that the seaward extent of the transect is 20m below CD and the landward extent 2.55m above CD.



The image on the left shows transect 14 seabed characterisation. More than the outer half of the transect is characterised as Gravel and sand as being the predominant seabed type. The gravel is not supported in the samples as these show only sand but it is considered that the seabed here is likely to be compacted gravel that was not able to be sampled with the Van Veen.

xv. Filey Bay -

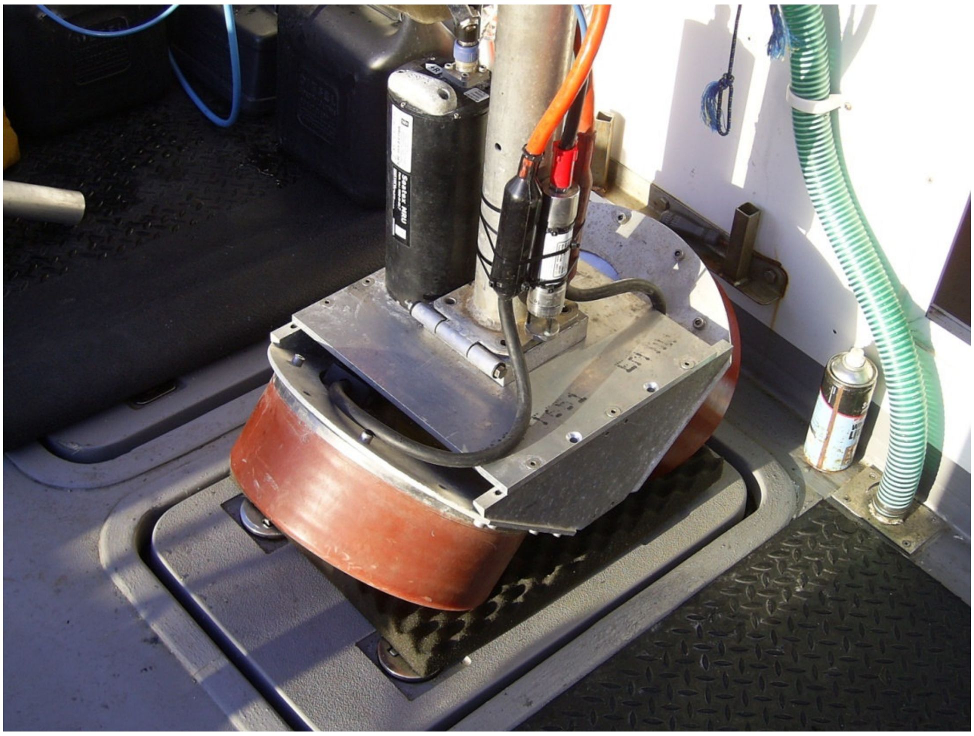
This transect is 3100m long on a bearing of 050° from the shore and with an inshore level of 0m above OD and a maximum depth of 25.1m below OD. Chart Datum at Scarborough is 3.25m below OD. This therefore means that the seaward extent of the transect is 21.85m below CD and the landward extent 3.25m above CD.



The image on the left shows transect 15 seabed characterisation. The light blue bands are areas of larger seabed sediment fractions such as gravel. This is only evident in sample A4534_15_5 however and it is considered that this is a result of the gravel being compacted in the seabed thereby precluding sampling in most cases.

b. Equipment Used

The bathymetric survey was carried out using a Kongsberg EM3002 single head MBES. This is an advanced, high resolution swathe echosounder with dynamically focussed beams. The Kongsberg EM3002 MBES is a high-resolution seabed mapping and inspection system which meets the standards required for survey precision in the specification of this survey. The minimum operating depth is 0.7m below the transducer, and in typical operating conditions the system is effective to depths of 150m. We utilised our own 8m catamaran for this survey which has been specifically designed and built for shallow water surveys.



Kongsberg EM3002 in the dual head configuration

The EM3002 was controlled using Kongsberg SIS software online and data distributed from this to Hypack's Hysweep acquisition program.

SIS was used for the following aspects of the data gathering process:

- Control of the beam forming and steering both in transmit and receive modes
- Application of Sound Velocity in real time to allow for beam steering at the array face and ray tracing in the water column

The EM3002 system has a high ping rate of up to 40 Hz as controlled in SIS. The system was operated at maximum ping rate achievable throughout the survey. The ping rate was therefore controlled by the depth of water in the area and as depths in the survey ranged between 0 and 28m, the system achieved very high ping rates throughout the data gathering phase.

The system forms 254 discrete beams from a 130º x 1.5˚ pitch stabilised swathe. With these swathe characteristics 100% insonification of the seabed is achievable at vessel speeds of up to 10 knots in shallow water. Survey speeds during this work however did not exceed 5 knots due to the shallow nature and proximity of navigational hazards. Across track coverage of up to four times depth is possible with this single head system. Data was gathered in SIS with a swathe of 130º selected which achieves this 4x capability thereby maximising productivity of the system.

The EM3002 sonar is capable of operating in 3 separate modes; equiangular, equidistant and high density equidistant. The system was operated in high density equidistant mode throughout this survey to achieve maximum resolution in the bathymetry. This methodology takes the available 254 beams and uses interferometric techniques in the outer regions of each swathe to measure an additional two data points within the outer beams of each ping.

Data density and resolution is thereby increased 3 fold in these more data sparse regions, providing greater resolution and a more even distribution of soundings across the swathe when compared to standard equiangular settings. Every ping is Roll and Pitch stabilised to a limit of 10°. During this survey roll and pitch never exceeded this amount therefore meaning that the beam will always have been steered successfully vertically downwards.

Motion compensation was achieved using a Seatex MRU 5, which performed well throughout the survey. This system measures and outputs heave, pitch and roll at a rate of 20 Hz to the multibeam data gathering system. This is applied in real time both to electronically steer the beams on transmission to allow for pitch and roll and also to correct for vessel motion on reception and calculation of depth and position on the seabed of every sounding. Motion data was thoroughly examined during the processing of the MBES data and no editing was required.

Full patch tests were carried out for each transect in this survey to confirm the alignment of the sensor head to the vessel reference frame.

Data was gathered with a planned insonification of 200%. This allows online and post survey quality assurance checks to be carried out reliably. These were found in all cases to confirm the calibration values that were applied to the system.

The MBES system was corrected for sound velocity using an online SV probe at the transducer face thereby allowing the system to electronically form and steer the beams accordingly to allow for refraction in the water column. Additionally sound velocity dips were taken prior to commencing sounding and whenever the SV at the array face differed by more than 2ms-1 from the equivalent value in the last full SV cast. The full SV cast was used to correct for beam ray tracing.

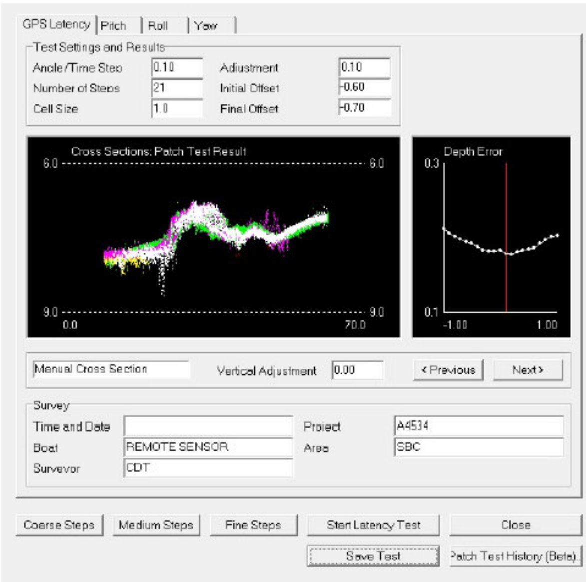
Data gathering was done in Hypack and this system was then also used to post-process in the HySweep software. This allowed utilisation of RTK height for correction of the tidal variation during the data gathering phase. This system is used to process data and to form the x, y, z gridded product.

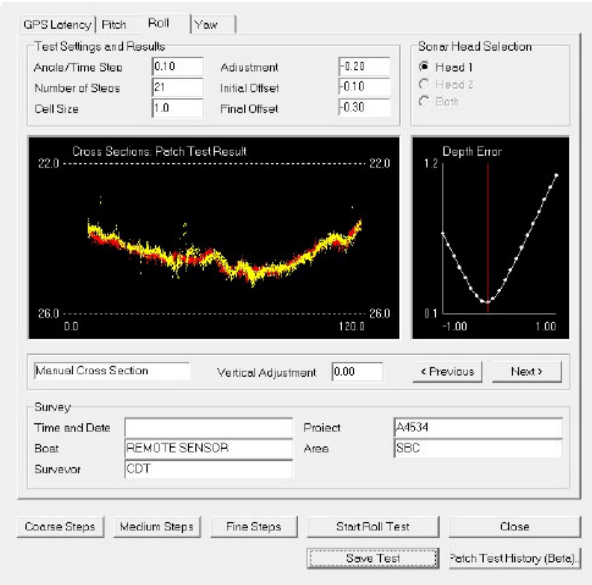
The multibeam system as a whole has exceeded IHO Special order standards at all times throughout the conduct of this work.

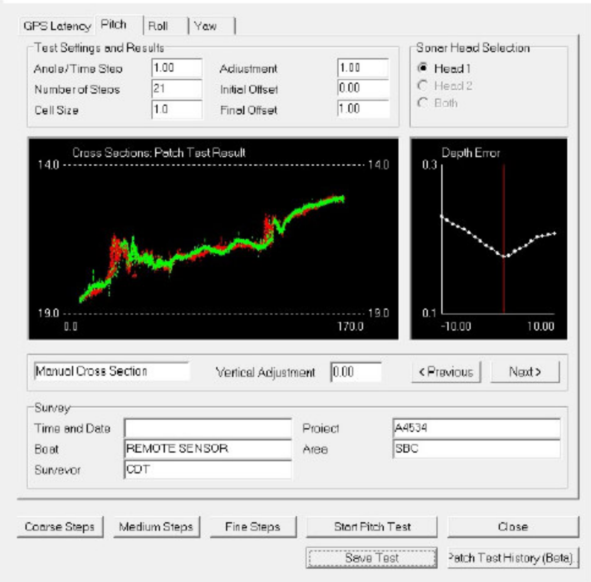
Details of data processing procedures are at Annex C.

c. System Calibration

The system is rigidly mounted and pinned on a pole to ensure that it is deployed to the same vertical position and orientation with respect to the vessel reference frame after any periods of recovery for transit. The sonar is mounted vertically below the GPS position antenna on the survey vessel to negate GPS/Sonar layback errors. A standalone calibration check was carried out on each individual data set in the processing stage in order to confirm the calibration values of the system. Additional calibrations were carried out on the change of any significant component of the sonar or navigation system. Calibration values of the system are below:







d. Data Gathering Procedures

The methodology intended for all transects was:

- Mobilise to nearest base port.
- Transit to transect.
- Run the full length centreline in from the 20m contour using Multibeam Echosounder.
- Run the full length left of centre line out from as shallow as workable to the 20m contour.
- Run the full length right of centre line from the 20m contour to as shallow as workable.
- Run the half length right of centre line from as shallow as workable to approximately the 15m contour to achieve the desired minimum swath width over the entire transect.
- Run the half length left of centre line from approximately the 15m contour to as shallow as workable.

