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14/08/2017	Final

Contents

Introduction

Technological improvements in bathymetric survey equipment and the widespread introduction of multibeam echosounder systems (MBES) within the offshore survey industry have meant that it is now increasingly cost-effective to achieve 100% sea floor coverage. Although the primary purpose is generally to survey the bathymetry of the seabed, interpretation of acoustic backscatter information and groundtruthing data collected during the survey, in combination with the bathymetry, can be used to produce indicative maps of other features, such as marine habitats, substrate type and anthropogenic features.

A swath bathymetry survey of the seabed between Robin Hood’s Bay and Flamborough Head (HI1472, Figure 1) was commissioned by the Maritime Coastguard Agency, as part of the Civil Hydrography Programme (CHP) and extended into the coastal zone with contribution from Scarborough Borough Council. The survey area covered 798 km^2 extending to 22km offshore and was completed in February 2016. The survey delivered 100% seafloor coverage to IHO Order 1a, along with backscatter and groundtruthing sediment samples. An adjoining survey (HI1358, Figure 1) had been commissioned by East Riding of Yorkshire Council (ERYC) in 2008 and habitat mapped by the Channel Coastal Observatory (CCO). Data from this survey will be included in the maps, for completeness.

All data collected through the National Network of Regional Coastal Monitoring Programmes and the Maritime and Coastguard Agency’s CHP are collected to meet the CHP Specification, fully validated, supported with metadata, and freely available under the Open Government Licence.

Scarborough Borough Council (SBC) commissioned the CCO to interpret the available bathymetry, backscatter and groundtruthing data to inform a range of coastal management, marine conservation, and planning policy objectives.

This report describes the methodology and interpretation of the bathymetry, backscatter and groundtruthing data through a series of detailed thematic maps, including surficial substrate, EUNIS level 3 marine habitats and anthropogenic features.

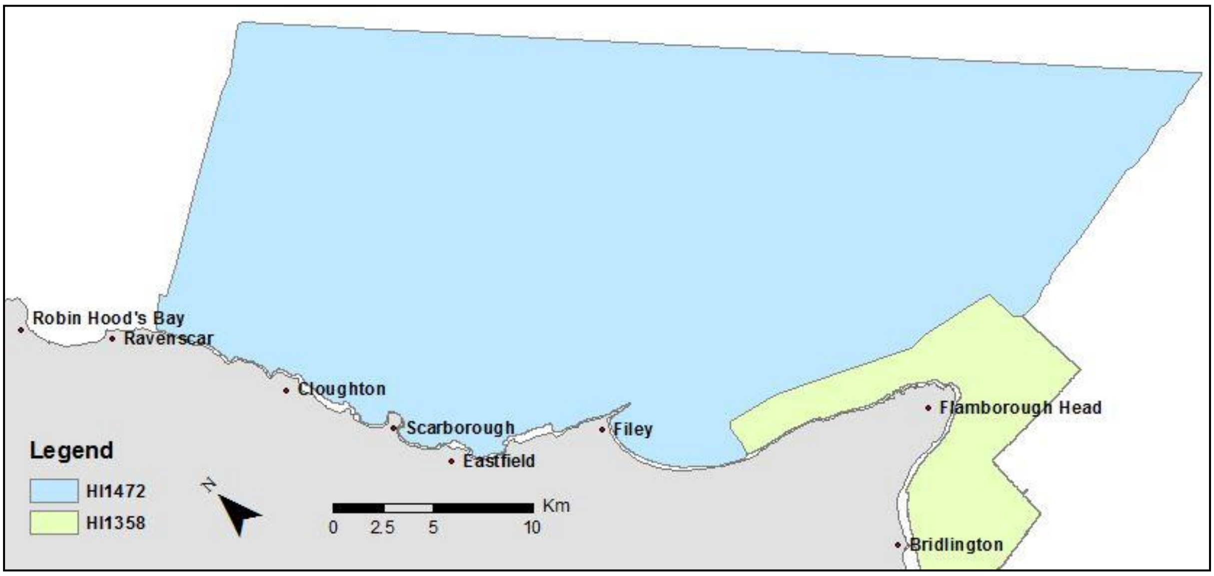


Figure 1: Survey coverage. HI1472 ‘Robin Hood’s Bay to Flamborough Head’ (SBC survey, 2015) and previous overlapping survey HI1358 ‘Flamborough Head to Spurn Point’ (ERYC Survey, 2008)

Marine Habitat Classification Scheme

Marine habitats were mapped using the European Nature Information System (EUNIS) habitat classification, as modified by the Joint Nature Conservation Committee (JNCC, see http://jncc.defra.gov.uk/pdf/04_05_introduction.pdf). EUNIS is a hierarchical classification ranging from basic descriptions (high level classifications) such as littoral rock, to very detailed descriptions (low level classifications). Up to 6 levels are defined but Levels 4-6 involve the biology and accordingly the MBES survey can be used to map to Level 3 only; nevertheless, the results of Level 3 and substrate mapping can be used by other agencies who might wish to map to a more detailed level.

Level 1 Environment (marine)

A single category is defined within EUNIS to distinguish the marine environment from terrestrial and freshwater habitats.

Level 2 Broad habitats

These are extremely broad divisions of national and international application for which EC Habitats Directive Annex I habitats (*e.g.* reefs, mudflats and sandflats not covered by seawater at low tide) are the approximate equivalent. At EUNIS Level 2, there are eight broad marine habitats classifications (Table 1).

Typical UK boundary depths	Rock	Rock and thin Sediment	Sediment
	Littoral Rock	*Littoral Rock and thin Sediment*	*Littoral Sediment*
MLWS	*Infralittoral Rock*	*Infralittoral Rock and thin Sediment*	*Sublittoral Sediment*
20m OD	*Circalittoral Rock*	*Circalittoral Rock and thin Sediment*	

Table 1: EUNIS Level 2 marine habitat classifications

Level 3 Main habitats

These serve to provide very broad divisions of national and international application which reflect major differences in biological character. They are equivalent to the intertidal Sites of Special Scientific Interest (SSSI) selection units (for designation of shores in the UK) (JNCC, 1996) and can be used as national mapping units. At EUNIS Level 3 (Table 2), the broad habitat types from EUNIS Level 2 are sub-divided further based on sediment type, wave exposure and tidal current strength.

Rock			Rock and thin Sediment			Sediment			
High energy littoral rock	*Moderate energy littoral rock*	*Low energy littoral rock*	*High energy littoral rock and thin Sediment*	*Moderate energy littoral rock and thin Sediment*	*Low energy littoral rock and thin Sediment*	*Littoral mud*	*Littoral sand*	*Littoral mixed sediment*	*Littoral coarse sediment*
High energy infralittoral rock	*Moderate energy infralittoral rock*	*Low energy infralittoral rock*	*High energy infralittoral rock and thin Sediment*	*Moderate energy infralittoral rock and thin Sediment*	*Low energy infralittoral rock and thin Sediment*	*Sublittoral mud*	*Sublittoral sand*	*Sublittoral mixed sediment*	*Sublittoral coarse sediment*
High energy circalittoral rock	*Moderate energy circalittoral rock*	*Low energy circalittoral rock*	*High energy circalittoral rock and thin Sediment*	*Moderate energy circalittoral rock and thin Sediment*	*Low energy circalittoral rock and thin Sediment*				

Table 2: EUNIS Level 3 marine habitat classifications

In the classifications, 'Rock' refers collectively to bedrock, stable and artificial substrata (concrete, wood, metal). 'Rock and thin Sediment' collectively refers to areas where Rock is only covered by a thin veneer of sediment and at times the geology beneath the sediment can be defined or becomes visible. Seismic and acoustic surveys of such as areas often suggest that they should be classified as Rock habitats. However, grab samples or video trawls if available suggest the area should be classified as sediment. These type of habitats can show characteristics of both hard and soft substrate with both epifauna and infauna present. Rock and thin Sediment acts as an interim between the pure Rock and Sediment areas. Cobbles and pebbles with gravel and coarse sand are collectively referred to as 'Coarse Sediment'. 'Mixed Sediment' consists of mixtures of gravel, sand and mud which may contain stones and shells.

The littoral zone lies landward of Mean Low Water Springs (MLWS) with the sublittoral zone seaward of MLWS. For areas of 'Rock" or 'Rock and thin Sediment', the sublittoral zone is split into the infralittoral zone and the circalittoral zone based upon site-specific biological parameters (see Marine Habitat Boundaries section).

Habitat Mapping Methodology

Bathymetry, backscatter and groundtruthing data were used to provide information for the production of maps displaying anthropogenic features (*e.g.* cables and pipelines, wrecks, trawl marks and sea defence structures), substrate type and EUNIS Level 3 seabed habitat maps (Figure 2).

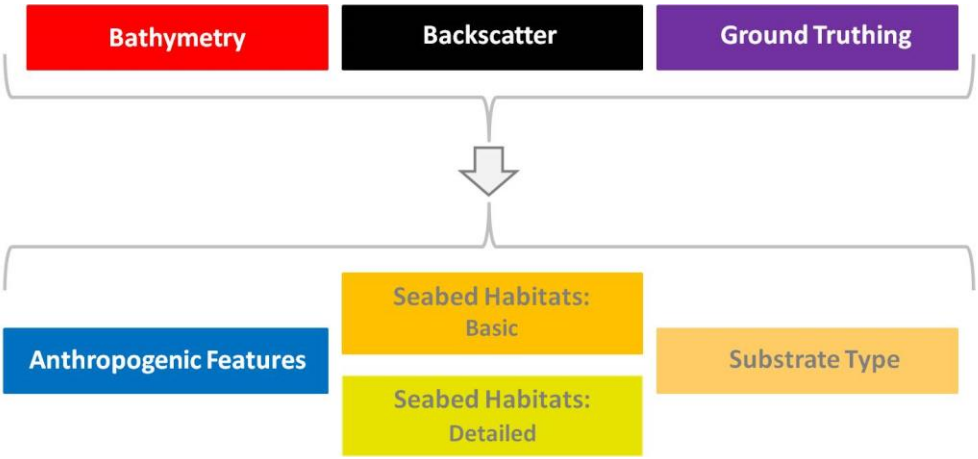


Figure 2: Seabed mapping stages

Bathymetry

The IHO Order 1a standard swath bathymetry surveys commissioned by the Northeast Regional Coastal Monitoring Programme and the Maritime & Coastguard Agency (MCA), were collected in accordance with the MCA Civil Hydrography Programme Survey Specification A (March 2016). The survey commenced on 17^{th} November 2015 and was completed on 28^{th} February 2016. Bathymetry data were acquired using a hull-mounted Kongsberg EM2040C Multibeam Echo-Sounder (MBES). The UKHO undertook quality-control of the data and produced a quality-controlled data set in WGS84/Chart Datum, at 1m resolution.

The bathymetry data was loaded into CARIS HIPS and SIPS 9.1 in order to export the files as one single layer for subsequent use in ArcGIS v10.2. Figure 3a illustrates the high resolution of the bathymetry and superimposed on aerial photography. Figure 3a also demonstrates the required overlap with land-based survey data thus avoiding the well-known "white ribbon" strip of seabed close to the shore where data seldom is captured. Depths in a number of the figures are colour-coded with orange colours indicating shallow depths and dark blue the deepest areas.

Hillshade

Within ArcGIS v10.2, a hillshade layer was derived which is a form of artificial sun-illumination which helps to enhance depth changes and features in the bathymetry dataset. This layer is particularly useful for displaying and enhancing areas of bedforms and seabed of variable texture where there are numerous depth changes across relatively short distances. Figure 3b illustrates how the hillshade layer can enhance the bathymetry.

Seabed Slope

The seabed slope map distinguishes those areas of the seabed that have a steep gradient or sharp changes in slope from those areas which are relatively flat; this aids the identification of bedrock and geological features, sedimentary bedforms and anthropogenic features (e.g. pipelines and channels). The seabed slope is derived within ArcGIS by calculating the slope angle of the seabed using a central cell and comparing its value to those around it. An extensive rock platform extending from Filey Brigg and other geological features clearly illustrate the change in slope angle (Figure 3c). The colour scheme used is a classified symbology dividing the slope angles into 9 categories. Green indicates relatively flat or low angle topography, with increasing slope represented by gradation from yellow to orange, and red indicating steepest slope angles.

Backscatter

The intensity of the return acoustic signal, termed “backscatter” indicates the nature and relative composition of the seabed. This can provide information on the roughness and texture of the seabed substrate, and variability and changes in sediment type. Backscatter files were delivered by the survey contractor in a post-processed file format as a mosaiced GeoTIFF image.

Many factors can influence backscatter intensity, for example, changes in seabed slope or adjustments to survey vessel equipment configurations. It is not simply the case that a given backscatter intensity represents a defined sediment type. The backscatter data layer does not provide information as to what types of sediment the boundaries are showing – for example gravel to sand or sand to mud. To define this substrate type or marine habitat, combined analysis of bathymetry, backscatter and groundtruthing information is required. Backscatter, therefore, requires expert analysis and must be viewed in combination with bathymetry and groundtruthing information to give confidence in the resulting substrate and marine habitat maps.

The importance of backscatter for substrate classification and habitat mapping can be seen by the changes in the intensity (grey scale) of the backscatter that are not visible in the bathymetry, as exemplified in Figure 3d. Since the backscatter boundaries are observed across numerous survey track lines, it can be concluded that these denote a real change in seabed texture; for example, either constrained pockets of sediment within an area of exposed or outcropping bedrock, or of a different grain-size to the surrounding substrate.

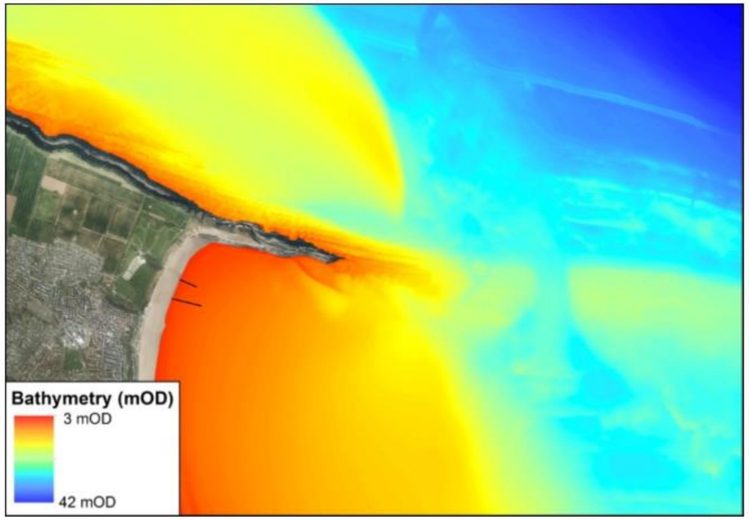


Figure 3a: Bathymetry, Filey Head

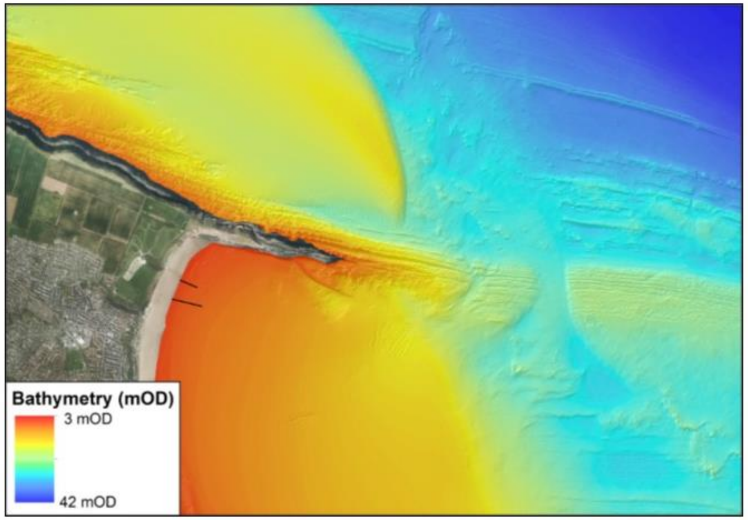


Figure 3b: Bathymetry with hillshade, Filey Head

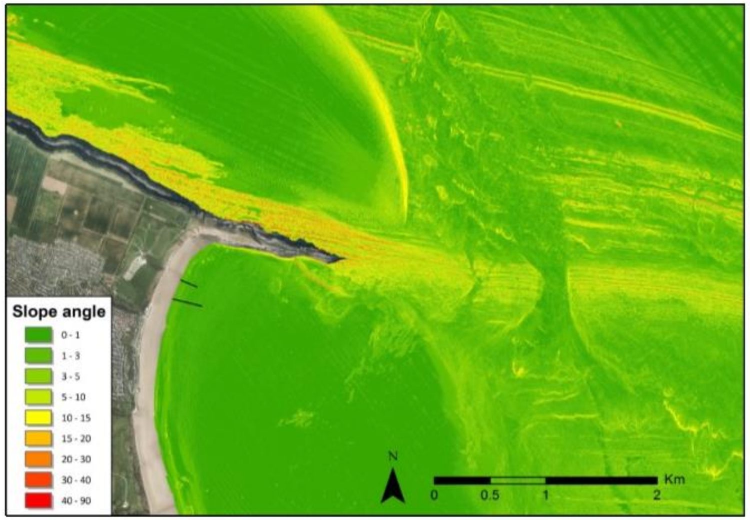


Figure 3c: Slope angle (degrees), Filey Head

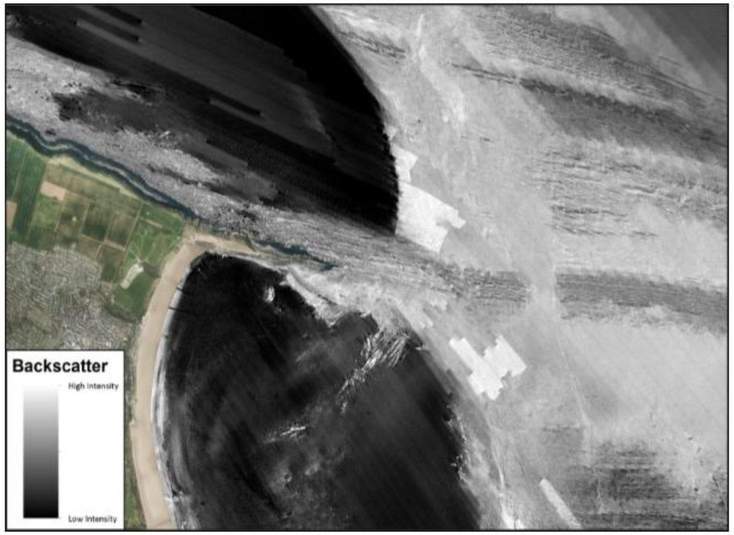


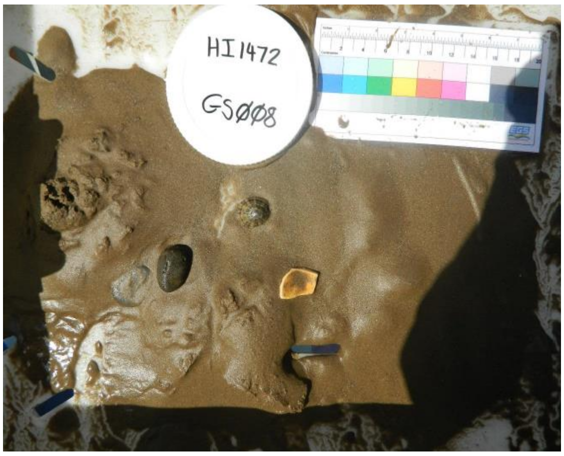
Figure 3d: Backscatter (Intensity), Filey Head

Groundtruthing

Groundtruthing data is a key requirement to enable the production of detailed substrate, marine habitat and biotope-type maps. A wide range of information can be useful, such as sediment samples, photographs and videos of seabed and features, topographic beach survey data for inter-tidal areas, nearshore marine geology maps (solid and drift) and visual dive records and observations.

65 sediment samples were taken during the Robin Hood's Bay to Flamborough Head survey, as per the MCA Civil Hydrography Programme Specification. Figure 4 shows some examples of the sediment types identified in the survey area and full extent of the sediment points can be found in Appendix 3.

Sandy Mud



Sand

Mixed Sediment

Coarse Sediment

Figure 4: Sediment variation in the nearshore zone: Sandy Mud, Sand, Mixed Sediment and Coarse Sediment

An assessment of sediment volume recovered from each sample also provided an indication of the thickness of sediment. This aided interpretation in areas of seabed where the surface expression of the underlying geology was spatially variable. Further substrate information was sourced from JNCC marine recorder, Seasearch, BGS and Scarborough Borough Council.

Hydrodynamic Data

To inform the interpretation of the marine habitats within the area of interest information from the Northeast Regional Coastal Monitoring Programme's network of waverider buoys was used. In particular, a Datawell Waverider MKIII buoy located approximately 4.5km offshore of Scarborough, in 19 m of water, was used to assess the hydrodynamic conditions. Tidal currents were estimated from UKHO Admiralty Chart tidal diamonds. These data were collectively assessed against national indicative criteria to determine the typical hydrodynamic energy conditions within the study area.

Marine Habitat Boundaries

A number of boundaries are needed to comply with the EUNIS habitat classification system. A littoral to sublittoral boundary was created by producing a Mean Low Water Springs (MLWS) contour using the MLWS level for Scarborough of 0.9 mCD.

A boundary for the infralittoral to circalittoral boundary is required, which is known as the depth at which only 1% of light will penetrate to the seabed. UKSeaMap have created a broad scale resolution habitat map that follows EUNIS habitat classification which was created in 2010 (McBreen *et al.,* 2011) and updated in 2016. The UKSeaMap 2010 Technical Report modelled the depth that light penetrates to the seabed. Combining this with real measurements of Secchi disk depths gathered during the survey, the infralittoral - circalittoral depth has been set at 10 mCD as a value for the entire area. Both boundaries were created by producing a contour in ArcGIS v10.2 using the bathymetry data.

Energy boundaries are also required for EUNIS level 3 classification. The UKSeaMap 2010 Technical Report (McBreen *et al.*, 2011) categorised the majority of the survey area seabed as being exposed to moderate energy, with part of the infralittoral area being exposed to high energy.

Evidence for using these definitions is found in the CCO Annual Wave Report 2016 for the Scarborough waverider, which reports the average 12 monthly significant wave height (Hs) as 1.04m and recorded 8 storms that created conditions that exceeded local 3.25m significant wave height. The largest recorded significant wave height (over a half hour period) was 4.98 m and the highest monthly average Hs was 1.59 m in the month of January. Using average wave characteristics, a depth can be calculated where wave energy will regularly interact with the seabed.

Admiralty tidal stream currents at the surface indicate that during peak spring flows the tidal stream can be between 1.4 and 2.2 knots throughout the area.

Using all of the above data allowed the seabed to be classified into useful indicative habitat and substrate maps. Some boundaries are definitive, such as the edge of a rock platform or a protruding rocky outcrop. Other boundaries, especially those between sediment types and the infralittoral – circalittoral boundary, cannot always be treated as definitive because the change is gradual and can vary seasonally. The boundary is placed in the best position using the data available but often these boundaries transition imperceptibly into one another. Such boundaries cannot be treated as exact boundaries but as a representation of what is present in the survey area.

Substrate Map

A substrate map was derived by removing the depth boundaries and the ‘Rock and thin Sediment’ category. Where the seabed was categorised as ‘Rock and thin Sediment’ it was re-classified to reflect the surficial sediment type of the thin veneer of sediment overlying the rock. The example shown in Figure 5 indicates areas of bedrock and variations in broad sediment types.

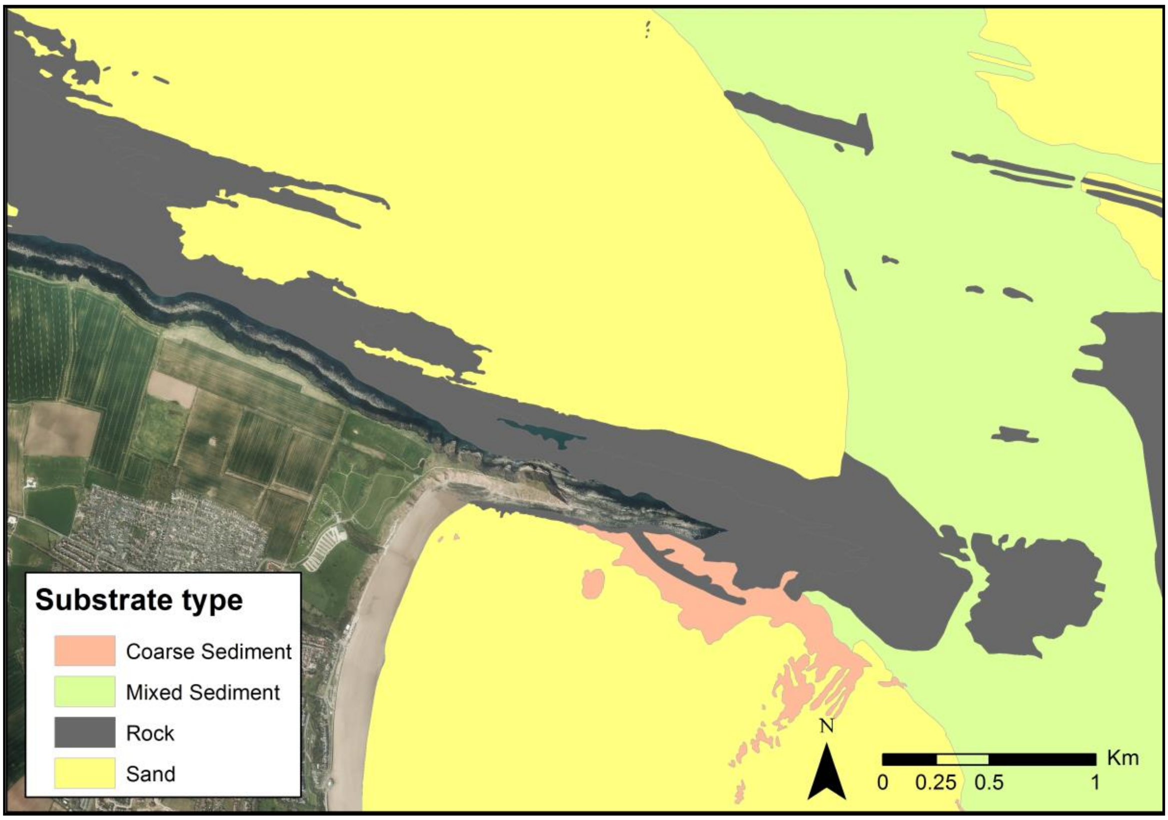


Figure 5: Substrate mapping, Filey Brigg

Anthropogenic Features

Anthropogenic features were identified in the bathymetry, including the dredge marks and sea defences surrounding Scarborough Harbour illustrated below in Figure 6. Such features are easily discernible using the hillshade layer.

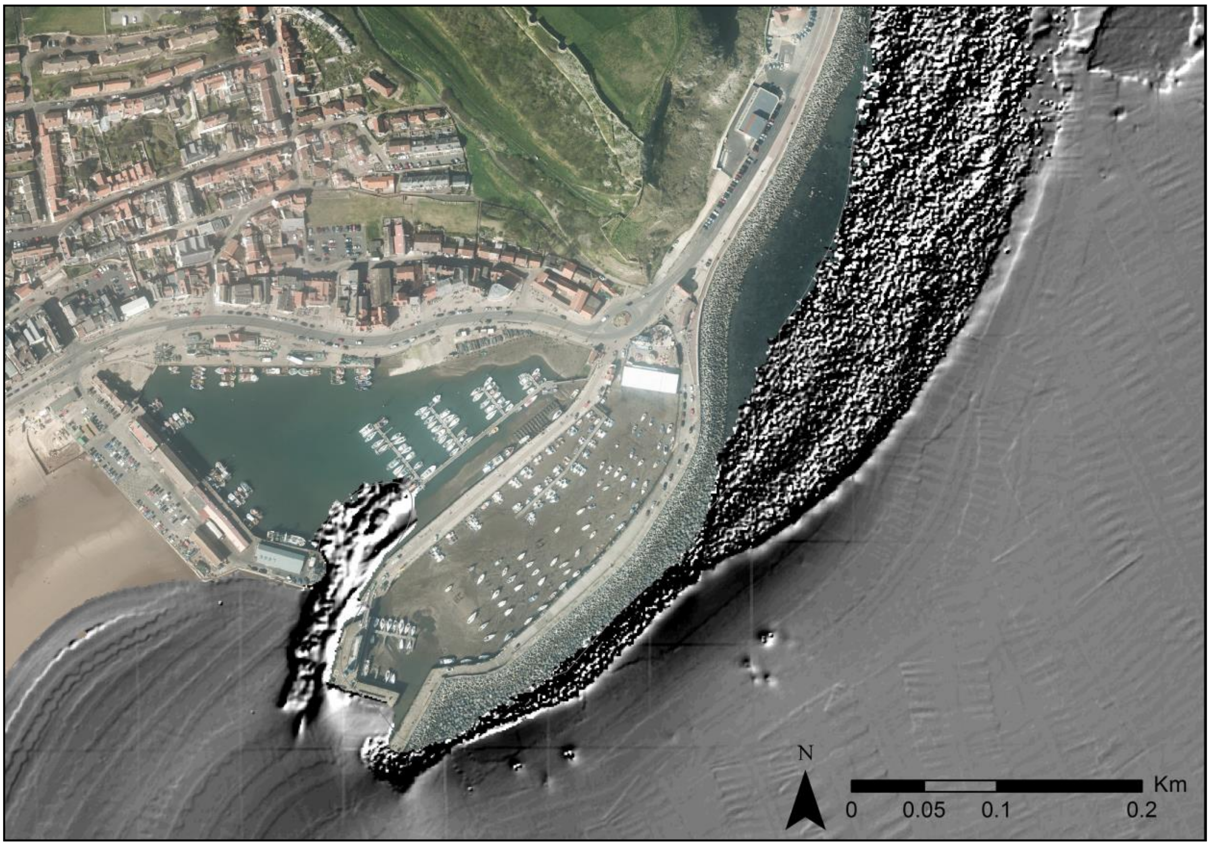


Figure 6: Anthropogenic features, Scarborough Harbour

A total of 167 wrecks were identified in the Robin Hood's Bay to Flamborough Head survey area, of which 48 were unidentified before this survey. A further 149 wrecks within the survey area were listed by the UKHO, which were not observed in the data (*i.e.* wreck features which have since been buried by sediment, or deteriorated to a state that they are no longer discernible or detectable at the surface or through water column analysis).

Confidence

The MESH confidence assessment tool was used to determine confidence levels in the acquired remote sensing data, groundtruthing data and the interpreted mapping and data products, so that end-users can determine their adequacy for decision-making (see http://www.searchmesh.net/Default.aspx?page=1635).

Bathymetric data collected in accordance with and achieving compliance with the MCA Civil Hydrography Programme Specification generally produces a high confidence level due to the 100% seafloor coverage and vertical and horizontal positional accuracies. The Confidence Assessment for this marine habitat mapping report is 78 (Appendix 1), indicating a high level of confidence in the remote sensing data acquisition, groundtruthing available and interpretation of the various datasets to generate the series of maps and datasets.

Seabed Mapping Results

The swath bathymetry data are freely available, under Open Government Licence, from www.coastalmonitoring.org either as text, asci or SD (Fledermaus) files. The EUNIS Level 3 marine habitat map and substrate type maps are also available for viewing and download as shapefiles. Summary maps of:

- Bathymetry
- Backscatter
- Seabed slope
- Anthropogenic features
- EUNIS level 3 marine habitat
- Substrate

have been prepared for the following inshore sections of coastline:

- Ravenscar to Cloughton
- Scarborough
- Cayton Bay
- Filey Bay
- Filey Brigg

And the following offshore sections:

- Offshore - Flamborough Head
- Offshore - Filey Brigg
- Offshore – Ravenscar to Cayton Bay

Ravenscar to Cloughton

The Ravenscar to Cloughton section of coastline is characterised by steep cliffs, lined with boulder fields and a rock platform extending offshore. The rock platform is clearly exposed and runs continuously along this stretch below the mean low water (MLW) mark and is classed as either *High Energy Infralittoral* or *Circalittoral Rock*. Boulders and cobbles can clearly be seen covering the rock platform, evident in both aerial photography and the bathymetry data. Two sections of rock platform to the eastern and western extent of this stretch of coastline extend approximately 1.3 km offshore from the base of the cliffs.

The rock platform gradually increases in depth until it sinks below the sediment found further offshore, which is thick enough to mask the geology. In places sediment extends shoreward, covering the underlying geology up to a few hundred meters away from MLW. The sediment remains thick enough to cover the underlying geology offshore for up to 3.7km before it reappears in the bathymetry, classified as *Moderate Energy Rock and thin Sediment*. Interesting geological formations are present and discussed in the 'Offshore – Ravenscar to Cayton Bay' section.

The sediment located between the nearshore rock platform and rock and thin sediment found offshore is defined as *Sublittoral Sand* and sediment grab samples gathered indicate the sediment is 'fine sand' and 'muddy sand'. As indicated in the substrate map and clearly illustrated using the bathymetry and anthropogenic map for Ravenscar to Cloughton, the majority of the *Sublittoral Sand* is covered by bedforms (Figure 7).

These bedforms are well defined and complex with a mixture of sand waves, ripples and dunes ranging in size from 0.2 m – 3 m in amplitude, found at depths of 25mCD and deeper. The presence of bedforms is usually an indicator of sediment transport and the availability of sediment in the area. The orientation of the bedforms, perpendicular to tidal stream data, suggests a Northeast/Southeast sediment transport orientation. However, the dominant sediment transport direction cannot be clearly ascertained by the shape of the bedforms. The smaller sand waves and ripples are generally symmetrical with sinuous crest lines and the large sand dunes become wider and increase in amplitude (1 m to 3 m) towards the North-West.

Wreck marks can be indicators of local current direction and can often give an insight into sediment transport direction. The interaction of wrecks within complex sediment beds, especially with the presence of dunes, can be complex (Garlan *et al.*, 2015). The wrecks present within the large system of bedforms all show various amounts of interaction with the seabed. The wreck in Figure 7 has two large scour marks, buildup of sediment on both sides, a long depression and an initial lack of bedforms to the southeast; whereas wrecks in different areas of the bedform system show little or no interaction with the seabed.

