White Cross Offshore Windfarm Environmental Statement

Chapter 8: Marine Geology, Oceanography and Physical Processes

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Appendix 8.C: Ocean Ecology (2022) Benthic Survey Report

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Glossary of Acronyms

Acronym	Definition
BEIS	Department for Business, Energy and Industrial Strategy
CEA	Cumulative Effect Assessment
Cefas	Centre for the Environment and Fisheries and Aquaculture Science
CPA	Coast Protection Act
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
EEA	European Economic Area
EIA	Environmental Impact Assessment
ES	Environmental Statement
ETG	Expert Topic Group
EU	European Union
FEPA	Food and Environmental Protection Act
HRA	Habitats Regulation Assessment
IPCC	Intergovernmental Panel on Climate Change
km	Kilometre
Km^2	Square kilometre
m	Metre
MCZ	Marine Conservation Zone
MMO	Marine Management Organisation
NGC	National Grid Company
NPS	National Policy Statement
OWL	Offshore Wind Ltd
RCP	Representative Concentration Pathways
SAC	Special Area of Conservation
SPM	Suspended Particulate Material
SSSI	Site of Special Scientific Interest
UK	United Kingdom

Glossary of Terminology

Defined Term	Description
Applicant	Offshore Wind Limited.
Cumulative effects	The effect of the Project taken together with similar effects from a number of different projects, on the same single receptor/resource. Cumulative effects are those that result from changes caused by other past, present or reasonably foreseeable actions together with the Project.
Department for Business, Energy and Industrial Strategy (BEIS)	Government department that is responsible for business, industrial strategy, science and innovation and energy and climate change policy and consent under Section 36 of the Electricity Act.
Environmental Impact Assessment (EIA)	Assessment of the potential impact of the proposed Project on the physical, biological and human environment during construction, operation and decommissioning.
Export Cable Corridor	The area in which the export cables will be laid, either from the Offshore Substation or the inter-array cable junction box (if no offshore substation), to the National Grid Company Onshore Substation comprising both the Offshore Export Cable Corridor and Onshore Export Cable Corridor.
Landfall	Where the offshore export cables come ashore (up to MHWS).
Mean high water springs	The average tidal height throughout the year of two successive high waters during those periods of 24 hours when the range of the tide is at its greatest.
Mean low water springs	The average tidal height throughout a year of two successive low waters during those periods of 24 hours when the range of the tide is at its greatest.
Mitigation	Mitigation measures have been proposed where the assessment identifies that an aspect of the development is likely to give rise to significant environmental impacts, and discussed with the relevant authorities and stakeholders in order to avoid, prevent or reduce impacts to acceptable levels. For the purposes of the EIA, two types of mitigation are defined: • Embedded mitigation: consisting of mitigation measures that are identified and adopted as part of the evolution of the project design, and form part of the project design that is assessed in the EIA • Additional mitigation: consisting of mitigation measures that are identified during the EIA process specifically to reduce or eliminate any predicted significant impacts. Additional mitigation is therefore subsequently adopted by OWL as the EIA process progresses.
Offshore Development Area	The Windfarm Site (including wind turbine generators, substructures, mooring lines, seabed anchors, inter-array cables and Offshore Substation Platform (as applicable)) and Offshore Export Cable Corridor to MHWS at