- A minimum of 50% overlap between adjacent lines was maintained at all times during data gathering to allow statistical analysis of the data and quality assurance.

e. Tidal Reduction

Tidal data was gathered by way of Real Time Kinematic GPS (RTK). The Trimble VRS Now network using Ordnance Survey Active GPS network data was used to provide RTK corrections throughout. This data is referred to Ordnance Datum on provision and allowed a great degree of freedom in data gathering and ease of operation in processing.

f. Processing Methodology

Processing was carried out in Hypack MB Max software. This allowed the checking of all navigation information, motion correction, tidal application and calibrations. After these checks were carried out the data was edited with an operator inspecting the data line by line to ensure that there was no extraneous noise remaining in the data. The data was then gridded at 1m resolution to allow statistical cleaning. MB Max statistical cleaning tools were used with this 1m gridded data where the statistics within each 1m cell were used to ensure that all data kept within a cell was within 2σ of the cell average thereby eliminating any noise. This cleaned data was then saved as generic sensor format (gsf) which is readable by any sonar processing package. A 1m gridded xyz was saved and then all points were saved in xyz format. The tidal data used to reduce the soundings to chart datum were exported to a file in the format time, height of tide with the file extension tdx. This file is readable in any text editing tool such as notepad.

4. Survey Data – Grab Sampling

a. Results of the Survey

The grab samples taken during the survey were packaged immediately on recovery in 5L plastic pails and sent to Stirling University's laboratory for analysis. The Results of this analysis are included in the accompanying document

Aspect Land A4534 PSA samples July 2010.pdf

Samples were able to be obtained in most of the survey areas. Where samples have not been achieved this is due to failure to retrieve a useable sample after 3 negative attempts. In all cases this was due to hard seabed such as compacted gravels or rock.

b. Equipment Used

The samples were taken using a top opening 0.045m^2 Van Veen grab. This proved suitable for sampling in all but the hardest seabed types experienced during the survey.

c. Processing Methodology

The processing methodology is detailed in the accompanying document

Aspect Land A4534 PSA samples July 2010.pdf

5. Geodesy and Datum

Both Horizontal and Vertical control throughout the survey was established using the Trimble VRS™ networked RTK service. ETRS89 coordinates obtained through this system are converted through OSTN02™ to result in OSGB national grid of Great Britain coordinates. The accuracy of this system was checked on site prior to the commencement of surveys by comparison against previously established control points on the jetty alongside the landing stage. These checks found the VRS system to provide reliable vertical and horizontal accuracy within the specification required for this survey.

The horizontal datum used throughout the survey is OSGB36 (OSTN02 ™).

OSTN02™ defines OSGB36 National Grid in conjunction with the National GPS Network. In this respect OSTN02™ can be considered error free (not including any GPS positional errors). The agreement between OSTN02™ and the old triangulation network stations (down to 3rd order) is 0.1m rms.

The VRS system allows RTK precision as detailed in Annex B.

The Vertical Datum used for all data is Ordnance Datum.

6. Vessel

The vessel used for the hydrographic survey was Aspect Surveys' Remote Sensor, an 8m catamaran of fibreglass construction certified Cat III by the Maritime and Coastguard Agency for work up to 20nm offshore

The shallow draft and manoeuvrability of this vessel ideally suited it to survey these confined waters. Additionally the integral diesel generator alleviated power issues during these extended surveys.

7. Personnel

The following personnel were involved during the survey:

NAME	POSITION
C Thomson	Hydrographic Survey / QA
G J Campbell	QA
G T Campbell	Hydrographic Survey / Processing
G Taylor	Vessel Skipper

Annex A to

A4534
Dated 27 Aug 10

Environmental Information

The meteorlological conditions varied throughout the period of the survey however the early months of 2010 saw the harshest winter conditions in many years. During this period the winds were predominantly easterly and this resulted in very well developed swells that prevented data gathering from being progressed at the previously envisaged rate. Weather information for the period of the survey data gathering is below:

Feb-10	Mean Daily Temperature	Sea Level Pressure	Wave Height	Wave Direction
5	6.6	997	1.4	↖
6	5.6	1016.5	1.5	←
7	5.8	1024.5	1	←
8	4.1	1020	1.3	↙
9	2.8	1020.3	1.7	↙
10	-0.3	1024	2.5	↙
11	1.7	1027.2	2.1	↓
12	3.7	1029.3	1.4	↓
13	1.7	1027.8	1.3	↙
14	6.2	1018	1.2	↙
15	5.2	1000	0.6	↙
16	2.6	989.4	1.3	↙
17	1.1	991.6	1	↑
18	1.6	993.3	1.1	↖
19	-0.1	994.1	1.1	↖
20	-0.7	994.9	1.5	↙
21	0.6	991.3	1.5	↙
22	0.8	992.3	1.4	↙
23	1.4	994.6	1.4	↓
24	1.8	989.2	1.7	↙
25	3.4	985.7	1.5	←
26	3	989.7	1.6	←
27	3.6	993.6	2.6	↓
28	2.6	996.1	2	↓

Mar-10	Mean Daily Temperature	Sea Level Pressure	Wave Height	Wave Direction
1	2	1009.4	2	
2	0.8	1022.3	1.2	
3	3.7	1021.3	1.7	
4	1.3	1027.6	1.2	
5	5	1030.9	0.9	
6	5.3	1029.4	1.7	
7	5	1032.7	1	
8	2.7	1032.7	0.4	
9	3	1033.8	0.3	
10	2.2	1033	0.9	
11	3.8	1026.6	0.9	
12	6.6	1025.9	0.9	
13	6.9	1030.3	1.4	
14	7.6	1029.1	1.4	
15	7.5	1025	1.6	
16	6.9	1020.6	1.5	
17	8.9	1012.1	1	
18	8.8	1001.7	0.9	
19	8.7	1003.6	1.3	
20	6.8	1004.8	0.4	
21	6.4	1010.9	0.6	
22	7.8	1006.3	1	
23	6.4	1008.7	1.1	
24	6.8	999.2	1.1	
25	6.6	997.1	0.9	
26	7.2	991.3	0.9	
27	7.5	1001.4	-	
28	6.6	1003	0.6	
29	4.4	997.4	1	
30	2.3	986	1.7	
31	3.3	993.7	1.9	

Apr-10	Mean Daily Temperature	Sea Level Pressure	Wave Height	Wave Direction
1	4.3	1001.6	1.6	↓
2	5.3	998.8	0.7	↓
3	5.6	999.4	1	↓
4	6.3	1009.1	0.5	↓
5	9.2	1004.5	0.9	↓
6	8.1	1004.2	1	↖
7	7.6	1019.7	1.3	↓
8	8.1	1027.7	0.4	→
9	8.2	1031.9	0.6	↗
10	9	1033.1	0.2	↖
11	8	1031.8	0.1	↖
12	8.3	1031	0.5	↘
13	8.9	1030.1	0.5	↘
14	7.1	1027.3	1.4	↓
15	6.5	1028.1	0.9	↓
16	5.9	1028.8	0.7	↙
17	8	1020.3	0.7	↙
18	7.9	1017.1	0.6	↙
19	5.8	1018.6	1	↙
20	6.1	1019.6	1.3	↙
21	6.2	1022.9	1.7	↑
22	6.4	1018.2	1.5	→
23	8.6	1013.5	0.7	↓
24	8.4	1013.9	0.8	↓
25	-	-	1.2	↗
26	11.2	1023.2	0.6	↓
27	9.2	1021.2	0.7	↗
28	10.9	1011.1	0.8	↓
29	10.2	1007.3	0.9	↗
30	9	1004.8	0.6	↖

May-10	Mean Daily Temperature	Sea Level Pressure	Wave Height	Wave Direction
1	8.3	1010.6	0.5	↗
2	7.1	1020.1	1.1	↗
3	6.7	1028.2	1.6	↖
4	9.1	1029.4	1.9	↓
5	9.8	1022	1.2	↓
6	10.2	1016.8	0.9	↓
7	8.6	1019.5	0.7	↓
8	7.6	1020.7	2.3	↓
9	8.2	1016.6	1.7	↙
10	7.2	1016.5	0.9	↙
11	6	1015.9	1.6	↓
12	6.2	1017.3	1.1	↓
13	7.6	1009.1	1.1	↙
14	8.7	1008.2	1	↙
15	9.3	1013.3	0.3	↙
16	9.4	1014.3	0.4	↗
17	10.1	1023.3	0.2	↓
18	11	1026.1	0.4	↓
19	11.4	1026	0.5	↖
20	13.3	1031	0.2	←
21	14.7	1031.4	0.2	↘
22	15.4	1028.7	0.2	↑
23	14.1	1022.9	0.5	↙
24	11.7	1017.8	0.6	←
25	9.3	1016	0.5	↙
26	8.7	1012.9	1.2	↖
27	8.7	1008.4	1.1	↙
28	9.7	1011.4	1.1	↙
29	10.5	1007.8	0.7	←
30	10.6	1014.1	0.7	↑
31	11.7	1020.1	2.9	↓

Jun-10	Mean Daily Temperature	Sea Level Pressure	Wave Height	Wave Direction
1	11.6	1014.8	1.3	↓
2	13	1021.2	0.4	→
3	14.8	1021.9	0.4	←
4	15.5	1018.1	0.2	↓
5	12.9	1017.8	0.6	↖
6	12.2	1014.4	0.4	↖
7	12.3	1008.8	0.4	↙
8	13.3	1003.7	0.5	↙
9	13.1	1010.3	0.9	↙
10	12.4	1016.2	1.6	↓
11	11.4	1012.4	1.6	↖
12	11.7	1017.8	0.8	↖
13	12.1	1014.1	1.3	↙
14	13	1022.4	1.1	↙
15	13.2	1030.6	0.8	←
16	13.1	1027.8	1	↙
17	13.9	1025.6	0.5	↙