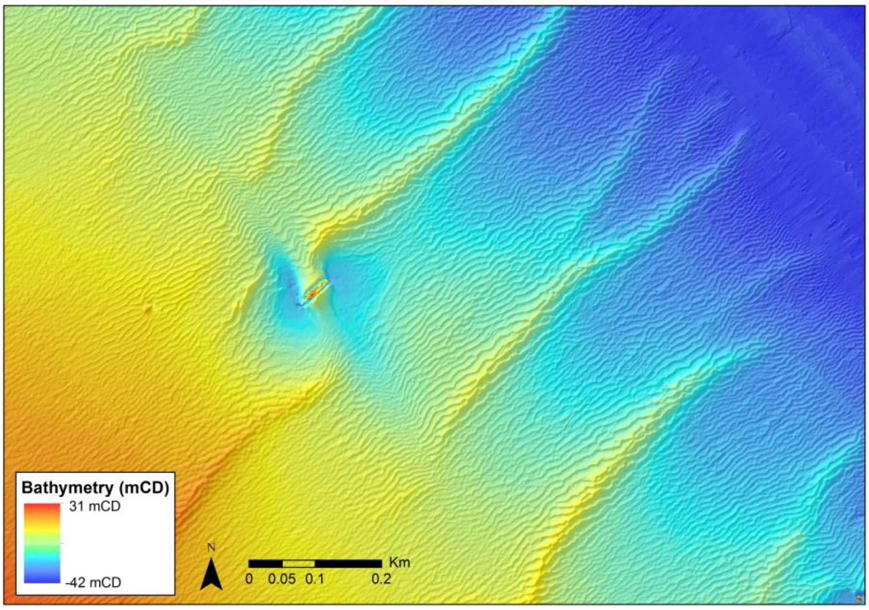
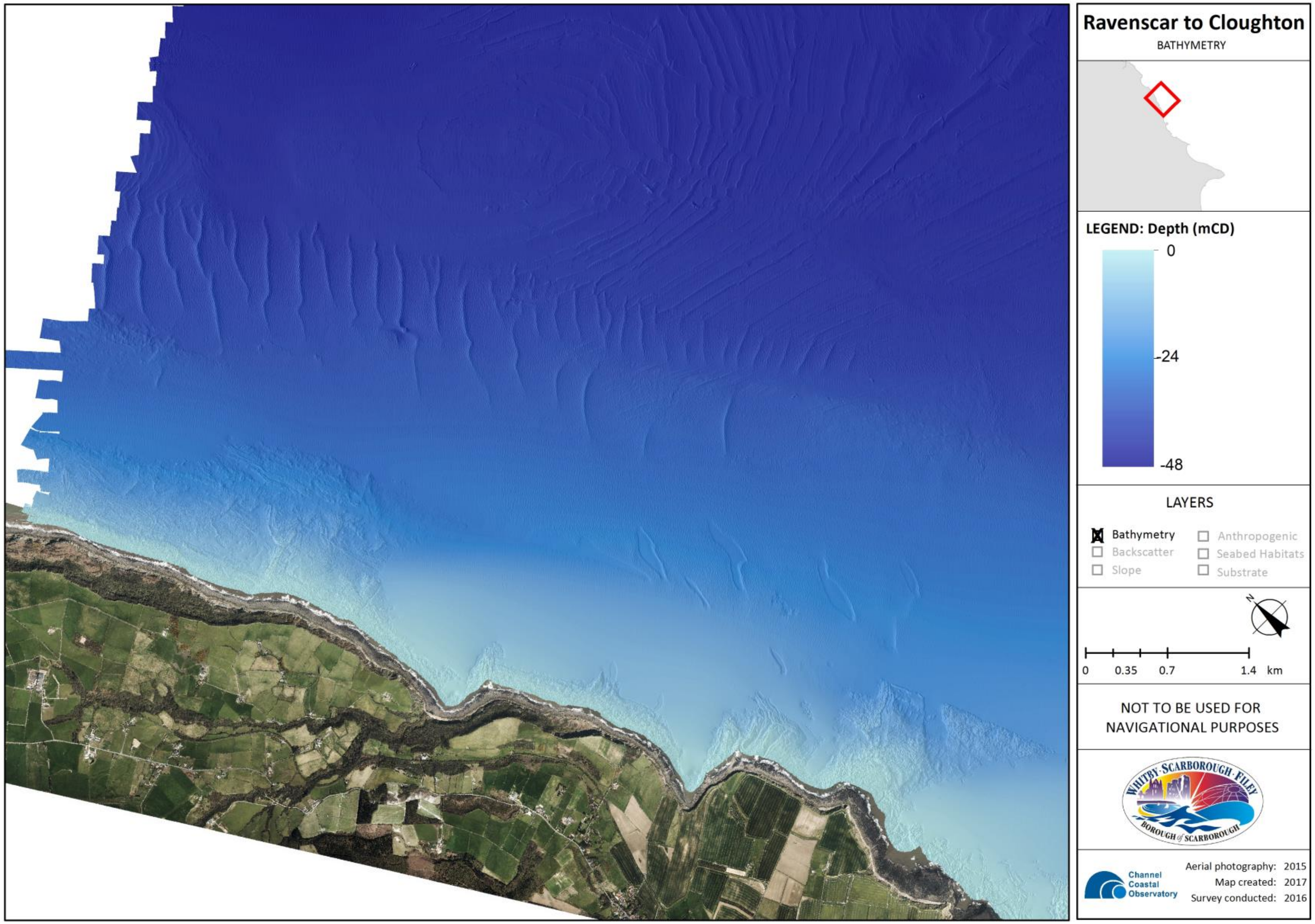
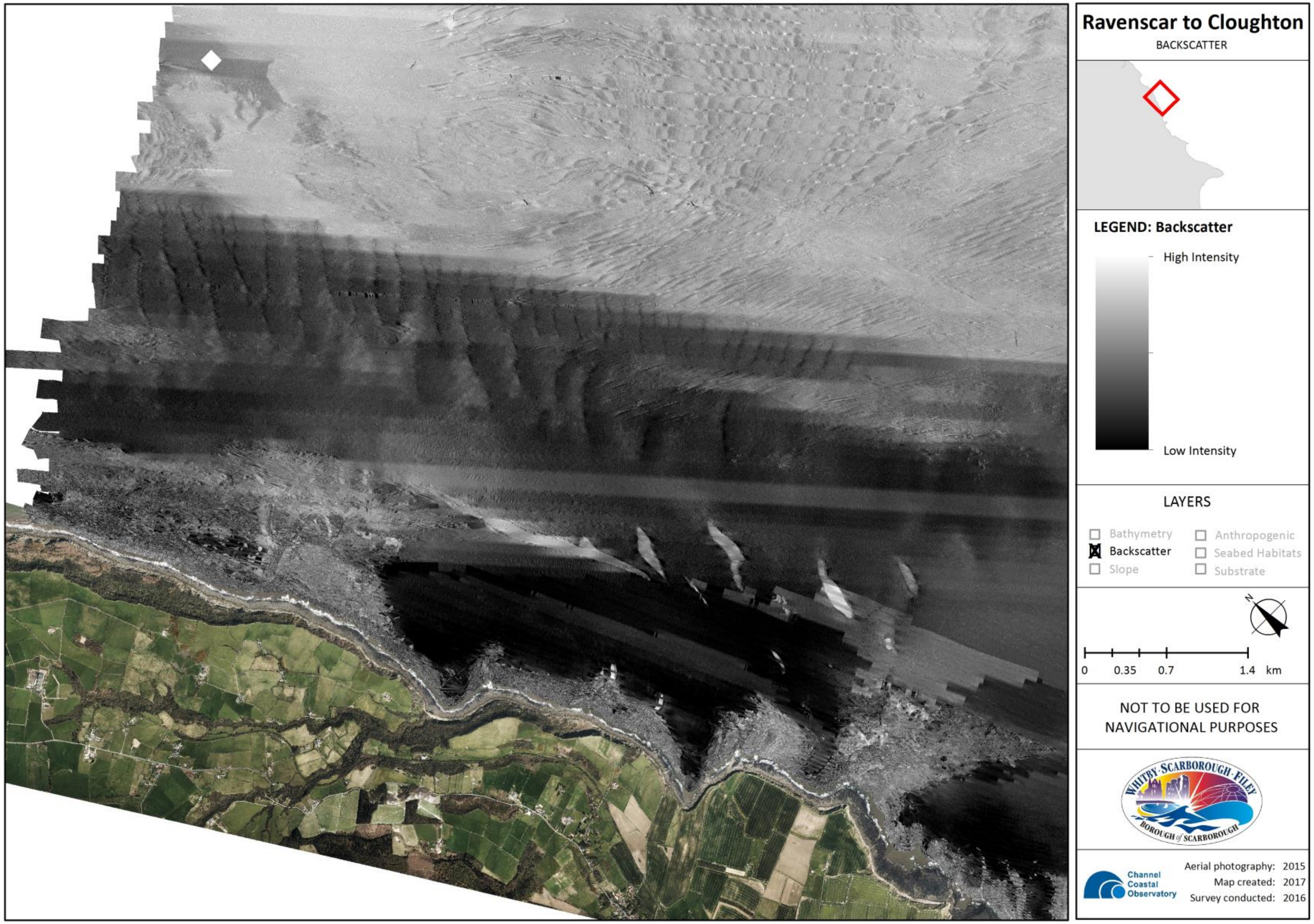


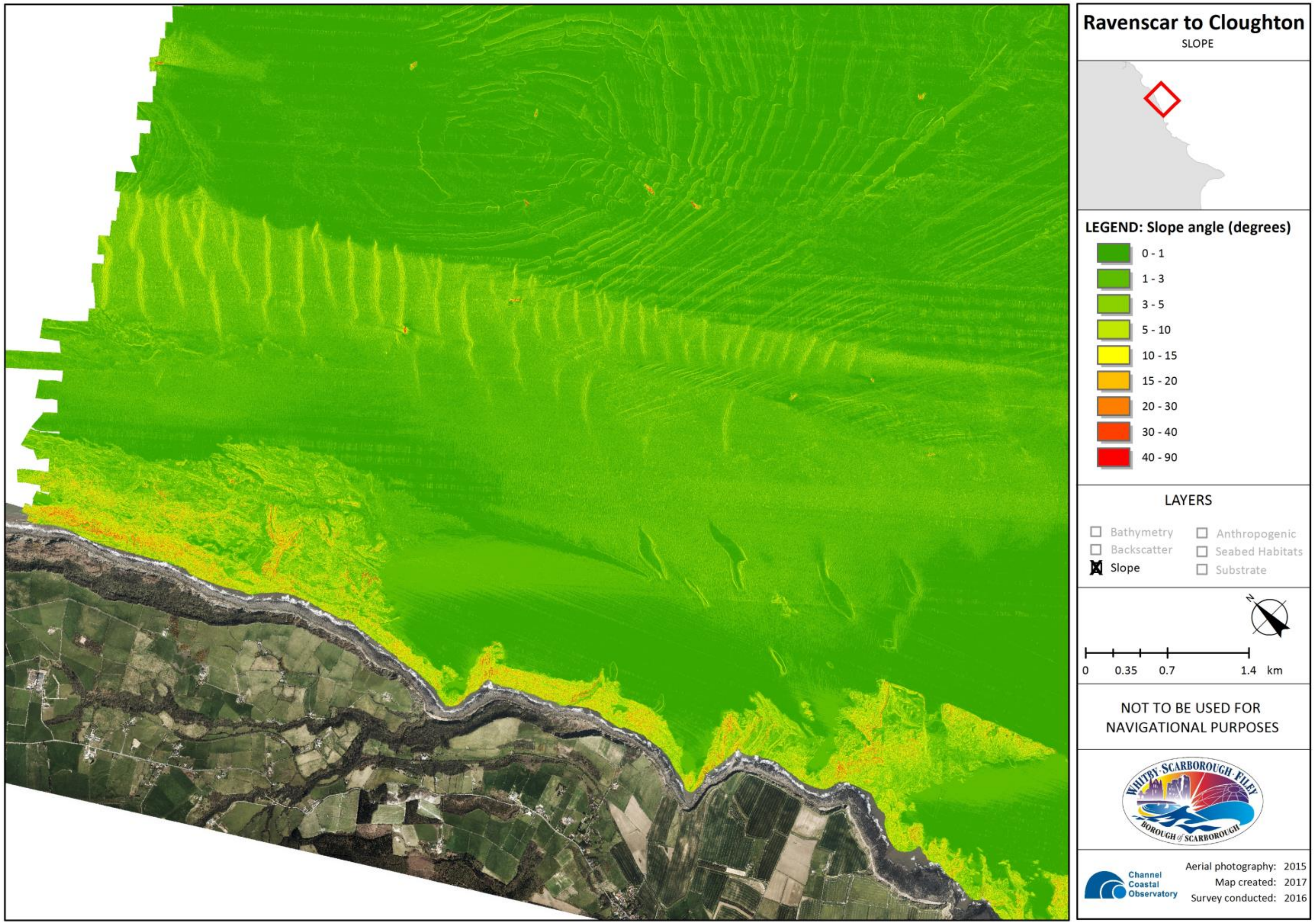
Figure 7: Example of bedforms and wreck marks

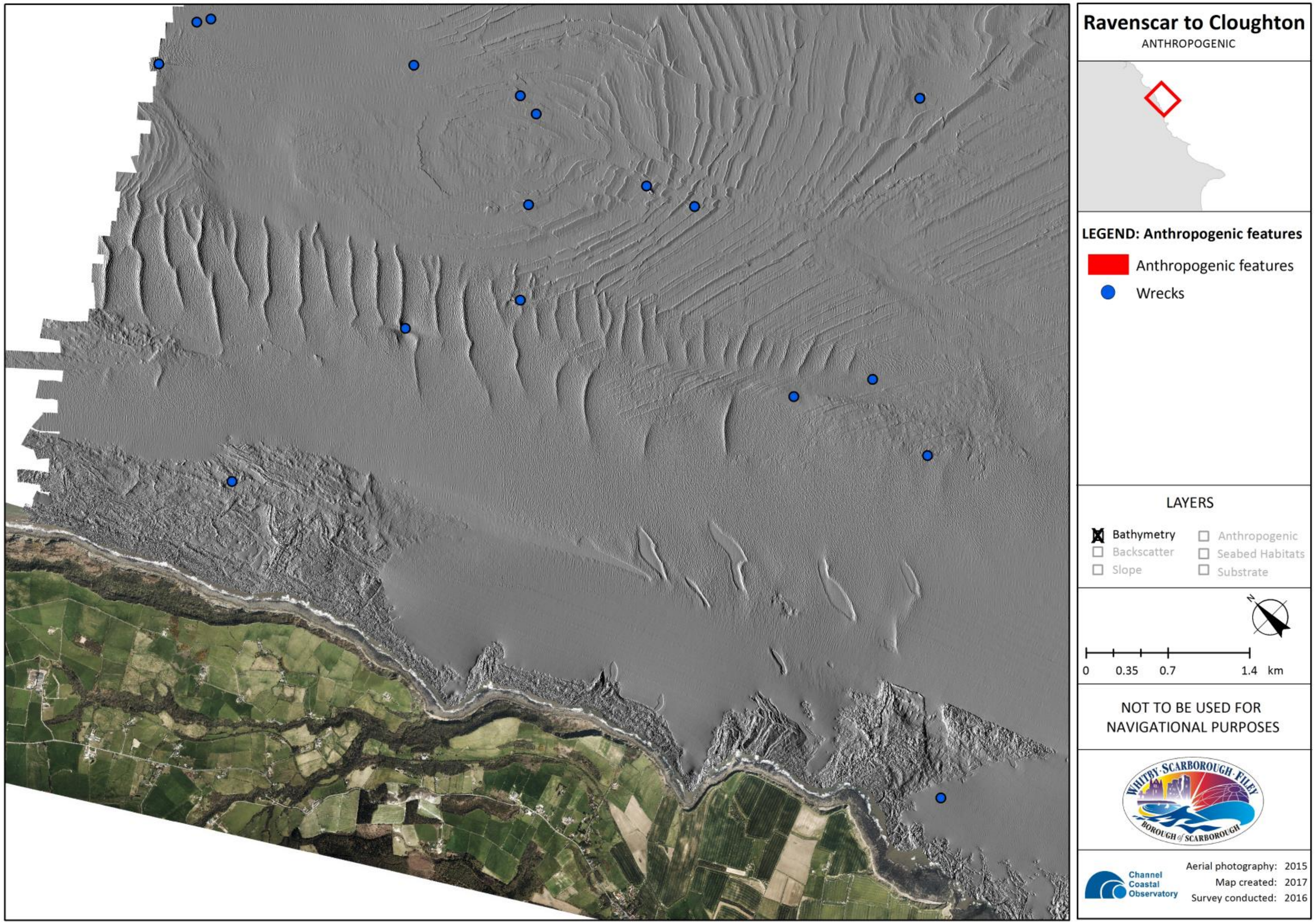
The backscatter clearly indicates that there are different sediment types present. Pockets of *Sublittoral Coarse sediment* are found throughout the *Sublittoral Sand*, usually defined by a small drop-off between 0.50 – 0.80m in depth. The backscatter also clearly outlines where the *Sublittoral Sand* ends and the rock and thin sediment layer begins.

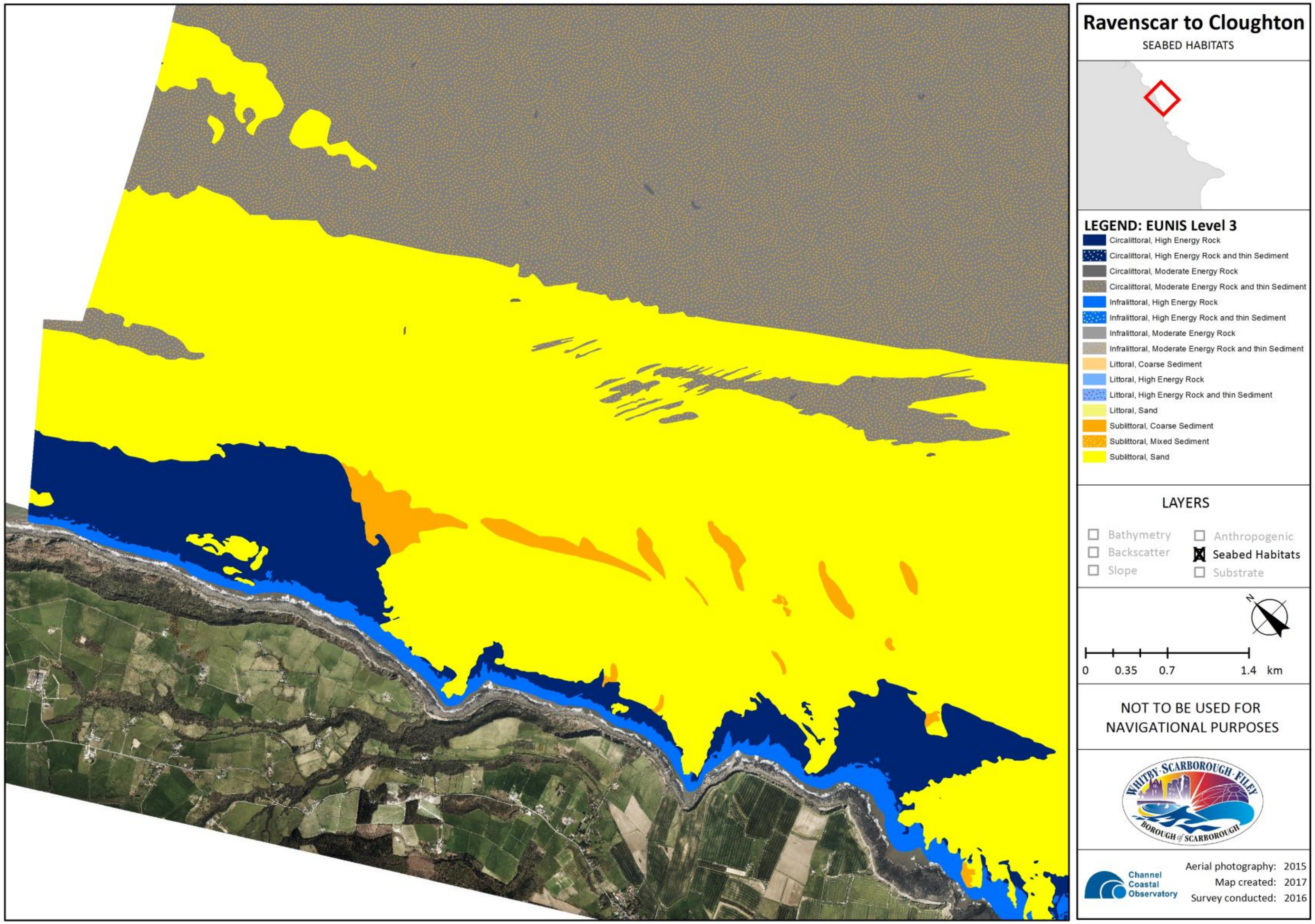
No anthropogenic features were identified and 17 wrecks can be found in this section.

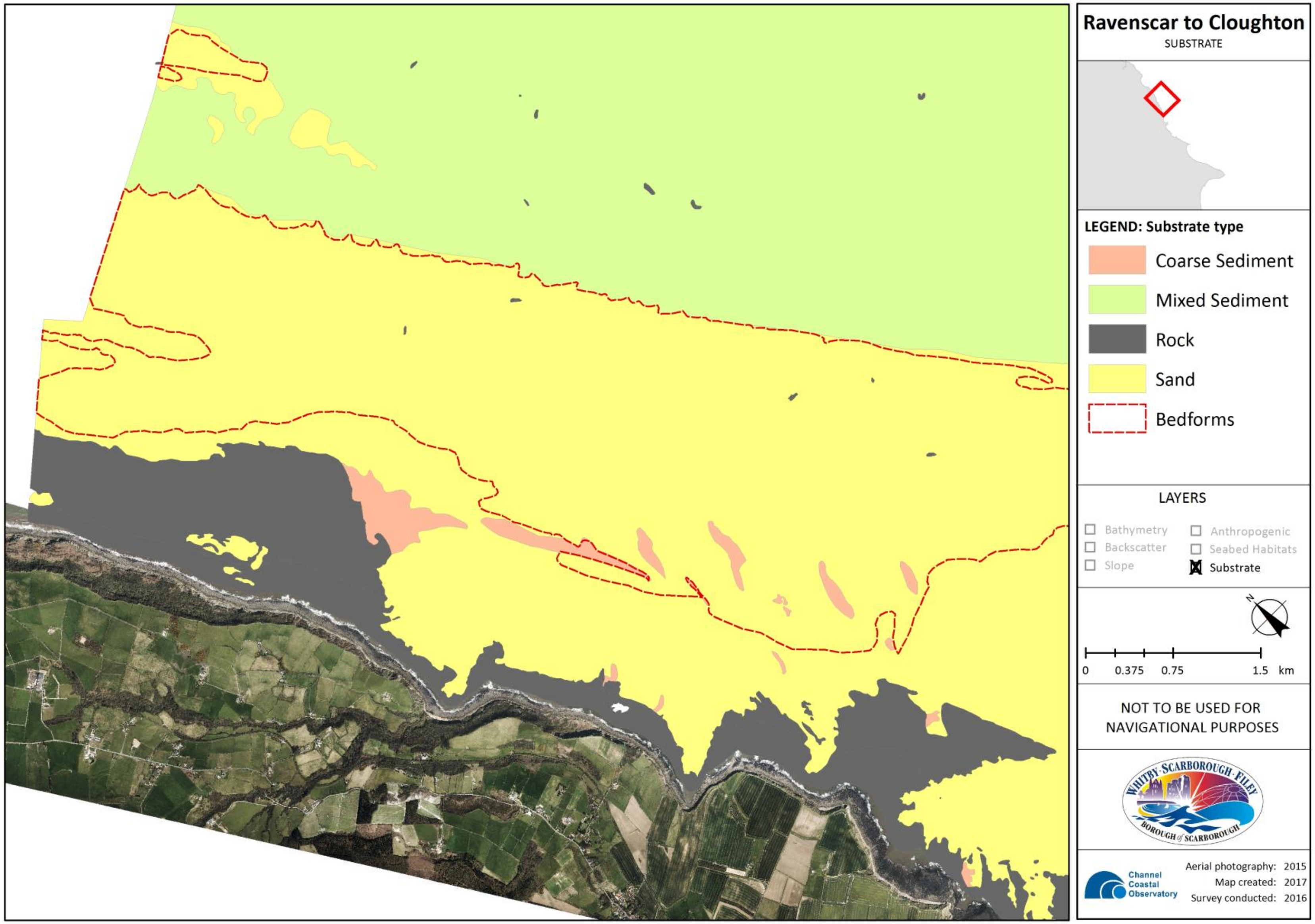

Ravenscar to Cloughton
BATHYMETRY
LEGEND: Depth (mCD)
0
-24
-48
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0
0.35
0.7
1.4 km
NOT TO BE USED FOR
NAVIGATIONAL PURPOSES
WHITBY SCARBOROUGH FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Ravenscar to Cloughton
BACKSCATTER
LEGEND: Backscatter
High Intensity
Low Intensity
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0
0.35
0.7
1.4
km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY SCARBOROUGH FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Ravenscar to Cloughton
SLOPE
LEGEND: Slope angle (degrees)
0 - 1
1 - 3
3 - 5
5 - 10
10 - 15
15 - 20
20 - 30
30 - 40
40 - 90
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0
0.35
0.7
1.4
km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY-SCARBOROUGH-FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Ravenscar to Cloughton
ANTHROPOGENIC
LEGEND: Anthropogenic features
Anthropogenic features
Wrecks
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0
0.35
0.7
1.4
km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY-SCARBOROUGH-FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Ravenscar to Cloughton
SEABED HABITATS
LEGEND: EUNIS Level 3
Circalittoral, High Energy Rock
Circalittoral, High Energy Rock and thin Sediment
Circalittoral, Moderate Energy Rock
Circalittoral, Moderate Energy Rock and thin Sediment
Infralittoral, High Energy Rock
Infralittoral, High Energy Rock and thin Sediment
Infralittoral, Moderate Energy Rock
Infralittoral, Moderate Energy Rock and thin Sediment
Littoral, Coarse Sediment
Littoral, High Energy Rock
Littoral, High Energy Rock and thin Sediment
Littoral, Sand
Sublittoral, Coarse Sediment
Sublittoral, Mixed Sediment
Sublittoral, Sand
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0
0.35
0.7
1.4 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016

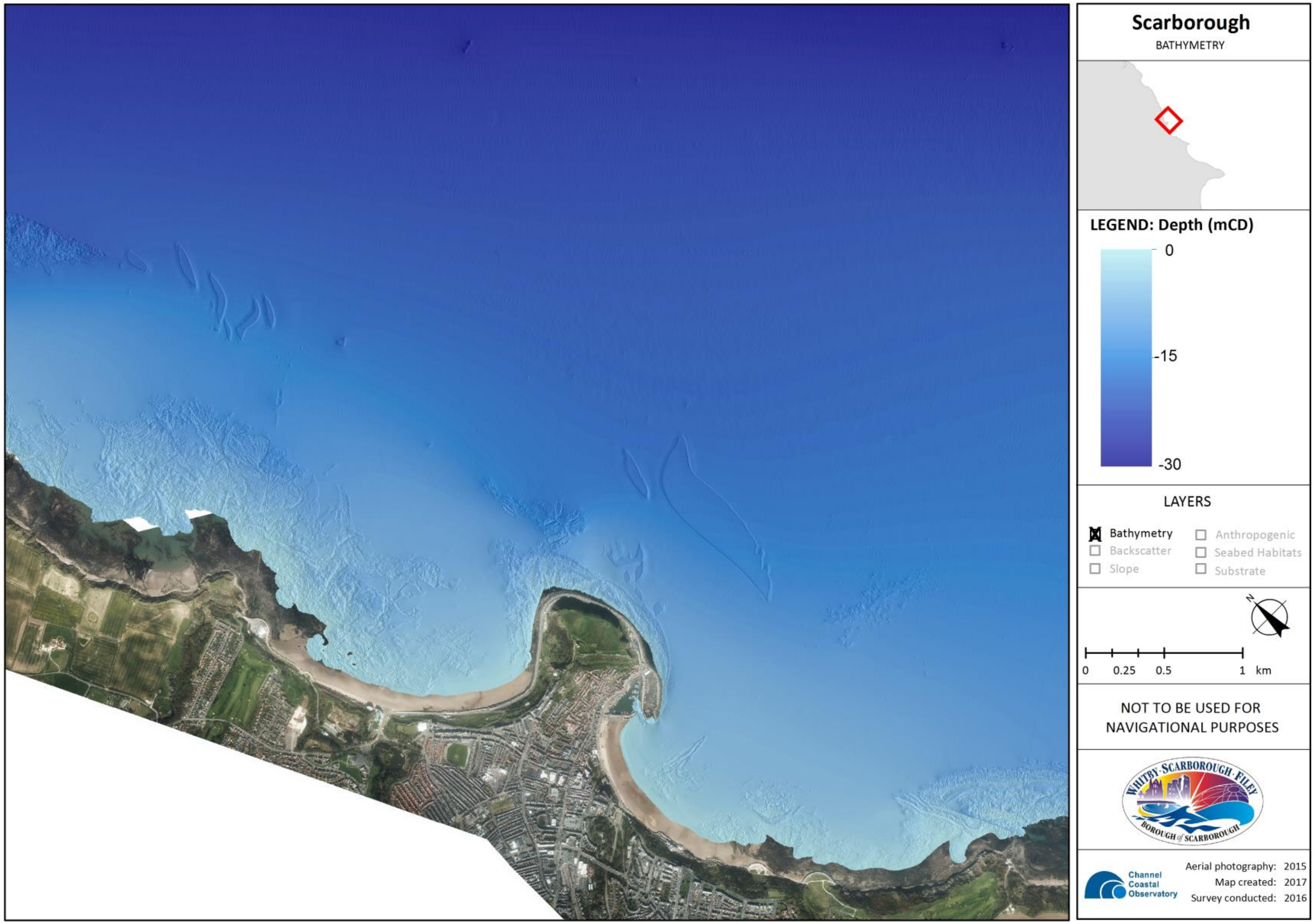

Ravenscar to Cloughton
SUBSTRATE
LEGEND: Substrate type
Coarse Sediment
Mixed Sediment
Rock
Sand
Bedforms
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0
0.375
0.75
1.5
km
NOT TO BE USED FOR
NAVIGATIONAL PURPOSES
WHITBY SCARBOROUGH FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016

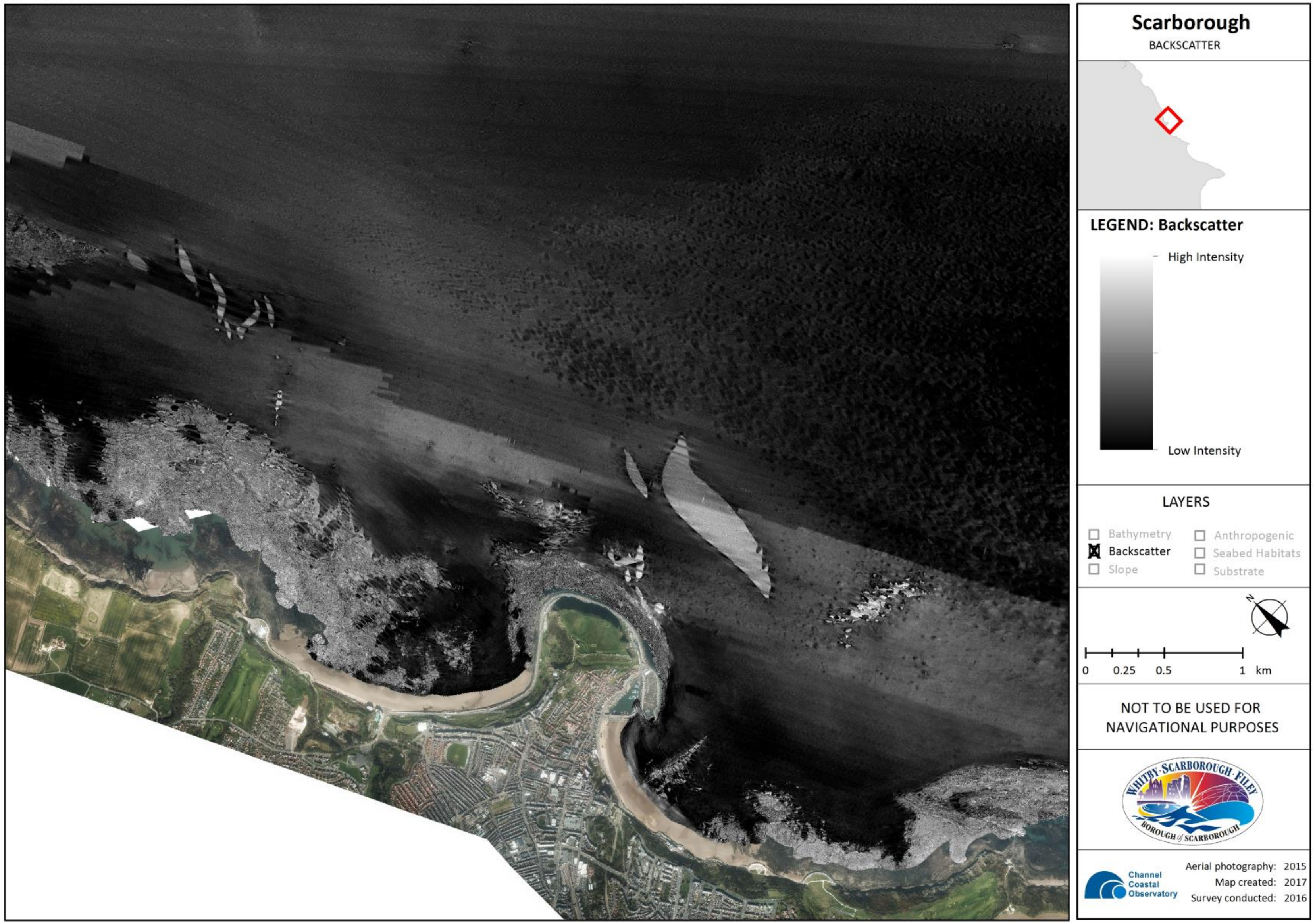
Scarborough

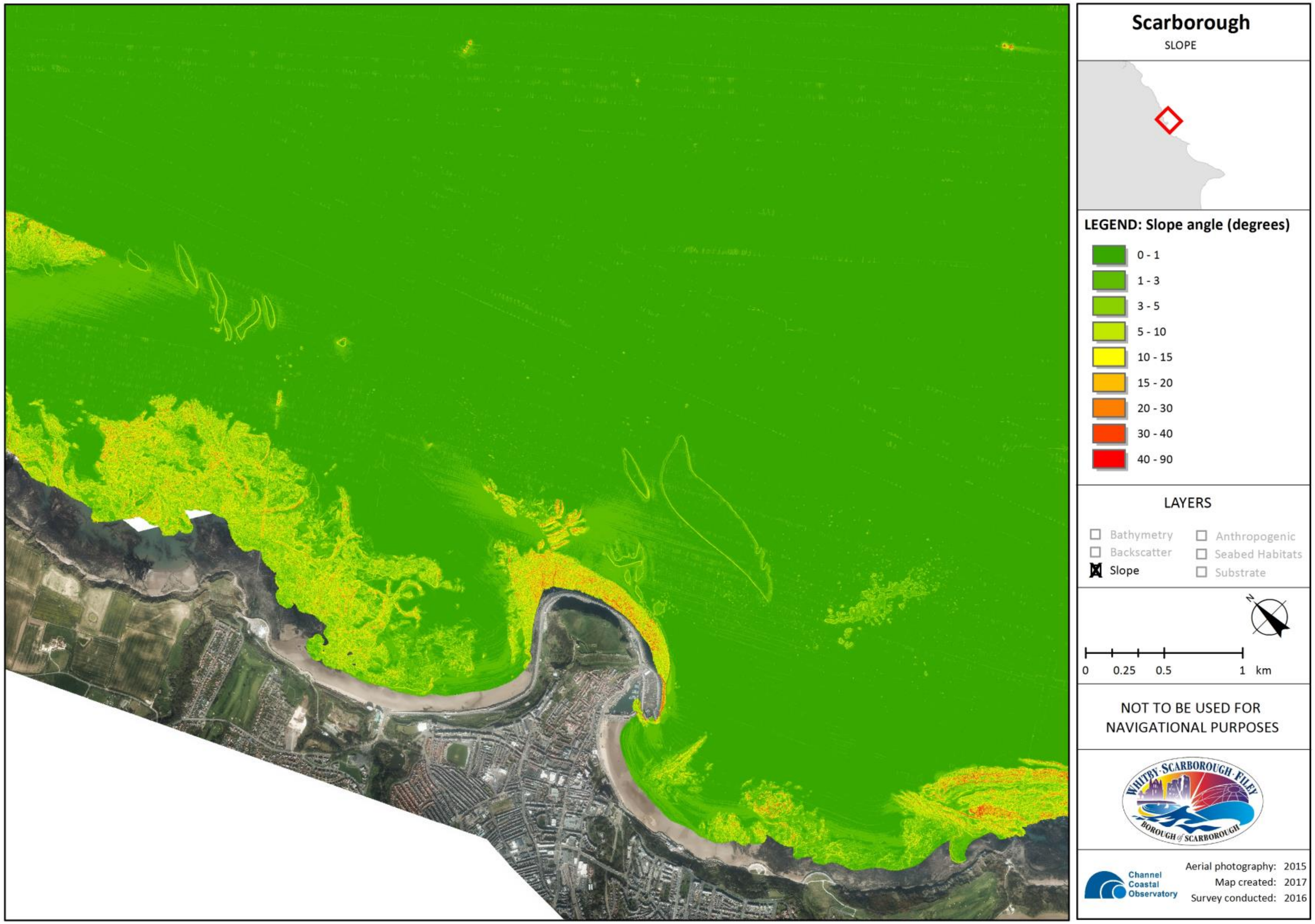
The main feature of this section is Scarborough Headland which divides Scarborough's North and South Bay's. The sediment forming these two bays interrupts the rock platforms to the North and South with sediment thick enough to cover the underlying geology present up to Mean Low Water. Areas of rock platform are still exposed in both bays and would be visible at low tide.