Defined Term	Description
	the Landfall. This encompasses the part of the project that is the focus of this application and Environmental Statement and the parts of the project consented under Section 36 of the Electricity Act and the Marine and Coastal Access Act 2009.
Offshore Export Cable Corridor	The proposed offshore area in which the export cables will be laid, from Offshore Substation Platform or the inter-array cable junction box to the Landfall.
Offshore Infrastructure	All of the offshore infrastructure including wind turbine generators, substructures, mooring lines, seabed anchors, Offshore Substation Platform and all cable types (export and inter-array). This encompasses the infrastructure that is the focus of this application and Environmental Statement and the parts of the project consented under Section 36 of the Electricity Act and the Marine and Coastal Access Act 2009.
the Offshore Project	The Offshore Project for the offshore Section 36 and Marine Licence application includes all elements offshore of MHWS. This includes the infrastructure within the windfarm site (e.g. wind turbine generators, substructures, mooring lines, seabed anchors, inter-array cables and Offshore Substation Platform (as applicable)) and all infrastructure associated with the export cable route and landfall (up to MHWS) including the cables and associated cable protection (if required).
Offshore Substation Platform	A fixed structure located within the Windfarm Site, containing electrical equipment to aggregate the power from the wind turbines and convert it into a more suitable form for export to shore.
the Onshore Project	The Onshore Project for the onshore TCPA application includes all elements onshore of MLWS. This includes the infrastructure associated with the offshore export cable (from MLWS), landfall (up to MHWS), onshore export cable and associated infrastructure and new onshore substation (if required).
Offshore Wind Limited	Offshore Wind Ltd (OWL) is a joint venture between Cobra Instalaciones Servicios, S.A., and Flotation Energy Ltd.
the Project	the Project is a proposed floating offshore windfarm called White Cross located in the Celtic Sea with a capacity of up to 100MW. It encompasses the project as a whole, i.e. all onshore and offshore infrastructure and activities associated with the Project.
Project Design Envelope	A description of the range of possible elements that make up the Project design options under consideration. The Project Design Envelope, or 'Rochdale Envelope' is used to define the Project for Environmental Impact Assessment (EIA) purposes when the exact parameters are not yet known but a bounded range of parameters are known for each key project aspect.
Scour protection	Protective materials to avoid sediment being eroded away from the base of the foundations as a result of the flow of water.
White Cross Offshore Windfarm	Up to 100MW capacity offshore windfarm including associated onshore and offshore infrastructure.

Defined Term	Description
Wind Turbine Generators (WTG)	The wind turbine generators convert wind energy into electrical power. Key components include the rotor blades, nacelle (housing for electrical generator and other electrical and control equipment) and tower. The final selection of project wind turbine model will be made post-consent application.
Windfarm Site	The area within which the wind turbines, Offshore Substation Platform and inter-array cables will be present.
Works completion date	Date at which construction works are deemed to be complete and the windfarm is handed to the operations team. In reality, this may take place over a period of time.

8. Chapter 8: Marine Geology, Oceanography and Physical Processes

8.1 Introduction

1. This chapter of the Environmental Statement (ES) describes the potential impacts of the White Cross Offshore Windfarm Project (the Offshore Project) on marine geology, oceanography and physical processes. The chapter provides an overview of the existing environment for the Project, followed by an assessment of the potential impacts and associated mitigation for the construction, operation, and decommissioning phases.

2. The ES has been finalised with due consideration of pre-application consultation to date (see **Chapter 7: Consultation**) and the ES will accompany the application to the Marine Management Organisation (MMO) on behalf of the Secretary of State for Business for The Department for Business, Energy and Industrial Strategy (BEIS) for Section 36 Consent and relevant Marine Licences under the Marine and Coastal Access Act (2009).

3. This ES chapter:

- Presents the existing environmental baseline established from desk studies, and consultation
- Presents the potential environmental effects on marine geology, oceanography and physical processes arising from the Offshore Project, based on the information gathered and the analysis and assessments undertaken
- Identifies any assumptions and limitations encountered in compiling the environmental information
- Highlights any necessary monitoring and/or mitigation measures which could prevent, minimise, reduce or offset the possible environmental effects identified in the EIA process.

8.2 Policy, Legislation and Guidance

4. **Chapter 3: Policy and Legislative Content** describes the wider policy and legislative context for the Offshore Project. The principal policy and legislation used to inform the assessment of potential impacts on marine geology, oceanography and physical processes for the Offshore Project are outlined in this section.

8.2.1 National Policy Statements

5. The assessment of potential impacts upon marine geology, oceanography and physical processes has been made with specific reference to the relevant National

Policy Statements (NPS). These are the principal decision making documents for Nationally Significant Infrastructure Projects (NSIPs). Those relevant to the Offshore Project are:

- Overarching NPS for Energy (EN-1) (Department of Energy and Climate Change (DECC) 2011a)
- NPS for Renewable Energy Infrastructure (EN-3) (DECC 2011b).

6. The specific assessment requirements for marine geology, oceanography and physical processes, as detailed in the NPS, are summarised in **Table 8.1** together with an indication of the section of this ES chapter where each is addressed.

7. It is noted that the NPS for Energy (EN-1) and the NPS for Renewable Energy Infrastructure (EN-3) are in the process of being revised. Draft versions were published for consultation in September 2021 (Department for Business Energy and Industrial Strategy (BEIS), 2021a and BEIS 2021b respectively). A review of these draft versions has been undertaken in the context of this ES chapter.