Annex B to
A4534
Dated 27 Aug 10

Drawing Register

Title	Content
A4534_1_Herd Sands	Multibeam bathymetry and seabed characterisation
A4534_2_Whitburn Bay	Multibeam bathymetry and seabed characterisation
A4534_3_Salterfern Rocks	Multibeam bathymetry and seabed characterisation
A4534_4_Blast Beach	Multibeam bathymetry and seabed characterisation
A4534_5_Hartlepool North Sands	Multibeam bathymetry and seabed characterisation
A4534_6_Saltburn-by-the-Sea	Multibeam bathymetry and seabed characterisation
A4534_7_Skinningrove	Multibeam bathymetry and seabed characterisation
A4534_8_Runswick Bay	Multibeam bathymetry and seabed characterisation
A4534_9_Sandsend	Multibeam bathymetry and seabed characterisation
A4534_10_Whitby West Beach	Multibeam bathymetry and seabed characterisation
A4534_11_Robin Hood's Bay	Multibeam bathymetry and seabed characterisation
A4534_12_Scarborough North	Multibeam bathymetry and seabed characterisation
A4534_13_Scarborough South	Multibeam bathymetry and seabed characterisation
A4534_14_Cayton Bay	Multibeam bathymetry and seabed characterisation
A4534_15_Filey Bay	Multibeam bathymetry and seabed characterisation

Rendered Data

Folder Name	File Name
A4534_1	A4534_1_Herd Sands_1m_OD.xyz
A4534_1	A4534_1_Herd Sands_ALL_OD.xyz
A4534_1	A4534_1_Herd Sands_TIDE.tdx
A4534_2	A4534_2_Whitburn Bay_1m_OD.XYZ
A4534_2	A4534_2_Whitburn Bay_ALL_OD.xyz
A4534_2	A4534_2_Whitburn Bay_TIDE.tdx
A4534_2	A4534_2_Whitburn Bay TOPO_OD.xyz
A4534_3	A4534_3_Salterfen Rocks_1m_OD.XYZ
A4534_3	A4534_3_Salterfen Rocks_ALL_OD.xyz
A4534_3	A4534_3_Salterfen Rocks_TIDE.tdx
A4534_3	A4534_3_Salterfen Rocks_TOPO_OD.XYZ
A4534_4	A4534_4_Blast Beach_1m_OD.XYZ
A4534_4	A4534_4_Blast Beach_ALL_OD.xyz
A4534_4	A4534_4_Blast Beach_TIDE.tdx
A4534_4	A4534_4_Blast Beach_TOPO_OD.XYZ

Rendered Data (Contd)

Folder Name	File Name
A4534_5	A4534_5_Hartlepool North Sands_1m_OD.xyz
A4534_5	A4534_5_Hartlepool North Sands_ALL_OD.xyz
A4534_5	A4534_5_Hartlepool North Sands_TIDE.tdx
A4534_6	A4534_6_Saltburn-by-theSea_1m_OD.xyz
A4534_6	A4534_6_Saltburn-by-theSea_ALL_OD.xyz
A4534_6	A4534_6_Saltburn-by-theSea_TIDE.tdx
A4534_7	A4534_7_Skinningrove_1m_OD.xyz
A4534_7	A4534_7_Skinningrove_ALL_OD.xyz
A4534_7	A4534_7_Skinningrove_TIDE.tdx
A4534_7	A4534_7_Skinningrove_TOPO_OD.XYZ
A4534_8	A4534_8_Runswick Bay_1m_OD.xyz
A4534_8	A4534_8_Runswick Bay_ALL_OD.xyz
A4534_8	A4534_8_Runswick Bay_TIDE.tdx
A4534_8	A4538_8_Runswick Bay_TOPO_OD.XYZ
A4534_9	A4534_9_Sandsend_1m_OD.xyz
A4534_9	A4534_9_Sandsend_ALL_OD.xyz
A4534_9	A4534_9_Sandsend_TIDE.tdx
A4534_10	A4534_10_Whitby West Beach_1m_OD.xyz
A4534_10	A4534_10_Whitby West Beach_ALL_OD.xyz
A4534_10	A4534_10_Whitby West Beach_TIDE.tdx
A4534_10	A4534_10_Whitby West Beach_TOPO_OD.XYZ
A4534_11	A4534_11_Robin Hood's Bay_1m_OD.xyz
A4534_11	A4534_11_Robin Hood's Bay_ALL_OD.xyz
A4534_11	A4534_11_Robin Hood's Bay_TIDE.tdx
A4534_11	A4534_11_Robin Hood's Bay_TOPO_OD.XYZ
A4534_12	A4534_12_Scarborough North_1m_OD.xyz
A4534_12	A4534_12_Scarborough North_ALL_OD.xyz
A4534_12	A4534_12_Scarborough North_TIDE.tdx
A4534_13	A4534_13_Scarborough South_1m_OD.xyz
A4534_13	A4534_13_Scarborough South_ALL_OD.xyz
A4534_13	A4534_13_Scarborough South_TIDE.tdx
A4534_14	A4534_14_Cayton Bay_1m_OD.xyz
A4534_14	A4534_14_Cayton Bay_ALL_OD.xyz
A4534_14	A4534_14_Cayton Bay_TIDE.tdx
A4534_15	A4534_15_ Filey Bay_1m_OD.xyz
A4534_15	A4534_15_ Filey Bay_ALL_OD.xyz
A4534_15	A4534_15_ Filey Bay_TIDE.tdx
A4534_Transits\Transit 1-2	20100824_1PPC_5-0m_OD.xyz
A4534_Transits\Transit 1-2	20100824_ALLPOINTS_OD.xyz
A4534_Transits\Transit 1-2	2010__0391140_1.hs2
A4534_Transits\Transit 1-2	2010__0391216_1.hs2
A4534_Transits\Transit 1-2	2010__0391140_1.gsf
A4534_Transits\Transit 1-2	2010__0391216_1.gsf

Rendered Data (Contd)

Folder Name	File Name
A4534_Transits\Transit 2-3	20100824_1PPC_5-0m_OD.xyz
A4534_Transits\Transit 2-3	20100824_ALLPOINTS_5-0m_OD.xyz
A4534_Transits\Transit 2-3	2010__0381315_1.hs2
A4534_Transits\Transit 2-3	2010__0381329_1.hs2
A4534_Transits\Transit 2-3	2010__0381351_1.hs2
A4534_Transits\Transit 2-3	2010__0381315_1.gsf
A4534_Transits\Transit 2-3	2010__0381329_1.gsf
A4534_Transits\Transit 2-3	2010__0381351_1.gsf
A4534_Transits\Transit 3-4	20100824_1PPC_5-0m_OD.xyz
A4534_Transits\Transit 3-4	20100824_ALLPOINTS_5-0m_OD.xyz
A4534_Transits\Transit 3-4	2010__0781212_1.hs2
A4534_Transits\Transit 3-4	2010__0781212_1.gsf
A4534_Transits\Transit 4-5	20100824_ALLPOINTS_5-0m_OD.xyz
A4534_Transits\Transit 4-5	20100824_1PPC_5-0m_OD.xyz
A4534_Transits\Transit 4-5	2010__0781015_1.hs2
A4534_Transits\Transit 4-5	2010__0781050_1.hs2
A4534_Transits\Transit 4-5	2010__0781112_1.hs2
A4534_Transits\Transit 4-5	2010__0781141_1.hs2
A4534_Transits\Transit 4-5	2010__0781015_1.gsf
A4534_Transits\Transit 4-5	2010__0781050_1.gsf
A4534_Transits\Transit 4-5	2010__0781112_1.gsf
A4534_Transits\Transit 4-5	2010__0781141_1.gsf
A4534_Transits\Transit 5-6	20100824_ALLPOINTS_5-0m_OD.xyz
A4534_Transits\Transit 5-6	20100824_1PPC_5-0m_OD.xyz
A4534_Transits\Transit 5-6	2010__0771042_1.hs2
A4534_Transits\Transit 5-6	2010__0771112_1.hs2
A4534_Transits\Transit 5-6	2010__0771141_1.hs2
A4534_Transits\Transit 5-6	2010__0771213_1.hs2
A4534_Transits\Transit 5-6	2010__0771230_1.hs2
A4534_Transits\Transit 5-6	2010__0771252_1.hs2
A4534_Transits\Transit 5-6	2010__0771042_1.gsf
A4534_Transits\Transit 5-6	2010__0771112_1.gsf
A4534_Transits\Transit 5-6	2010__0771141_1.gsf
A4534_Transits\Transit 5-6	2010__0771213_1.gsf
A4534_Transits\Transit 5-6	2010__0771230_1.gsf
A4534_Transits\Transit 5-6	2010__0771252_1.gsf
A4534_Transits\Transit 6-7	20100825_1PPC_5-0m_OD.xyz
A4534_Transits\Transit 6-7	20100825_ALLPOINTS_5-0m_OD.xyz
A4534_Transits\Transit 6-7	2010__0761213_1.hs2
A4534_Transits\Transit 6-7	2010__0761241_1.hs2
A4534_Transits\Transit 6-7	2010__0761213_1.gsf
A4534_Transits\Transit 6-7	2010__0761241_1.gsf
A4534_Transits\Transit 7-8	20100825_1PPC_5-0m_OD.xyz

Rendered Data (Contd)

Folder Name	File Name
A4534_Transits\Transit 7-8	20100825_ALLPOINTS_5-0m_OD.xyz
A4534_Transits\Transit 7-8	2010__0491057_1.hs2
A4534_Transits\Transit 7-8	2010__0491133_1.hs2
A4534_Transits\Transit 7-8	2010__0491154_1.hs2
A4534_Transits\Transit 7-8	2010__0491057_1.gsf
A4534_Transits\Transit 7-8	2010__0491133_1.gsf
A4534_Transits\Transit 7-8	2010__0491154_1.gsf
A4534_Transits\Transit 8-9	20100825_1PPC_5-0m_OD.xyz
A4534_Transits\Transit 8-9	20100825_ALLPOINTS_5-0m_OD.xyz
A4534_Transits\Transit 8-9	2010__0491053_1.hs2
A4534_Transits\Transit 8-9	2010__0491057_1.hs2
A4534_Transits\Transit 8-9	2010__0491133_1.hs2
A4534_Transits\Transit 8-9	2010__0491053_1.gsf
A4534_Transits\Transit 8-9	2010__0491057_1.gsf
A4534_Transits\Transit 8-9	2010__0491133_1.gsf
A4534_Transits\Transit 9-10	20100825_1PPC_5-0m_OD.xyz
A4534_Transits\Transit 9-10	20100825_ALLPOINTS_5-0m_OD.xyz
A4534_Transits\Transit 9-10	2010__0471204_1.hs2
A4534_Transits\Transit 9-10	2010__0471204_1.gsf
A4534_Transits\Transit 10-11	20100826_1PPC_5-0m_OD.xyz
A4534_Transits\Transit 10-11	20100826_ALLPOINTS_5-0m_OD.xyz
A4534_Transits\Transit 10-11	2010__0481006_1.hs2
A4534_Transits\Transit 10-11	2010__0481036_1.hs2
A4534_Transits\Transit 10-11	2010__0481112_1.hs2
A4534_Transits\Transit 10-11	2010__0481145_1.hs2
A4534_Transits\Transit 10-11	2010__0481006_1.gsf
A4534_Transits\Transit 10-11	2010__0481036_1.gsf
A4534_Transits\Transit 10-11	2010__0481112_1.gsf
A4534_Transits\Transit 10-11	2010__0481145_1.gsf
A4534_Transits\Transit 11-12	20100826_1PPC_5-0m_OD.xyz
A4534_Transits\Transit 11-12	20100826_ALLPOINTS_5-0m_OD.xyz
A4534_Transits\Transit 11-12	2010__1591515_1.hs2
A4534_Transits\Transit 11-12	2010__1591534_1.hs2
A4534_Transits\Transit 11-12	2010__1591604_1.hs2
A4534_Transits\Transit 11-12	2010__1591633_1.hs2
A4534_Transits\Transit 11-12	2010__1591703_1.hs2
A4534_Transits\Transit 11-12	2010__1591515_1.gsf
A4534_Transits\Transit 11-12	2010__1591534_1.gsf
A4534_Transits\Transit 11-12	2010__1591604_1.gsf
A4534_Transits\Transit 11-12	2010__1591633_1.gsf
A4534_Transits\Transit 11-12	2010__1591703_1.gsf
A4534_Transits\Transit 12-13	20100826_1PPC_5-0m_OD.xyz