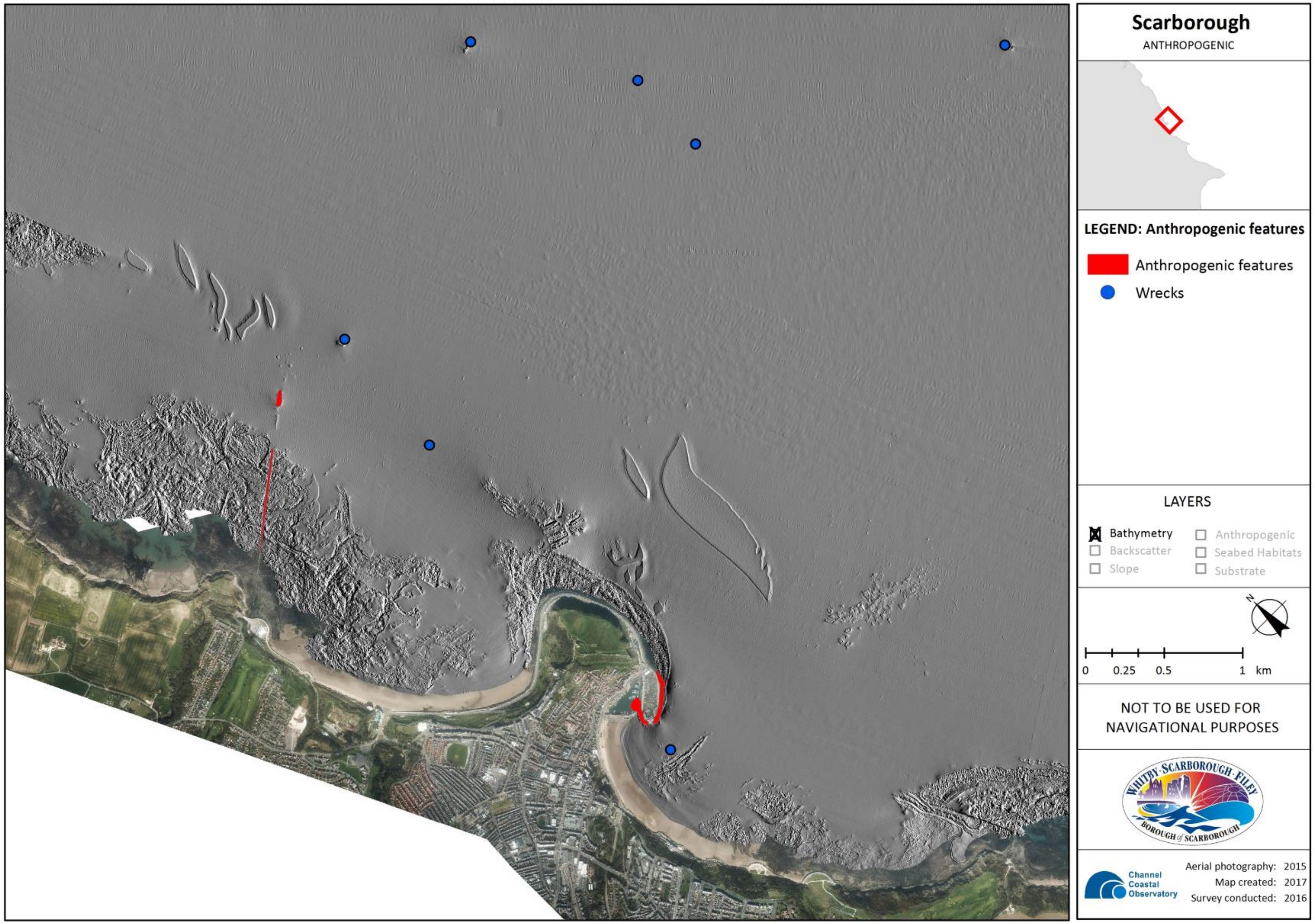
The rock platform, classified as *High Energy Infralittoral* or *Circalittoral Rock*, is present to the North and South of Scarborough Headland and extends up to 1km offshore in places, and gradually increases in depth before being covered by sediment. The majority of the seabed in this area is composed of featureless *Sublittoral Sand*. The backscatter illustrates this with the rock platform, outcrops and patches of coarse sediment outlined clearly in the darker coloured fine sand. The sandy seabed close to shore is generally devoid of bedforms and gently sloping with the only major features being slight depressions of approximately 0.5m lined with *Sublittoral Coarse sediment* (similar to those in the previous section), easily identifiable in the backscatter.

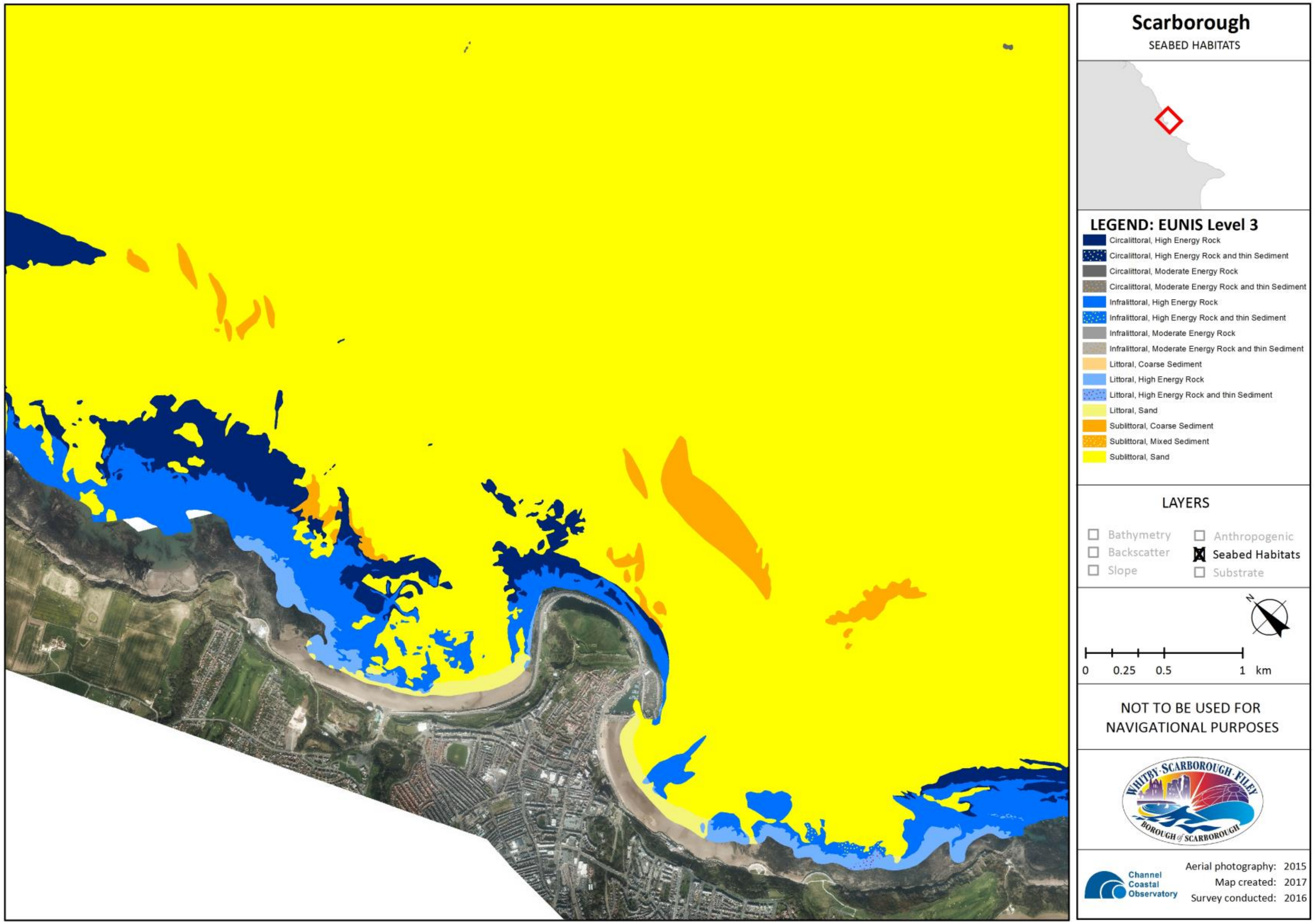
Anthropogenic features are present around Scarborough Headland including the rock revetment protecting the castle and marina, dredge marks at the entrance to the harbour and a pipeline crossing the rock platform in North Bay and ending in an outfall further offshore. Seven wrecks were identified. The scour marks surrounding the four wrecks furthest offshore indicate that the currents further offshore are oriented Northwest/Southeast but do not indicate which direction sediment transport is dominant.

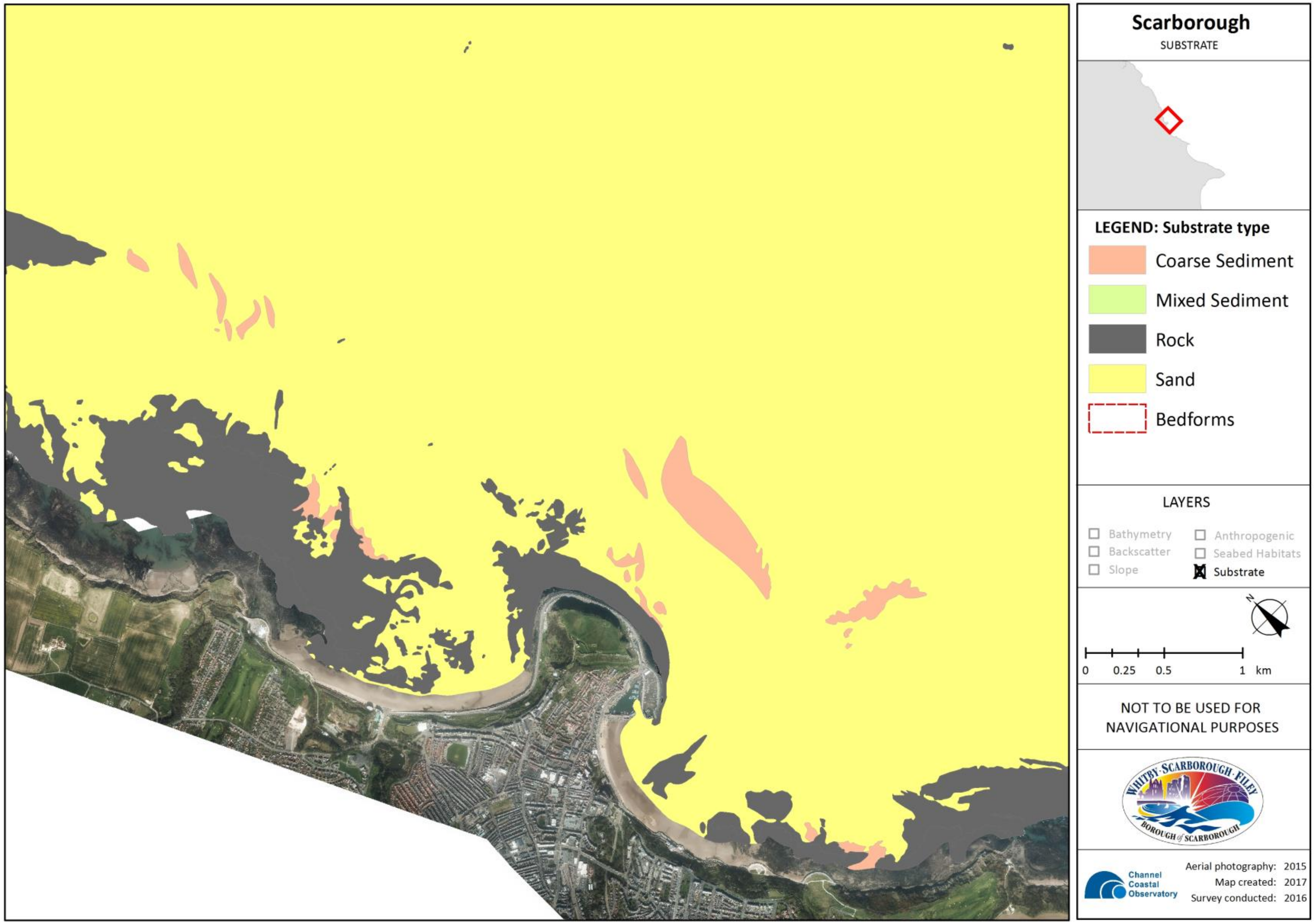

Scarborough
BATHYMETRY
LEGEND: Depth (mCD)
0
-15
-30
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0
0.25
0.5
1
km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Scarborough
BACKSCATTER
LEGEND: Backscatter
High Intensity
Low Intensity
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0
0.25
0.5
1
km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY SCARBOROUGH FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Scarborough
SLOPE
LEGEND: Slope angle (degrees)
0 - 1
1 - 3
3 - 5
5 - 10
10 - 15
15 - 20
20 - 30
30 - 40
40 - 90
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.25 0.5 1 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY·SCARBOROUGH·FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Scarborough
ANTHROPOGENIC
LEGEND: Anthropogenic features
Anthropogenic features
Wrecks
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.25 0.5 1 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY SCARBOROUGH FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Scarborough
SEABED HABITATS
LEGEND: EUNIS Level 3
Circalittoral, High Energy Rock
Circalittoral, High Energy Rock and thin Sediment
Circalittoral, Moderate Energy Rock
Circalittoral, Moderate Energy Rock and thin Sediment
Infralittoral, High Energy Rock
Infralittoral, High Energy Rock and thin Sediment
Infralittoral, Moderate Energy Rock
Infralittoral, Moderate Energy Rock and thin Sediment
Littoral, Coarse Sediment
Littoral, High Energy Rock
Littoral, High Energy Rock and thin Sediment
Littoral, Sand
Sublittoral, Coarse Sediment
Sublittoral, Mixed Sediment
Sublittoral, Sand
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0
0.25
0.5
1 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY SCARBOROUGH FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Scarborough
SUBSTRATE
LEGEND: Substrate type
Coarse Sediment
Mixed Sediment
Rock
Sand
Bedforms
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.25 0.5 1 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY·SCARBOROUGH·FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016

Cayton Bay

The nearshore seabed along this section of coastline is dominated by rock platform, with the exception of Cayton Bay. The geology runs perpendicular to the coast and a number of interesting geological features are exposed in the rock platform, including some interesting folding in the centre of Cayton Bay (Figure 8).

The remaining seabed is gently sloping and covered by featureless *Sublittoral Sand* which is thick enough to cover any underlying geology. An area of bedforms can be seen in the Eastern corner of the maps which are part of a formation that starts at Filey Brigg (further detail in Filey Bay section). To the north-east of the bedforms is an area of *Sublittoral Mixed sediment* and *Circalittoral Rock and thin Sediment*. The mixed sediment is clearly identified from the backscatter and can be observed gradually blending with the darker sand; a clear example of a transitional boundary between sediment types.

Nine wrecks were found in this section of seabed, all with multiple scour marks confirming the thickness of sediment in the area.

The main habitats found are *Sublittoral Sand* and *High Energy Littoral*, *Infralittoral* and *Circalittoral Rock*. Rock has been defined as 'High Energy' where the seabed is consistently exposed to both breaking and unbroken wave energy. Areas of 'Moderate Energy' have been defined further offshore where the increased depth of the seabed means wave energy interacts with the seabed less frequently.

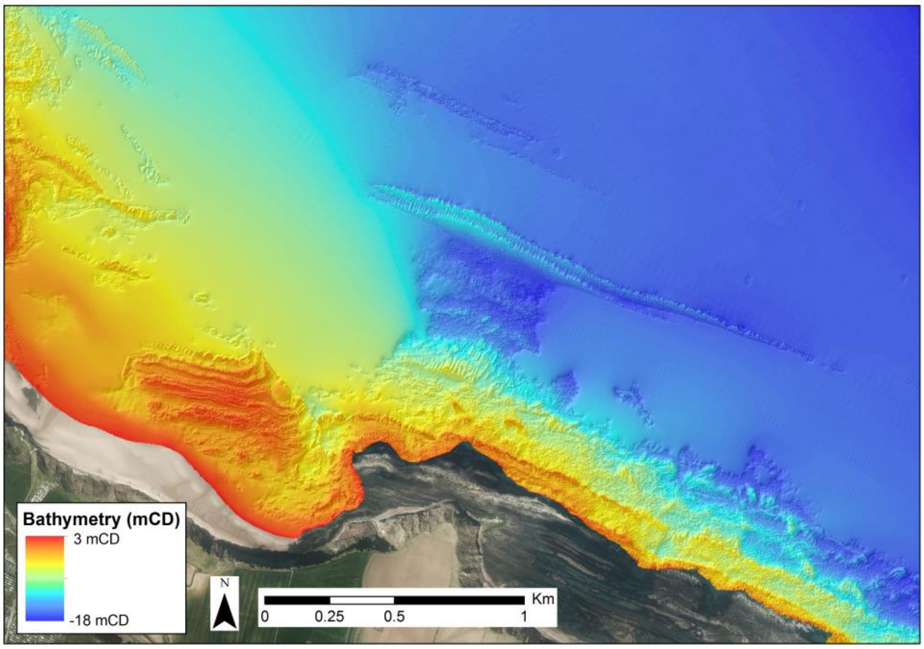
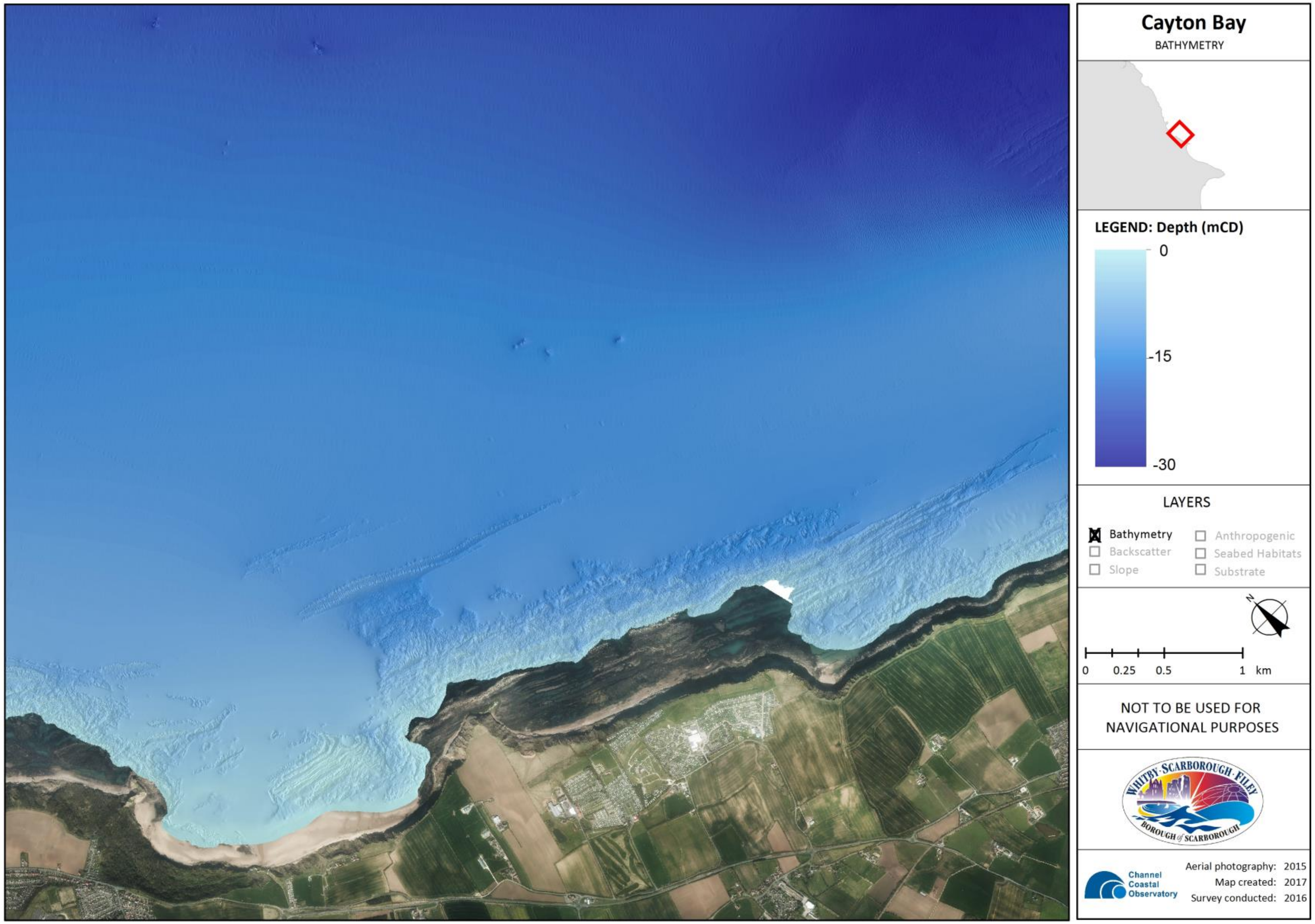
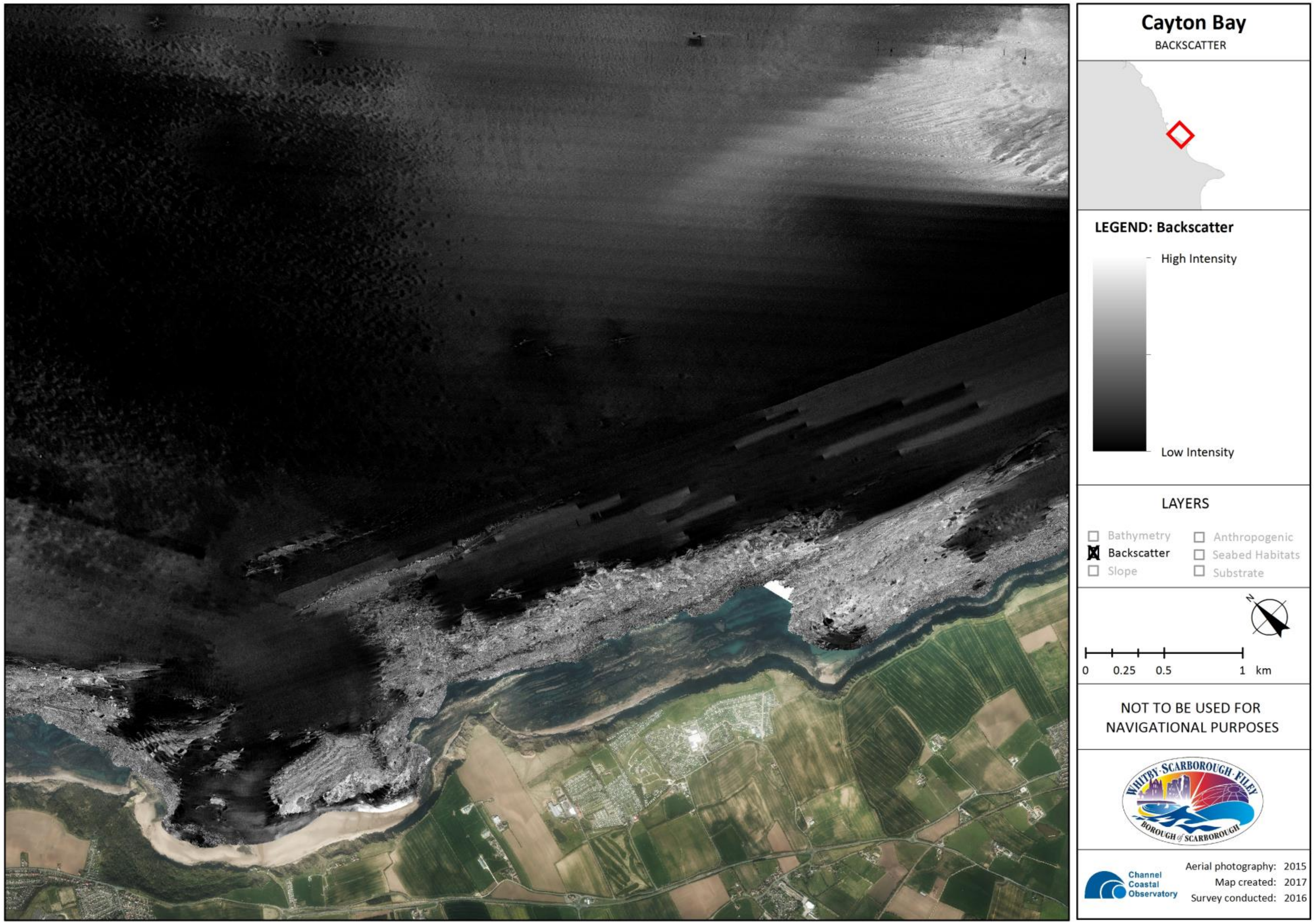
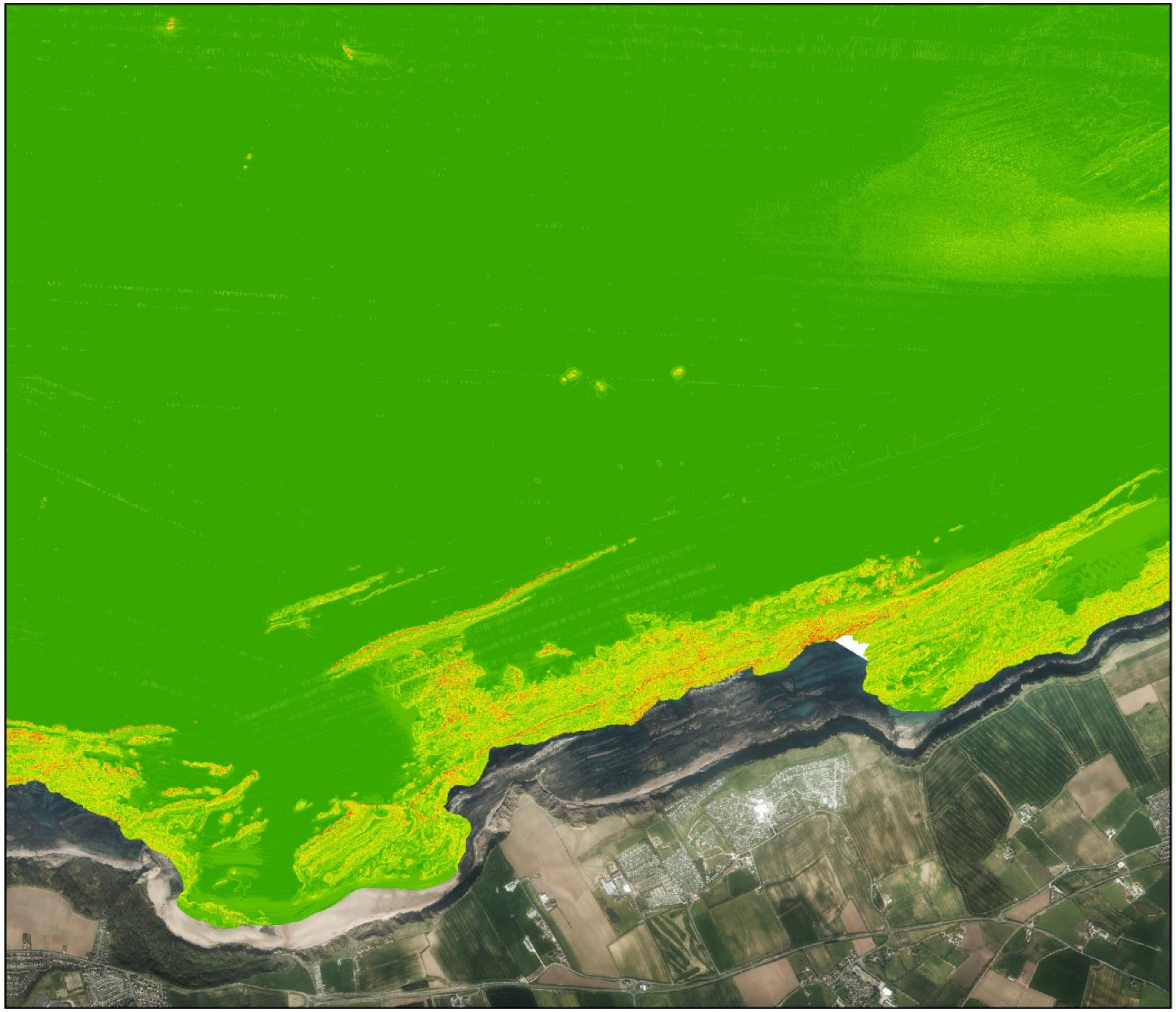


Figure 8: Exposed geology to the west of Cayton Bay

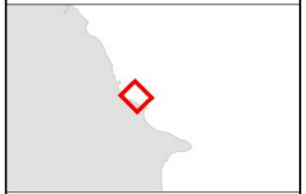

Cayton Bay
BATHYMETRY
LEGEND: Depth (mCD)
0
-15
-30
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.25 0.5 1 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY-SCARBOROUGH-FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Cayton Bay
BACKSCATTER
LEGEND: Backscatter
High Intensity
Low Intensity
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0
0.25
0.5
1
km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY·SCARBOROUGH·FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016



Cayton Bay

SLOPE



LEGEND: Slope angle (degrees)

- 0 - 1
- 1 - 3
- 3 - 5
- 5 - 10
- 10 - 15
- 15 - 20
- 20 - 30
- 30 - 40
- 40 - 90

LAYERS

- ☐ Bathymetry
- ☐ Backscatter
- ☒ Slope
- ☐ Anthropogenic
- ☐ Seabed Habitats
- ☐ Substrate