8. **Table 8.1** includes a section for the draft version of NPS (EN-1 and EN-3) in which relevant additional NPS requirements not presented within the current NPS (EN-1 and EN-3) have been included. A reference to the particular requirement's location within the draft NPS and to where within this ES chapter or wider ES it has been addressed has also been provided. NPSs are statutory documents which set out the government's policy on specific types of Nationally Significant Infrastructure Projects (NSIPs) and are published in accordance with the Planning Act 2008. Although the Offshore Project is not an NSIP, it is recognised that due to its size of up to 100MW and its location in English waters, certain NPS are considered relevant to the Offshore Project and decision-making and are referred to in this ES.

Table 8.1 Summary of NPS EN-1 and EN-3 provisions relevant to marine geology, oceanography and physical processes

Summary	How and where this is considered in the ES
NPS for Energy (EN-1)	
'where relevant, applicants should undertake coastal geomorphological and sediment transfer modelling to predict and understand impacts and help identify relevant mitigating or compensatory measures' – **EN-1, Section 5.5, paragraph 5.5.6**	The approach adopted in this ES for all impacts is conceptual and evidence-based. This was agreed in general terms through the Marine Geology Expert Topic Group (ETG).

Summary	How and where this is considered in the ES
'the ES should include an assessment of the effects on the coast. In particular, applicants should assess: • The impact of the proposed project on coastal processes and geomorphology, including by taking account of potential impacts from climate change. If the development will have an impact on coastal processes the applicant must demonstrate how the impacts will be managed to minimise adverse impacts on other parts of the coast • The implications of the proposed project on strategies for managing the coast as set out in Shoreline Management Plans (SMPs) and any relevant Marine Plans (Objective 10 of the East Inshore and East Offshore Marine Plans is "To ensure integration with other plans, and in the regulation and management of key activities and issues, in the East Marine Plans, and adjacent areas" this therefore refers back to the objectives of the SMPs)… and capital programmes for maintaining flood and coastal defences • The effects of the proposed project on marine ecology, biodiversity and protected sites • The effects of the proposed project on maintaining coastal recreation sites and features • The vulnerability of the proposed development to coastal change, taking account of climate change, during the Project's operational life and any decommissioning period' – **EN-1, Section 5.5, paragraph 5.5.7**	The assessment of potential construction and operational impacts are described in **Section 8.5** and **Section 8.6**, respectively. The Offshore Project will not affect the policies presented in Shoreline Management Plan. Embedded mitigation to minimise potential impacts at the coast of cable installation and operation are described in **Section 8.3.5.** Effects on marine ecology biodiversity and protected sites are assessed in **Chapter 10: Benthic and Intertidal Ecology**, **Chapter 11: Fish and Shellfish Ecology, Chapter 12: Marine Mammal and Marine Turtle Ecology**, **and Chapter 13: Offshore Ornithology**. Effects on recreation are assessed in **Chapter 23: Socio-economics (including Tourism and Recreation)**. As described above the Offshore Project has been designed so that it is not vulnerable to coastal change or climate change.
'the applicant should be particularly careful to identify any effects of physical changes on the integrity and special features of Marine Conservation Zones, candidate marine Special Areas of Conservation (SACs), coastal SACs and candidate coastal SACs, coastal Special Protection Areas (SPAs) and potential SCIs and	The potential offshore receptors to morphological change are Lundy Island and the Devon coast. The potential to affect their integrity is assessed with respect to changes in seabed level caused by cable installation (**Section 8.5.1**, **Section 8.5.2**, and **Section 8.5.3**) and interruption to