A4534_Transits\Transit 12-13	20100826_ALLPOINTS_5-0m_OD.xyz

Rendered Data (Contd)

Folder Name	File Name
A4534_Transits\Transit 12-13	2010__1591427_1.hs2
A4534_Transits\Transit 12-13	2010__1591427_1.gsf
A4534_Transits\Transit 13-14	20100826_1PPC_5-0m_OD.xyz
A4534_Transits\Transit 13-14	20100826_ALLPOINTS_5-0m_OD.xyz
A4534_Transits\Transit 13-14	2010__1671516_1.hs2
A4534_Transits\Transit 13-14	2010__1671512_1.hs2
A4534_Transits\Transit 13-14	2010__1671512_1.gsf
A4534_Transits\Transit 13-14	2010__1671516_1.gsf
A4534_Transits\Transit 14-15	20100826_1PPC_5-0m_OD.xyz
A4534_Transits\Transit 14-15	20100826_ALLPOINTS_5-0m_OD.xyz
A4534_Transits\Transit 14-15	2010__1681001_1.hs2
A4534_Transits\Transit 14-15	2010__1681037_1.hs2
A4534_Transits\Transit 14-15	2010__1681057_1.hs2
A4534_Transits\Transit 14-15	2010__1681001_1.gsf
A4534_Transits\Transit 14-15	2010__1681037_1.gsf
A4534_Transits\Transit 14-15	2010__1681057_1.gsf

Annex C to
A4534
Dated 27 Aug 10

Horizontal and Vertical Positioning system precision

TRIMBLE MS860 Geodetic grade GPS Receiver and Heading system, utilising RTK corrections.

	HORIZONTAL ACCURACY	**VERTICAL ACCURACY**
REAL TIME KINEMATIC	±10mm + 1ppm RMS	±20mm + 1ppm RMS

All horizontal positions in the survey are referred to Ordnance Datum (Newlyn).

Annex D to
A4534
Dated 27 Aug 10

Multibeam Echosounder Calibration

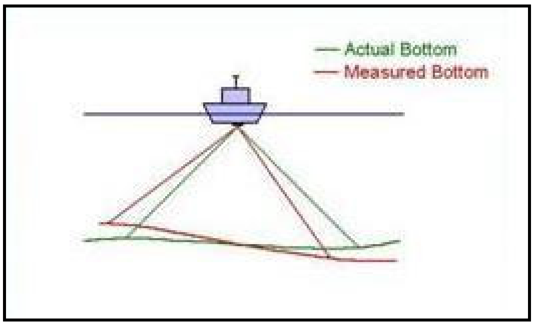
Patch tests are tests which are performed after initial equipment installation, and periodically thereafter as well as if sensors are modified, to quantify any residual biases from the initial system alignment.

During this calibration series, four separate tests must be performed to determine residual alignment biases for:

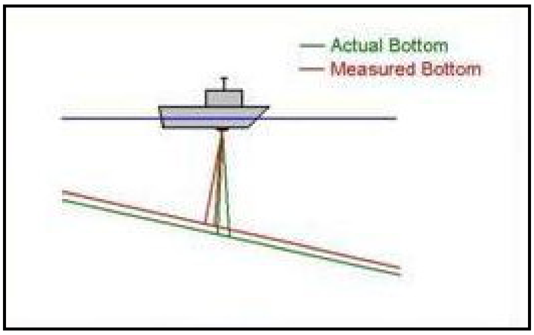
- Roll offset
- Position Time Delay (Latency)
- Pitch Offset
- Yaw (Heading) Offset

Errors relating to Multibeam

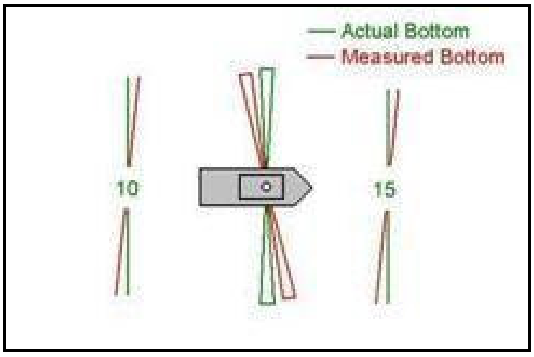
Roll: Sonar and Motion Reference Unit (MRU) alignment relative to vertical.
Can cause large depth and position errors at outer beams.



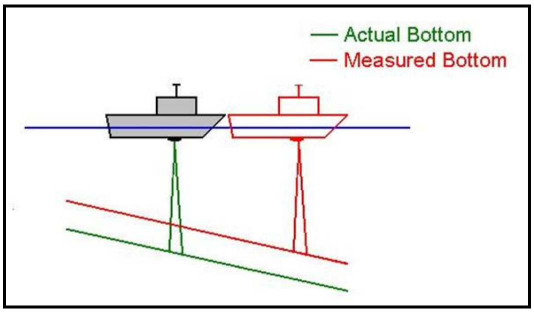
Pitch: Sonar and MRU alignment relative to vertical.
Can cause depth and position errors across the swath.



Yaw (Heading): Sonar and MRU alignment relative to vertical
Can cause depth and position errors across the swath.



Latency: The delay between position and fix transmission.
Will cause positional errors.
Error is independent of multibeam system.



Annex E to
A4534
Dated 27 Aug 10

Data Processing Procedures

Bathymetric Data

Multibeam Processing Stages

Kongsberg SIS software was used to control the MBES system during the data gathering phase.

Data was simultaneously logged in Kongsberg SIS and HYPACK HYSWEEP software to ensure data redundancy were a computer to fail.

After data gathering the data was post processed in HYPACK MBMax where the following stages of processing were undertaken:

- Navigation data was processed.
- Motion Sensor data was examined and edited as required.
- Automatic filtering of the data was carried out.
- Individual lines of MBES sounding data were manually edited.
- Processed files were loaded into Fledermaus visualisation and editing software and fully quality assured before being unloaded back to Hypack.
- The data was gridded at an appropriate post spacing for the scale of plot requested by the client. This was exported to AutoCAD for presentation.
- The data was contoured at 1m intervals in Hypack and exported to AutoCAD.
- X,Y, Z, files at 0.5m post spacing were generated and exported in Hypack. These higher density data files will be rendered to the client in ASCII X,Y,Z format.

Annex F to
A4534
Dated 27 Aug 10

Standard Disclaimer

1. All client-supplied data is taken on trust as being accurate and correct, and the sub contractor cannot be held responsible for the quality and accuracy of that data set.

2. Geophysical interpretation of bathymetry and sonar is based on an informed opinion of the supplied data, and is subject to inherent errors outwith the control of the interpretational geophysicist, which include but are not limited to GPS positioning errors, navigation busts, data quality, assumed speed velocity sediment profiles in the absence of Geotechnical data, sub bottom profile pulse width, and induced scaling errors therein associated with seismic signature.

3. The limits of this survey are defined by the data set; outwith the survey limits are not covered at any level by the sub contractor.

4. The data is accurate at the time of data acquisition, the sub contractor cannot be held responsible for environmental changes, and the client by accepting this report accepts that the environment of the seabed is subject to continuous change, that items of debris, hard contacts etc. may move, appear, be relocated or removed, thickness of surficial sediment change out with the knowledge of the sub contractor and they will not be held responsible for such actions at any level.

Appendix B

Particle Size Analysis Report

2010

UNIVERSITY OF STIRLING

Particle Size Analysis Samples A4534-2009/10

Aspect Land and Hydrographic Surveys Ltd

Environmental Services at the Institute of Aquaculture
University of Stirling
July 2010

Information sheet only

	Distribution:	Client, file
Environmental Services **Institute of Aquaculture, University of Stirling** **Stirling, FK9 4LA** **Tel: +44 1786 467878 Fax: +44 1786 472133**	**Project no:**	ES 2009-10 M008
	Client:	Aspect Land and Hydrographic Surveys Ltd.

Report:	Laboratory Analysis Report		
Title:	Particle Size Analysis of A4534 samples		
Author:	Dr Richard Corner	**Date:**	July 2010

INTRODUCTION

This report summarises the methods used and results of particle size analysis of sediment samples identified as A4534 series, collected over the period February 2010 to June 2010. Sediment samples were delivered to Stirling in white plastic buckets, having previously undergone no treatment or preservation. Each bucket was identified with the sample number in the format A4534-xx-y, xx presumably representing transect number and y representing sample number from that transect; and contained the date and time of collection, GPS position and sample number (Appendix A Table A.1).

METHODS

Analysis for particle sizing was conducted in 2 stages, through a process of wet sieving and dry sieving.

An aqueous solution of sodium hexametaphosphate $(NaPO_3)_6$ is used to prevent clumping and concretion of the fine particles of sediment. The solution was made using 6.2g of crystalline $(NaPO_3)_6$ dissolved in one litre of water; warmed under the hot tap to ensure all the $(NaPO_3)_6$ had dissolved. A representative sample weighing approximately 25g was weighed accurately on a 4 decimal place (dp) analytical balance (Mettler AJ100, Mettler-Toledo Ltd, Leicester, UK). This was placed into a 500ml glass beaker, to which 10ml aqueous sodium hexametaphosphate and 250ml of tap water was added. The content of the beaker was stirred using a glass rod for 6 minutes and then allowed to stand overnight. After 24 hours the sample was re-stirred for a further 6 minutes before being washed through a 63µm sieve. Washing consisted of pudding the sieve in a white tray until the water ran clear. The sediment that remained on the sieve was further processed by dry sieving.