N

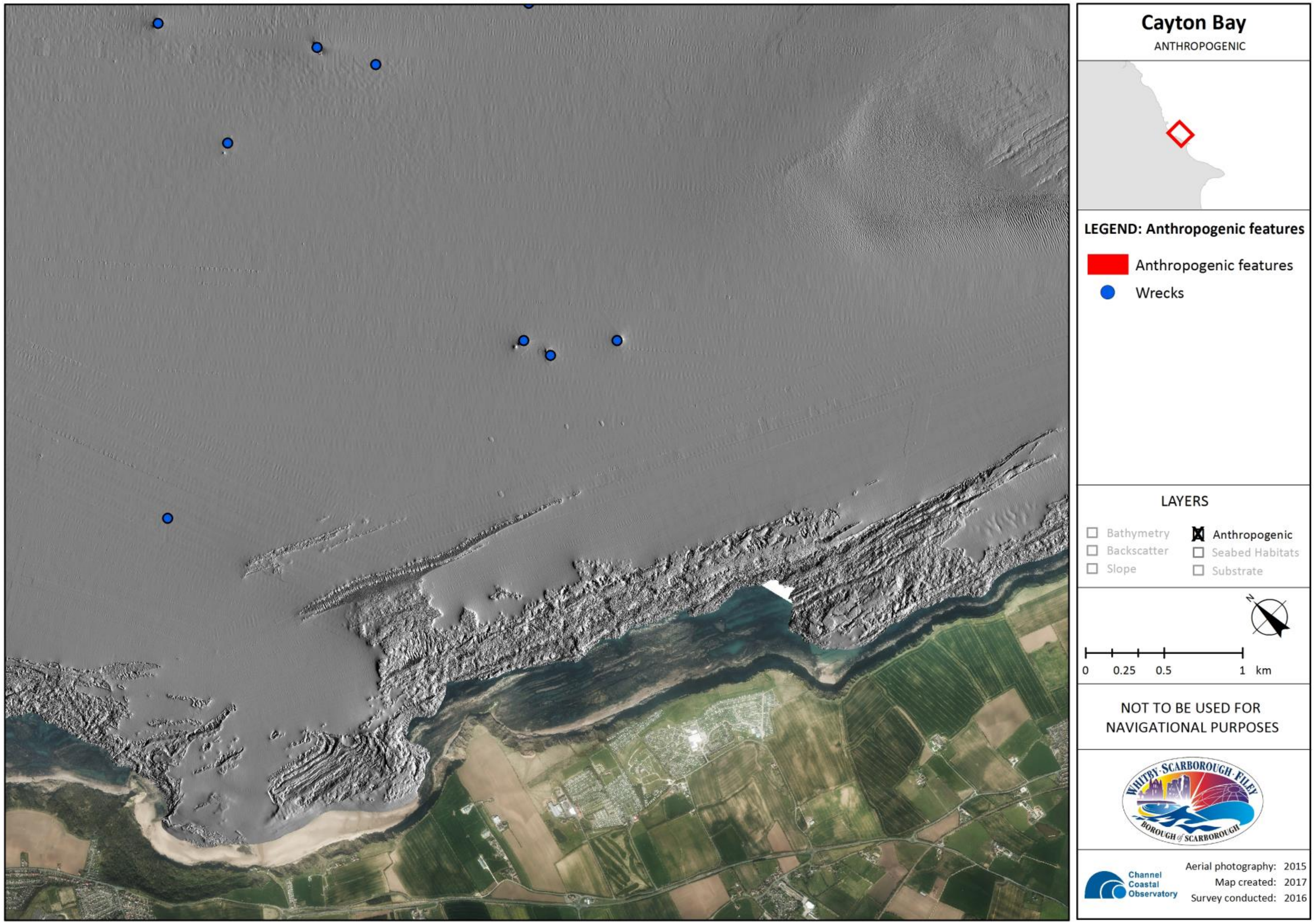
0 0.25 0.5 1 km

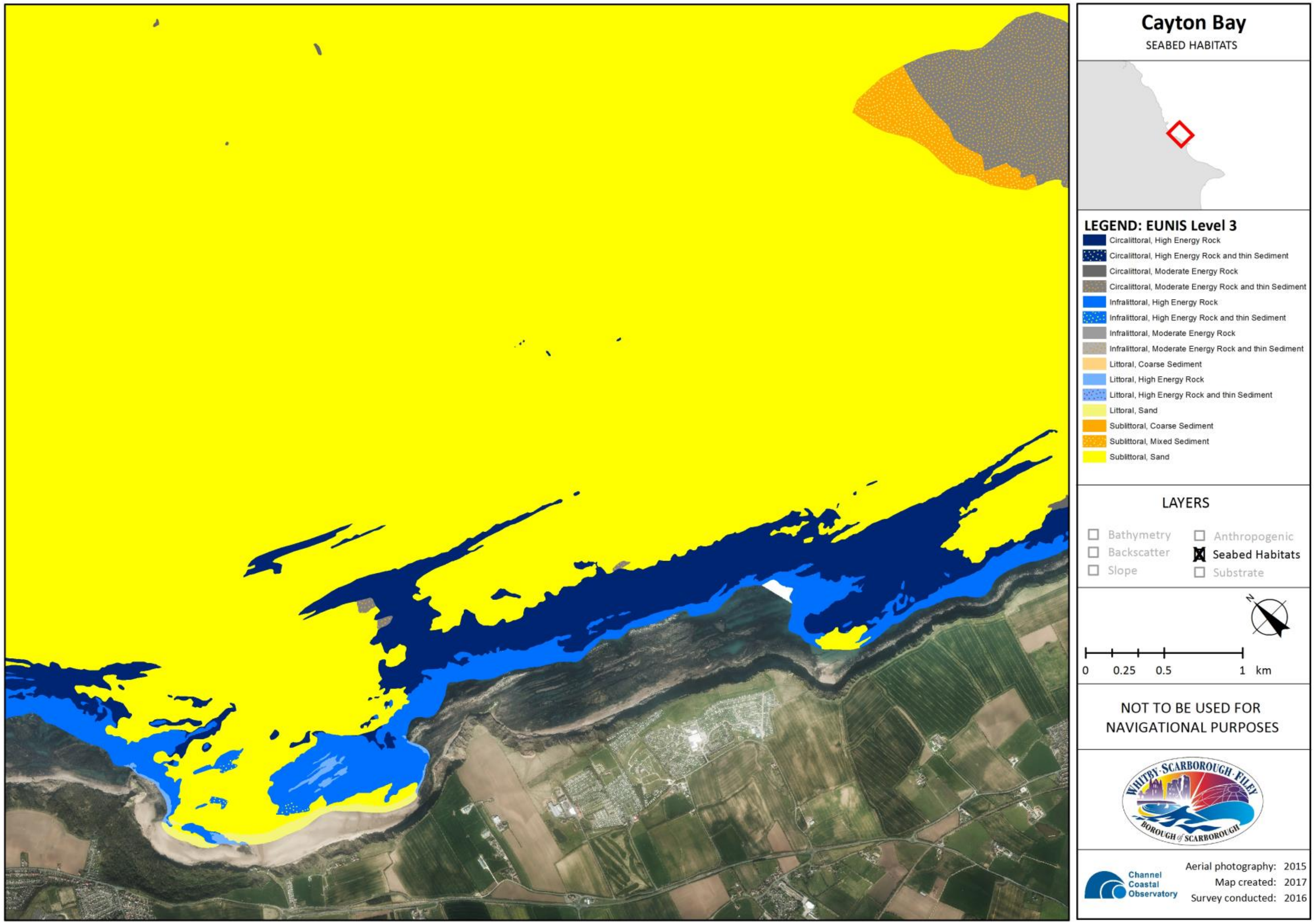
NOT TO BE USED FOR NAVIGATIONAL PURPOSES

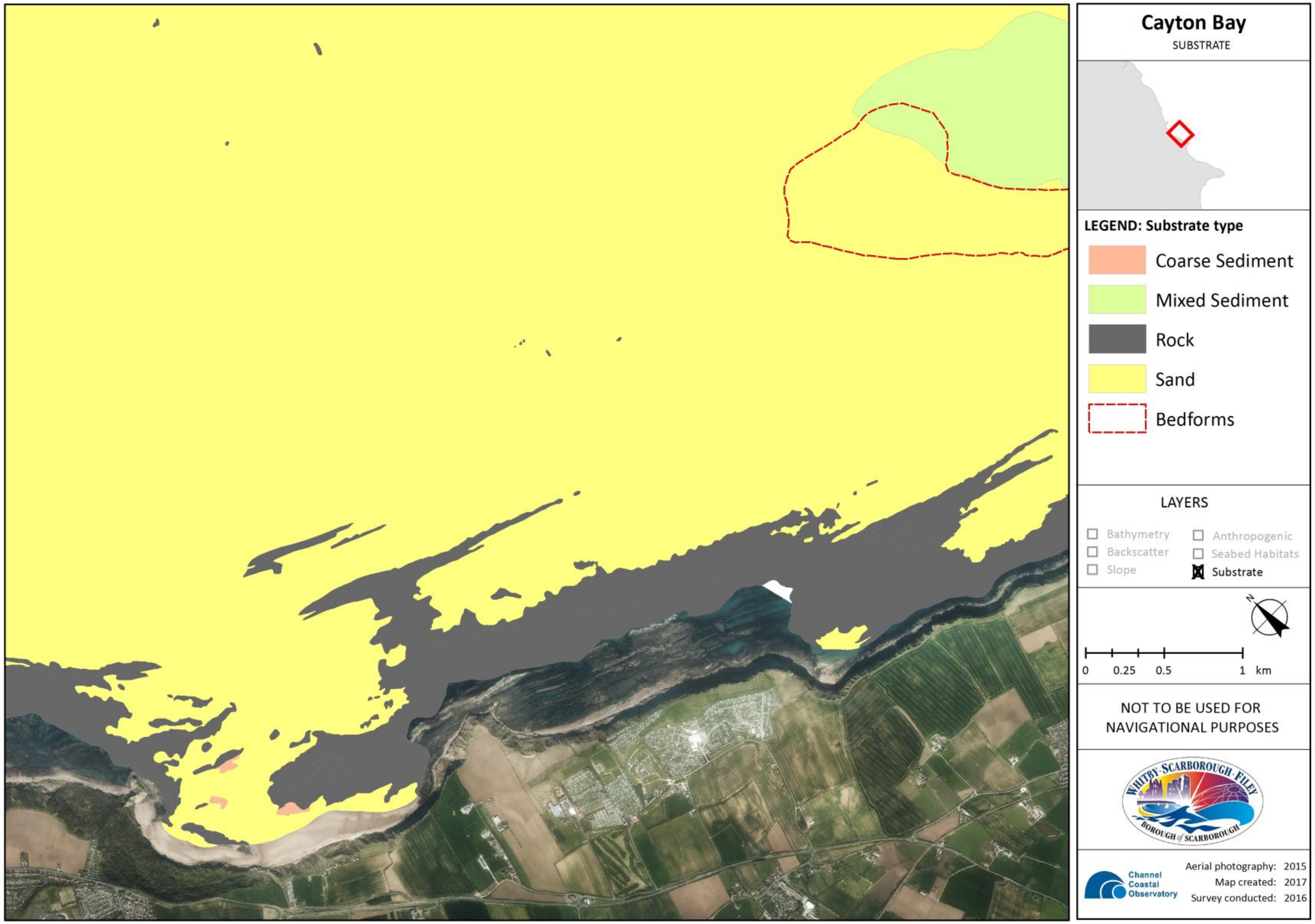
WHITBY·SCARBOROUGH·FILEY BOROUGH of SCARBOROUGH

Channel Coastal Observatory

Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Cayton Bay
ANTHROPOGENIC
LEGEND: Anthropogenic features
Anthropogenic features
Wrecks
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.25 0.5 1 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Cayton Bay
SEABED HABITATS
LEGEND: EUNIS Level 3
Circalittoral, High Energy Rock
Circalittoral, High Energy Rock and thin Sediment
Circalittoral, Moderate Energy Rock
Circalittoral, Moderate Energy Rock and thin Sediment
Infralittoral, High Energy Rock
Infralittoral, High Energy Rock and thin Sediment
Infralittoral, Moderate Energy Rock
Infralittoral, Moderate Energy Rock and thin Sediment
Littoral, Coarse Sediment
Littoral, High Energy Rock
Littoral, High Energy Rock and thin Sediment
Littoral, Sand
Sublittoral, Coarse Sediment
Sublittoral, Mixed Sediment
Sublittoral, Sand
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.25 0.5 1 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Cayton Bay
SUBSTRATE
LEGEND: Substrate type
Coarse Sediment
Mixed Sediment
Rock
Sand
Bedforms
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0
0.25
0.5
1 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY SCARBOROUGH FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016

Filey Bay

A prominent feature of Filey Bay is the rock outcrop forming the seaward extension of Filey Brigg. The rock outcrops continue eastwards and contributes to a complex seabed further offshore (refer to Filey Brigg section).

The northern limit of the Bay is marked by Filey Brigg, a natural headland formed from more resistant geology of Coralline Limestone and Calcareous Grit (sandstone) (British Geological Survey onshore geology map[1]). The coastline changes orientation at Filey Brigg and forms Filey Bay, a large sandy bay of unbroken sand labelled as Ampthill and Kimmeridge Clay on the BGS onshore geology map[1]. The seabed in the sheltered northern part of the bay deepens gradually and smoothly offshore.

A nearshore bar system is evident in the exposed southern end of the bay. The nearshore bar runs continuously from the southern extent of Filey Bay northwards to approximately the Primrose Valley Holiday Park. A cross-section of the bars and banks is given in Figure 9. The location of the cross-sections can be found on the anthropogenic map. A trough has formed between the beach and the first bar which is outlined in the backscatter by material with higher intensity, this could be coarser sand or sediment. Approximately 300m offshore of the Mean Low Water mark, a secondary sand bank is also observed and again using the backscatter it can be identified as the lighter sediment compared to the darker fine sediment further offshore in the bay.

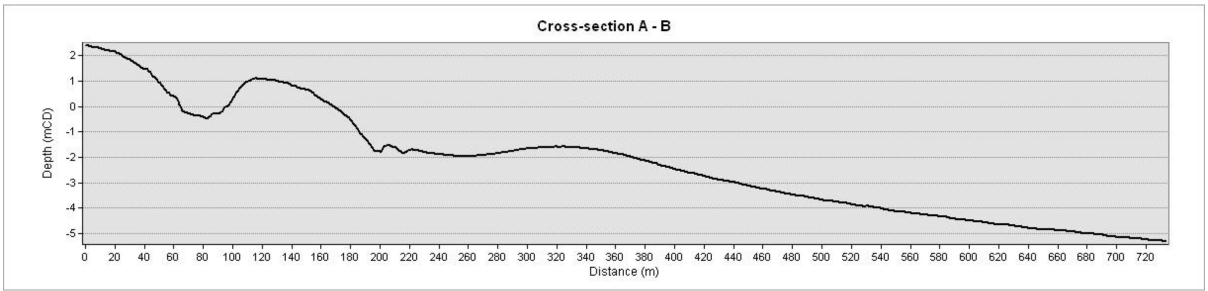


Figure 9: Cross-section A-B illustrating nearshore bar system

Featureless *Sublittoral Sand* covers the majority of the seabed, increasing steadily in depth until the edge of the rock and thin sediment, up to 3km offshore of MLW. BGS took a drill sample within Filey Bay (1983)[2] and the core shows the first two metres being fine sand layered on top of what is thought to be Kimmeridge Clay.

As shown in Figure 10, the seabed deepens steeply offshore (up to 10m in depth over 500m) which coincides with the boundary between the sediment and rock and thin sediment.

[1] http://mapapps2.bgs.ac.uk/geoindex/home.html

[2] http://marinedata.bgs.ac.uk/Samples/WEB/54N001W/54N001W_551.pdf

The geology becomes distinguishable again at the base of the slope. A thin veneer of sediment still covers the majority of the geology, although the geology is exposed in places.

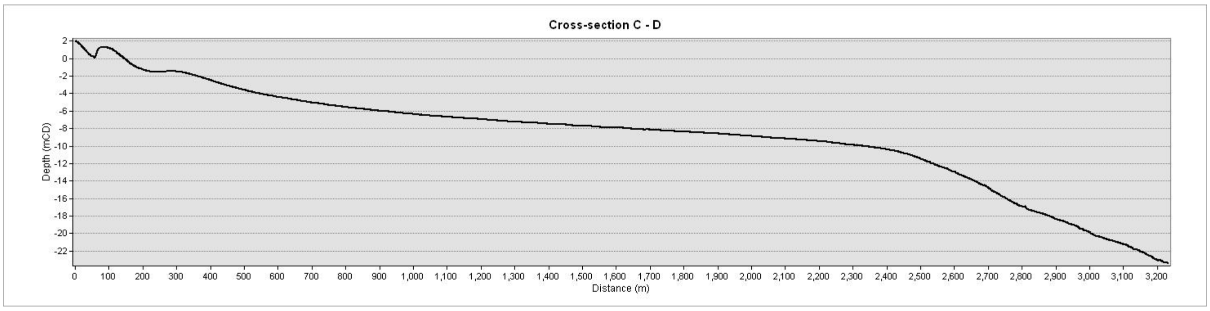


Figure 10: Cross-section C-D illustrating bathymetry

Fingers of *Sublittoral Coarse sediment* can be seen extending into the sandy sediment, mainly along the face of this slope. Which fill depressions similar to those found at the Ravenscar to Cloughton and Scarborough sections, approximately 0.5 mCD in depth. These are clearly identified in the backscatter and outlined by the slope angle map. The thin veneer of sediment covering the *Moderate Energy Rock and thin Sediment* has been classed as mixed sediment, using the sediment grabs and backscatter.

Filey Brigg is an area of interest for archaeologists and, in the past, has been used as a source of building materials for the local area. Known locally as 'Spittal Rocks' they can be seen extending out along the south side of Filey Brigg and is thought to be the remains of a Roman harbour or quarrying site (Clark and Robinson, 1997).

To the north of Filey Brigg a large bank of sediment is present, curving away to the west. This layer of *Sublittoral Sand* rises steeply, up to 14 m change in depth over 120m in places, above the rock and thin sediment. Bedforms are present along its eastern flank indicating high currents caused by the rapid change in depth and possibly amplified by the complex bathymetry surrounding Filey Brigg.

Analysis of these bedforms shows an interesting pattern. Bedforms along the southern flank against the rock platform, show a sediment transport direction from west to east. Near the sand bank the bedforms change orientation and the bedforms moving along the eastern flank indicate sediment transport from southeast to northwest (Figure 11). This formation of bedforms continues to migrate westwards along the edge of this bank gradually spreading out and disappearing as the seabed levels out.

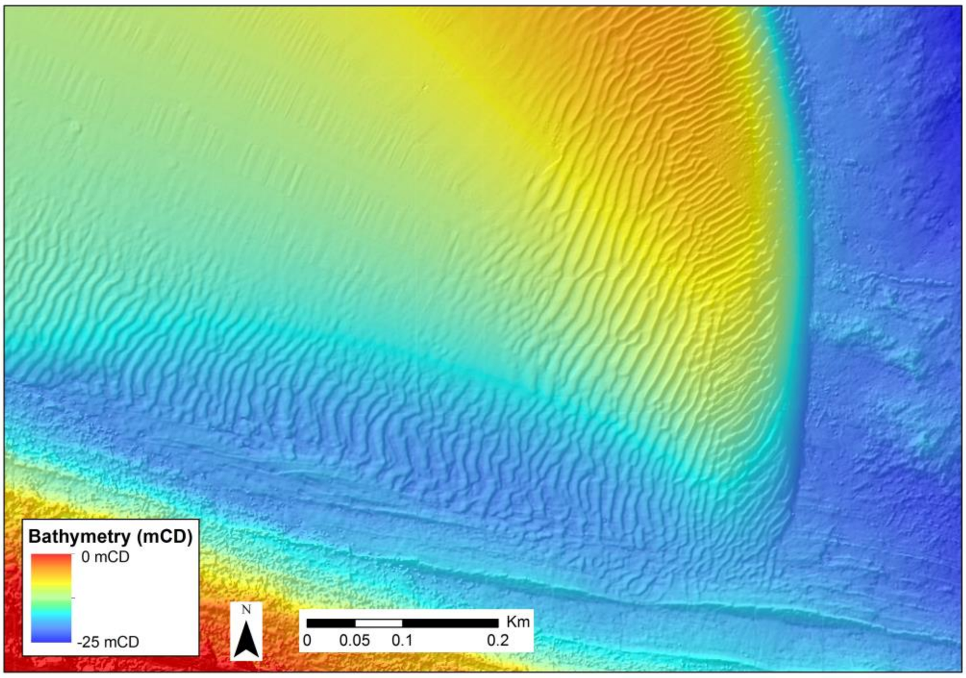
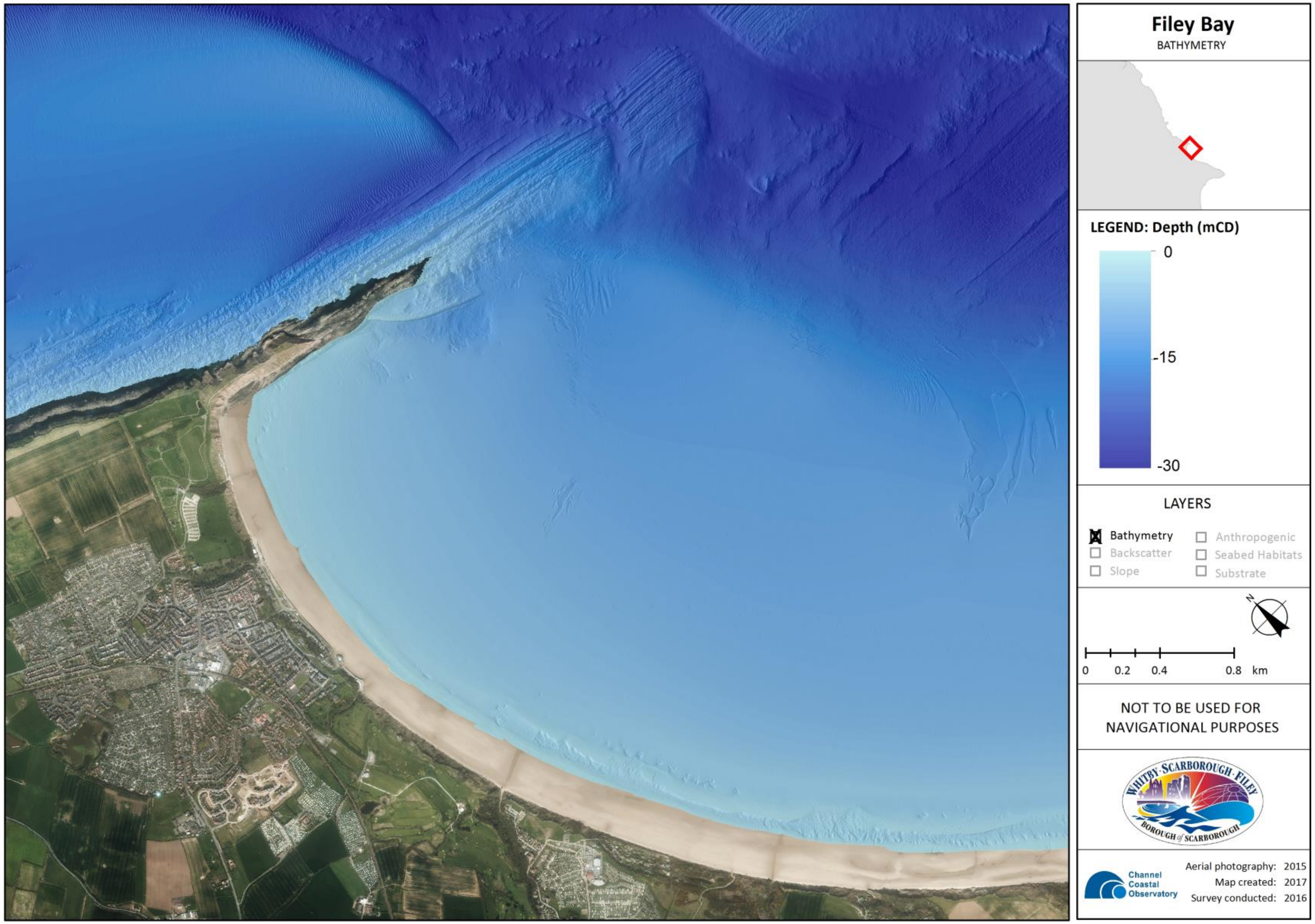
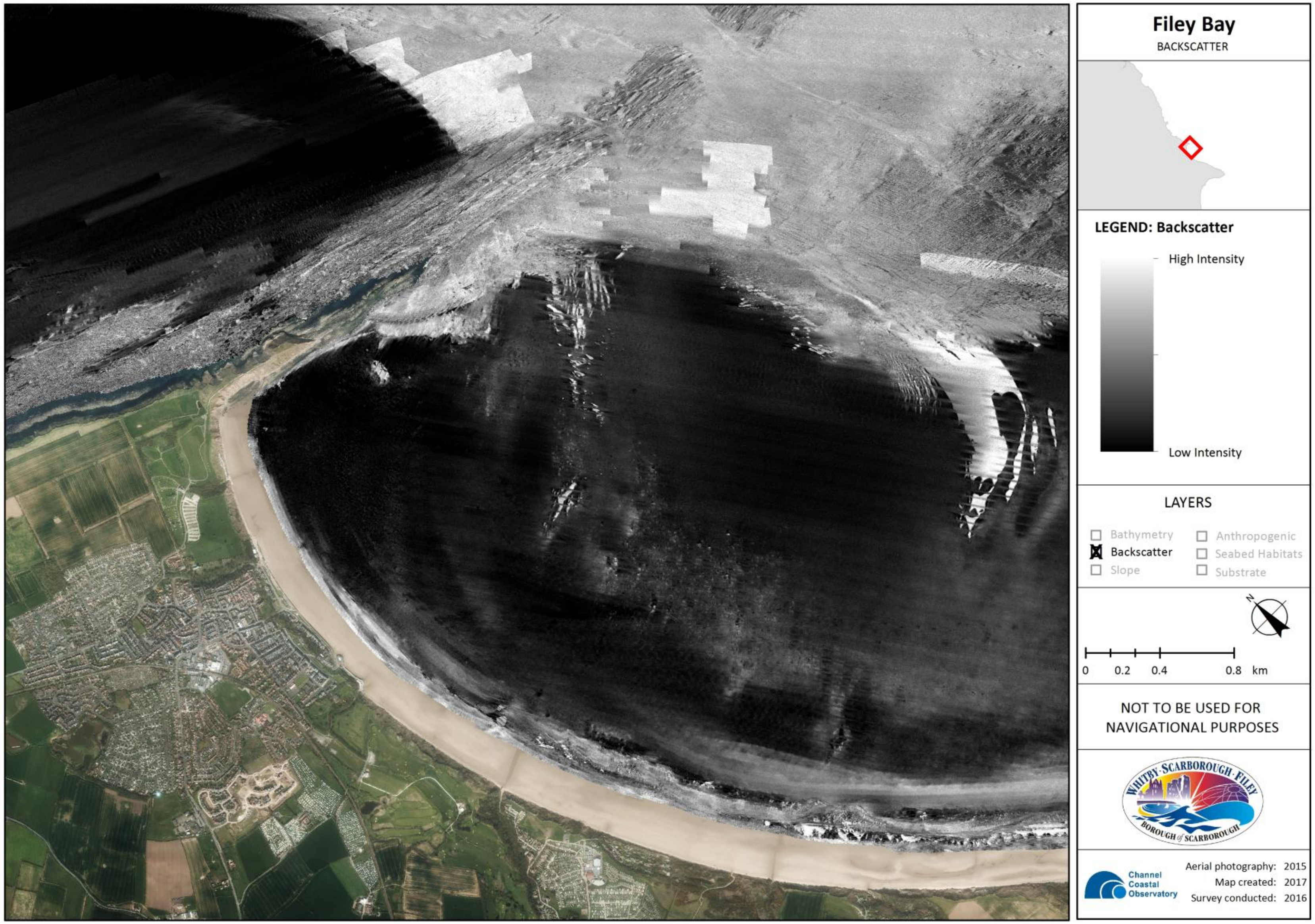
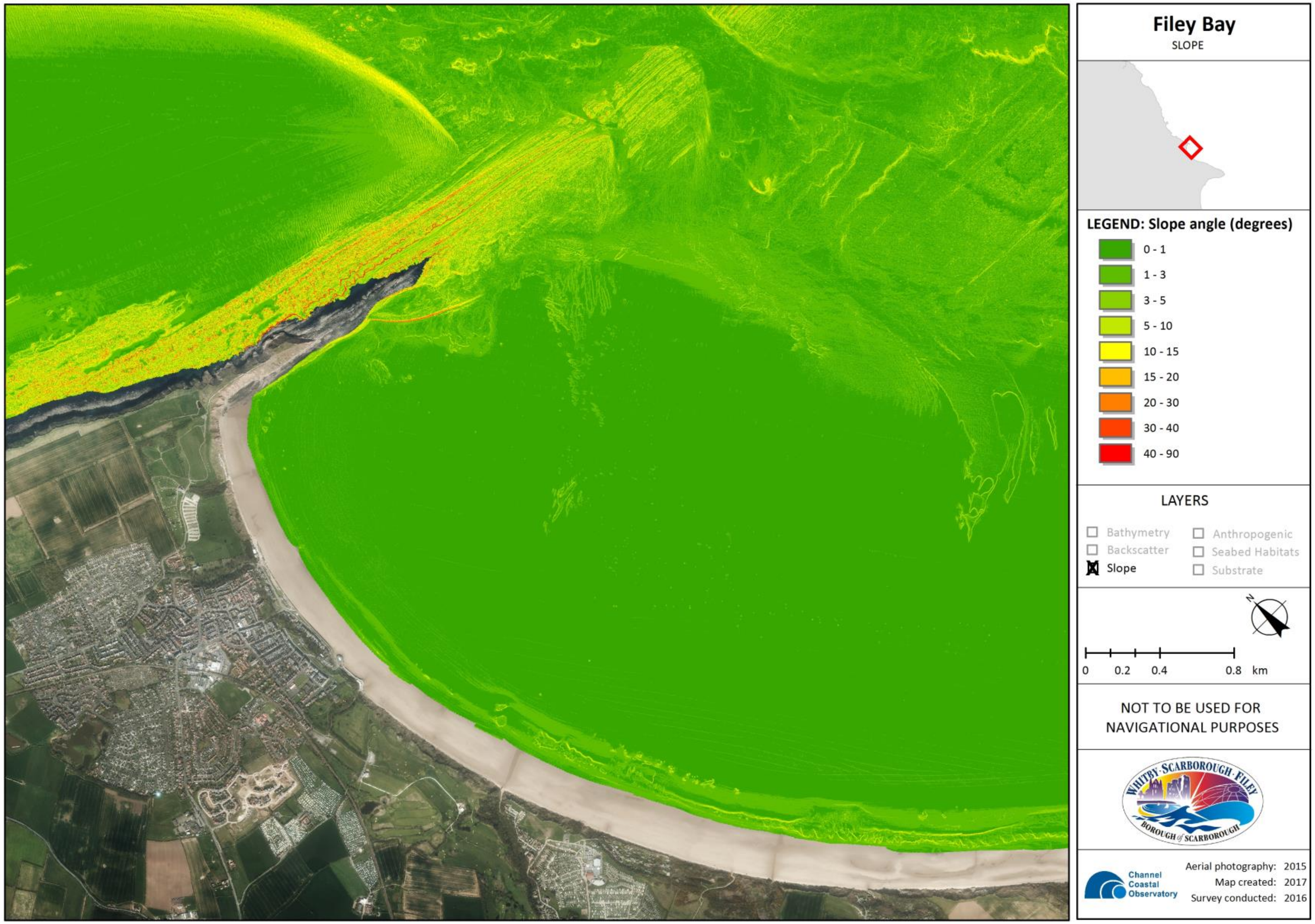


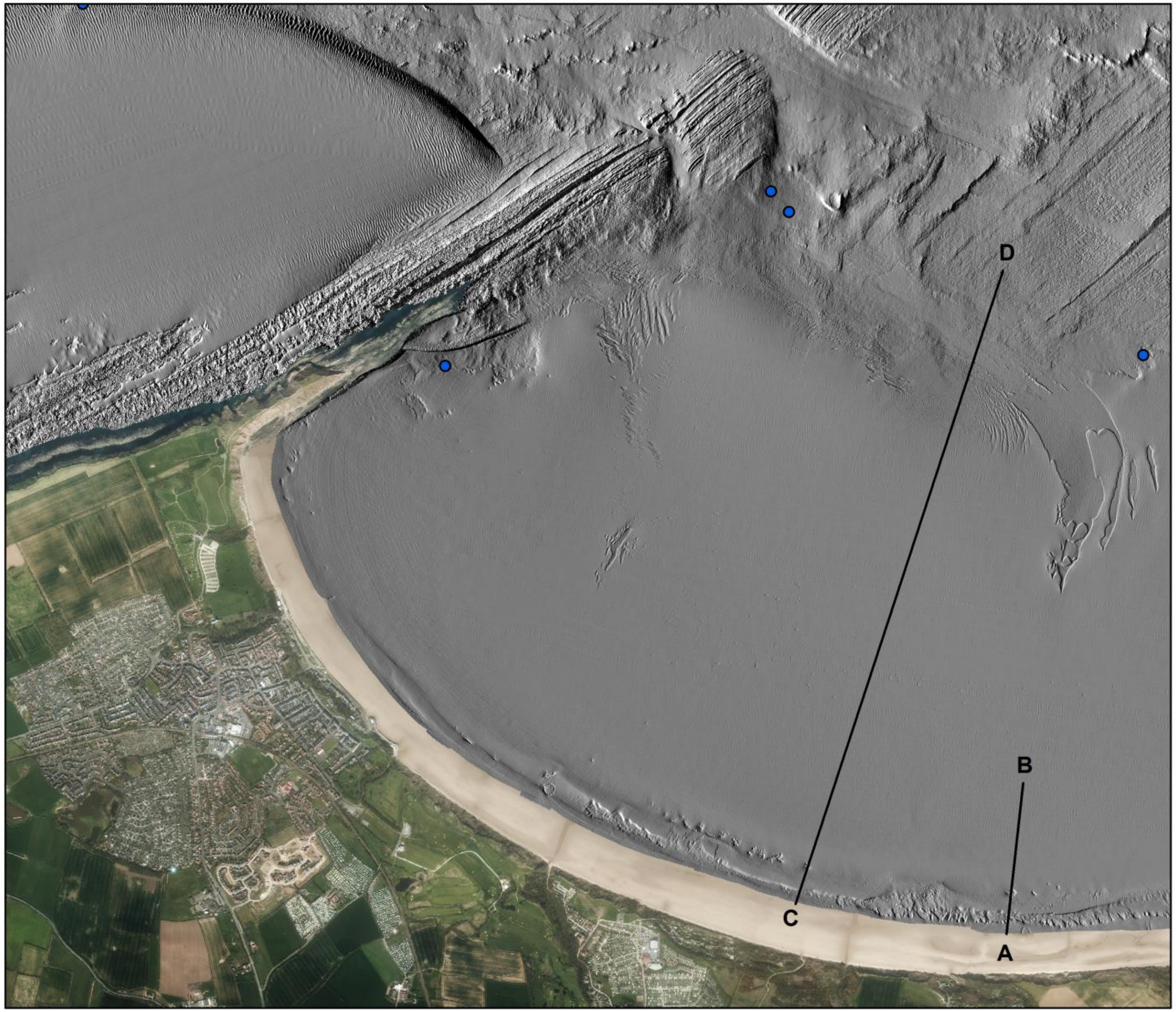
Figure 11: Bedforms along sandbar to the North of Filey Brigg

No anthropogenic features have been identified, 4 wrecks are present.


Filey Bay
BATHYMETRY
LEGEND: Depth (mCD)
0
-15
-30
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.2 0.4 0.8 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY-SCARBOROUGH-FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Filey Bay
BACKSCATTER
LEGEND: Backscatter
High Intensity
Low Intensity
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
0 0.2 0.4 0.8 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Filey Bay
SLOPE
LEGEND: Slope angle (degrees)
0 - 1
1 - 3
3 - 5
5 - 10
10 - 15
15 - 20
20 - 30
30 - 40
40 - 90
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.2 0.4 0.8 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY · SCARBOROUGH · FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016



Filey Bay
ANTHRPOGENIC

LEGEND: Anthropogenic features

- Anthropogenic features
- Wrecks

LAYERS

- Bathymetry
- Backscatter
- Slope
- Anthropogenic
- Seabed Habitats
- Substrate

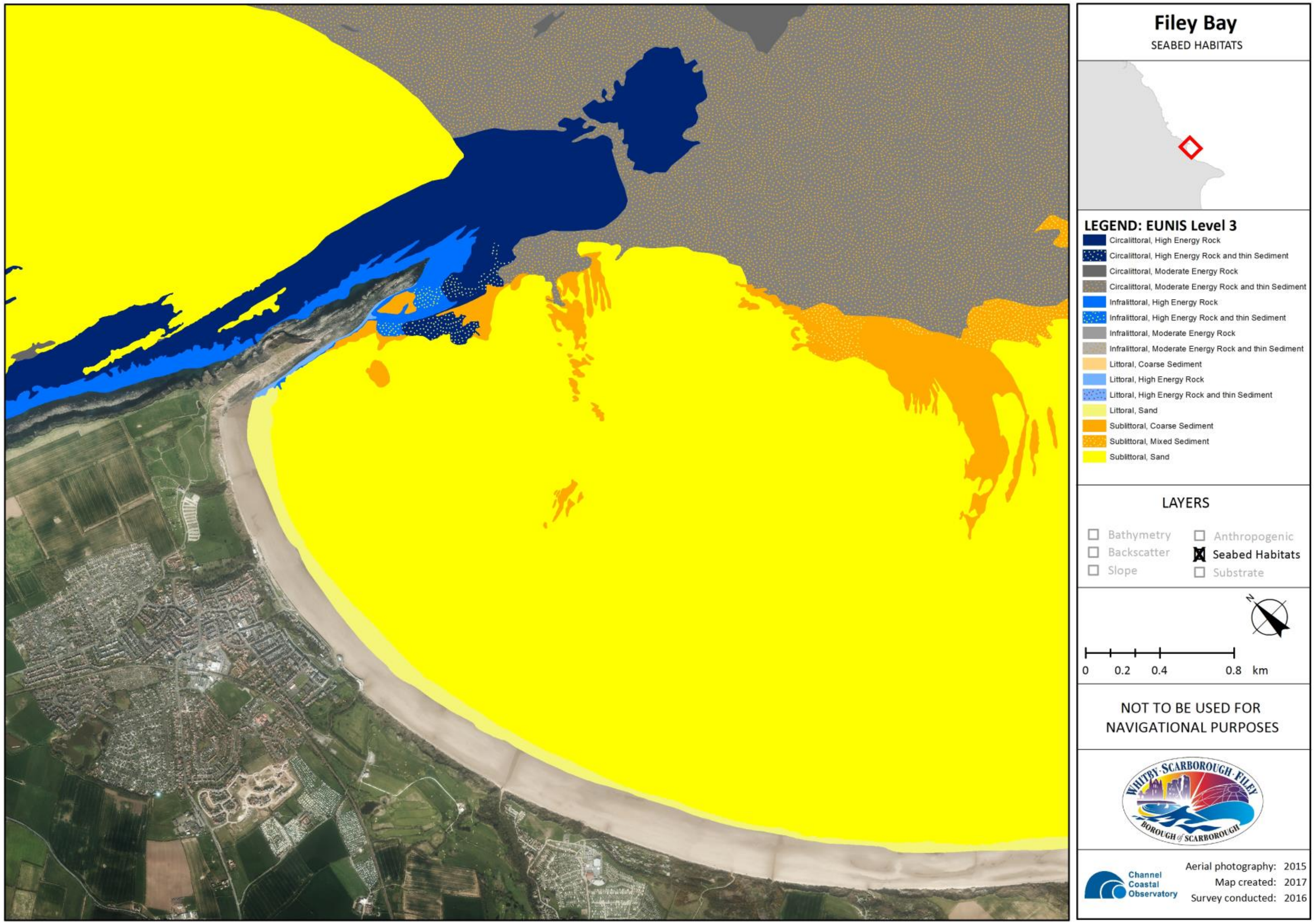
0 0.2 0.4 0.8 km

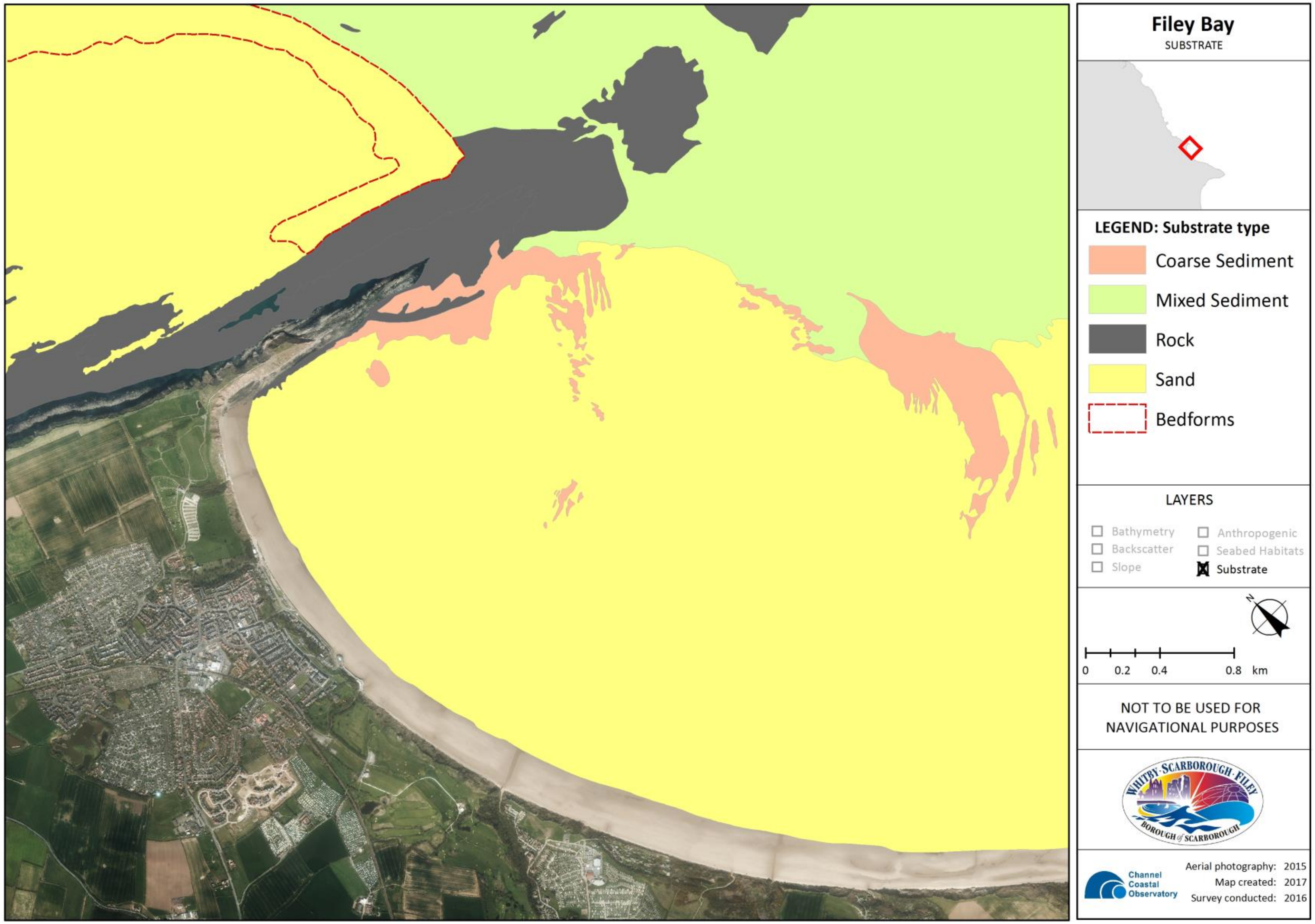
NOT TO BE USED FOR NAVIGATIONAL PURPOSES

WHITBY-SCARBOROUGH-FILEY BOROUGH of SCARBOROUGH

Channel Coastal Observatory

Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Filey Bay
SEABED HABITATS
LEGEND: EUNIS Level 3
Circalittoral, High Energy Rock
Circalittoral, High Energy Rock and thin Sediment
Circalittoral, Moderate Energy Rock
Circalittoral, Moderate Energy Rock and thin Sediment
Infralittoral, High Energy Rock
Infralittoral, High Energy Rock and thin Sediment
Infralittoral, Moderate Energy Rock
Infralittoral, Moderate Energy Rock and thin Sediment
Littoral, Coarse Sediment
Littoral, High Energy Rock
Littoral, High Energy Rock and thin Sediment
Littoral, Sand
Sublittoral, Coarse Sediment
Sublittoral, Mixed Sediment
Sublittoral, Sand
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.2 0.4 0.8 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY·SCARBOROUGH·FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016



Filey Bay
SUBSTRATE
LEGEND: Substrate type
Coarse Sediment
Mixed Sediment
Rock
Sand
Bedforms
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.2 0.4 0.8 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY·SCARBOROUGH·FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016

Filey Brigg

The seabed surrounding Filey Brigg is a complex area of different habitats and sediment types (physically and geologically). The geology that forms Filey Brigg itself is exposed rocky outcrop of more resistant Corallian Limestone with clearly defined ridges that extends eastwards across the entire map. The rock outcrop initially extending from the mainland is quickly broken in two places forming steep channels before continuing offshore, gradually increasing in depth and becoming less prominent above the surrounding seabed. Rocky outcrops can be identified to the north of Filey Brigg, both exposed and covered by a thin veneer of sediment in a similar orientation to Filey Brigg.