Summary	How and where this is considered in the ES
Sites of Special Scientific Interest (SSSI)' [1] – **EN-1, Section 5.5, paragraph 5.5.9**	bedload sediment transport by cable protection (**Section 8.6.3**).
NPS for Renewable Energy Infrastructure (EN-3)	
"The assessment should include predictions of physical effect that will result from the construction and operation of the required infrastructure and include effects such as the scouring that may result from the proposed development" – **EN-3, Section 2.6, paragraph 2.6.193 and 2.6.194**	Each of the impacts in **Section 8.5** and **Section 8.6** cover the potential magnitude and significance of the physical (waves, tides and sediments) effects upon the baseline conditions resulting from the construction and operation of the Offshore Project. Scour resulting from the catenary action of the mooring lines and around the foundations of the mooring anchors is assessed in **Section 8.6.4**.
"where necessary, assessment of the effects on the subtidal environment should include: • Loss of habitat due to foundation type including associated seabed preparation, predicted scour, scour protection and altered sedimentary processes • Environmental appraisal of inter-array and cable routes and installation methods • Habitat disturbance from construction vessels extendible legs and anchors • Increased suspended sediment loads during construction • Predicted rates at which the subtidal zone might recover from temporary effects" **- EN-3, Section 2.6, paragraph 2.6.113**	See above for scour. The worst case scenario cable-laying techniques are jetting and/or ploughing and are considered in the cable construction assessments. The disturbance to the subtidal seabed caused by indentations due to installation vessels is assessed in **Section 8.5.1**. The potential increase in suspended sediment concentrations and change in seabed level is assessed in **Section 8.5.3** and **Section 8.6.4**. The recoverability of receptors is assessed for all the relevant impacts, particularly those related to changes in seabed level due to export cable installation (**Section 8.5.1**) and morphological and sediment transport effects due to cable protection measures for export cables (**Section 8.6.3**).
"an assessment of the effects of installing cable across the intertidal zone should include information, where relevant, about:	Landfall Site Selection and Assessment of Alternatives are provided in **Chapter 4: Site Selection and Assessment of Alternatives**

[1] Note that this has been amended in BEIS (2021a) to: *The applicant should be particularly careful to identify any effects of physical changes on the integrity and special features of Marine Protected Areas (MPAs). These could include MCZs, candidate marine Special Areas of Conservation (SACs), coastal SACs and candidate coastal SACs, coastal Special Protection Areas (SPAs) and potential coastal SPAs, Ramsar sites, Sites of Community Importance (SCIs) and potential SCIs and SSSIs*

Summary	How and where this is considered in the ES
• Any alternative landfall sites that have been considered by the applicant during the design phase and an explanation of the final choice • Any alternative cable installation methods that have been considered by the applicant during the design phase and an explanation of the final choice • Potential loss of habitat • Disturbance during cable installation and removal (decommissioning) • Increased suspended sediment loads in the intertidal zone during installation • Predicted rates at which the intertidal zone might recover from temporary effects" - **EN-3, Section 2.6, paragraph 2.6.81**	A range of cable installation methods may be required, and these are detailed in **Chapter 5: Project Description**. The worst case scenario for marine geology, oceanography and physical processes is provided in **Section 8.3.3**. Potential habitat loss in the intertidal zone is covered in **Chapter 10: Benthic and Intertidal Ecology**. Assessment of the potential disturbance and increased suspended sediment concentrations in the nearshore (including the intertidal zone) due to cable installation is provided in **Section 8.5.3**. The recoverability of the coastal receptor (Saunton Sands) is assessed for morphological and sediment transport effects due to cable protection measures at the coast (**Section 8.6.3**).
Draft Overarching NPS for Energy (EN-1) (BEIS, 2021a)	
"the ES should include an assessment of the effects on the coast. In particular, applicants should assess how coastal change could affect flood risk management infrastructure, drainage and flood risk" – **Draft EN-1, Section 5.6, paragraph 5.6.7**	As described above, the Offshore Project is designed so it is not vulnerable to coastal change or climate change. Potential flood risk impacts are considered in the separate Onshore Project EIA.
Draft NPS for Renewable Energy Infrastructure (EN-3) (BEIS, 2021b)	
"Assessment of the effects on the subtidal environment should include: • environmental appraisal of inter-array and export cable routes and installation/maintenance methods, including predicted loss of habitat due to predicted scour and scour protection • impacts on protected sites (e.g. HRA sites and MCZs)" **- Draft EN-3, Section 2.30, Paragraph 2.30.2**	An assessment of the potential impacts of the installation and maintenance of cable infrastructure (including consideration of the potential impact of cable protection measures) is undertaken for the relevant construction and operation impacts in **Section 8.5** and **Section 8.6**, respectively. The Lundy and Bideford to Foreland Point MCZs have been included as receptors within this chapter and so potential impacts on protected sites has been considered.
"An assessment of the effects of installing cable across the intertidal zone should follow The Crown Estate's cable route protocol and include information, where relevant, about:	A range of cable installation methods may be required, and these are detailed in **Chapter 5 Project Description**. The worst case scenario for marine geology,

Summary	How and where this is considered in the ES
• disturbance during cable installation, maintenance/repairs and removal (decommissioning) • increased suspended sediment loads in the intertidal zone during installation and maintenance/repairs • Protected sites (e.g. HRA sites, MCZs and SSSIs)" **- Draft EN-3, Section 2.21, Paragraph 2.27.3**	oceanography and physical processes is provided in **Section 8.3.3**. Assessment of the potential disturbance and increased suspended sediment concentrations in the nearshore (including the intertidal zone) due to cable installation is provided in **Section 8.5.1**, **Section 8.5.2**, and **Section 8.5.3**. The recoverability of the coastal receptor (Saunton Sands) is assessed for morphological and sediment transport effects due to cable protection measures at the coast (**Section 8.6.3**).