The sample retained on the sieve was dried for a minimum of 1 hour, or until completely dry, in an oven at 90ºC. After drying and cooling at room temperature, the sample was gently brushed from the sieve into a plastic weighing pan and accurately re-weighed on a 4 dp analytical balance. At this stage the difference in weight was the mass of particles less than 63µm in size removed through wet sieving as described above.

After re-weighing the sample was transferred to a series of eight stacked sieves (2mm, 1mm, 500µm, 250µm, 180µm, 125µm, 90µm and 63µm) plus a base pan, for dry sieving. The use of these specific sieve sizes ensures the sediment sample is divided according to the Wentworth Phi scale (Table 1). Samples are placed on to an Analysette 3 SPARTAN pulverisette 0 automatic shaker (Fritsch, Oberstein, Germany) and shaken for 10 minutes at an amplitude of 1.5. Under shaking, the sample falls through the stacked sieves until individual particles are retained. The content of individual sieves is then weighed in a tared plastic weighing pan on a 4 dp analytical balance. The weight of the contents of the base pan was added to the weight of the fraction removed through wet sieving to give the total weight of particles less than 63µm, identified in the Wentworth scale as a mixture of silt and clay.

The weight of each Phi (ϕ) grain size is converted to a percentage of the original samples weight and a cumulative frequency curve generated. Quartiles Q10, Mdϕ and Q30 (units = Phi) frequency lines are added where the curve intersects the cumulative frequency at 25%, 50% and 75% respectively, the values of Phi being read off the X-axis. Phi quartile skewness (skqϕ) is calculated as (Q10-Q30)/2)-Mdϕ (Holme and McIntyre, 1971). Median grain size is calculated from a standard curve represented by the equation $1000.3e^{-0.6934X}$, where X is equal to Mdϕ. Kurtosis and skewness of the distribution of weight of sediment within each Wentworth scale partition was calculated using Wessa (2009). For both these values, however, their validity is truncated given that the distribution of sediment is limited to phi-scores between -2 and 4 and not the total of all possible phi-scores and therefore true normal distributions and deviations from this are not possible given the data requested be analysed.

Table 1: Relationship between particle sizes, Wentworth phi (φ) units under the Wentworth classification of sediment.

Particle Size Range (mm)	*φ* Units	Grade name
> 256	< -8.0	Boulder
256 to 64	-8.0 to -6.0	Cobble
64 to 4	-6.0 to -2.0	Pebble
4 to 2	-2.0 to -1.0	Granule
2 to 1	-1.0 to 0.0	Very course sand
1 to 0.5	0.0 to 1.0	Coarse sand
0.5 to 0.25	1.0 to 2.0	Medium sand
0.25 to 0.125	2.0 to 3.0	Fine sand
0.125 to 0.0625	3.0 to 4.0	Very fine sand
0.0625 to 0.0039	4.0 to 8.0	Silt
< 0.0039	> 8.0	Clay

RESULTS

General comments:

Samples 2-2 and 3-4 (highlighted in red in Tables) contained virtually no sediment but significant quantities of seawater, which rendered the sample un-usable.

Samples 3-5, 4-4, 6-4 and 11-1 contained a significant proportion by weight above 2mm in size, which rendered calculation of the Wentworth parameters, plus kurtosis and skewness impossible (Table 2). All these samples can be considered very coarse sand Table 3).

Samples 2-1, 3-1, 6-5, 7-2 and 7-4 were compromised to some extent, with necessary removal of a single large stone and algal frond(s) from the sample, which means assessment of grain size was compromised. This was particularly the case for samples 2-1, 3-1, 7-2 and 7-4 where less than ½ the normal dry weight of sediment (25g) was available for analysis. Nonetheless this “less than normal” amount of sediment was able to be evaluated.

Recovery of the sediment through the analytical process was greater than 99% in all samples (Appendix B, Table B-1), which means the data and assessment is a reliable measure of the particle grain size distribution.

Transect description:

Data associated with the descriptions below is available in Table 2 and 3.

Transect 1:

Samples 1-1 and 1-3 were similar in sediment type with a high proportion of fine and medium sand, and a median particle size (MPS) of 423 and 400µm respectively. Sample 1-2 had a higher proportion of very fine sand which reduced the MPS to fine sand (215µm). In all three samples the proportion of mud/silt was below 5%. Overall this transect can be considered a mix of very fine to medium sands with a low proportion of mud/silt. Quartile deviation and quartile skewness were low which indicates a good distribution of grain sizes in the sample around the median value. Relative to the mean, however, all samples are generally skewed to more fine particulates (skewness is moderately positive). The low values of kurtosis in samples 1-1 and 1-3 indicate a relatively normal distribution, whereas the 2.03 indicates a more peaked normal distribution (=leptokurtic) in sample 1-2.

Transect 2:

Transect 2 information is limited to one sample, 2-2 having been un-usable. In sample 2-1 only 12g of sediment was available for analysis, compared to the usual 25g. The MPS in sample 2-1 is impacted by the very high proportion of mud/silt (<63 µm) (62.9%) compared to the other particle sizes, followed by more medium sand than either very fine or fine sand present. The data is thus (quartile) skewed towards this small grain size (MPS 81.3 µm). This also affects the skewness from mean distribution (towards finer particles) and the leptokurtic (peaked) nature of the distribution.

Transect 3:

Transect 3 information is limited to 3 out of 4 samples, sample 3-4 having been un-usable. Sample 3-1 is similar to sample 2-1 above, with 14.7g of sediment assessed. It also contains a high proportion of mud/silt (62.8%), which skews towards an overall MPS (81.3 µm). The distribution is also leptokurtic. Samples 3-2 and 3-3 have a higher proportion of very fine and fine sand relative to mud/silt fraction which was below 10% in both cases. Transect 3 thus maintains, in places, a high mud/silt component, but in the main is composed of fine sand.

Transect 4:

It was not possible to calculate Wentworth parameters and kurtosis or skewness from the mean for sample 4-4, which contained particles which were nearly all above 2mm in size (very coarse sand), and comparatively large proportion of mud/silt particles but with no great distribution of other sizes. Sample 4-4 varied from the remaining samples in transect 4, which contained a low proportion of these larger and fine mud/silt particles. Of the three, Sample 4-1 had a slightly larger MPS (382 µm – Medium sand) compared to the identical 4-2 and 4-3 samples where MPS was in the fine sand category (164 µm). The distribution of particle size in sample 4-1 was slightly flattened (Platykurtic), compared to the other 2 samples, which tend to be more peaked (leptokurtic) in nature.

Transect 5:

Sample 5-1 has a relatively high proportion of fine sand (64%) and medium sand (25.2%). Sample 5-2 has a similar distribution shape, but tends towards a higher proportion of very fine sand and fine sand, followed by sample 5-3 and 5-4 which have a high proportion of mud/silt (30 and 37% respectively) and very fine sand (53 and 26% respectively) relative to the remaining particles sizes. Thus the data is more skewed towards finer grained particles through samples 5-1 to 5-4. In all samples the proportion of sediment above 2mm in size was very small (5.5% in 5-4 and less than 1% in the other samples), although the presence of 5.5% in sample 5-4 increases the quartile deviation and quartile skewness of this sample compared to the others..

Transect 6:

It was not possible to calculate Wentworth parameters and kurtosis or skewness from the mean for sample 6-4, which contained particles which were nearly all above 2mm in size (80.4% very coarse sand) and distorted the distribution. Although 6.5 was able to be calculated the distribution is again very uneven (high values for skewness and kurtosis) because 88.4% of the grains were below 63 µm, which means the values gained are less reliable. The estimate of very fine sand, is probably an over-estimate as a result, and the sediment should be considered mud/silt.

Station 6-1 has a marginally larger MPS (211 µm) than the either sample 6-1 or 6-2 (192 and 179 µm) respectively, but all three samples are firmly within the fine sand grain category. With 82.6% fine sand sample 6-1 is slightly more leptokurtic (peaked in distribution) than the other two samples, although both of these are also leptokurtic in distribution.

Transect 7:

During analysis the amount of sediment available in samples 7-2 and 7-4 was lower (approx 9g dry weight) compared to the normal level of 25g of sediment (dry weight) that would typically be used for analysis. So the results of both these samples are compromised. However, distribution of particles within this limited sample was possible and shows that the majority of the dry weight was within the very fine and fine sand category. Kurtosis values are low and indicate only a slightly peaked distribution with the normal range, although with a skewness towards finer particles.

Samples 7-1 is more leptokurtic (kurtosis: 4.51) than all other 7-series samples, having a higher proportion of the dry weight of sediment skewed (2.1) towards the fine sand category (76.9%). MPS of sample 7-1 (214 µm) is larger than any other samples (144-175 µm), but all locations can be categorised as fine sand. Sample 7-3 has the highest mud/silt % (11.9%) of all the other 7-series samples. It contains 52.5% very fine sand grains and 28.7% fine sand grains and overall fit just within the fine sand category (MPS 155 µm).

Transect 8:

Sample 8-1 has a high proportion of fine sand (67.5%) and slightly more medium sand (16.5%) than very fine sand (13.1%). Thus the overall distribution if of fine sand but with an MPS of 234 µm is bordering medium sand status. Sample 8-4 has a slightly lower proportion of fine sand (54.8%) and higher proportion of medium sand (26.9%) to give an overall MPS of 305 µm (medium sand). Kurtosis values for both these samples are relatively low, indicating a standard distribution, but slightly skewed towards finer particles.

Sample 8-2 and 8-3 have broadly similar quantities of very fine sand (48 and 42.8% respectively) and fine sand (37.6 and 47.4%) but sample 8-2 has a larger concentration of mud/silt (12.2%) than sample 8-3 (4%), which account for the difference in MPS (157 vs 179 µm respectively). Both of these samples are categorised as fine sand.

Transect 9:

The % of mud/silt in all 9-series samples was low, at less than 5%. Samples 9-2 to 9-4 also have a low quantity of particles above 0.5mm and a leptokurtic distribution is indicated with the majority of each sample (77%, 84% and 91% respectively) in the fine sand category. This oversimplifies the situation, however, as within these figure more than half the % is accounted for in the sieve size >125 µm and thus proportionately nearer to medium sand than to very fine sand. For this reason both 9-2 and 9-3 are just within the “fine sand” category, whilst sample 9-4 is marginally above this in the “medium sand” category.

90% of sample 9-1 by dry weight is equally split between categories fine sand and medium sand, and although the distribution is slightly more flattened (platykurtic) it is also skewed towards slightly larger particles for the remainder of the sample and results in an MPS of 517 µm or marginally within the coarse sand category.