The presence of Filey Brigg may increase the velocity and turbulence of local currents due to the change in depth and also the narrow channels between exposed rock outcrops. Surrounding the exposed rocky outcrops is an area of *Circalittoral Moderate Energy Rock and thin Sediment*. The underlying geology is visible and the thin veneer of sediment has been classified as mixed sediment. The rock and thin sediment is surrounded by *Sublittoral Sand* thick enough to cover the underlying geology. To the north the sandy seabed is featureless. To the Northeast a large bank of sediment is located covered in bedforms (discussed in Filey Bay section). Lining the south side of the rock and thin sediment is a band of *Sublittoral Coarse sediment* identifiable in the backscatter by higher levels of intensity. The coarse sediment extends into the sandy sediment in fingers and all form depressions (Figure 12d).

There is a large sediment feature located in the east of this map and split by Filey Brigg (Figure 12a). The feature is clearly highlighted in the bathymetry and backscatter as an area of lower intensity, and appears between the transition of sediment to rock and thin sediment. The formation starts to the south as a number of potentially migrating sand dunes covered in smaller bedforms before a single ridge is formed. In places the ridge rises up to 7m above the seabed as illustrated in Figure 13 (The cross-section location can be found on the anthropogenic map). Bedforms line both sides of the ridge and continue on the seabed to the northeast; the seabed to the east is featureless, indicating less sediment. The main ridge splits into a number of smaller sand dunes (Figures 12a & 12b) before it reaches Filey Brigg. Certain bedforms can be seen covering the rock platform in places before being interrupted and continuing to the north of Filey Brigg.

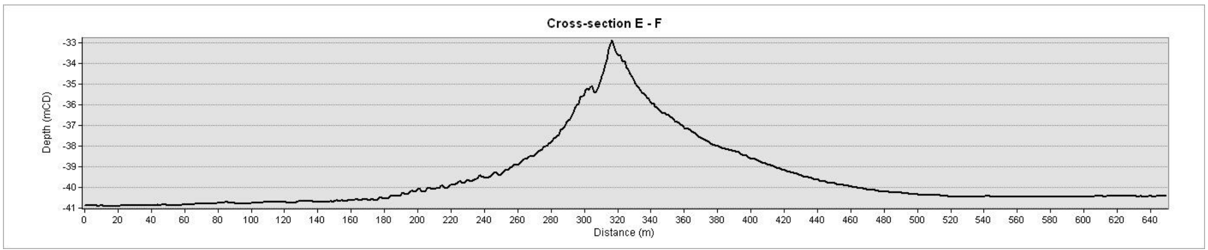


Figure 13: Bathymetry of sand ridge

A number of wrecks in the area have created complex scour and wreck marks. Scour marks are found to the east and west sides of the most prominent wrecks (Figure 12c) and have an impact on the seabed over a distance of 600m in places. Scouring is found on both sides of the wrecks indicating a Northwest/Southeast current orientation. The eastern scour mark is much larger, however, a salient and bedforms had formed to the west of the wreck.

The inshore section to the east of Filey Bay, known as Bempton Cliffs, was surveyed by East Riding of Yorkshire Council in 2008 and mapped by the Channel Coastal Observatory in 2013[3]. It is outlined in red and labelled as HI1358 in the following maps for this section.

44 wrecks were found within the extents of this set of maps but no anthropogenic features are clearly identifiable.

[3] http://www.channelcoast.org/reports/

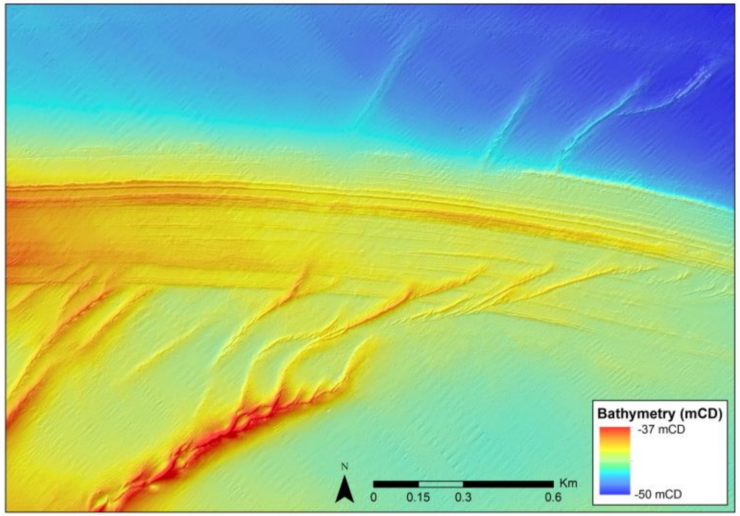


Figure 12a: Large bedform feature

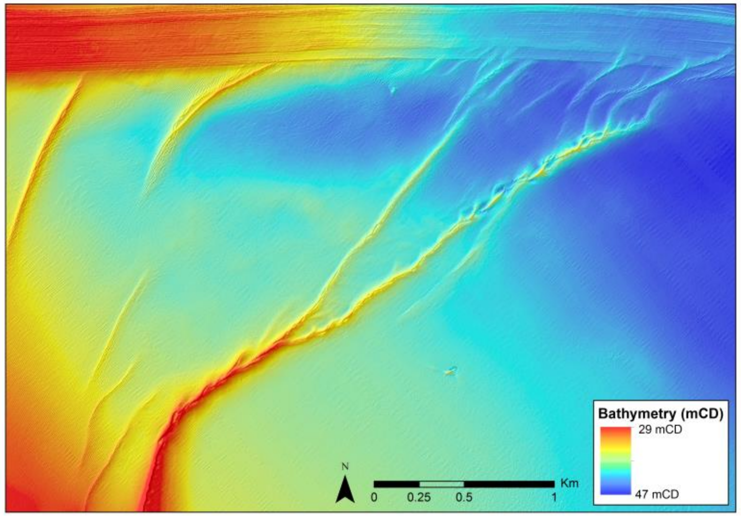


Figure 12b: Large bedform feature

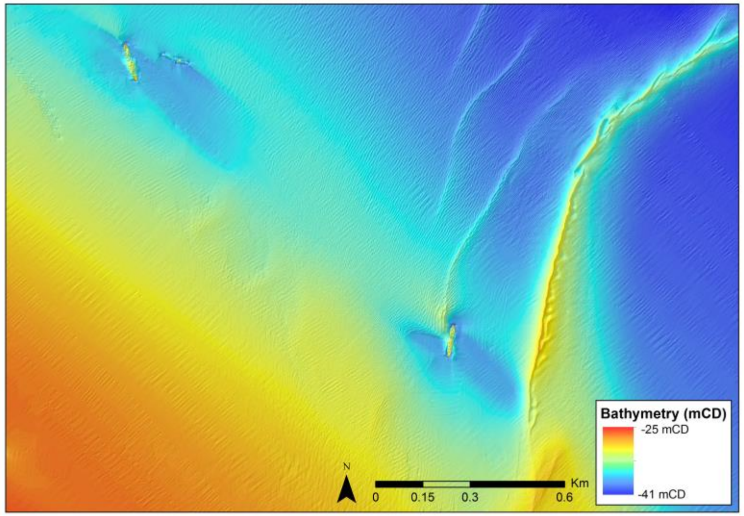


Figure 12c: Wreck marks

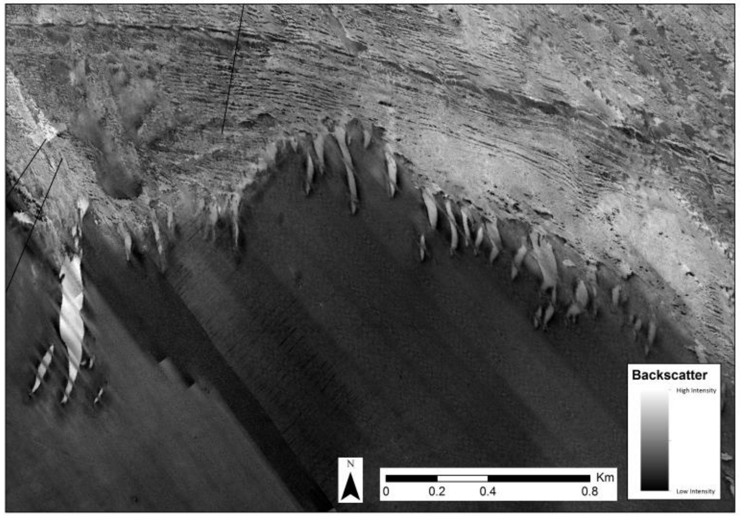
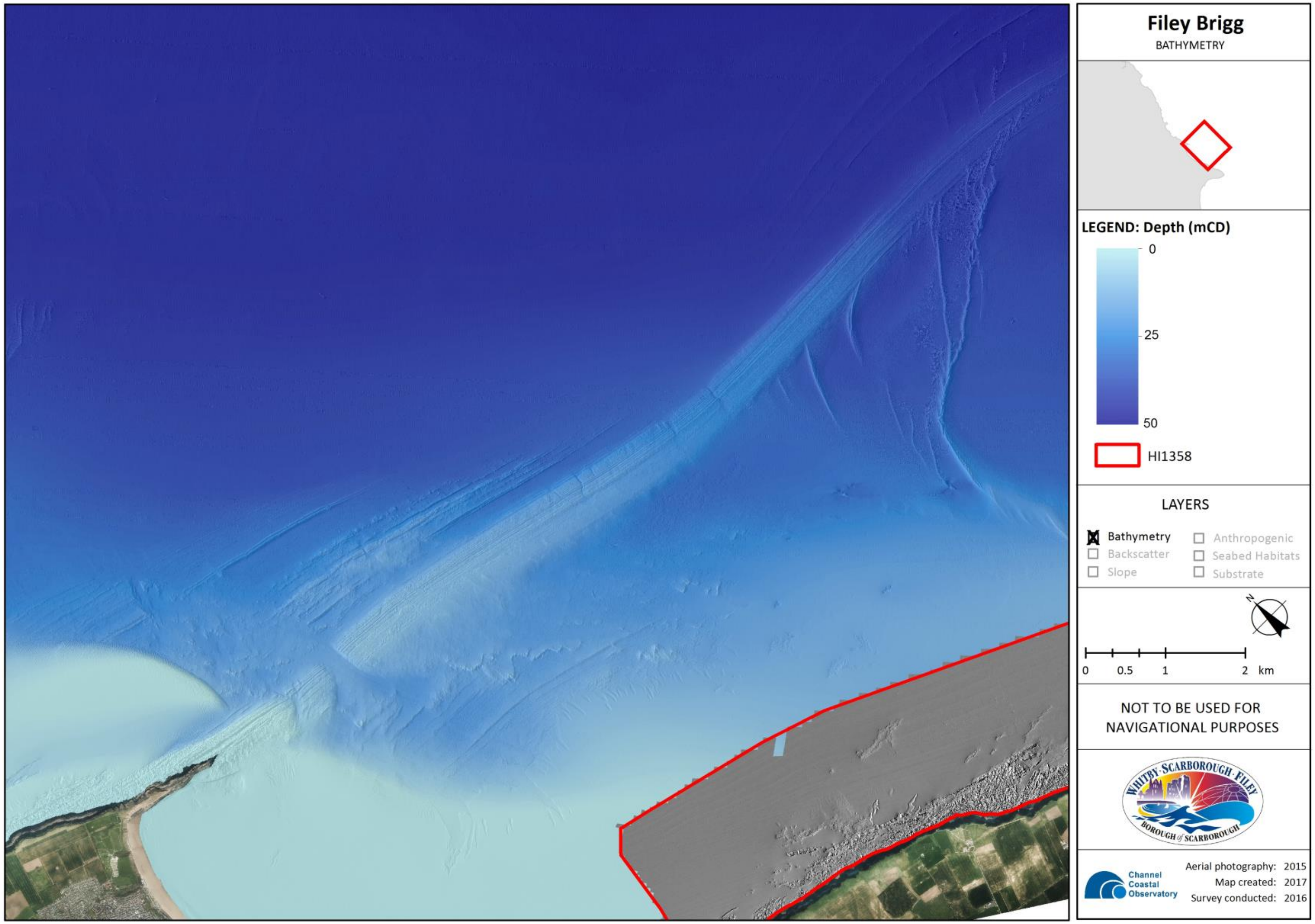
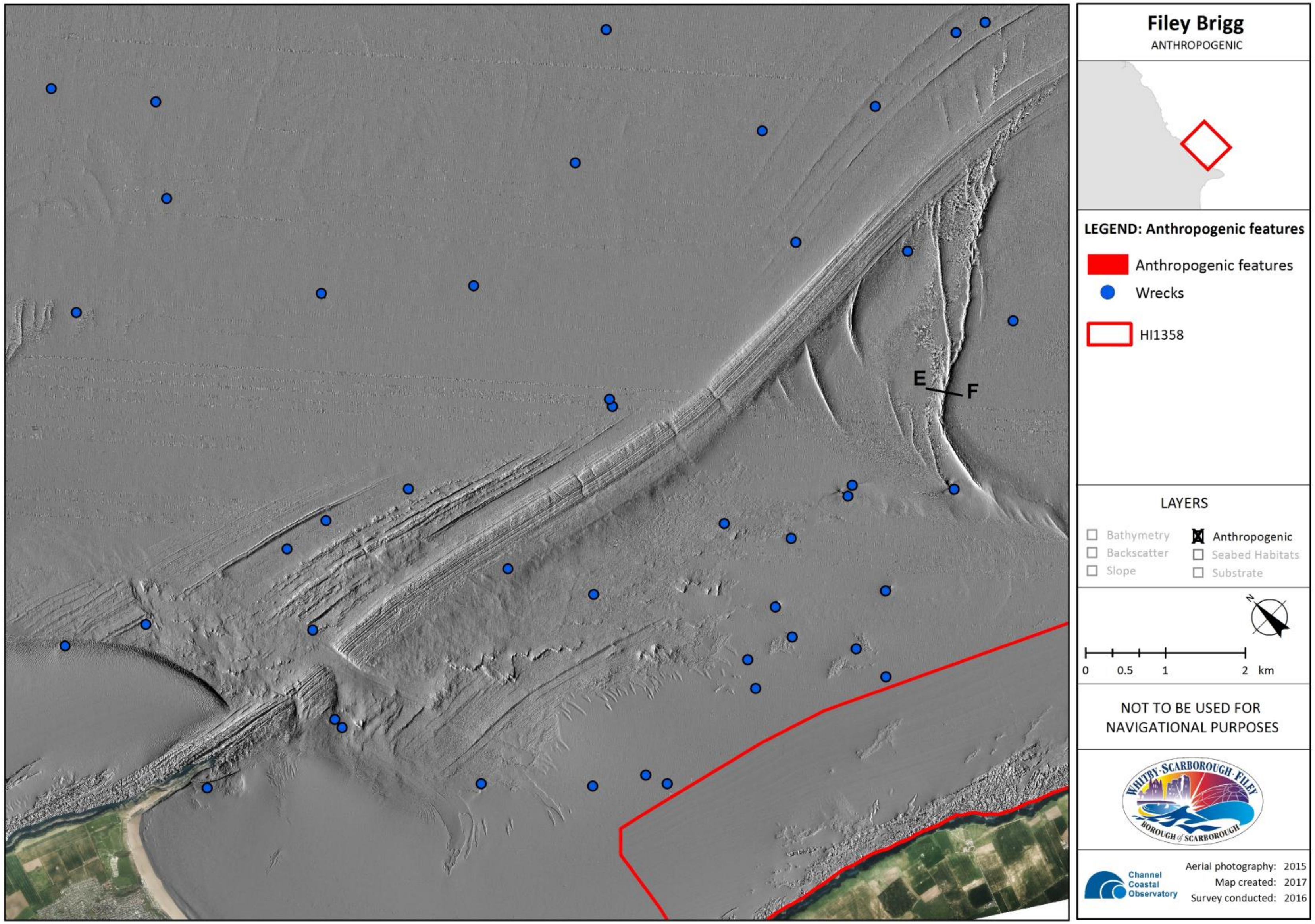


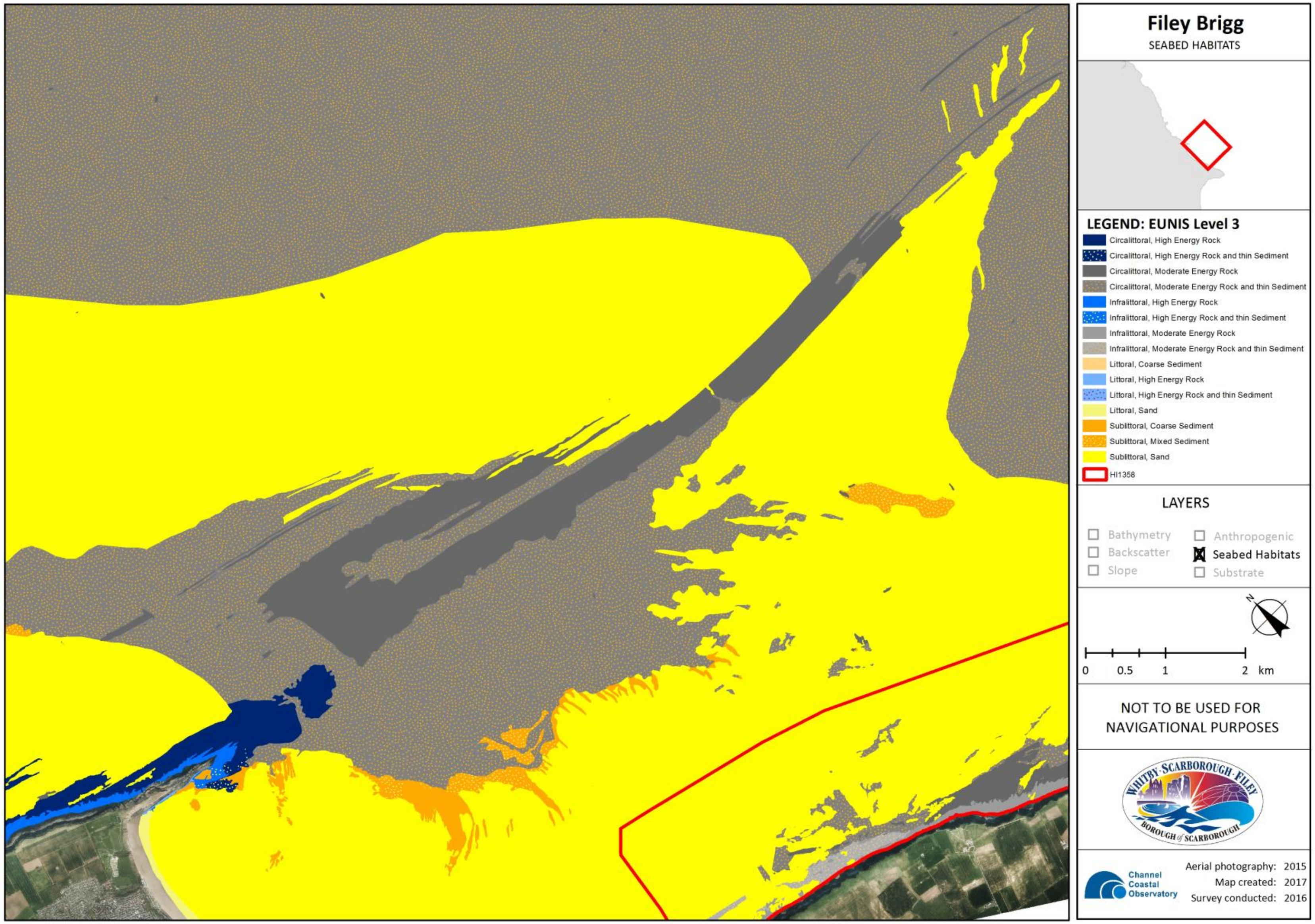
Figure 12d: Fingers of coarser sediment

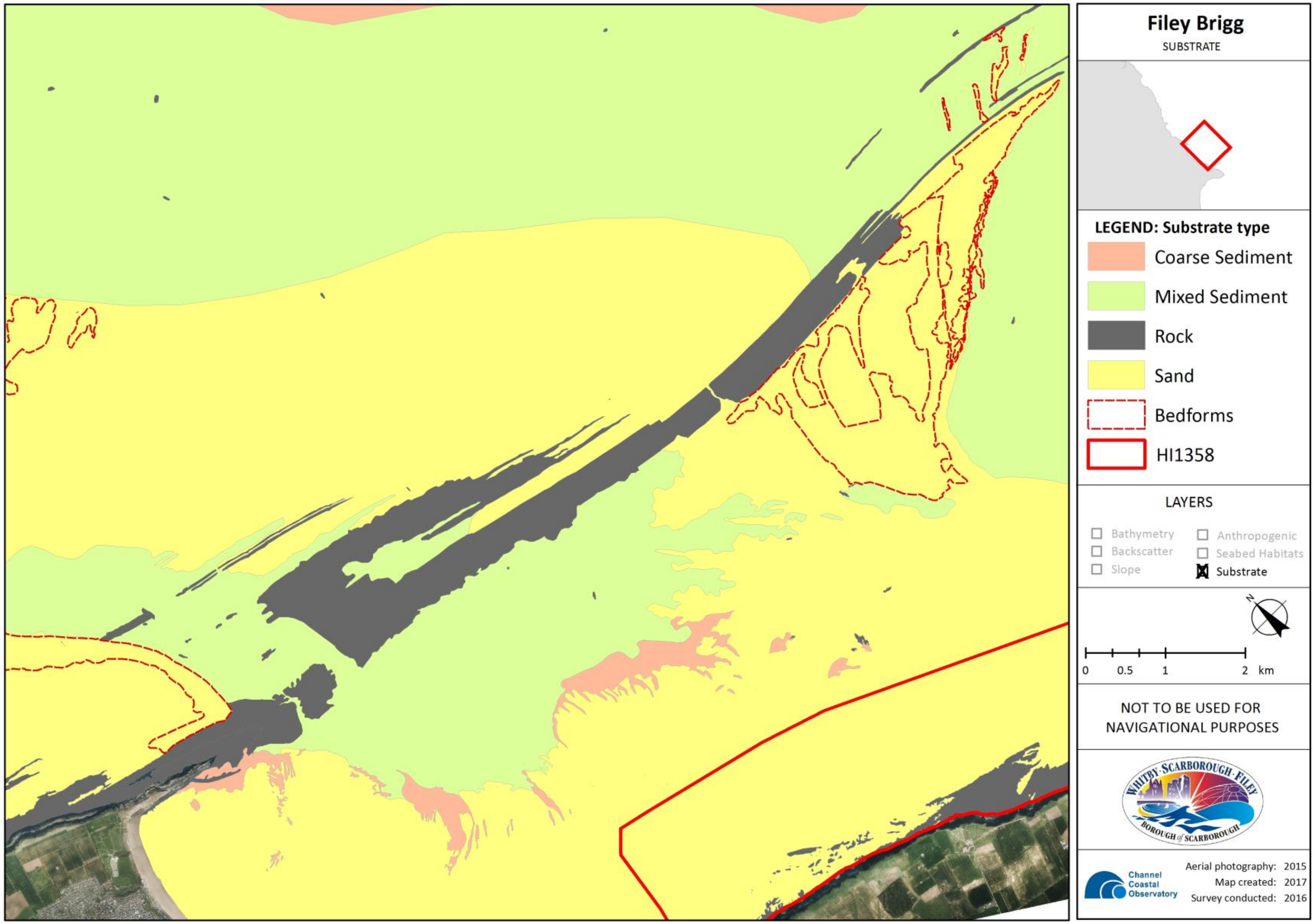

Filey Brigg
BATHYMETRY
LEGEND: Depth (mCD)
0
25
50
HI1358
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0
0.5
1
2 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Filey Brigg
BACKSCATTER
LEGEND: Backscatter
High Intensity
Low Intensity
HI1358
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0
0.5
1
2
km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY SCARBOROUGH FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Filey Brigg
SLOPE
LEGEND: Slope angle (degrees)
0 - 1
1 - 3
3 - 5
5 - 10
10 - 15
15 - 20
20 - 30
30 - 40
40 - 90
HI1358
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.5 1 2 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY·SCARBOROUGH·FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Filey Brigg
ANTHROPOGENIC
LEGEND: Anthropogenic features
Anthropogenic features
Wrecks
HI1358
E
F
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
0 0.5 1 2 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY SCARBOROUGH FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Filey Brigg
SEABED HABITATS
LEGEND: EUNIS Level 3
Circalittoral, High Energy Rock
Circalittoral, High Energy Rock and thin Sediment
Circalittoral, Moderate Energy Rock
Circalittoral, Moderate Energy Rock and thin Sediment
Infralittoral, High Energy Rock
Infralittoral, High Energy Rock and thin Sediment
Infralittoral, Moderate Energy Rock
Infralittoral, Moderate Energy Rock and thin Sediment
Littoral, Coarse Sediment
Littoral, High Energy Rock
Littoral, High Energy Rock and thin Sediment
Littoral, Sand
Sublittoral, Coarse Sediment
Sublittoral, Mixed Sediment
Sublittoral, Sand
HI1358
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.5 1 2 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY·SCARBOROUGH·FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Filey Brigg
SUBSTRATE
LEGEND: Substrate type
Coarse Sediment
Mixed Sediment
Rock
Sand
Bedforms
HI1358
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
0 0.5 1 2 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY·SCARBOROUGH·FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016

Offshore - Flamborough Head

The nearshore rock platform extends offshore from Flamborough Head for up to 2km with clearly defined geology, including folding and fracturing, and gradually increases in depth before a thin layer of sediment starts to obscure the geology in places.

The majority of this map is classified as *Moderate Energy Rock and thin Sediment* but the seabed is not featureless. The underlying geology can be identified beneath a thin veneer of sediment and in places rocky ridges are exposed. The majority of the exposed *Circalittoral Moderate Energy Rock* is part of the Filey Brigg formation continuing offshore. At the eastern end of this formation a number of faults can be detected in the rocky ridge (Figure 14). To the north of the main ridge the geology can be seen folding. The rocky outcrops covered by only a thin veneer of sediment are highlighted in the backscatter and the slope maps.

Towards the south-east corner of the map, a large area of exposed rock is present between approximately 46 and 49mCD (Figure 14). The exposed rock rises gradually from South to North with up to a 4m cliff running along the north-west to north-eastern flank. Patches of bedforms are found on the northern flank of the exposed rock suggesting high currents around the steep drop off.

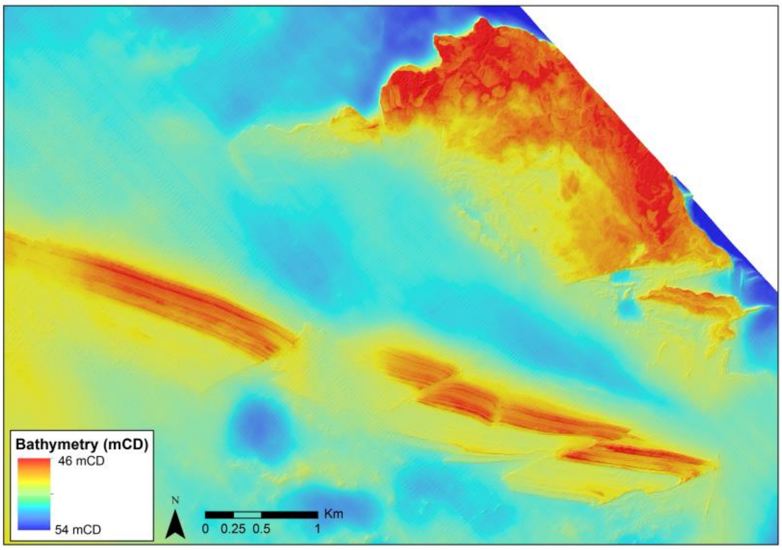


Figure 14: Exposed Circalittoral Moderate Energy Rock

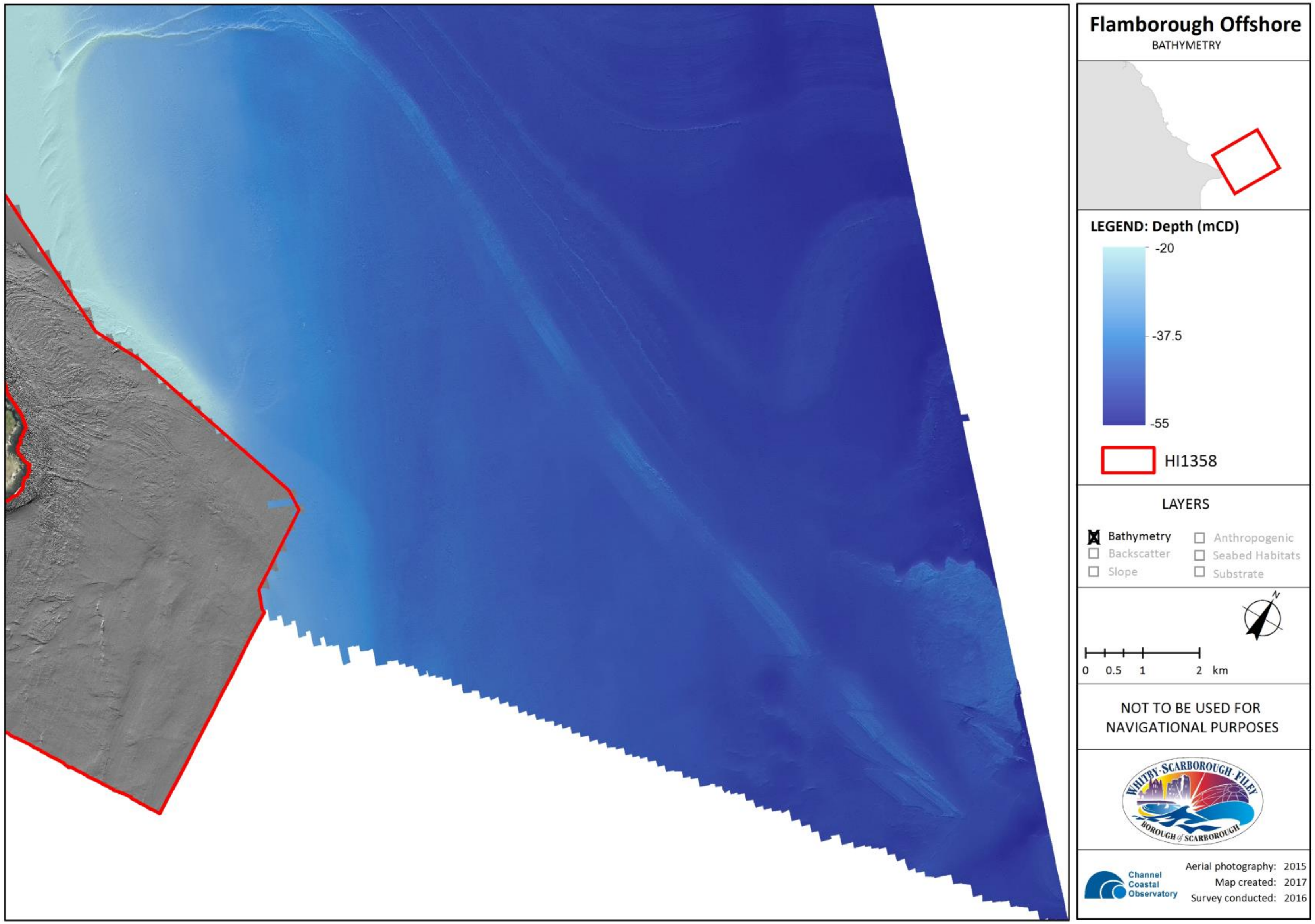
The sediment covering the *Moderate Energy Rock and thin Sediment* has been classified as either coarse or mixed sediment. As mentioned in the introduction, not all boundaries can be definitive but will transition from one sediment type to another gradually. Sediment samples clearly show a difference in sediment types the backscatter intensity does change over a wide area. The boundaries between these two sediment types are indicative only and more groundtruthing would be needed to improve their positioning.

There are two long narrow ridges of *Sublittoral Sand* which have definite boundaries and clearly stand out in the backscatter. The northern ridge rises up to 2.5m above the surrounding seabed with a narrow strip of bedforms evident on both sides of the ridge. The southern ridge has similar bedforms but is not as prominent; rising up to 1m above the surrounding seabed. They are possibly the remains of glacial moraines formed by glaciers during the last ice age (Dove, 2017).