8.2.2 Other

9. In addition to the NPS, there are a number of pieces of legislation, policy and guidance applicable to the assessment of marine geology, oceanography and physical processes. These include:

   - The Marine Policy Statement (MPS, HM Government, 2011) provides the high-level approach to marine planning and general principles for decision making that contribute to achieving this vision. It also sets out the framework for environmental, social and economic factors that need to be considered in marine planning. Regarding the topics covered by this chapter the key reference is in section 2.6.8.6 of the MPS which states: "…*Marine plan authorities should not consider development which may affect areas at high risk and probability of coastal change unless the impacts upon it can be managed. Marine plan authorities should seek to minimise and mitigate any geomorphological changes that an activity or development will have on coastal processes, including sediment movement*."

10. The MPS is also the framework for preparing individual Marine Plans and taking decisions affecting the marine environment. The Marine Plan relevant to the Offshore Project is the South West Inshore and the South West Offshore Marine Plan (HM Government, 2021) which includes policy relating to marine geology, oceanography and physical processes. These policies are summarised in **Table 8.2**.

Table 8.2 The South West Inshore and South West Offshore Marine Plan policy relating to marine geology, oceanography and physical processes

Policy code	Policy text	Policy aim
SW-CC-1	Proposals that conserve, restore or enhance habitats that provide flood defence or carbon sequestration will be supported. Proposals that may have significant adverse impacts on habitats that provide a flood defence or carbon sequestration ecosystem service must demonstrate that they will, in order of preference: a) avoid; b) minimise; c) mitigate - adverse impacts so they are no longer significant; d) compensate for significant adverse impacts that cannot be mitigated.	Proposals that conserve, restore or enhance habitats that provide flood defence or carbon sequestration will be supported. Habitats that provide flood defence and carbon sequestration contribute to natural resilience for coastal communities that are vulnerable to coastal erosion and change. SW-CC-1 requires proposals to manage impacts, enabling these important habitats to continue to provide this valuable service. Proposals that cannot avoid, minimise and mitigate or, or as a last resort, compensate for significant adverse impacts, will not be supported.
SW-CC-2	Proposals in the south west marine plan areas should demonstrate for the lifetime of the project that they are resilient to the impacts of climate change and coastal change.	The effects of climate change are wide-ranging and can include sea level rise, coastal flooding and rising sea temperatures. SW-CC-2 adds provision to enable enhanced resilience of developments, activities and ecosystems within the south west marine plan areas to the effects of climate change and coastal change.
SW-CC-3	Proposals in the south west marine plan areas, and adjacent marine plan areas, that are likely to have significant adverse impacts on coastal change, or on climate change adaptation measures inside and outside of the proposed project areas, should only be supported if they can demonstrate that they will, in order of preference: a) avoid; b) minimise; c) mitigate - adverse impacts so they are no longer significant.	Large areas of the south west inshore marine plan area coastline are subject to or vulnerable to change. SW-CC-3 ensures proposals do not exacerbate coastal change, enabling communities to be more resilient and better able to adapt to coastal erosion and flood risk where identified. SW-CC-3 also supports proposals that do not compromise existing adaptation measures, which will enable an improvement in the resilience of coastal communities to coastal erosion and flood risk. Proposals that cannot avoid, minimise and mitigate significant adverse impacts will not be supported.

11. In addition to NPS, MPS and South West Inshore and South West Offshore Marine Plan, guidance on the generic requirements, including spatial and temporal scales, for marine geology, oceanography and physical processes studies associated with offshore wind farm development is provided in five main documents:

- Guidance on Environmental Impact Assessment in Relation to Dredging Applications (Office of the Deputy Prime Minister, 2001)
- Offshore Windfarms: Guidance Note for Environmental Impact Assessment in respect of Food and Environmental Protection Act (FEPA) and Coast Protection Act (CPA) requirements: Version 2 (Cefas, 2004)
- Review of Cabling Techniques and Environmental Effects applicable to the Offshore Windfarm Industry (BERR, 2008)
- Coastal Process Modelling for Offshore Windfarm Environmental Impact Assessment (Lambkin *et al*., 2009)
- Guidelines for Data Acquisition to support Marine Environmental Assessments of Offshore Renewable Energy Projects (Cefas, 2011).