Transect 10:

With almost 50% of sample 10-2 above 1mm in size the medium grain size for this sample is 1.93mm or very coarse sand. The highest proportion of grains for samples 10-1 and 10-3 are within the fine sediment category (63.5 and 83.2% respectively) but the proportion in size categories either side of this, results in a classification of fine sand for 10-1 (MPS 239 µm) and a classification of medium sand (MPS 281 µm) for sample 10-3.

Transect 11:

It was not possible to calculate Wentworth parameters and kurtosis or skewness from the mean for sample 11-1, which contained particles which were predominantly above 2mm in size (64.3% very coarse sand), and because the uniformity in distribution across all other size categories was uniform.

92% of sample 11-2 is either very fine or fine sand and the MPS at 175 µm is firmly within the fine sand category. Sample 11-3 is slightly more platykurtic (kurtosis -0.23) than many of the samples analysed, and is also less skewed that sample 10-2, which results in an MPS of 289 µm in the medium grain size category.

Transect 12:

Kurtosis values above 3 for each sample 12-x indicates a reasonably high level of peakedness within the particle distribution, focused in the main as a high proportion of “fine sand” (72%, 75% and 61% for samples 12-1, 12-2 and 12-3 respectively). Skewness data across all samples also indicated a propensity to skew in favour of smaller grain sizes than larger ones. There is some variation within the samples as to how much of the samples fit within each size category, but the net result is a fairly similar MPS (201 - 231 µm).

Transect 13:

Like sample series-12, all samples within series-13 fall within an MPS in the fine sand category; 13-2 being the smallest MPS at 135 µm and samples 13-3 being the largest (MPS 216 µm) at the opposite end of the fine sand range (125 - 250 µm). Samples 13-1 and 13-3 have a higher proportion of particles within the range 63-125 µm range (very fine sand) but the distribution of particles within the other categories varies and evens out the differences between very fine and fine sand.

Transect 14:

Kurtosis values and skewness values in series-14 samples are all broadly similar and indicate leptokurtic (peaked) data distribution skewed towards finer particle sizes. 63 – 65% very fine particles in samples 14-2 to 14-5 are balanced out to some extend by marginally higher proportions of sediment above 2mm in size, compared to samples 14-1 and 14-2 which have a higher proportion of fine sediments but lower amount in the larger size categories. Samples 14-3 to 14-5 have an MPS approximately the same, at around 150 µm; compared to the other two samples (190-220 µm) but all MPS’s are within the fine sand category.

Transect 15:

Sample 15-4 differs most from the other series-15 samples, containing 72% of the sediment above “medium sand”, 37.5% of which is above 2mm in size. The classification for sample 15-4 is very coarse sand, having an MPS of 1.2mm. Although sample 15-1 has a high proportion of fine sand (81.8%; leptokurtic), it has a relatively low proportion of small particles, which skews the data overall, to give a medium sand categorisation (MPS 285 µm). Sample 15-2 and 15-3 are similar in nature with MPS’s of 179 and 192 µm respectively, which is firmly within the category of fine sand.

Overall observations:

Most of the kurtosis and skewness data are positive and indicate both a peaked distribution and a distribution skewed towards finer particles, with exceptions. Across all samples the average contribution of mud/silt is low at 9.5% and the proportion above 250 µm (i.e. medium sand and above) accounts for 19.3% of the samples. The remainder of the samples, and the majority (71%) of the sediment grains, where very fine or fine sand.

Table 2: ***Particle size parameters for subtidal sediment samples collected between February and June 2010 at site A4534. Calculated using a wet-dry sieve method; results based on the Wentworth Classification Scheme. No data available for samples highlighted in red (see text) and samples to be considered with suspicion in light blue (see text). nc = not calculable.***

Sample ID (A4534-x-x)	Median φ Score	φ Quartile Deviation	φ quartile Skewness	Kurtosis	Skewness	Median Grain Size (μm)	Classification
1-1	1.24	0.71	0.08	0.30	1.32	423.37	Medium sand
1-2	2.22	0.36	-0.05	2.03	1.55	214.59	Fine sand
1-3	1.32	0.63	-0.01	0.23	1.34	400.52	Medium sand
2-1	3.62	1.41	-1.21	8.40	2.87	81.28	Very fine sand
2-2							-
3-1	3.62	0.80	-0.60	8.74	2.94	81.28	Very fine sand
3-2	2.53	0.32	0.04	0.25	1.34	173.08	Fine sand
3-3	2.79	0.30	0.02	1.33	1.41	144.53	Fine sand
3-4							-
3-5	nc	nc	nc	nc	nc	nc	Very coarse sand
4-1	1.39	0.77	0.00	-1.04	0.95	381.55	Medium sand
4-2	2.61	0.28	-0.02	1.74	1.64	163.74	Fine sand
4-3	2.61	0.33	-0.04	2.63	1.72	163.74	Fine sand
4-4	nc	nc	nc	nc	nc	nc	Very coarse sand
5-1	1.75	0.67	-0.17	-1.43	0.87	297.26	Medium sand
5-2	2.64	0.25	-0.02	3.05	1.90	160.37	Fine sand
5-3	2.99	0.47	0.13	-0.67	1.01	125.81	Fine sand
5-4	3.09	1.46	-0.86	5.22	2.13	117.38	Very fine sand
6-1	2.24	0.21	-0.04	5.54	2.32	211.63	Fine sand
6-2	2.38	0.21	0.03	3.46	2.00	192.05	Fine sand
6-3	2.48	0.26	0.04	1.18	1.64	179.19	Fine sand
6-4	nc	nc	nc	nc	nc	nc	Very coarse sand
6-5	3.75	0.14	-0.01	8.99	3.00	74.28	Very fine sand
7-1	2.22	0.25	-0.06	4.51	2.10	214.59	Fine sand
7-2	2.51	0.39	0.11	0.69	1.24	175.50	Fine sand
7-3	2.71	0.38	0.00	0.07	1.11	152.77	Fine sand
7-4	2.79	0.57	-0.21	0.38	1.37	144.53	Fine sand
8-1	2.09	0.53	-0.24	0.61	1.27	234.83	Fine sand
8-2	2.67	0.39	0.03	-0.66	0.94	157.07	Fine sand
8-3	2.48	0.32	0.02	0.04	1.23	179.19	Fine sand
8-4	1.71	0.61	-0.61	2.64	1.76	305.62	Medium sand
9-1	0.95	0.60	0.07	0.94	1.55	517.66	Coarse sand
9-2	2.21	0.28	-0.07	4.04	2.05	216.08	Fine sand
9-3	2.26	0.19	-0.03	6.24	2.45	208.72	Fine sand
9-4	1.85	0.37	-0.01	3.05	1.96	277.35	Medium sand
10-1	2.06	0.59	-0.28	0.21	1.16	239.76	Fine sand
10-2	-0.95	0.93	-0.08	-1.88	0.59	1932.92	Very coarse sand
10-3	1.83	0.44	-0.04	1.19	1.59	281.22	Medium sand
11-1	nc	nc	nc	nc	nc	nc	Very coarse sand
11-2	2.51	0.27	0.04	0.76	1.54	175.50	Fine sand
11-3	1.79	0.66	-0.15	-0.23	1.13	289.13	Medium sand
12-1	2.21	0.33	-0.13	3.74	1.95	216.08	Fine sand
12-3	2.11	0.42	-0.21	3.23	1.95	231.59	Fine sand
12-4	2.31	0.33	0.03	4.18	1.94	201.60	Fine sand
13-1	2.32	0.26	0.03	3.91	1.92	200.21	Fine sand
13-2	2.88	0.45	0.03	-1.92	0.46	135.78	Fine sand
13-3	2.21	0.28	-0.10	5.22	2.27	216.08	Fine sand
13-4	2.54	0.33	0.04	0.36	1.37	171.88	Fine sand
13-5	2.72	0.28	0.01	2.19	1.60	151.72	Fine sand
14-1	2.18	0.33	-0.13	2.72	1.83	220.62	Fine sand
14-2	2.38	0.22	0.02	3.29	1.90	192.05	Fine sand
14-3	2.70	0.32	0.13	1.20	1.34	153.83	Fine sand
14-4	2.73	0.28	0.00	2.62	1.70	150.67	Fine sand
14-5	2.72	0.29	0.00	2.00	1.58	151.72	Fine sand
15-1	1.81	0.45	-0.05	1.49	1.63	285.15	Medium sand
15-2	2.48	0.35	-0.05	0.76	1.42	179.19	Fine sand
15-3	2.38	0.34	0.06	1.86	1.62	192.05	Fine sand
15-4	-0.28	2.08	-0.65	1.95	1.44	1214.65	Very coarse sand

Table 3: ***Percentage composition by weight of particle sizes for sediment samples collected between February and June 2010 at site A4534. . Calculated using a wet-dry sieve method; results based on the Wentworth Classification Scheme. No data available for samples highlighted in red (see text) and samples to be considered with suspicion in light blue (see text).***