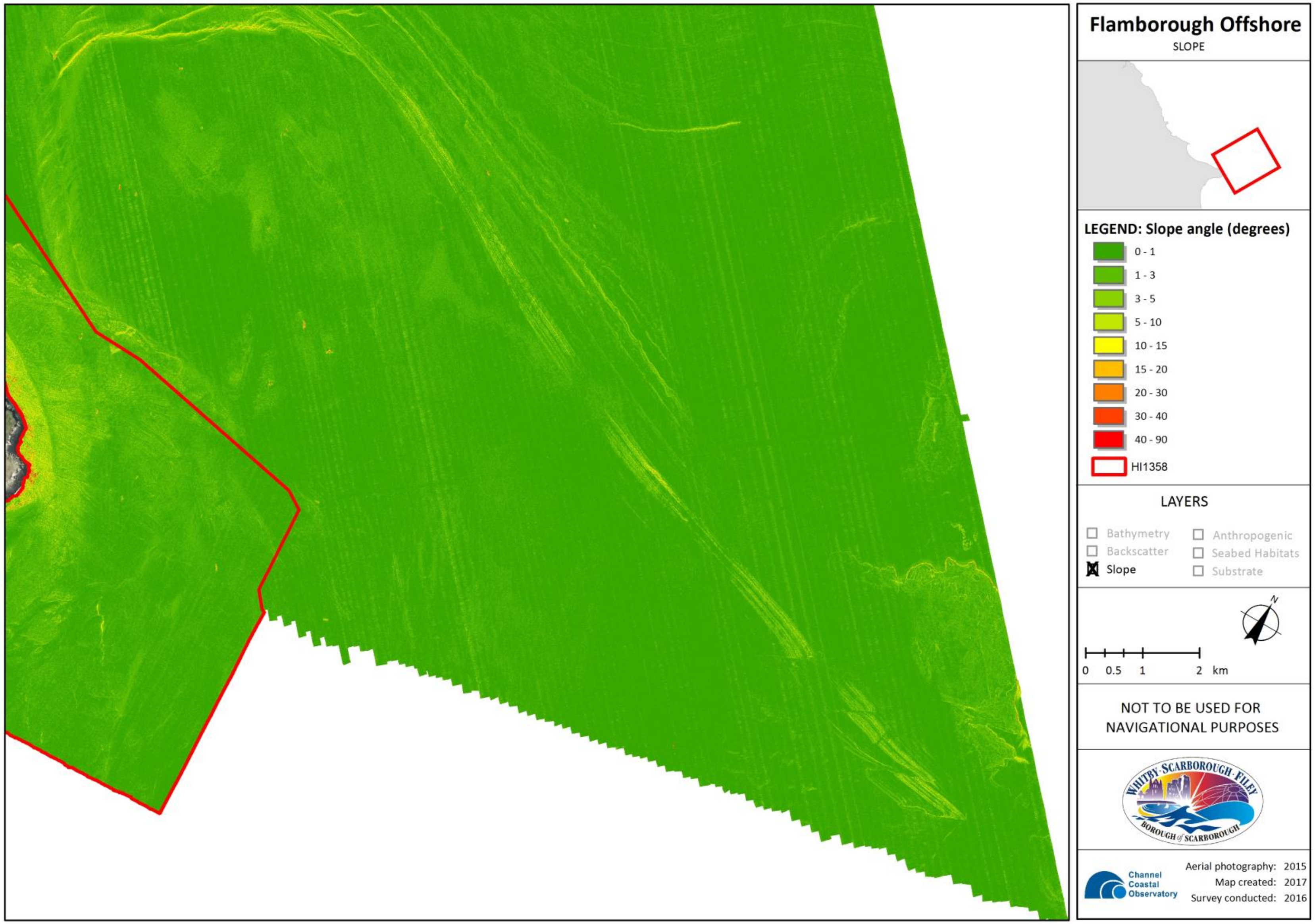
26 wrecks are located on this map and no obvious anthropogenic features. Analysis of scour marks surrounding the wrecks, where present, does not indicate any sediment transport. This is not surprising with the apparent lack of sediment found offshore.

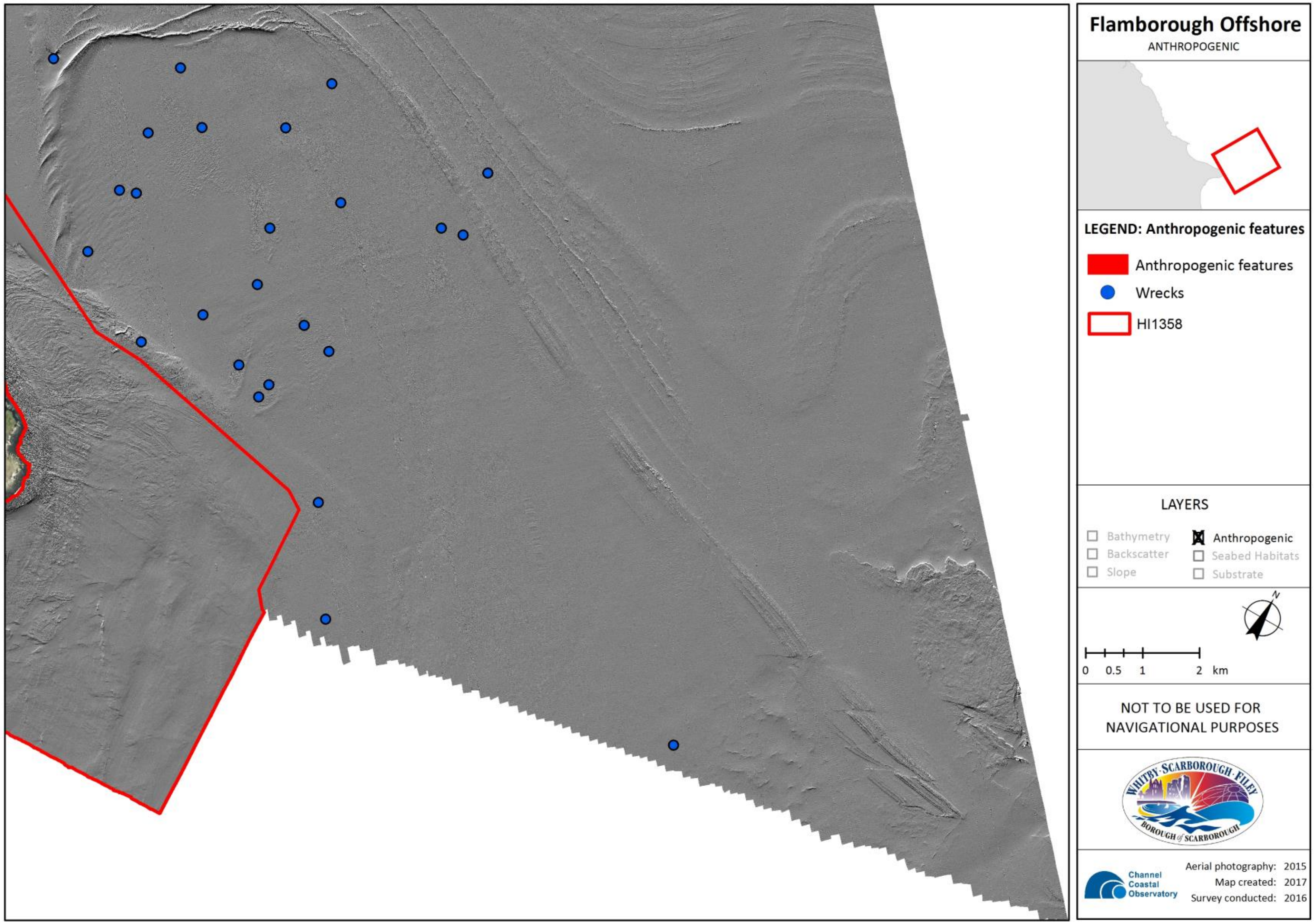
The inshore 1km of this section was surveyed by East Riding of Yorkshire Council in 2008 and mapped by the Channel Coastal Observatory in 2013[4]. This area is outlined in red on the maps in this section and labelled as HI1358 on the following maps.

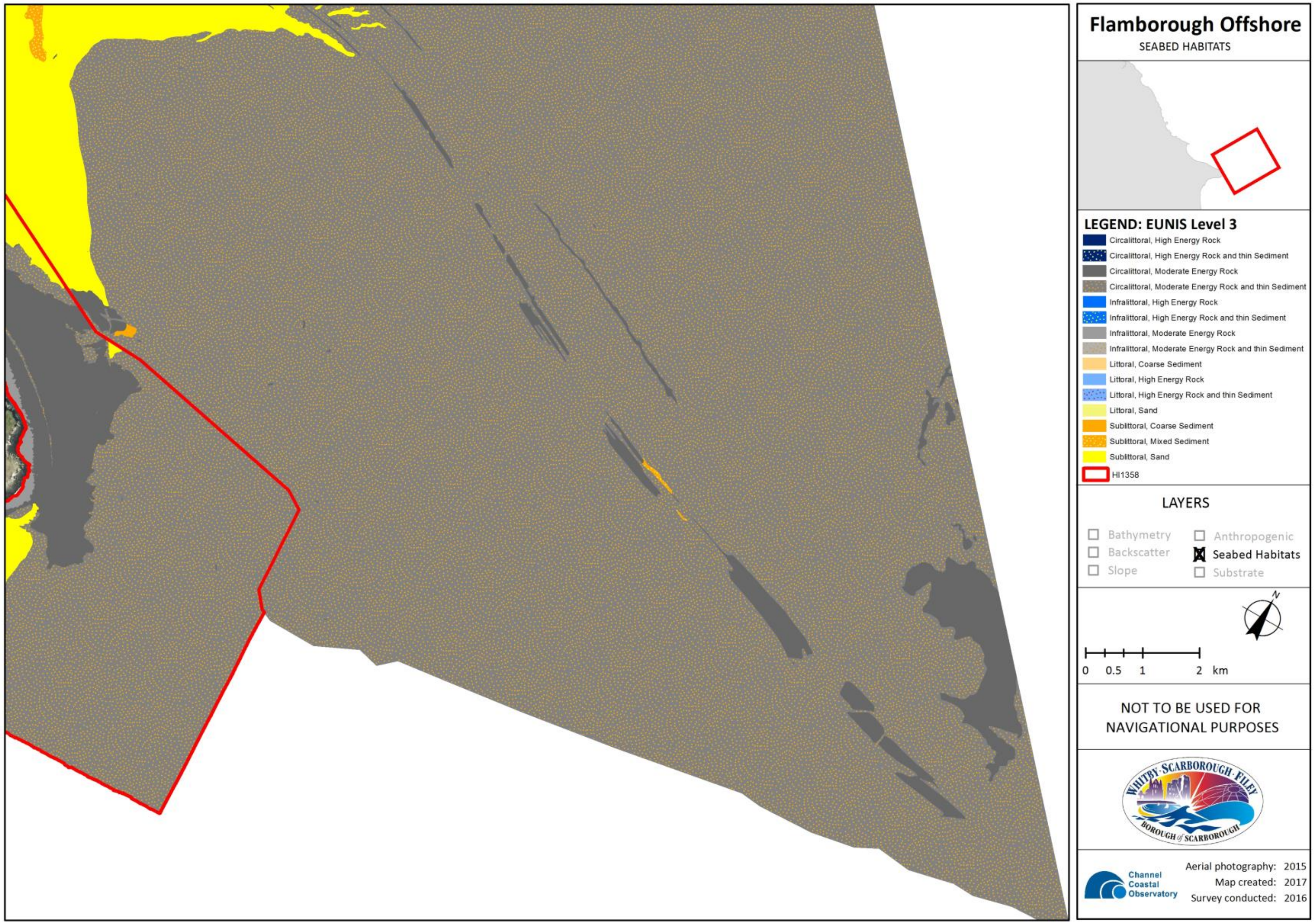
[4] http://www.channelcoast.org/reports/

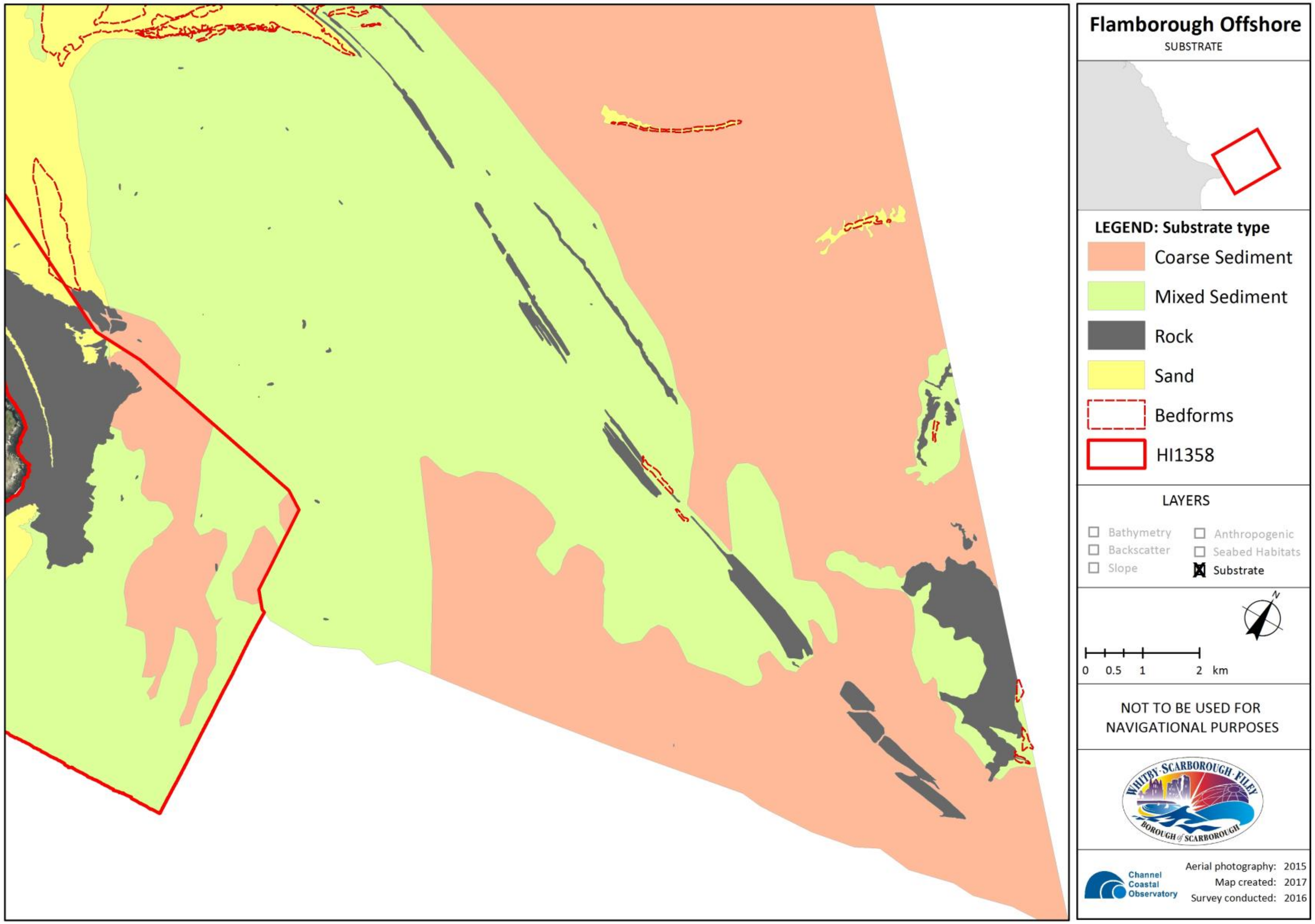

Flamborough Offshore
BATHYMETRY
LEGEND: Depth (mCD)
-20
-37.5
-55
HI1358
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.5 1 2 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY·SCARBOROUGH·FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Flamborough Offshore
BACKSCATTER
LEGEND: Backscatter
High Intensity
Low Intensity
HI1358
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.5 1 2 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY-SCARBOROUGH-FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Flamborough Offshore
SLOPE
LEGEND: Slope angle (degrees)
0 - 1
1 - 3
3 - 5
5 - 10
10 - 15
15 - 20
20 - 30
30 - 40
40 - 90
HI1358
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.5 1 2 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY-SCARBOROUGH-FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Flamborough Offshore
ANTHROPOGENIC
LEGEND: Anthropogenic features
Anthropogenic features
Wrecks
HI1358
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
0 0.5 1 2 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Flamborough Offshore
SEABED HABITATS
LEGEND: EUNIS Level 3
Circalittoral, High Energy Rock
Circalittoral, High Energy Rock and thin Sediment
Circalittoral, Moderate Energy Rock
Circalittoral, Moderate Energy Rock and thin Sediment
Infralittoral, High Energy Rock
Infralittoral, High Energy Rock and thin Sediment
Infralittoral, Moderate Energy Rock
Infralittoral, Moderate Energy Rock and thin Sediment
Littoral, Coarse Sediment
Littoral, High Energy Rock
Littoral, High Energy Rock and thin Sediment
Littoral, Sand
Sublittoral, Coarse Sediment
Sublittoral, Mixed Sediment
Sublittoral, Sand
HI1358
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.5 1 2 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY·SCARBOROUGH·FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016

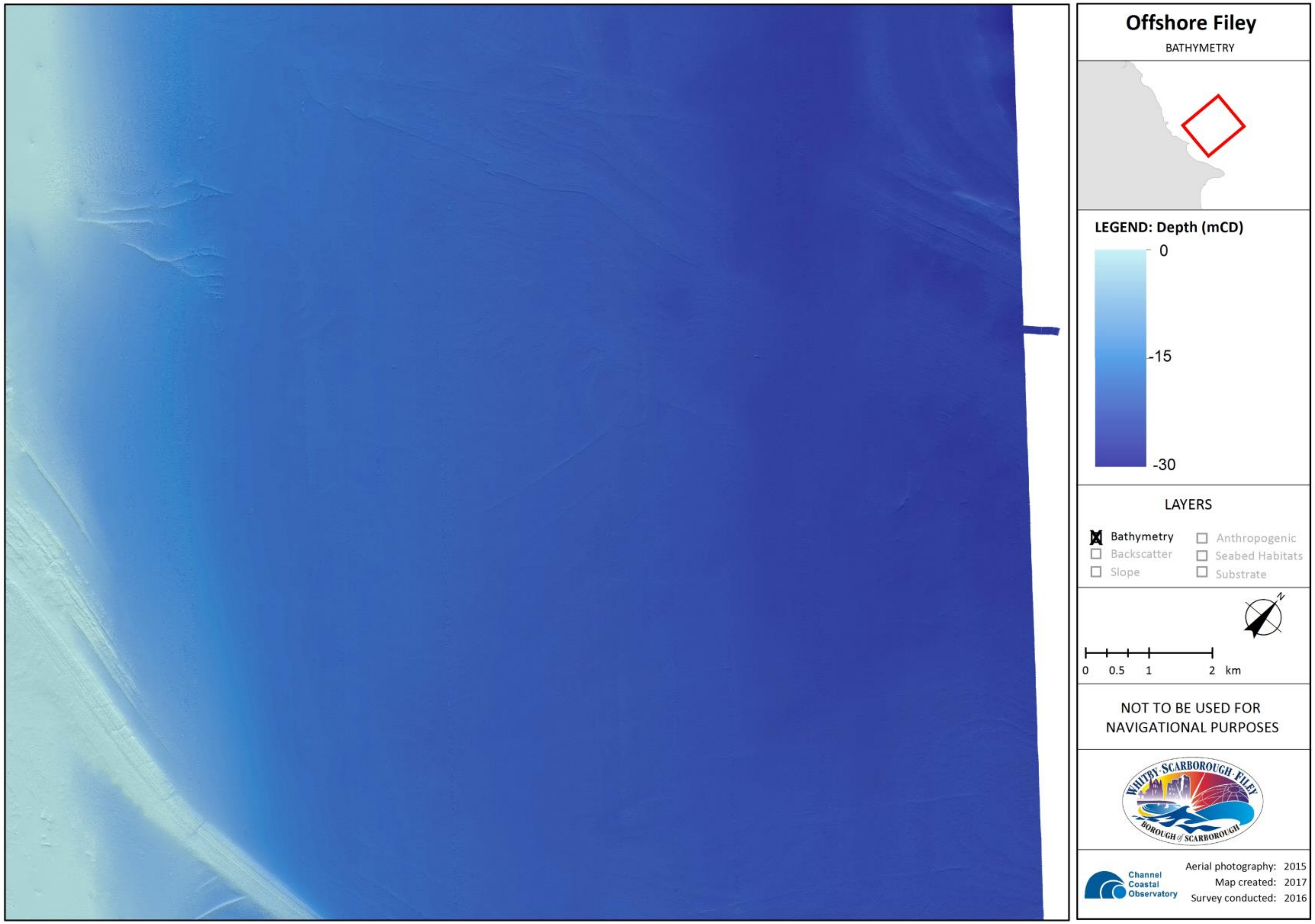

Flamborough Offshore
SUBSTRATE
LEGEND: Substrate type
Coarse Sediment
Mixed Sediment
Rock
Sand
Bedforms
HI1358
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.5 1 2 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY·SCARBOROUGH·FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016

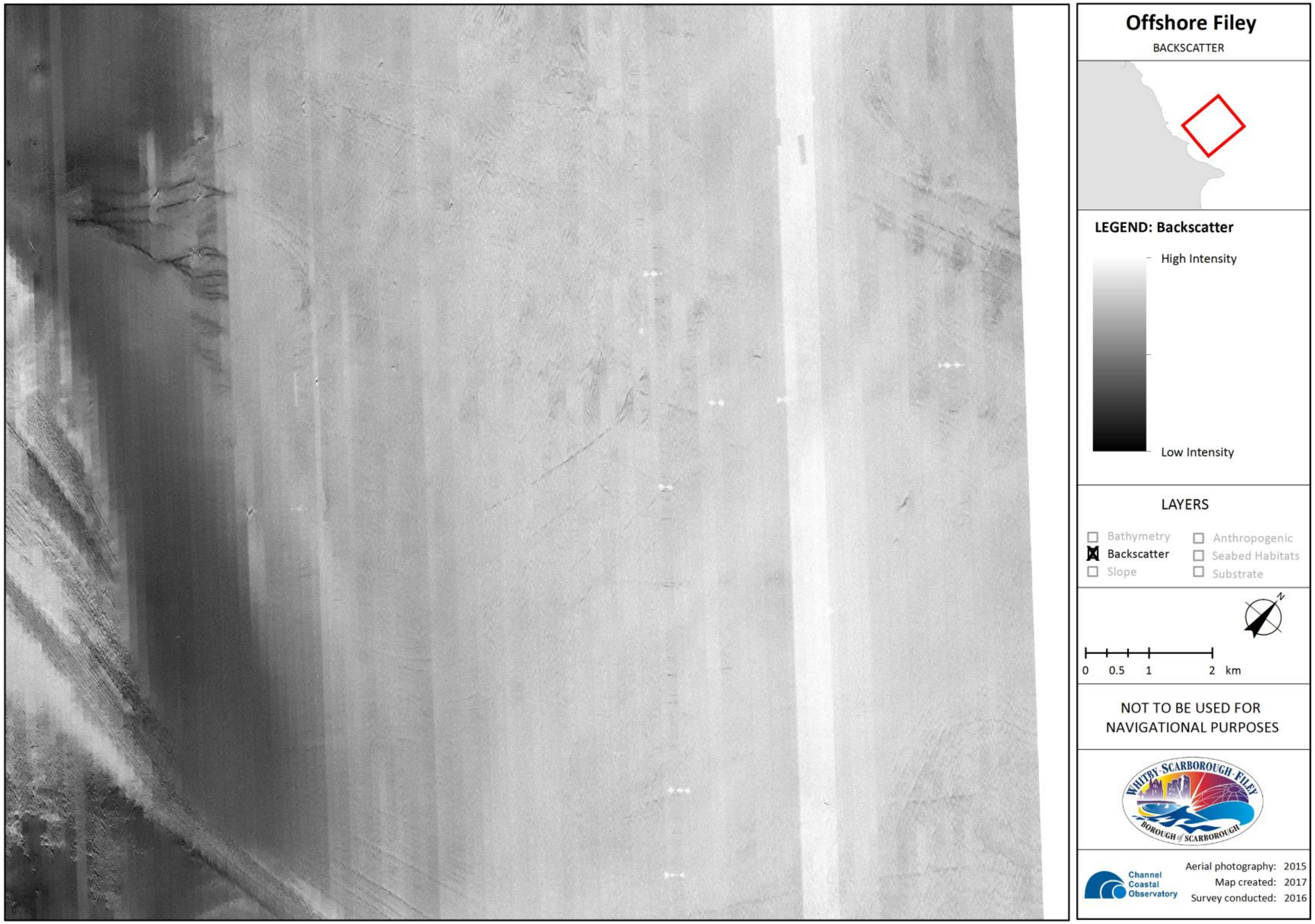
Offshore – Filey Brigg

This section of seabed refers to the area offshore and directly North of the Filey Brigg section. The majority of this seabed is classified as *Moderate Energy Rock and thin Sediment*, with the exception of the rocky outcrops that form part of the Filey Brigg formation.

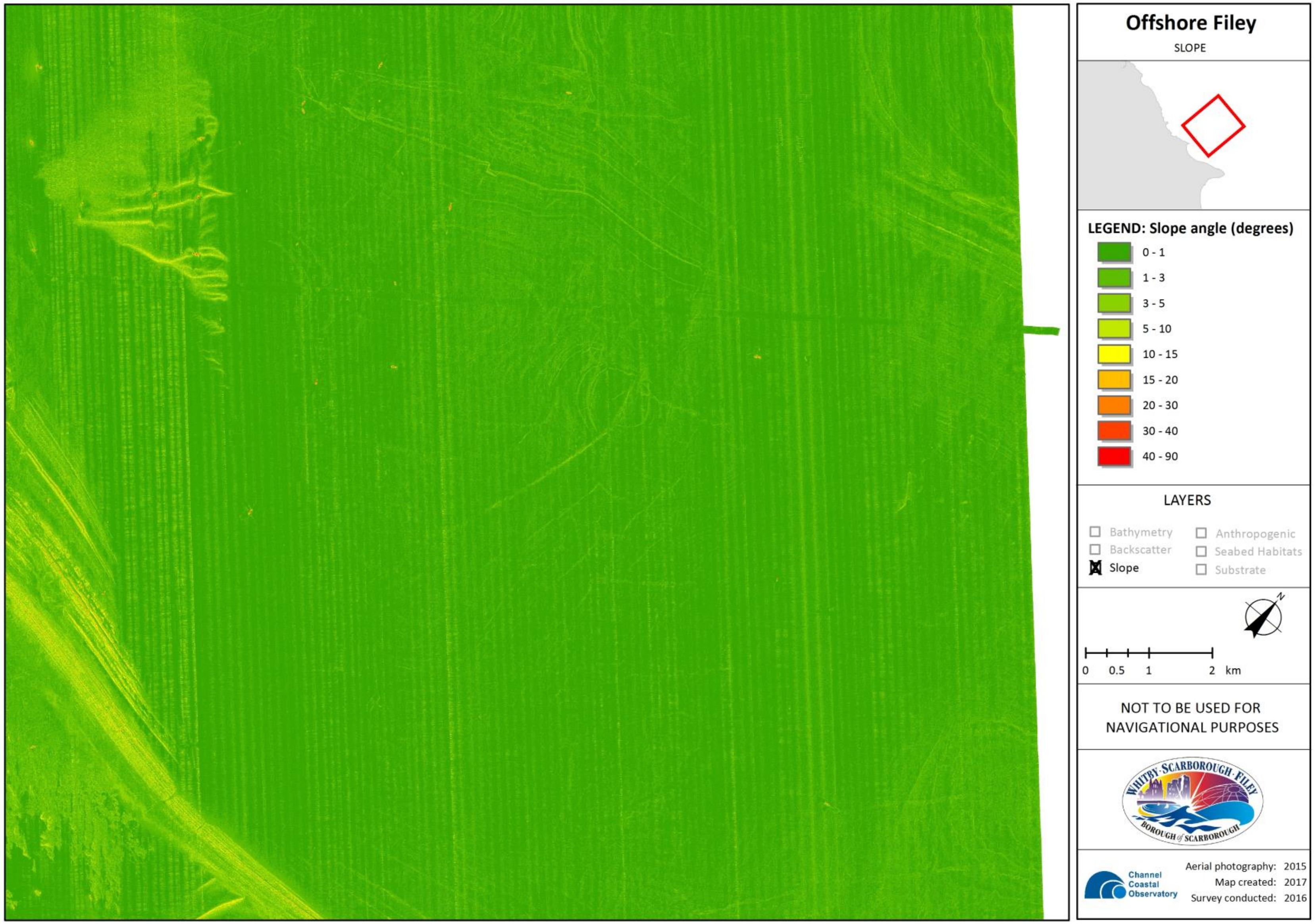
The seabed is gently sloping and lacking any significant areas of sediment, the area of bedforms to the east of the map are discussed in the Ravenscar to Cloughton offshore section. Using the slope, anthropogenic and backscatter maps, the underlying geology can be clearly picked out. The rock and thin sediment has been split between coarse and mixed sediment. As was found in the Offshore Flamborough Head section this boundary is again transitional and only indicative.

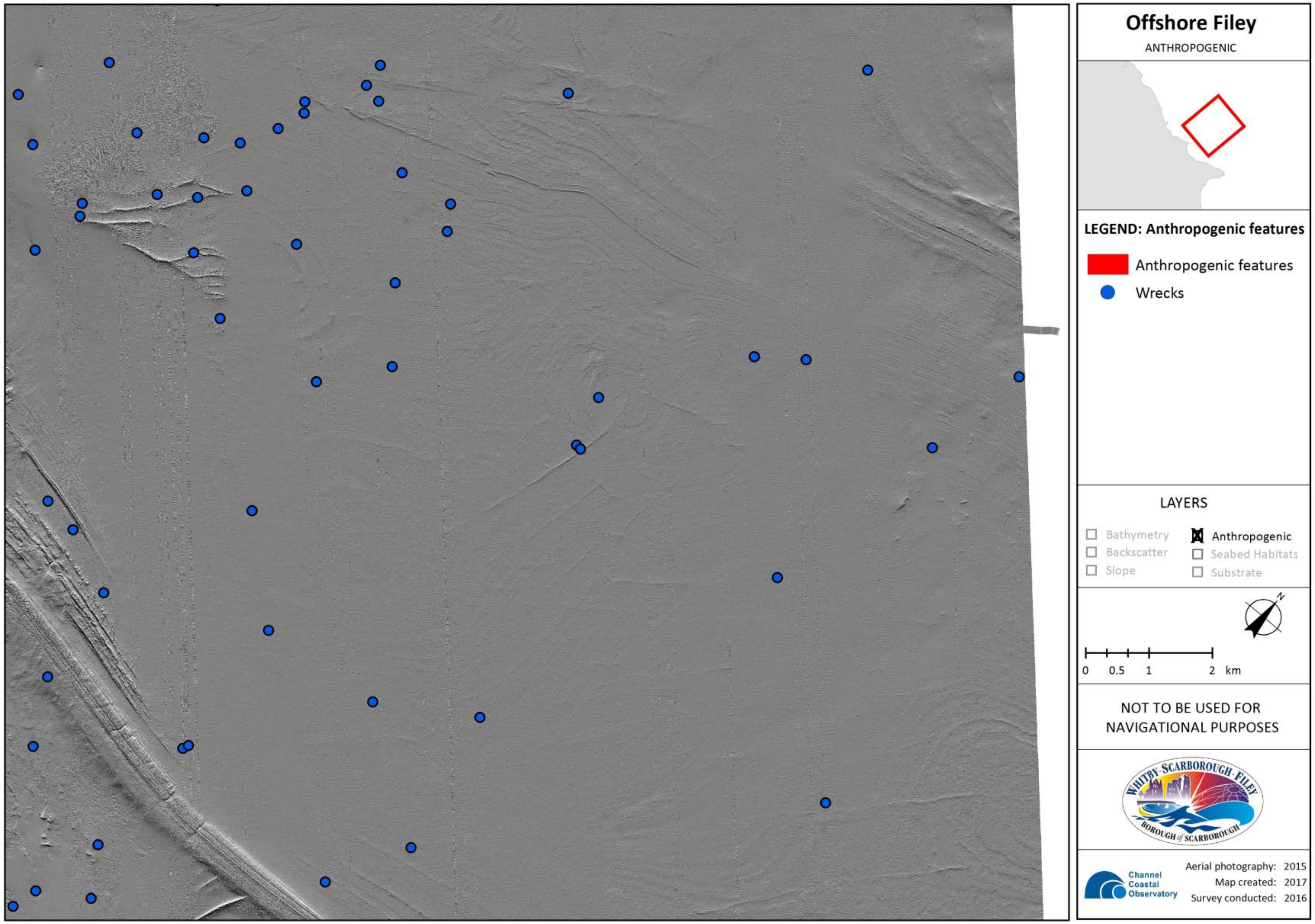
55 wrecks have been identified on this map but no clear anthropogenic features.

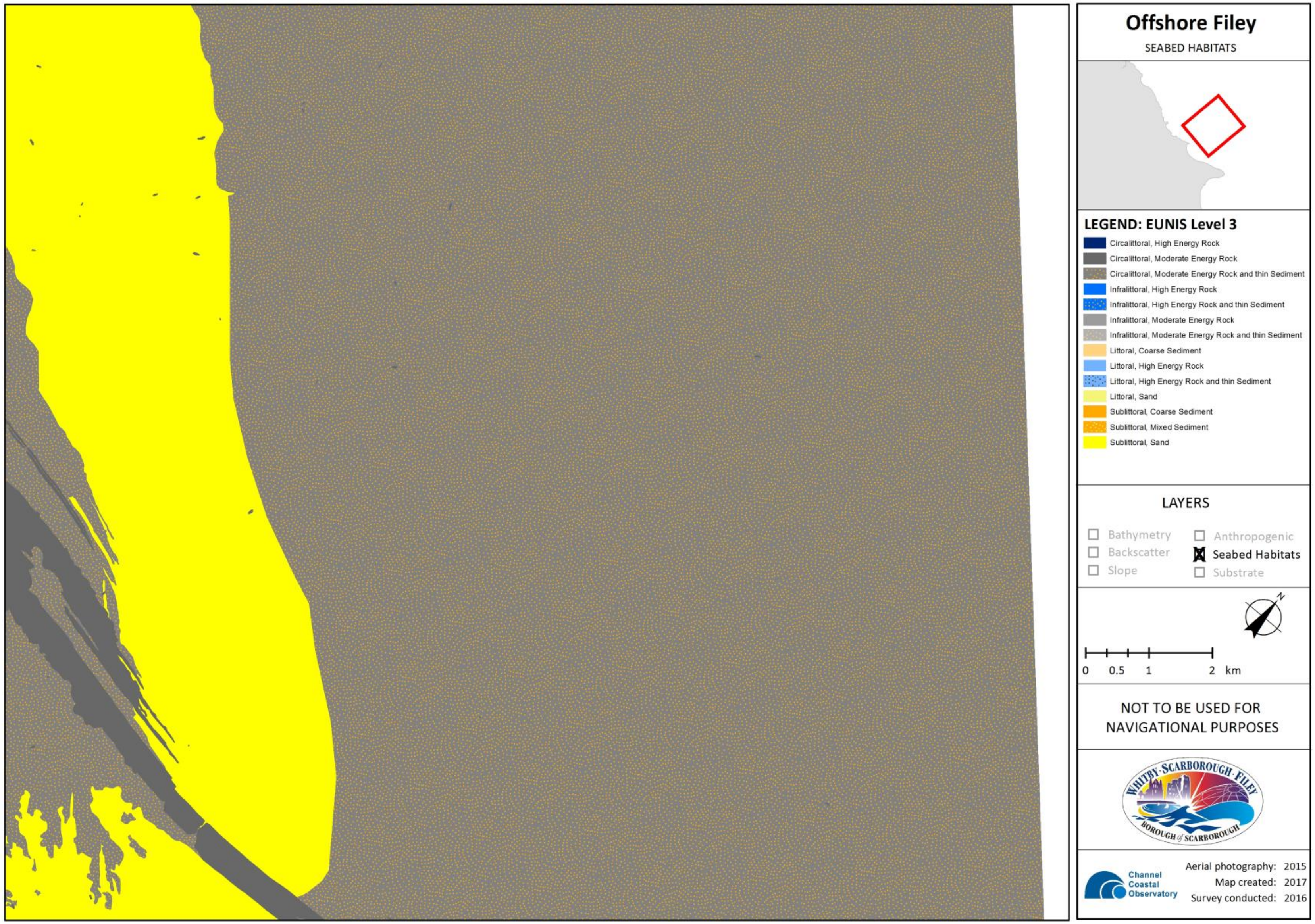

Offshore Filey
BATHYMETRY
LEGEND: Depth (mCD)
0
-15
-30
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.5 1 2 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY SCARBOROUGH FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016



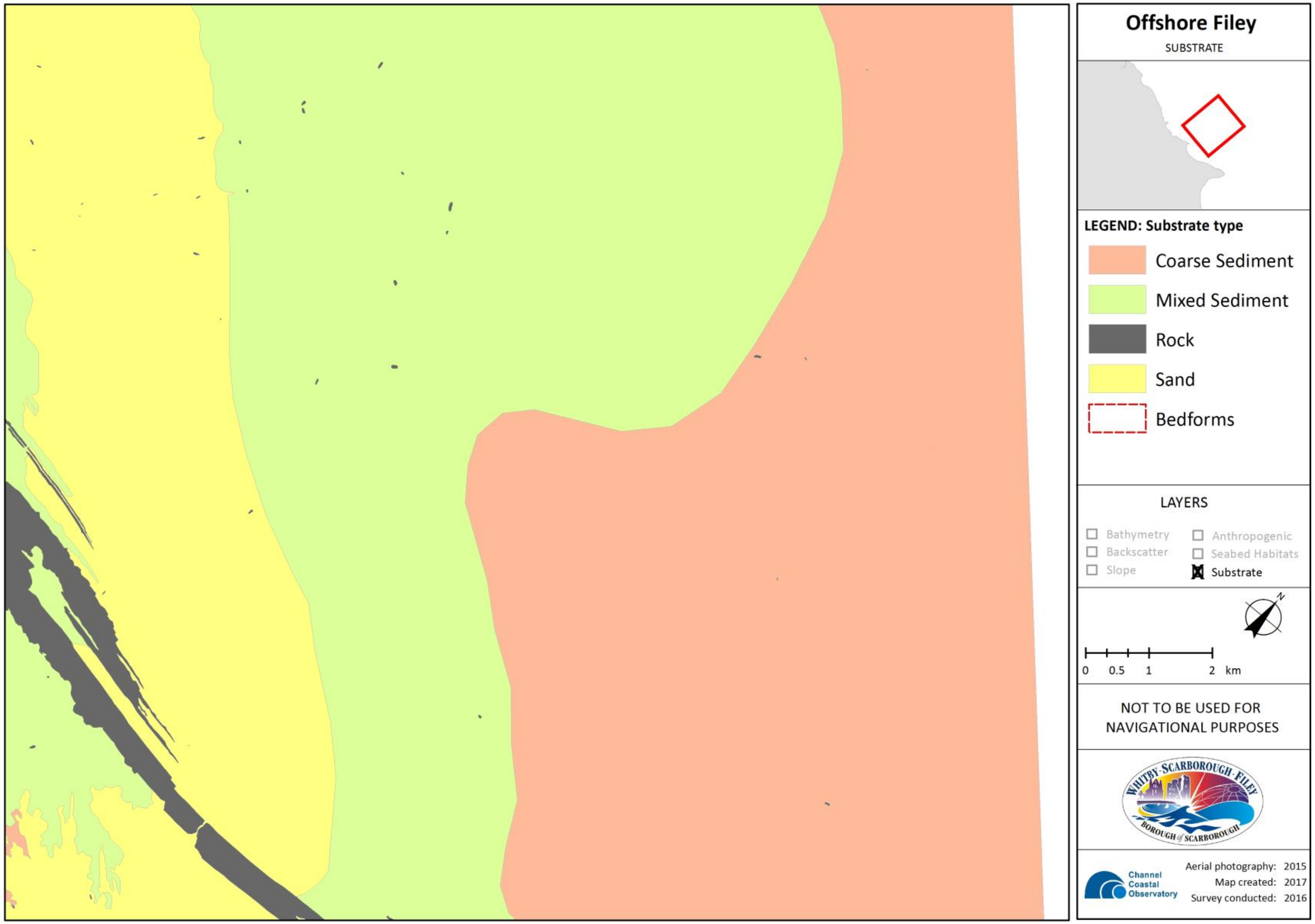
Offshore Filey
BACKSCATTER
LEGEND: Backscatter
High Intensity
Low Intensity
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.5 1 2 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY·SCARBOROUGH·FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Offshore Filey
SLOPE
LEGEND: Slope angle (degrees)
0 - 1
1 - 3
3 - 5
5 - 10
10 - 15
15 - 20
20 - 30
30 - 40
40 - 90
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.5 1 2 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY · SCARBOROUGH · FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Offshore Filey
ANTHROPOGENIC
LEGEND: Anthropogenic features
Anthropogenic features
Wrecks
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.5 1 2 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY·SCARBOROUGH·FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016



Offshore Filey
SEABED HABITATS
LEGEND: EUNIS Level 3
Circalittoral, High Energy Rock
Circalittoral, Moderate Energy Rock
Circalittoral, Moderate Energy Rock and thin Sediment
Infralittoral, High Energy Rock
Infralittoral, High Energy Rock and thin Sediment
Infralittoral, Moderate Energy Rock
Infralittoral, Moderate Energy Rock and thin Sediment
Littoral, Coarse Sediment
Littoral, High Energy Rock
Littoral, High Energy Rock and thin Sediment
Littoral, Sand
Sublittoral, Coarse Sediment
Sublittoral, Mixed Sediment
Sublittoral, Sand
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.5 1 2 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Offshore Filey
SUBSTRATE
LEGEND: Substrate type
Coarse Sediment
Mixed Sediment
Rock
Sand
Bedforms
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.5 1 2 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY-SCARBOROUGH-FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016

Offshore – Ravenscar to Cayton Bay

This section refers to the offshore seabed between Ravenscar and Cayton Bay and will discuss features Northwest of the *Sublittoral Sand.* Almost the entirety of this area has been classified as *Moderate Energy Rock and thin Sediment* and the geology can be detected clearly offshore but in numerous locations throughout the map. Small islands of sand waves have been identified offshore, but considering the depth and isolation of these bedforms it is assumed they are moribund relics.

A large bedform feature is located in the southern corner of this map (Figure 15) on the boundary between the *Sublittoral Sediment* and *Moderate Energy Rock and thin Sediment*. This feature consists of large sand ridges covered in sand waves and ripples with the main ridges are up to 5m higher than the surrounding seabed. A number of wrecks are embedded in this feature which could be anchoring the feature in place on the seabed. The sand waves continue westwards from this main feature and are not present to the east. Analysis of scour marks and sediment accumulation surrounding the wrecks does not suggest a clear dominant direction of sediment transport.

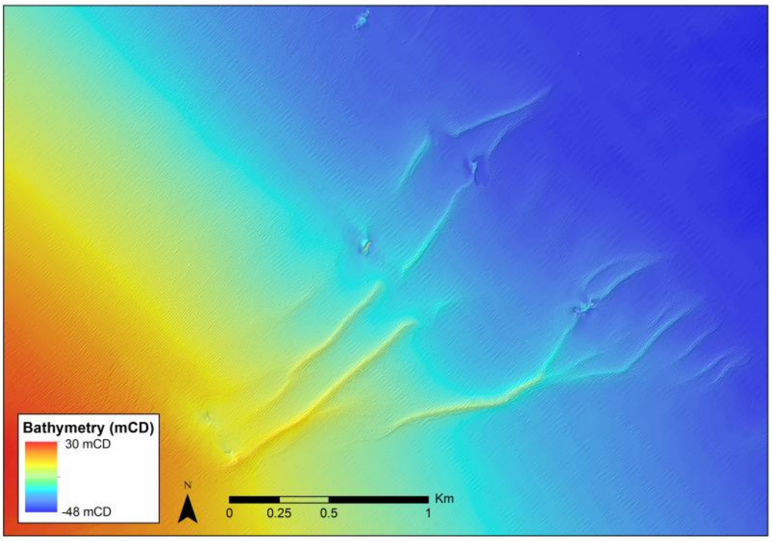


Figure 15: Large bedform feature and integrated wrecks

The seabed itself is generally flat and gently sloping, but a number of large geological features are visible, including the two shown in Figures 16a & 16b, where numerous fault lines and areas of folding can be identified.

The thin veneer of sediment covering the rock and thin sediment has been classified as either mixed sediment or coarse sediment. Grab samples indicate different sediment types are present but as previously mentioned, the boundary is transitional and the definitive boundary is just an indicator.

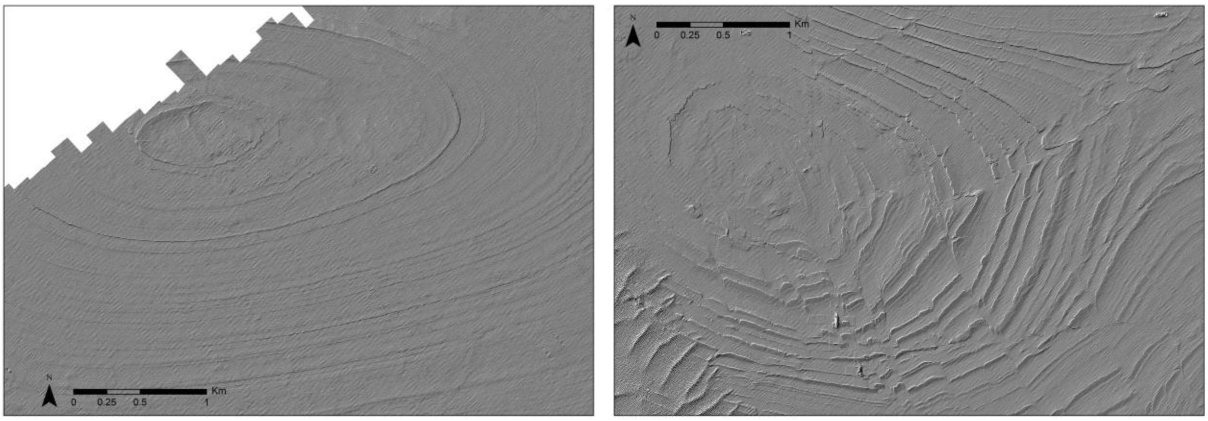
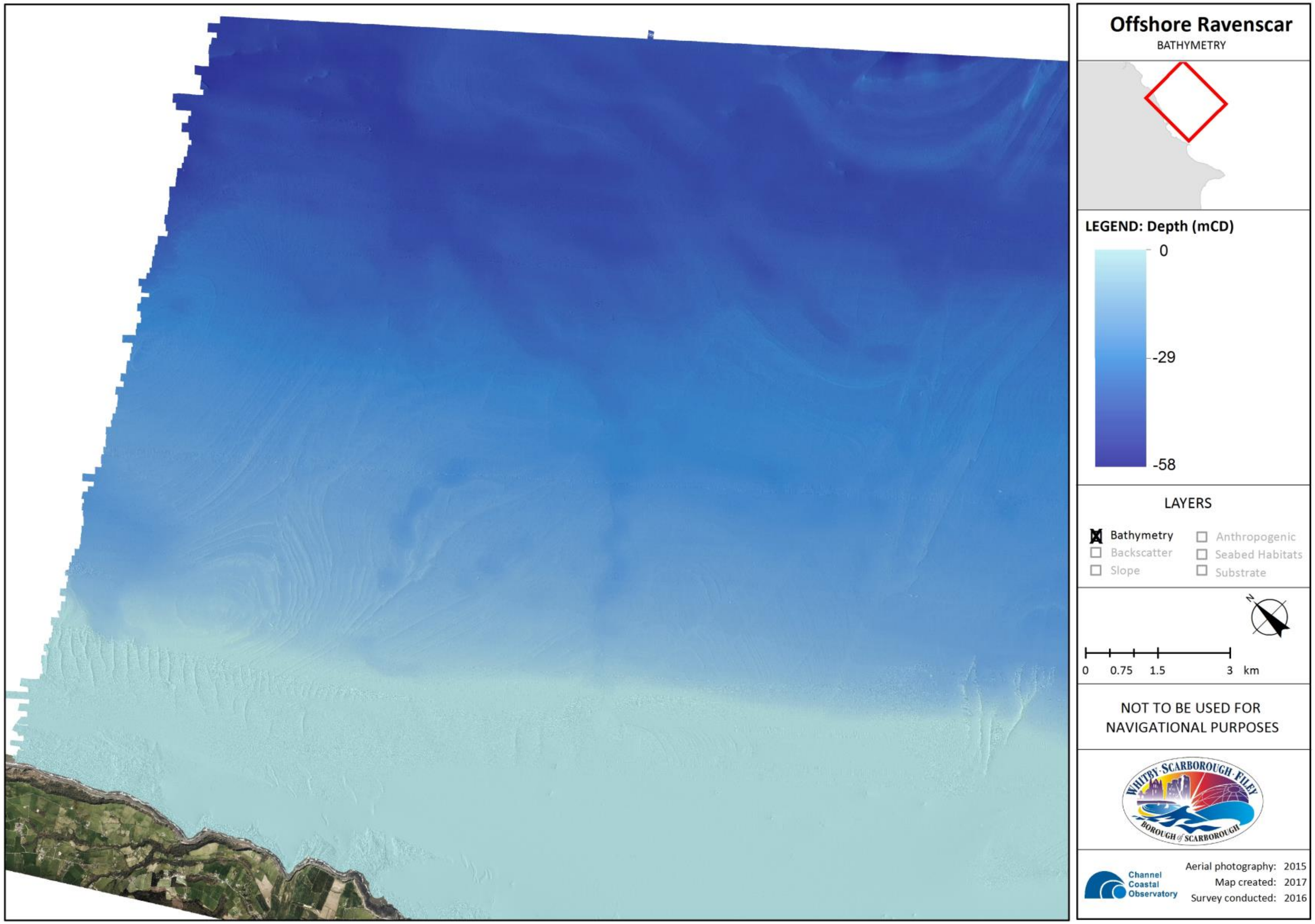


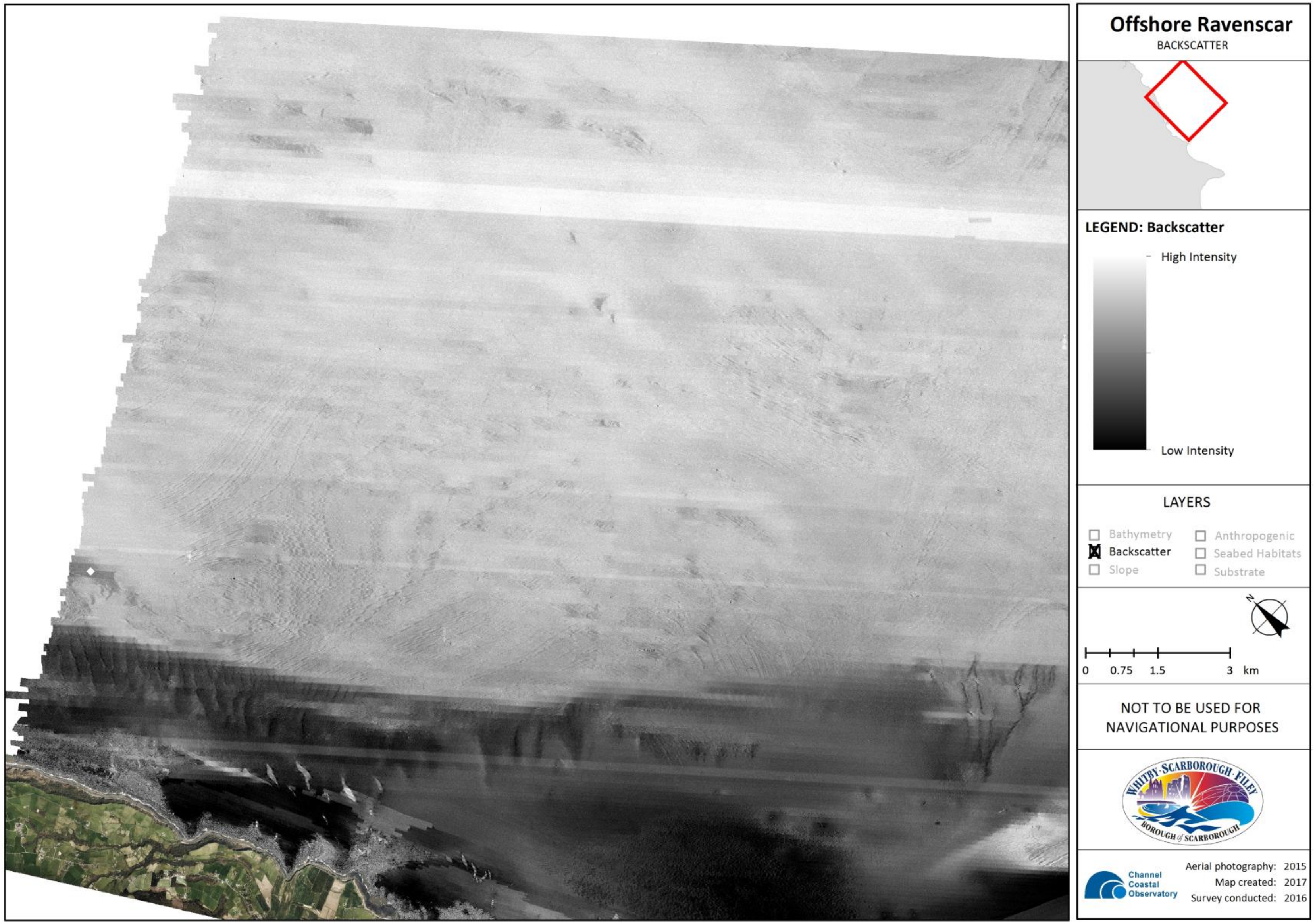
Figure 16a & 16b: Geological features outlined through the rock and thin sediment

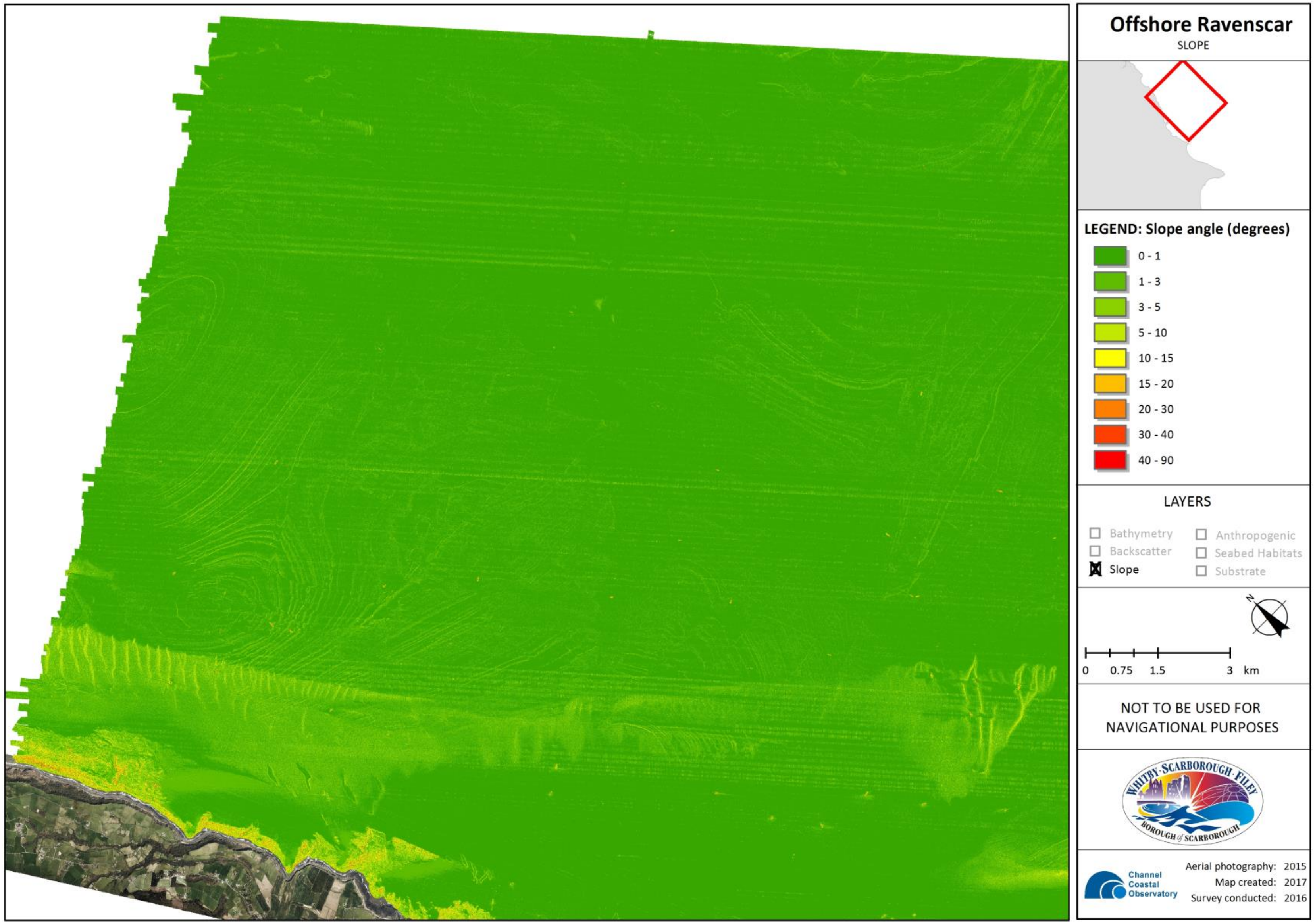
The geological features in Figures 16a & 16b are similar to those found in another multibeam bathymetry survey from the coast of Dorset, known as the Lulworth Banks. This survey has recently been geologically mapped by British Geological Survey to match the onshore geology with outstanding results (Sanderson *et al.*, 2017).

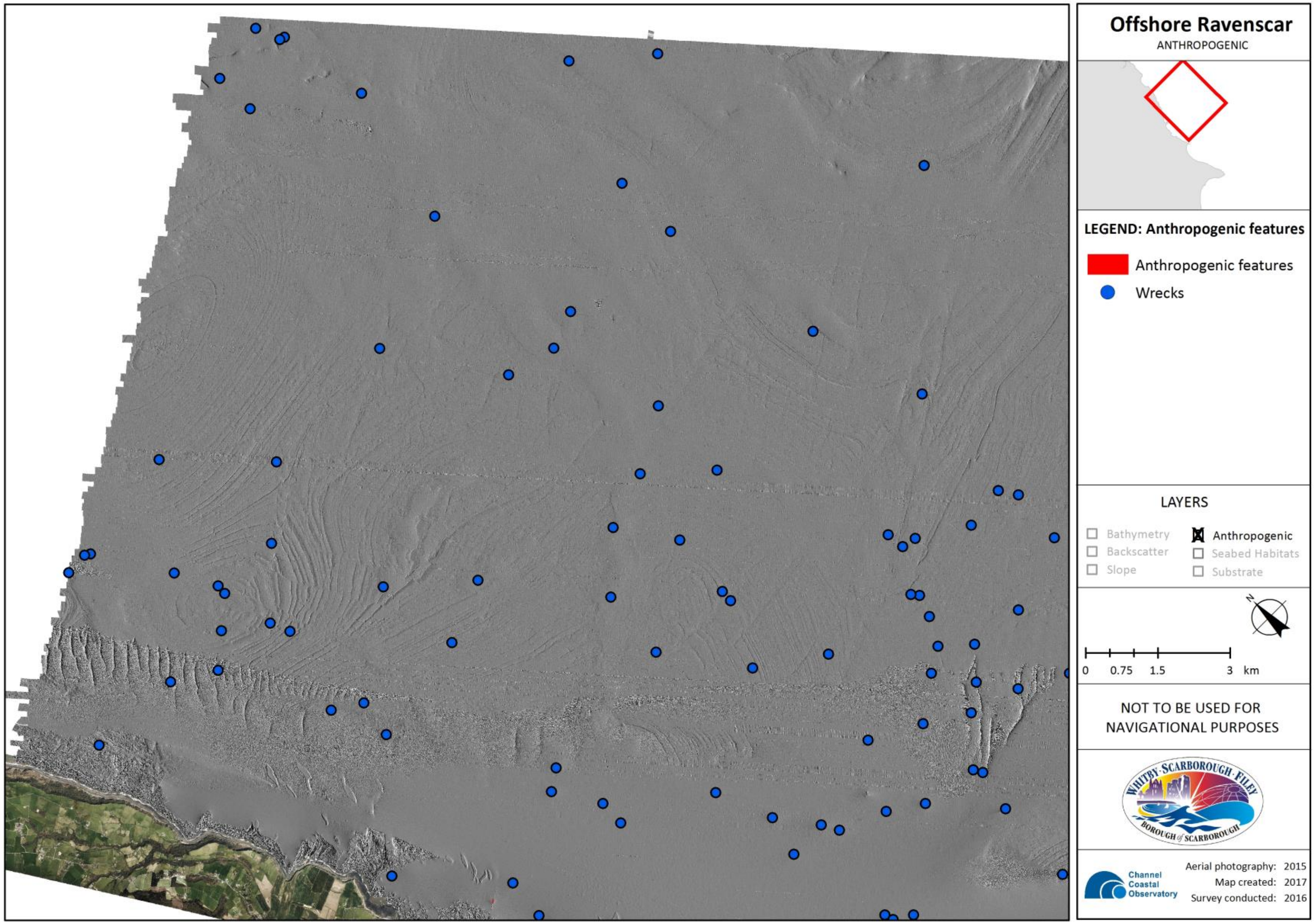
It is often not appreciated that large areas of the continental shelves are actually sediment starved and consequently thousands of square kilometres of seabed are in fact exposed bedrock. On the UK shelf this is particularly true of the Eastern English Channel region (James *et al.*, 2011). The bathymetry data from this entire survey confirms that the offshore area is characterised by an extensive area of rock and thin sediment; classed as *Moderate Energy Circalittoral Rock and thin Sediment*. However, this does allow for some spectacular geology to be visible.

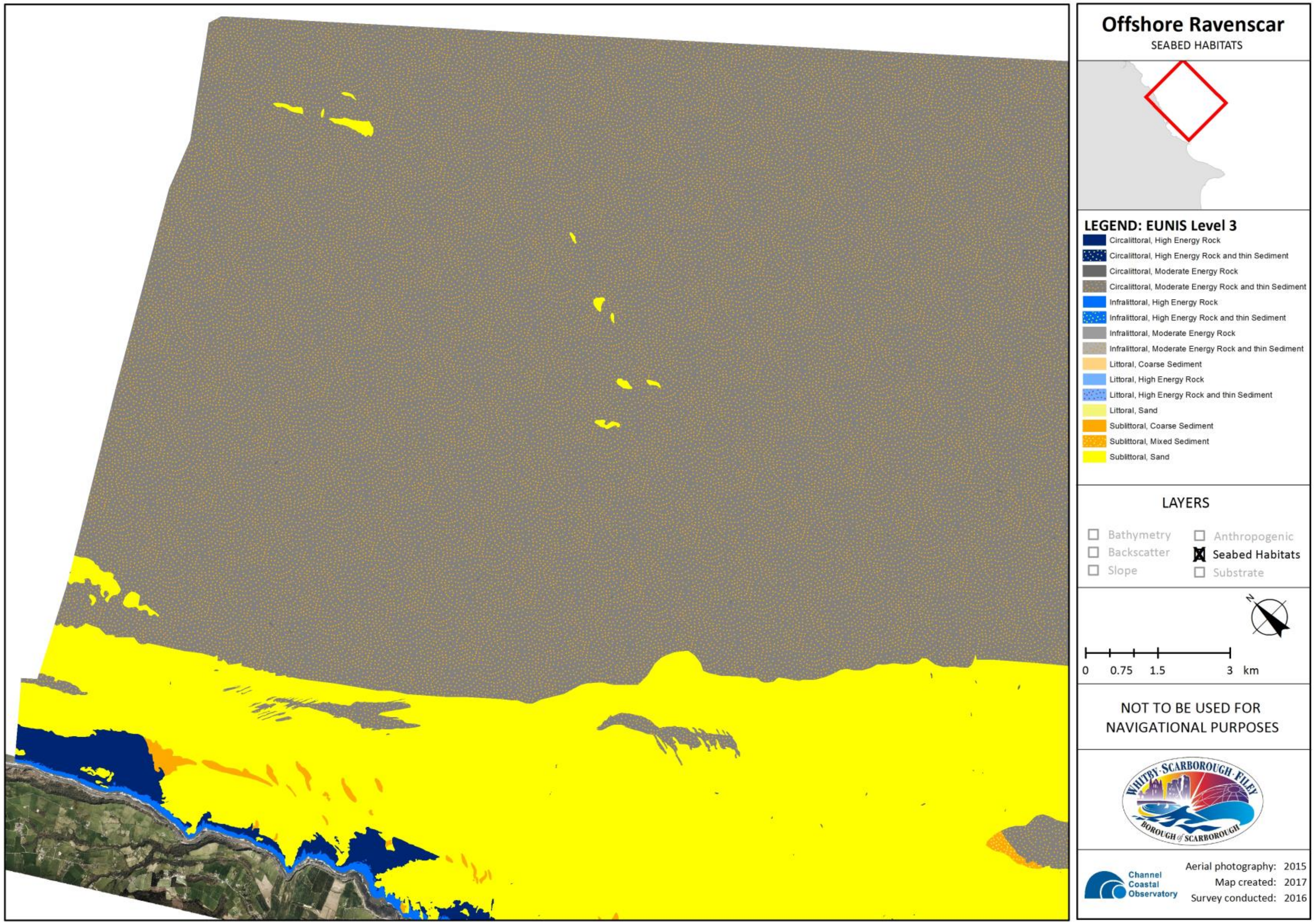
No obvious anthropogenic features have been identified in this section and 90 wrecks are located on the map.

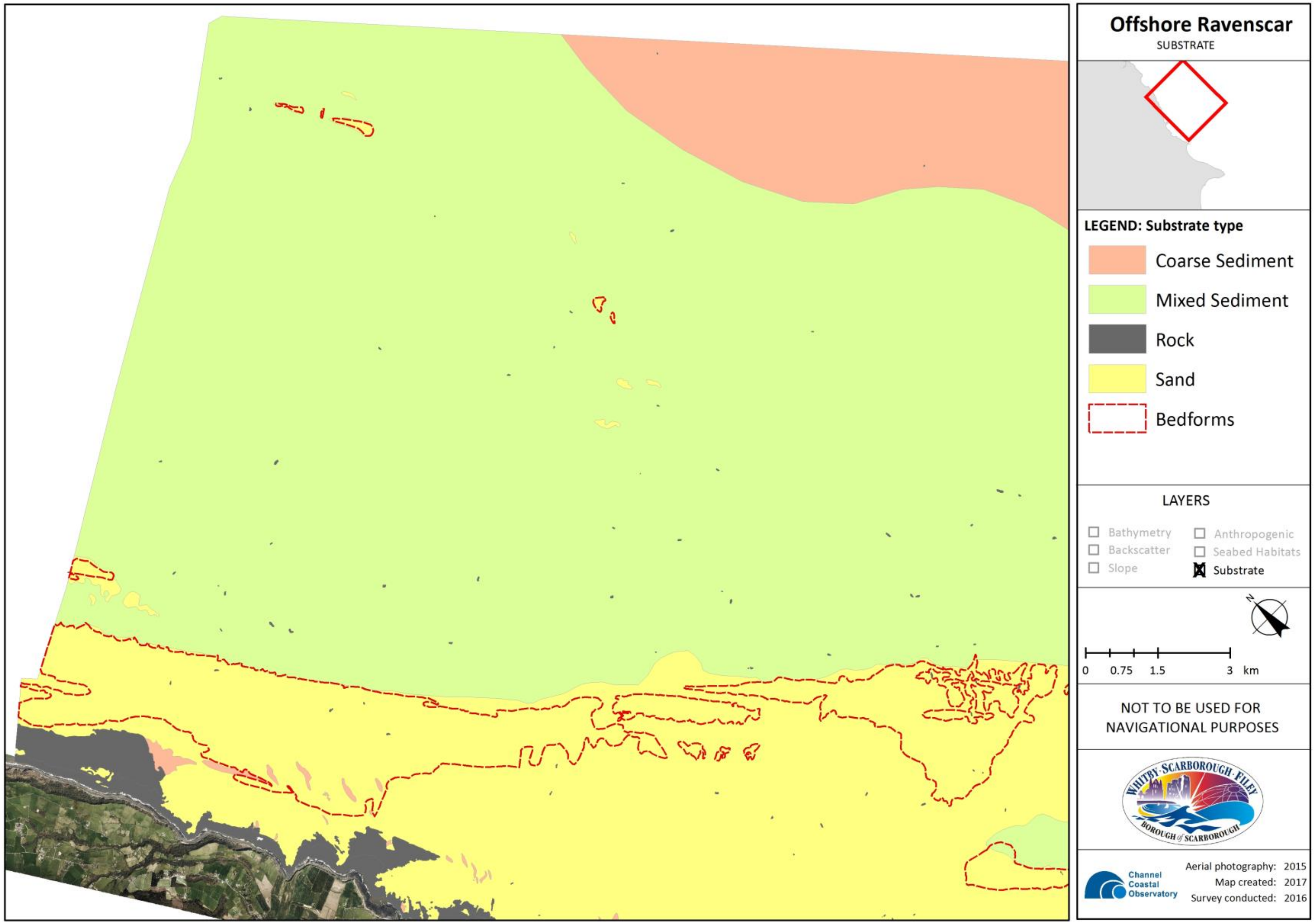

Offshore Ravenscar
BATHYMETRY
LEGEND: Depth (mCD)
0
-29
-58
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.75 1.5 3 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY SCARBOROUGH FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Offshore Ravenscar
BACKSCATTER
LEGEND: Backscatter
High Intensity
Low Intensity
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.75 1.5 3 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY-SCARBOROUGH-FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Offshore Ravenscar
SLOPE
LEGEND: Slope angle (degrees)
0 - 1
1 - 3
3 - 5
5 - 10
10 - 15
15 - 20
20 - 30
30 - 40
40 - 90
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.75 1.5 3 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY SCARBOROUGH FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Offshore Ravenscar
ANTHROPOGENIC
LEGEND: Anthropogenic features
Anthropogenic features
Wrecks
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.75 1.5 3 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Offshore Ravenscar
SEABED HABITATS
LEGEND: EUNIS Level 3
Circalittoral, High Energy Rock
Circalittoral, High Energy Rock and thin Sediment
Circalittoral, Moderate Energy Rock
Circalittoral, Moderate Energy Rock and thin Sediment
Infralittoral, High Energy Rock
Infralittoral, High Energy Rock and thin Sediment
Infralittoral, Moderate Energy Rock
Infralittoral, Moderate Energy Rock and thin Sediment
Littoral, Coarse Sediment
Littoral, High Energy Rock
Littoral, High Energy Rock and thin Sediment
Littoral, Sand
Sublittoral, Coarse Sediment
Sublittoral, Mixed Sediment
Sublittoral, Sand
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.75 1.5 3 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Offshore Ravenscar
SUBSTRATE
LEGEND: Substrate type
Coarse Sediment
Mixed Sediment
Rock
Sand
Bedforms
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 0.75 1.5 3 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
Whitby Scarborough Filey
Borough of Scarborough
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016

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Acknowledgements

Data interpretation was undertaken with the advice and guidance of Dr Justin Dix (University of Southampton) and Dr Tim Le Bas (NERC). Valuable groundtruthing and substrate information was kindly provided by JNCC marine recorder, British Geological Survey Geoindex's and the Northeast Regional Coastal Monitoring Programme. The MCA's Civil Hydrography Programme bathymetry data kindly provided by colleagues from the MCA hydrographic team under Open Government Licence.