Sample ID (A4534-x-x)	% silt / clay (< 0.063mm)	% very fine sand (0.063 to 0.125mm)	% fine sand (0.125 to 0.25mm)	% medium sand (0.25 to 0.5mm)	% coarse sand (0.5 to 1mm)	% very coarse sand (1 to 2mm)	% granule (over 2mm)
1-1	0.8	8.4	48.8	40.8	0.3	0.3	0.0
1-2	4.9	21.9	64.6	7.1	1.1	0.3	0.2
1-3	2.9	4.5	55.8	33.8	2.6	0.3	0.0
2-1	62.9	5.1	7.0	11.6	4.0	2.6	6.7
2-2							
3-1	62.8	8.0	12.5	6.6	6.4	2.0	1.3
3-2	9.3	44.0	44.0	2.2	0.3	0.1	0.0
3-3	8.3	67.2	23.6	0.8	0.1	0.0	0.0
3-4							
3-5	0.7	0.4	0.4	0.6	0.5	0.5	97.1
4-1	4.3	4.6	52.7	32.9	5.3	0.2	0.0
4-2	5.0	54.5	35.3	4.3	0.7	0.2	0.0
4-3	9.0	49.9	32.0	6.0	1.8	0.6	0.7
4-4	12.5	1.3	0.9	0.6	0.4	0.2	84.0
5-1	1.2	7.2	64.6	25.1	1.4	0.1	0.3
5-2	4.0	60.6	33.5	1.2	0.4	0.1	0.2
5-3	30.0	53.8	11.2	3.3	1.5	0.1	0.0
5-4	36.5	26.5	10.0	8.9	10.9	5.5	1.5
6-1	1.6	12.8	82.6	2.1	0.3	0.2	0.0
6-2	2.3	33.1	63.6	0.6	0.1	0.1	0.2
6-3	2.2	44.6	51.6	0.7	0.4	0.2	0.1
6-4	6.5	2.0	1.1	1.1	2.1	6.7	80.4
6-5	88.4	4.0	2.7	0.9	0.8	1.0	2.3
7-1	1.7	15.0	76.9	5.5	0.4	0.1	0.0
7-2	8.1	42.6	47.0	1.5	0.3	0.2	0.0
7-3	11.9	52.5	28.7	2.7	2.5	1.2	0.1
7-4	5.2	61.0	12.1	8.4	9.0	2.9	1.3
8-1	1.9	13.1	67.5	16.5	0.9	0.1	0.0
8-2	12.2	48.0	37.6	1.4	0.1	0.0	0.0
8-3	4.0	42.8	47.4	4.7	0.4	0.1	0.0
8-4	2.3	1.7	54.8	26.9	13.1	0.8	0.2
9-1	1.2	0.8	45.7	43.7	3.3	1.6	3.4
9-2	3.4	13.7	77.1	5.2	0.4	0.1	0.0
9-3	4.6	10.7	84.1	0.6	0.0	0.0	0.0
9-4	3.0	3.7	91.1	2.0	0.0	0.0	0.0
10-1	2.0	13.5	63.5	17.6	2.3	0.8	0.2
10-2	2.0	2.8	5.1	13.0	27.2	24.9	23.8
10-3	2.3	3.2	82.8	11.4	0.2	0.0	0.0
11-1	6.0	7.7	11.4	4.0	2.7	3.8	64.3
11-2	6.3	44.6	48.1	0.5	0.0	0.0	0.0
11-3	3.7	10.5	59.9	16.6	1.1	1.4	6.7
12-1	1.9	15.1	72.8	8.2	1.6	0.2	0.0
12-3	2.8	6.4	75.5	2.2	0.6	3.4	8.9
12-4	8.4	23.8	61.0	2.8	0.5	1.0	2.4
13-1	3.8	27.5	65.9	2.3	0.2	0.1	0.0
13-2	18.7	54.4	26.1	0.4	0.1	0.0	0.0
13-3	2.4	11.6	77.0	1.3	0.7	1.0	5.8
13-4	8.0	45.0	41.1	0.8	0.5	1.8	2.6
13-5	8.7	62.7	26.5	0.8	0.3	0.5	0.6
14-1	1.2	11.8	80.2	6.3	0.2	0.1	0.2
14-2	2.7	32.4	63.5	1.2	0.1	0.1	0.0
14-3	11.2	65.4	22.2	0.1	0.1	0.1	0.9
14-4	8.9	63.3	26.1	0.5	0.2	0.3	0.6
14-5	8.2	62.8	26.7	0.4	0.3	0.7	0.7
15-1	1.1	4.2	81.8	11.6	0.7	0.3	0.0
15-2	2.1	45.7	41.1	6.7	3.1	0.8	0.3
15-3	2.4	34.4	55.6	5.7	1.5	0.2	0.0
15-4	1.6	2.0	24.2	18.4	11.0	5.3	37.5

Appendix A: Table A.1 Sample GPS positions, date and time of collection

Sample	GPS E	GPS N	Time	Date
1-1	438345	567243	745	05-May-10
1-2	438742	567600	718	05-May-10
1-3	439488	568268	734	05-May-10
2-1	441427	561148	923	05-May-10
2-2	441786	561093	936	05-May-10
3-1	442020	554069	1151	05-May-10
3-2	442329	554082	1103	05-May-10
3-3	443322	554085	1052	05-May-10
3-4	444316	554100	1044	05-May-10
3-5	445308	554094	1034	05-May-10
4-1	443997	547510	1656	05-May-10
4-2	444573	547696	1646	05-May-10
4-3	445533	547979	1636	05-May-10
4-4	446488	548278	1627	05-May-10
5-1	450891	535645	1338	18-Mar-10
5-2	451197	536197	1353	18-Mar-10
5-3	451694	537024	1401	18-Mar-10
5-4	452193	537908	1412	18-Mar-10
6-1	466681	522277	933	18-Mar-10
6-2	466839	522689	944	18-Mar-10
6-3	467192	523607	947	18-Mar-10
6-4	467552	524556	956	18-Mar-10
6-5	467927	525499	1004	18-Mar-10
7-1	471449	520698	1130	17-Mar-10
7-2	471618	521166	1137	17-Mar-10
7-3	472184	522014	1146	17-Mar-10
7-4	472708	522855	1203	17-Mar-10
8-1	481258	519941	1553	18-Feb-10
8-2	481757	516376	1546	18-Feb-10
8-3	482524	517029	1537	18-Feb-10
8-4	482921	517363	1526	18-Feb-10
9-1	486656	512644	1425	16-Feb-10
9-2	487045	513302	1433	16-Feb-10
9-3	487555	514157	1445	16-Feb-10
9-4	487992	514878	1502	16-Feb-10
10-1	489155	512049	1020	16-Feb-10
10-2	489290	512478	1124	16-Feb-10
10-3	489598	513442	1145	16-Feb-10
11-1	495766	505382	1412	17-Feb-10
11-2	496224	505379	1301	17-Feb-10
11-3	497215	505364	1312	17-Feb-10
12-1	504086	489909	1132	08-Jun-10
12-3	505451	490839	1207	08-Jun-10
12-4	506118	491281	1217	08-Jun-10
13-1	504895	488112	1345	16-Jun-10
13-2	505415	488192		16-Jun-10
13-3	506416	488345	1403	16-Jun-10
13-4	507396	488473		16-Jun-10
13-5	508391	488604	1430	16-Jun-10
14-1	507005	484711		16-Jun-10
14-2	507346	485119	1837	16-Jun-10
14-3	508017	485891	1845	16-Jun-10
14-4	508618	486695	1850	16-Jun-10
14-5	509217	487500	1904	16-Jun-10
15-1	513411	477385	700	17-Jun-10
15-2	513925	477848	928	17-Jun-10
15-3	514701	478469	937	17-Jun-10
15-4	515482	479088	950	17-Jun-10

Appendix B: Table B.1 weight in grams and % within each weight category in the up to >2mm in the Wentworth scheme classification.

SAMPLE	WT (g)	SIEVE WT (g)	<63um (g)	<63um (%)	>63um (g)	>63um (%)	>90um (g)	>90um (%)	>125um (g)	>125um (%)	>180um (g)	>180um (%)	>250um (g)	>250um (%)	>500um (g)	>500um (%)	>1mm (g)	>1mm (%)	>2mm (g)	>2mm (%)	recovery	sieve wt (<63um)	weight lost after wet sieving thru 63um sive
1-1	25.0198	24.8198	0.2072	0.83	1.1213	4.48	0.9860	3.94	4.1319	16.51	8.0658	32.24	10.20271	40.78	0.0693	0.28	0.0806	0.32	0	0.000	99.38	0.0072	0.2
1-2	25.002	23.8392	1.2133	4.85	0.7871	3.15	4.6879	18.75	10.5375	42.15	5.6077	22.43	1.7749	7.10	0.2666	1.07	0.0784	0.31	0.0456	0.182	99.99	0.0505	1.1628
1-3	25.0058	24.3192	0.7187	2.87	0.2316	0.93	0.9050	3.62	3.9011	15.60	10.0483	40.18	8.4531	33.80	0.6608	2.64	0.0838	0.34	0	0.000	99.99	0.0321	0.6866
2-1	12.0233	4.5118	7.5609	62.89	0.2969	2.47	0.3216	2.67	0.2685	2.23	0.5781	4.81	1.3906	11.57	0.4797	3.99	0.3101	2.58	0.8081	6.721	99.93	0.0494	7.5115
2-2	no sample	-	#VALUE!	#VALUE!		#VALUE!		#VALUE!		#VALUE!		#VALUE!		#VALUE!		#VALUE!		#VALUE!		#VALUE!	#VALUE!		#VALUE!
3-1	14.7547	5.7138	9.2647	62.79	0.6153	4.17	0.5676	3.85	0.9474	6.42	0.9038	6.13	0.98	6.64	0.9403	6.37	0.2934	1.99	0.1897	1.286	99.64	0.2238	9.0409
3-2	25.0089	22.8261	2.3243	9.29	2.1675	8.67	8.8473	35.38	9.0379	36.14	1.9742	7.89	0.5412	2.16	0.0866	0.35	0.0209	0.08	0	0.000	99.96	0.1415	2.1828
3-3	24.995	23.6238	2.0689	8.28	5.9723	23.89	10.8174	43.28	5.186	20.75	0.7008	2.80	0.2104	0.84	0.0237	0.09	0.0072	0.03	0	0.000	99.97	0.6977	1.3712
3-4	no sample	-	#VALUE!	#VALUE!		#VALUE!		#VALUE!		#VALUE!		#VALUE!		#VALUE!		#VALUE!		#VALUE!		#VALUE!	#VALUE!		#VALUE!
3-5	249.17	247.82	1.6456	0.66	0.2209	0.09	0.6595	0.26	0.5486	0.22	0.3445	0.14	1.4193	0.57	1.2429	0.50	1.271	0.51	241.82	97.050	100.00	0.2956	1.35
4-1	25.0009	23.9436	1.0792	4.32	0.1109	0.44	1.0317	4.13	5.4071	21.63	7.7560	31.02	8.2217	32.89	1.3238	5.30	0.061	0.24	0	0.000	99.96	0.0219	1.0573
4-2	25.0002	23.9346	1.2539	5.02	2.6551	10.62	10.9664	43.87	7.4847	29.94	1.3453	5.38	1.0671	4.27	0.1789	0.72	0.0399	0.16	0.0059	0.024	99.99	0.1883	1.0656
4-3	25.0017	23.0768	2.2593	9.04	2.327	9.31	10.1384	40.55	6.0776	24.31	1.9242	7.70	1.5053	6.02	0.4434	1.77	0.1538	0.62	0.1678	0.671	99.98	0.3344	1.9249
4-4	35.9793	31.5738	4.4959	12.50	0.165	0.46	0.2884	0.80	0.1857	0.52	0.1505	0.42	0.2131	0.59	0.1559	0.43	0.0801	0.22	30.2182	83.988	99.93	0.0904	4.4055
5-1	25.0007	24.7208	0.298	1.19	0.1061	0.42	1.6996	6.80	7.9237	31.69	8.2289	32.91	6.2753	25.10	0.3585	1.43	0.0257	0.10	0.0813	0.325	99.99	0.0181	0.2799
5-2	25.0016	24.1479	0.9903	3.96	2.4462	9.78	12.6986	50.79	7.1978	28.79	1.1807	4.72	0.2902	1.16	0.1064	0.43	0.03079	0.12	0.0476	0.190	99.95	0.1366	0.8537
5-3	24.9989	19.2659	7.5003	30.00	4.8365	19.35	8.6095	34.44	2.1723	8.69	0.6395	2.56	0.8253	3.30	0.3731	1.49	0.0289	0.12	0.0115	0.046	99.99	1.7673	5.733
5-4	25.0023	17.7868	9.1369	36.54	3.864	15.45	2.7683	11.07	1.335	5.34	1.1670	4.67	2.23	8.92	2.7209	10.88	1.3786	5.51	0.3637	1.455	99.85	1.9214	7.2155
6-1	25.0016	24.6222	0.3954	1.58	0.2146	0.86	2.9842	11.94	15.0849	60.34	5.5603	22.24	0.5191	2.08	0.0808	0.32	0.059	0.24	0.0096	0.038	99.63	0.016	0.3794
6-2	25.0009	24.4589	0.574	2.30	0.7631	3.05	7.5081	30.03	13.9024	55.61	2.0100	8.04	0.1459	0.58	0.0302	0.12	0.0153	0.06	0.0454	0.182	99.97	0.032	0.542
6-3	25.0019	24.5859	0.5397	2.16	1.8523	7.41	9.2964	37.18	11.8749	47.50	1.0256	4.10	0.1731	0.69	0.0943	0.38	0.0468	0.19	0.0363	0.145	99.75	0.1237	0.416
6-4	320.61	300.54	20.879	6.51	3.383	1.06	3.0675	0.96	2.123	0.66	1.4922	0.47	3.6241	1.13	6.7525	2.11	21.3776	6.67	257.87	80.431	99.99	0.809	20.07
6-5	22.3056	2.8773	19.7135	88.38	0.4707	2.11	0.4219	1.89	0.3728	1.67	0.2243	1.01	0.1938	0.87	0.1825	0.82	0.2124	0.95	0.5078	2.277	99.97	0.2852	19.4283
7-1	25.0008	24.621	0.4343	1.74	0.3068	1.23	3.4481	13.79	13.5102	54.04	5.7269	22.91	1.3816	5.53	0.1039	0.42	0.028	0.11	0	0.000	99.76	0.0545	0.3798