Annex 1 Confidence Assessment

	RHB to Flamborough (NRMP, 2016)
Remote Technique	3
Remote Coverage	3
Remote Positioning	3
Remote Standards Applied	3
Remote Vintage	3
Biological Groundtruth Technique	2
Physical Groundtruth Technique	2
Groundtruth Positioning	3
Groundtruth Density	2
Groundtruth Standards Applied	3
Groundtruth Vintage	3
Groundtruth Interpretation	2
Remote Interpretation	3
Detail Level	1
Map Accuracy	3
Remote score	100
Groundtruth score	71
Interpretation score	67
Overall score	79

http://www.searchmesh.net/confidence/confidenceAssessment.html

Remote Techniques
An assessment of whether the remote technique(s) used to produce this map were appropriate to the environment they were used to survey. If necessary, adjust your assessment to account for technique(s) which, although appropriate, were used in deep water and consequently have a significantly reduced resolution (i.e. size of footprint):
3 = technique(s) highly appropriate
2 = technique(s) moderately appropriate
1 = technique(s) inappropriate

Remote Coverage
An assessment of the coverage of the remote sensing data including consideration of heterogeneity of the seabed. This can be simply achieved in a coverage x heterogeneity matrix, as illustrated below:

		Heterogeneity		
		Low	Moderate	High
Coverage	Poor (large gaps between swaths; Track spacing >100m)	2	1	1
	Moderate (50%; track spacing <100m)	3	2	1

	Good (100%; track spacing <50m)	3	3	3

Remote Positioning & Ground Truthing Position
An indication of the positioning method used for the remote / ground-truth data:
3 = differential GPS
2 = GPS (not differential) or other non-satellite 'electronic' navigation system
1 = chart based navigation, or dead-reckoning

Remote & Ground Truthing Standards Applied
An assessment of whether standards have been applied to the collection of the remote / ground-truth data. This field gives an indication of whether some data quality control has been carried out:
3 = remote / ground-truth data collected to approved standards
2 = remote / ground-truth data collected to 'internal' standards
1 = no standards applied to the collection of the remote / ground-truth data

Remote Vintage & Ground Truthing Vintage
An indication of the age of the remote / ground-truth data:
3 = < 5yrs old.
2 = 5 to 10 yrs old.
1 = > 10 years old

Biological Ground Truthing Technique
An assessment of whether the groundtruthing techniques used to produce this map were appropriate to the environment they were used to survey. Use scores for soft or hard substrata as appropriate to the area surveyed.

<u>Soft substrata predominate</u> (i.e. those having infauna and epifauna) 3 = infauna AND epifauna sampled AND observed (video/stills, direct human observation) 2= infauna AND epifauna sampled, but NOT observed (video/stills, direct human observation) 1 = infauna OR epifauna sampled, but not both. No observation.	<u>Hard substrata predominate</u> (i.e. those with no infauna) 3 = sampling included direct human observation (shore survey or diver survey) 2 = sampling included video or stills but NO direct human observation 1 = benthic sampling only (e.g. grabs, trawls)

Physical Ground Truthing Technique
An assessment of whether the combination of geophysical sampling techniques were appropriate to the environment they were used to survey. Use scores for soft or hard substrata as appropriate to the area surveyed.

<u>Soft substrata predominate</u> (i.e. gravel, sand, mud) 3 = full geophysical analysis 2 = sediments described following visual inspection of grab or core samples (e.g. slightly shelly, muddy sand) 1 = sediments described on the basis of remote observation (by camera).	<u>Hard substrata predominate</u> (i.e. rock outcrops, boulders, cobbles) 3 = sampling included in-situ, direct human observation (shore survey or diver survey) 2 = sampling included video or photographic observation, but NO in-situ, direct human observation 1 = samples obtained only by rock dredge

Ground Truthing Sample Density
An assessment of what proportion of the polygons or classes (groups of polygons with the same 'habitat' attribute) actually contain ground-truth data:
3 = Every class in the map classification was sampled at least 3 times
2 = Every class in the map classification was sampled
1 = Not all classes in the map classification were sampled (some classes have no ground-truth data)

Ground Truthing Interpretation
An indication of the confidence in the interpretation of the groundtruthing data. Score a maximum of 1 if physical ground-truth data but no biological ground-truth data were collected:
3 = Evidence of expert interpretation; full descriptions and taxon list provided for each habitat class
2 = Evidence of expert interpretation, but no detailed description or taxon list supplied for each habitat class
1 = No evidence of expert interpretation; limited descriptions available

Remote Interpretation
An indication of the confidence in the interpretation of the remotely sensed data. (Interpretation techniques can range from 'by eye' digitising by experts to statistical classification techniques):
3 = Appropriate technique used and documentation provided
2 = Appropriate technique used but no documentation provided
1 = Inappropriate technique used

Detail Level
The level of detail to which the 'habitat' classes in the map have been classified:
3 = Classes defined on the basis of detailed biological analysis
2 = Classes defined on the basis of major characterising species or lifeforms
1 = Classes defined on the basis of physical information, or broad biological zones

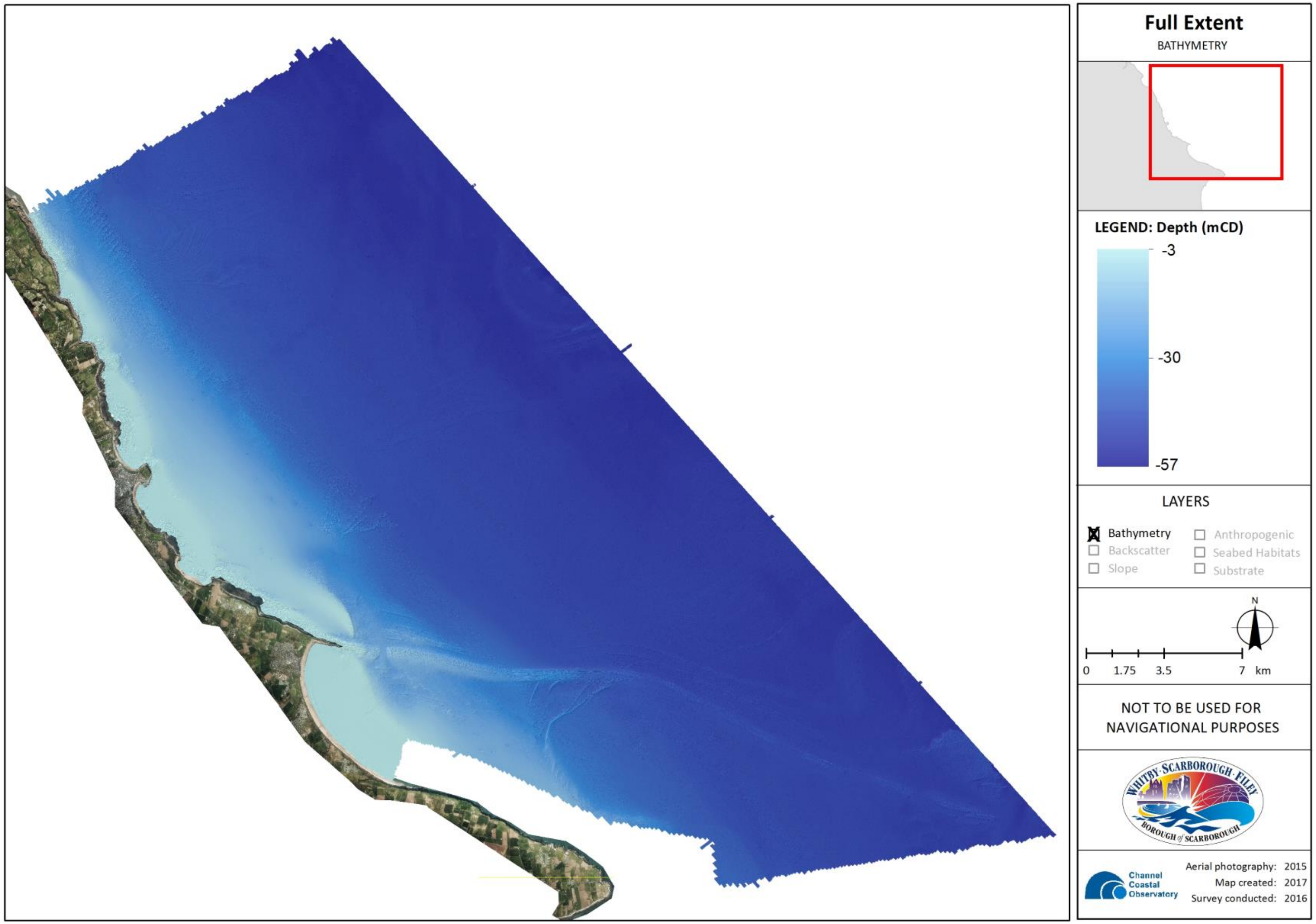
Map Accuracy
A test of the accuracy of the map:
3 = high accuracy, proven by external accuracy assessment
2 = high accuracy, proven by internal accuracy assessment
1 = low accuracy, proved by either external or internal assessment OR no accuracy assessment made

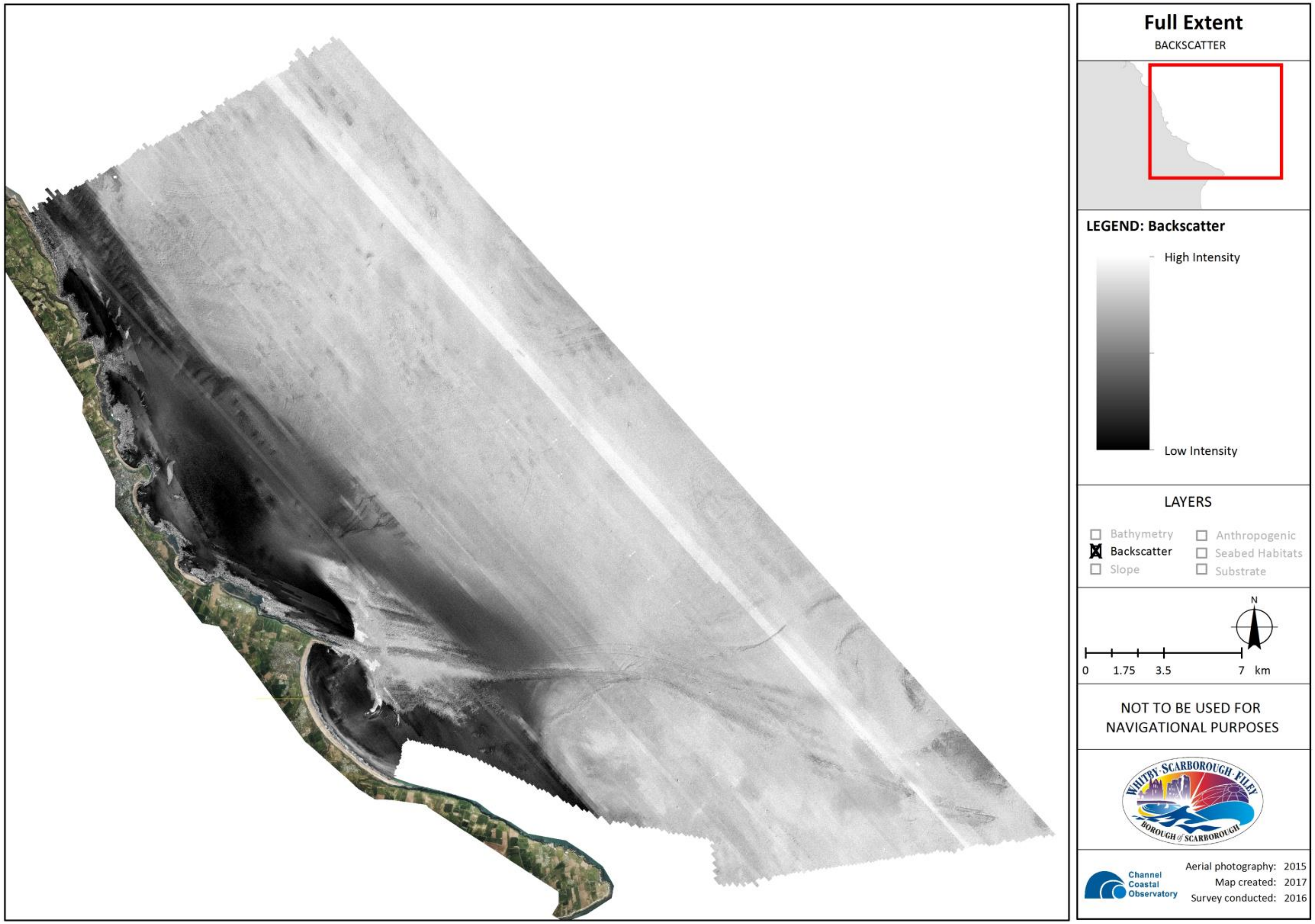
Annex 2 EUNIS Habitat Classification

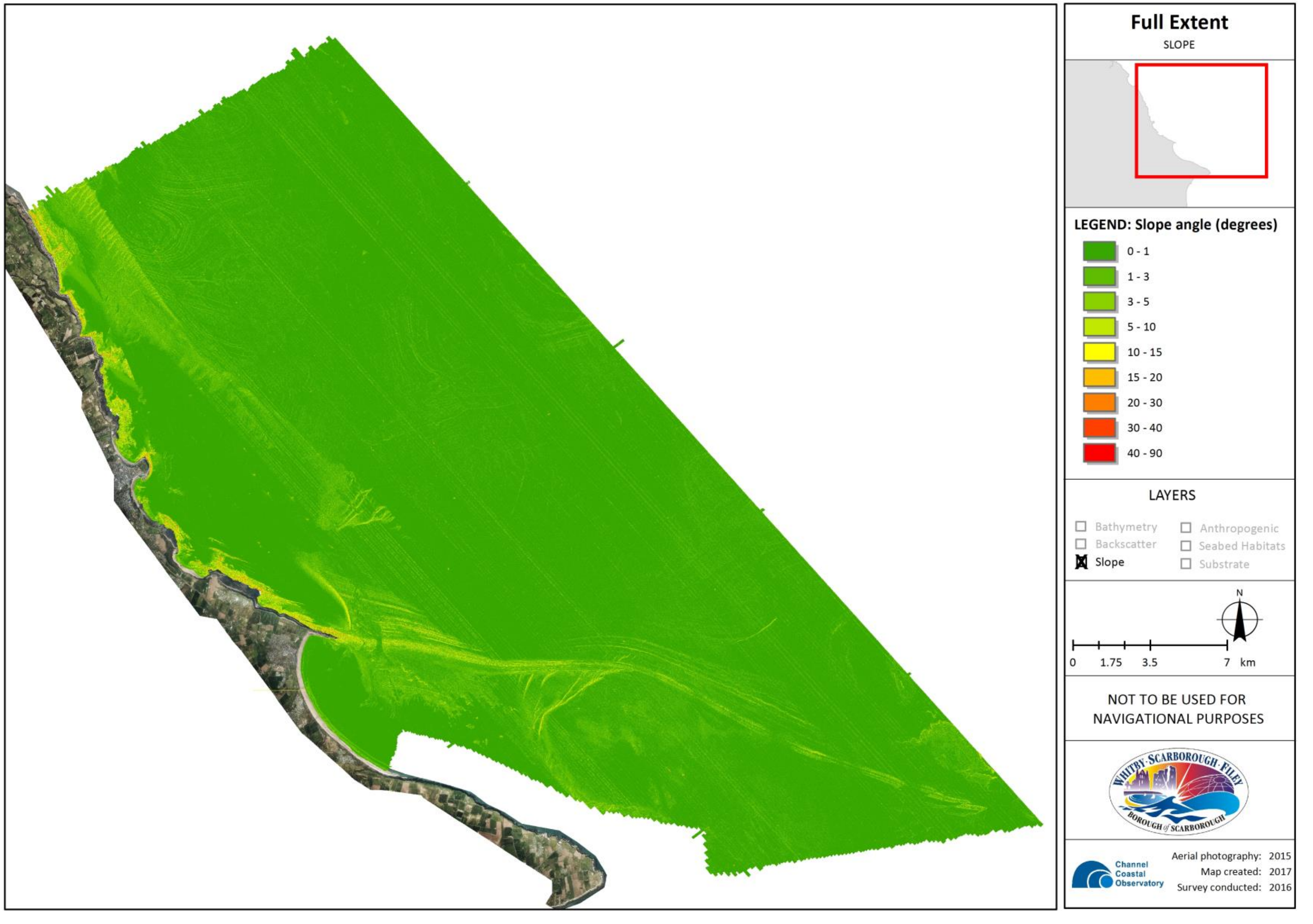
Name	Code	Description
High Energy Littoral Rock	A1.1	Extremely exposed to moderately exposed or tide-swept bedrock and boulder shores.
Littoral Coarse sediment	A2.1	Littoral coarse sediments include shores of mobile pebbles, cobbles and gravel, sometimes with varying amounts of coarse sand. The sediment is highly mobile and subject to high degrees of drying between tides.
Littoral Sand and muddy sand	A2.2	Shores comprising clean sands (coarse, medium or fine-grained) and muddy sands with up to 25% silt and clay fraction. Shells and stones may occasionally be present on the surface. The sand may be duned or rippled as a result of wave action or tidal currents. Littoral sands exhibit varying degrees of drying at low tide depending on the steepness of the shore, the sediment grade and the height on the shore.
Littoral Mixed sediment	A2.4	Shores of mixed sediments ranging from muds with gravel and sand components to mixed sediments with pebbles, gravels, sands and mud in more even proportions. By definition, mixed sediments are poorly sorted.
High Energy Infralittoral Rock	A3.1	Rocky habitats in the infralittoral zone subject to exposed to extremely exposed wave action or strong tidal streams.
Moderate Energy Infralittoral Rock	A3.2	Predominantly moderately wave-exposed bedrock and boulders, subject to moderately strong to weak tidal streams.
High Energy Circalittoral Rock	A4.1	Occurs on extremely wave-exposed to exposed circalittoral bedrock and boulders subject to tidal streams ranging from strong to very strong. Typically found in tidal straits and narrows.
Moderate Energy Circalittoral Rock	A4.2	Mainly occurs on exposed to moderately wave-exposed circalittoral bedrock and boulders, subject to moderately strong and weak tidal streams.
Sublittoral Coarse sediment	A5.1	Coarse sediments including coarse sand, gravel, pebbles, shingle and cobbles which are often unstable due to tidal currents and/or wave action. These habitats are generally found on the open coast or in tide-swept channels of marine inlets. They typically have a low silt content and a lack of a significant seaweed component.
Sublittoral Sand	A5.2	Clean medium to fine sands or non-cohesive slightly

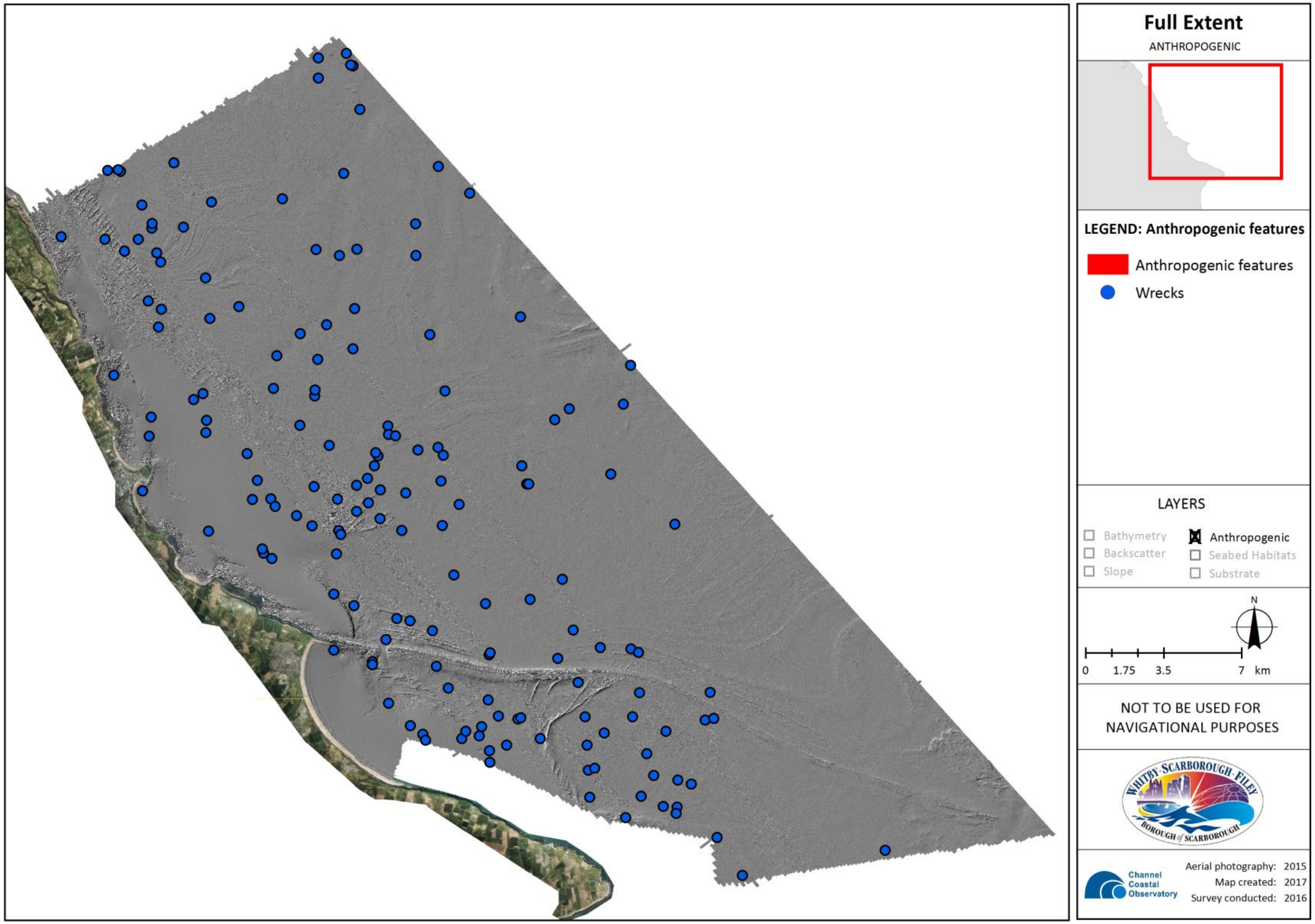
		muddy sands on open coasts, offshore or in estuaries and marine inlets. Such habitats are often subject to a degree of wave action or tidal currents which restrict the silt and clay content to less than 15%.
Sublittoral Mixed sediment	A5.4	Sublittoral mixed (heterogeneous) sediments found from the extreme low water mark to deep offshore circalittoral habitats. These habitats incorporate a range of sediments including heterogeneous muddy gravelly sands and also mosaics of cobbles and pebbles embedded in or lying upon sand, gravel or mud.

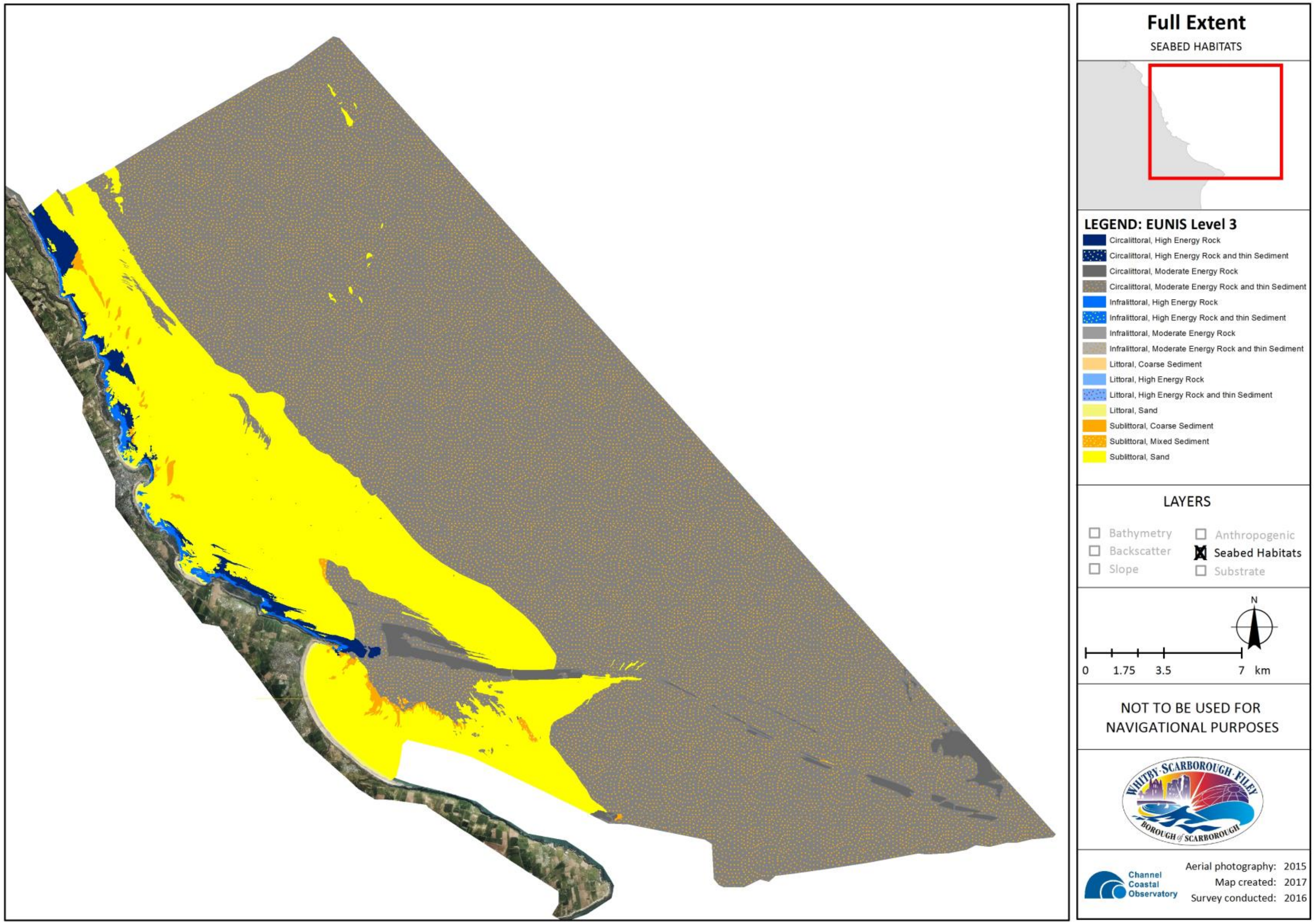
Annex 3 Full Maps

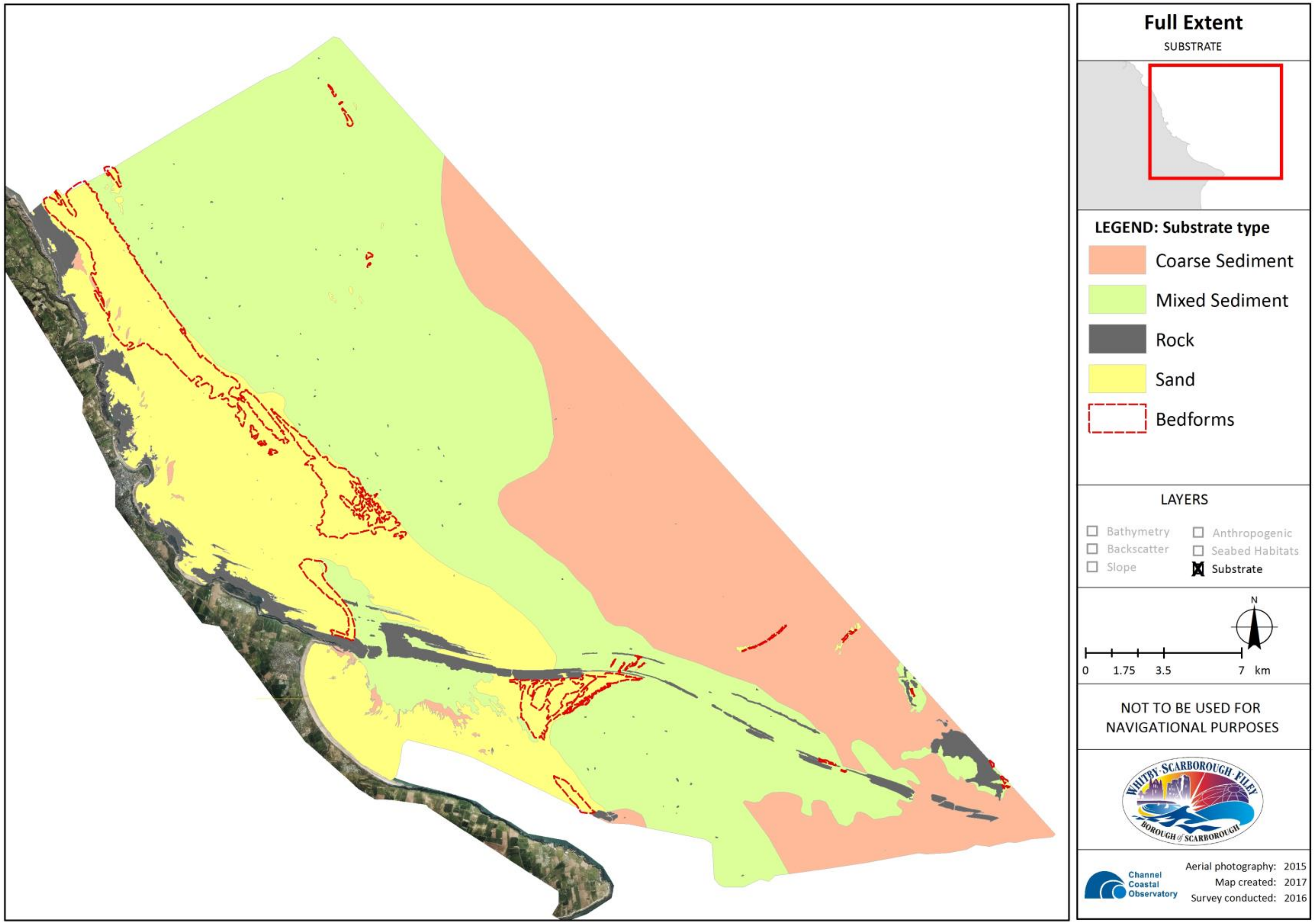

Full Extent
BATHYMETRY
LEGEND: Depth (mCD)
-3
-30
-57
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 1.75 3.5 7 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY-SCARBOROUGH-FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016

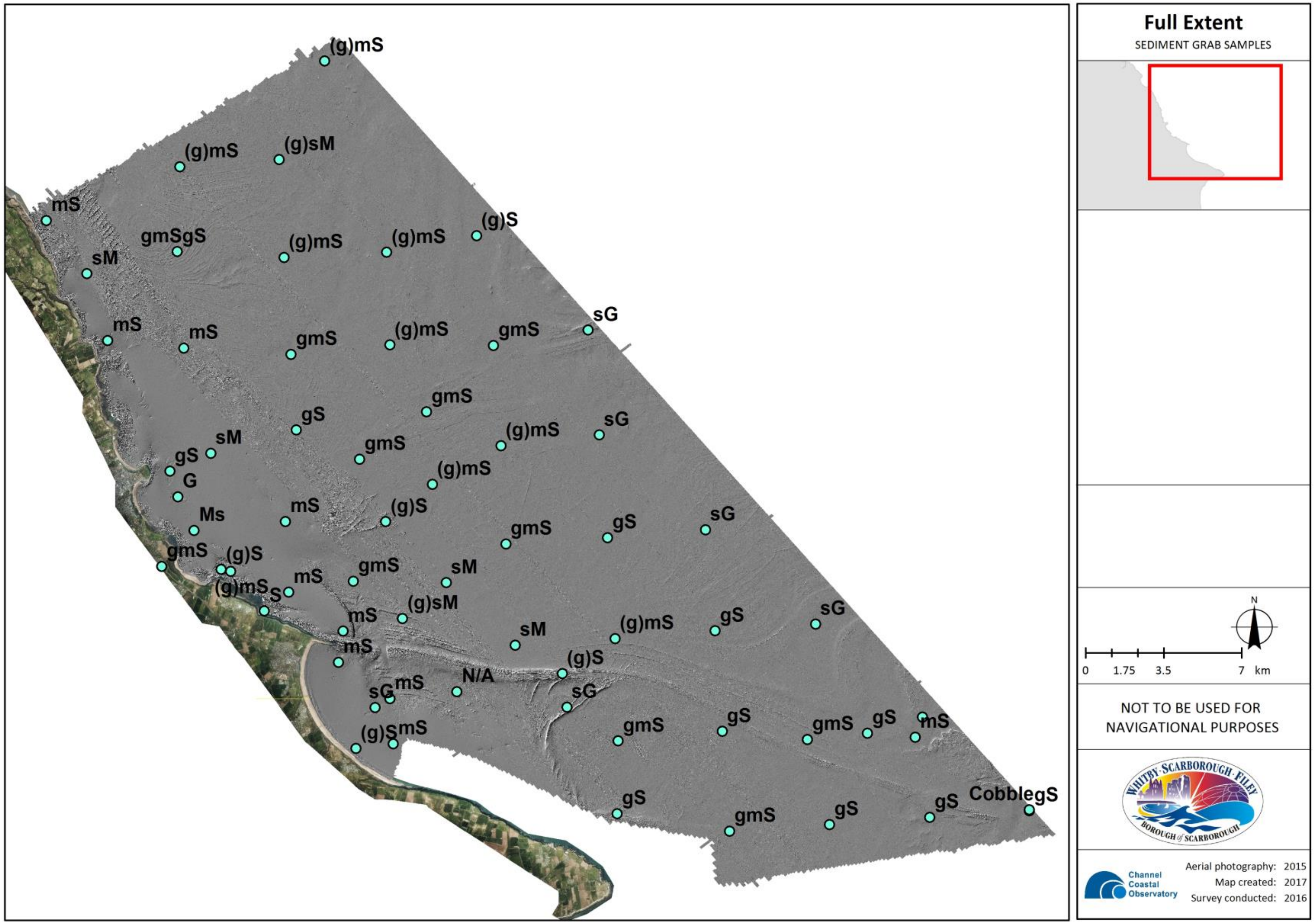

Full Extent
BACKSCATTER
LEGEND: Backscatter
High Intensity
Low Intensity
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0
1.75
3.5
7 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY·SCARBOROUGH·FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Full Extent
SLOPE
LEGEND: Slope angle (degrees)
0 - 1
1 - 3
3 - 5
5 - 10
10 - 15
15 - 20
20 - 30
30 - 40
40 - 90
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 1.75 3.5 7 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY SCARBOROUGH FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Full Extent
ANTHROPOGENIC
LEGEND: Anthropogenic features
Anthropogenic features
Wrecks
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 1.75 3.5 7 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY-SCARBOROUGH-FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Full Extent
SEABED HABITATS
LEGEND: EUNIS Level 3
Circalittoral, High Energy Rock
Circalittoral, High Energy Rock and thin Sediment
Circalittoral, Moderate Energy Rock
Circalittoral, Moderate Energy Rock and thin Sediment
Infralittoral, High Energy Rock
Infralittoral, High Energy Rock and thin Sediment
Infralittoral, Moderate Energy Rock
Infralittoral, Moderate Energy Rock and thin Sediment
Littoral, Coarse Sediment
Littoral, High Energy Rock
Littoral, High Energy Rock and thin Sediment
Littoral, Sand
Sublittoral, Coarse Sediment
Sublittoral, Mixed Sediment
Sublittoral, Sand
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 1.75 3.5 7 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY·SCARBOROUGH·FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Full Extent
SUBSTRATE
LEGEND: Substrate type
Coarse Sediment
Mixed Sediment
Rock
Sand
Bedforms
LAYERS
Bathymetry
Backscatter
Slope
Anthropogenic
Seabed Habitats
Substrate
N
0 1.75 3.5 7 km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY-SCARBOROUGH-FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016


Full Extent
SEDIMENT GRAB SAMPLES
(g)mS
(g)mS
(g)sM
mS
gmSgS
(g)mS
(g)mS
(g)S
sM
mS
mS
gmS
(g)mS
gmS
sG
gmS
gS
sM
gS
gmS
(g)mS
sG
G
(g)mS
Ms
mS
(g)S
gmS
gS
sG
gmS
(g)S
gmS
mS
sM
(g)mS
S
mS
(g)sM
sM
(g)mS
gS
sG
mS
(g)S
N/A
sG
sG
mS
gmS
gS
gmS
gS
mS
(g)S
mS
gS
gmS
gS
gS
CobblegS
N
0
1.75
3.5
7
km
NOT TO BE USED FOR NAVIGATIONAL PURPOSES
WHITBY·SCARBOROUGH·FILEY
BOROUGH of SCARBOROUGH
Channel Coastal Observatory
Aerial photography: 2015
Map created: 2017
Survey conducted: 2016