7-2	6.0657	5.697	0.4921	8.11	1.0018	16.52	1.5835	26.11	2.3281	38.38	0.5237	8.63	0.0939	1.55	0.0196	0.32	0.01	0.16	0	0.000	99.79	0.1234	0.3687
7-3	25.0005	22.5137	2.9739	11.90	4.2791	17.12	8.8585	35.43	6.4357	25.74	0.7409	2.96	0.6753	2.70	0.6371	2.55	0.307	1.23	0.0261	0.104	99.73	0.4871	2.4868
7-4	9.6454	9.4001	0.505	5.24	2.8352	29.39	3.0519	31.64	0.8628	8.95	0.3062	3.17	0.8079	8.38	0.8657	8.98	0.2799	2.90	0.1218	1.263	99.91	0.2597	0.2453
8-1	24.9987	24.5369	0.4635	1.85	0.5503	2.20	2.7305	10.92	9.983	39.93	6.9016	27.61	4.1209	16.48	0.2134	0.85	0.0284	0.11	0	0.000	99.97	0.0017	0.4618
8-2	24.9905	22.8957	3.0444	12.18	3.9842	15.94	7.9990	32.01	7.9444	31.79	1.4585	5.84	0.3568	1.43	0.0339	0.14	0.0089	0.04	0	0.000	99.36	0.9496	2.0948
8-3	24.9461	24.0995	1.0031	4.02	2.6385	10.58	8.0436	32.24	8.7896	35.23	3.0325	12.16	1.1716	4.70	0.1063	0.43	0.02	0.08	0	0.000	99.44	0.1565	0.8466
8-4	24.9997	24.4457	0.577	2.31	0.023	0.09	0.4118	1.65	1.8571	7.43	11.8307	47.32	6.7222	26.89	3.2721	13.09	0.1943	0.78	0.052	0.208	99.76	0.023	0.554
9-1	25.0017	24.7035	0.3066	1.23	0.0375	0.15	0.1643	0.66	2.7915	11.17	8.6406	34.56	10.9287	43.71	0.8346	3.34	0.4018	1.61	0.8496	3.398	99.81	0.0084	0.2982
9-2	25.0011	24.2362	0.8598	3.44	0.9834	3.93	2.4328	9.73	12.9041	51.61	6.3791	25.52	1.2994	5.20	0.093	0.37	0.021	0.08	0	0.000	99.89	0.0949	0.7649
9-3	24.995	23.9165	1.1385	4.55	0.4536	1.81	2.2186	8.88	15.7264	62.92	5.2836	21.14	0.1505	0.60	0.0088	0.04	0.003	0.01	0	0.000	99.95	0.06	1.0785
9-4	25.0007	24.2917	0.7444	2.98	0.209	0.84	0.7066	2.83	8.3813	33.52	14.4042	57.62	0.5099	2.04	0.0086	0.03	0	0.00	0	0.000	99.85	0.0354	0.709
10-1	25.0005	24.5383	0.4969	1.99	0.5797	2.32	2.7904	11.16	9.2801	37.12	6.6029	26.41	4.3909	17.56	0.5667	2.27	0.1899	0.76	0.042	0.168	99.76	0.0347	0.4622
10-2	24.9973	24.535	0.4984	1.99	0.3197	1.28	0.3697	1.48	0.6291	2.52	0.6557	2.62	3.2582	13.03	6.7902	27.16	6.215	24.86	5.9578	23.834	98.79	0.0361	0.4623
10-3	24.9997	24.4481	0.5855	2.34	0.2109	0.84	0.5766	2.31	8.8428	35.37	11.8659	47.46	2.8539	11.42	0.0561	0.22	0.0067	0.03	0	0.000	99.99	0.0339	0.5516
11-1	24.1542	22.8776	1.4505	6.01	0.8442	3.50	1.0041	4.16	1.3576	5.62	1.3986	5.79	0.9752	4.04	0.6549	2.71	0.9152	3.79	15.5377	64.327	99.93	0.1739	1.2766
11-2	24.9968	23.5644	1.5709	6.28	1.7926	7.17	9.3634	37.46	10.905	43.63	1.1215	4.49	0.1285	0.51	0.00119	0.00	0.00024	0.00	0	0.000	99.55	0.1385	1.4324
11-3	24.9997	24.1632	0.9131	3.65	0.7788	3.12	1.8537	7.41	6.8756	27.50	8.1085	32.43	4.146	16.58	0.2781	1.11	0.3411	1.36	1.6871	6.748	99.93	0.0766	0.8365
12-1	25.0464	24.6379	0.4868	1.94	0.6394	2.55	3.1497	12.58	12.2622	48.96	5.9834	23.89	2.0431	8.16	0.3885	1.55	0.0615	0.25	0	0.000	99.87	0.0783	0.4085
12-3	25.1119	24.449	0.7099	2.83	0.4355	1.73	1.1683	4.65	12.0759	48.09	6.8910	27.44	0.5535	2.20	0.1629	0.65	0.8552	3.41	2.2332	8.893	99.89	0.047	0.6629
12-4	25.1401	23.1648	2.1172	8.42	2.0076	7.99	3.9764	15.82	10.9217	43.44	4.4253	17.60	0.6934	2.76	0.1187	0.47	0.2423	0.96	0.6118	2.434	99.90	0.1419	1.9753
13-1	25.1383	24.4349	0.9527	3.79	2.2048	8.77	4.7004	18.70	12.0484	47.93	4.5123	17.95	0.5799	2.31	0.055	0.22	0.0207	0.08	0	0.000	99.75	0.2493	0.7034
13-2	24.9778	21.7241	4.6655	18.68	5.9831	23.95	7.6000	30.43	5.6681	22.69	0.8610	3.45	0.1107	0.44	0.0324	0.13	0.008	0.03	0	0.000	99.80	1.4118	3.2537
13-3	25.1267	24.591	0.6019	2.40	0.7102	2.83	2.2028	8.77	13.6056	54.15	5.7433	22.86	0.3389	1.35	0.1666	0.66	0.2427	0.97	1.4685	5.844	99.82	0.0662	0.5357
13-4	25.1752	23.2818	2.002	7.95	3.1588	12.55	8.1696	32.45	9.4197	37.42	0.9203	3.66	0.2092	0.83	0.1334	0.53	0.447	1.78	0.6637	2.636	99.80	0.1086	1.8934
13-5	25.2113	23.3246	2.1963	8.71	4.3164	17.12	11.4857	45.56	6.2478	24.78	0.4296	1.70	0.1961	0.78	0.0636	0.25	0.1169	0.46	0.1503	0.596	99.97	0.3096	1.8867
14-1	25.3588	25.0876	0.2993	1.18	0.4507	1.78	2.5432	10.03	12.8049	50.49	7.5308	29.70	1.5879	6.26	0.0569	0.22	0.0293	0.12	0.0437	0.172	99.95	0.0281	0.2712
14-2	25.1005	24.5338	0.6774	2.70	1.3412	5.34	6.7893	27.05	12.8586	51.23	3.0786	12.27	0.2973	1.18	0.031	0.12	0.0221	0.09	0	0.000	99.98	0.1107	0.5667
14-3	25.2961	23.2382	2.8353	11.21	5.6735	22.43	10.8779	43.00	5.4419	21.51	0.1658	0.66	0.0272	0.11	0.0238	0.09	0.0132	0.05	0.2262	0.894	99.96	0.7774	2.0579
14-4	25.3105	23.2928	2.243	8.86	4.0543	16.02	11.9784	47.33	6.2729	24.78	0.3280	1.30	0.1252	0.49	0.0411	0.16	0.0728	0.29	0.154	0.608	99.84	0.2253	2.0177
14-5	25.1526	23.2707	2.0694	8.23	4.2851	17.04	11.5039	45.74	6.4937	25.82	0.2287	0.91	0.1079	0.43	0.0793	0.32	0.1857	0.74	0.1639	0.652	99.86	0.1875	1.8819
15-1	25.0098	24.7371	0.2792	1.12	0.0548	0.22	0.9946	3.98	8.4346	33.73	12.0182	48.05	2.9054	11.62	0.1856	0.74	0.0726	0.29	0	0.000	99.74	0.0065	0.2727

15-2	25.4024	24.963	0.5413	2.13	2.0474	8.06	9.5605	37.64	7.6212	30.00	2.8237	11.12	1.7005	6.69	0.7967	3.14	0.211	0.83	0.0837	0.329	99.94	0.1019	0.4394
15-3	25.1111	24.5919	0.6	2.39	1.5798	6.29	7.0529	28.09	10.8515	43.21	3.1189	12.42	1.4336	5.71	0.377	1.50	0.0609	0.24	0	0.000	99.85	0.0808	0.5192
15-4	25.3558	24.9759	0.4041	1.59	0.1565	0.62	0.3420	1.35	1.3379	5.28	4.7879	18.88	4.6545	18.36	2.7879	11.00	1.3416	5.29	9.504	37.483	99.84	0.0242	0.3799