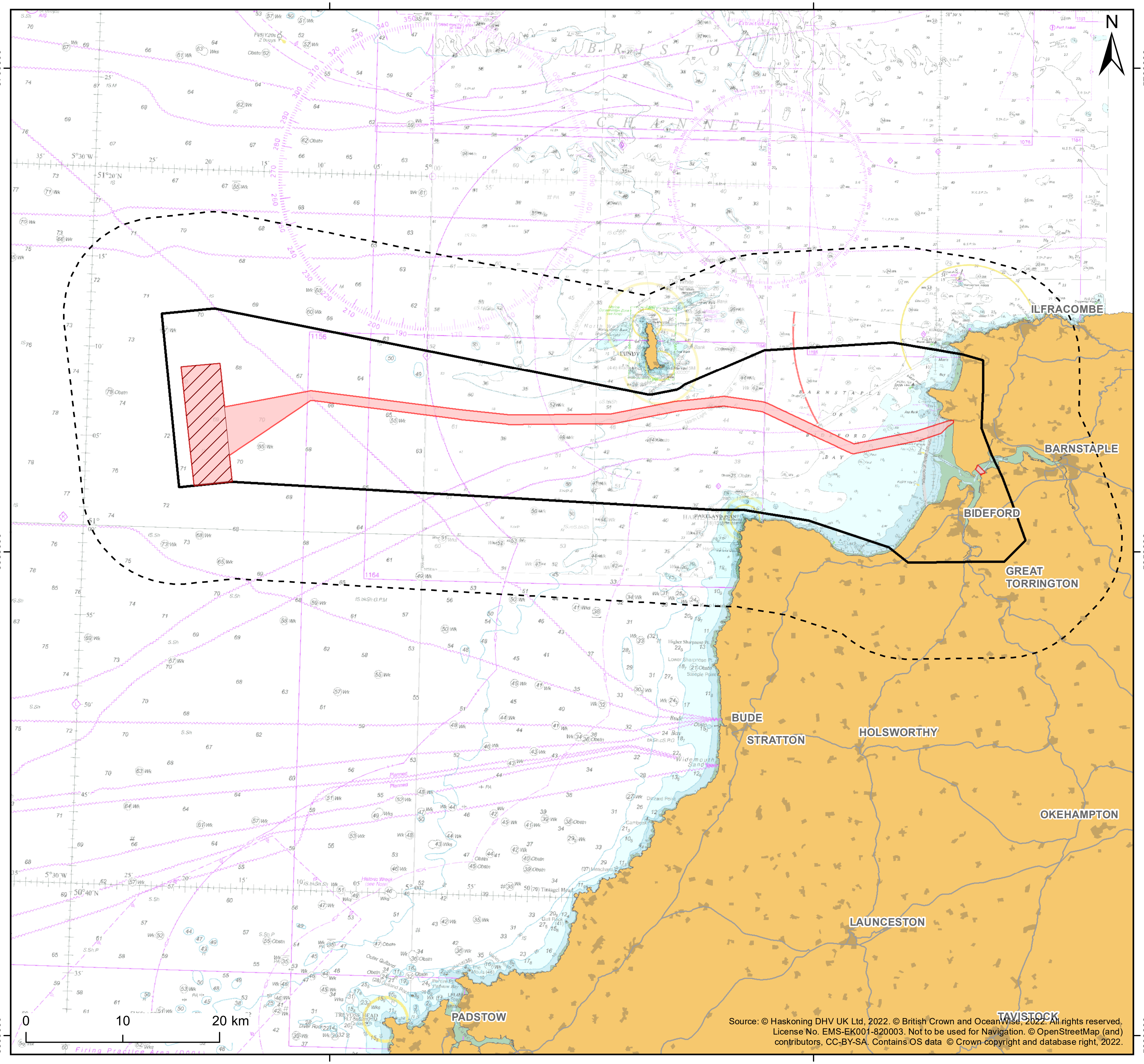
8.3 Assessment Methodology

8.3.1 Study Area

12. Details of the location of the Offshore Project and the offshore infrastructure are set out within **Chapter 5: Project Description**.

13. The marine geology, oceanography and physical processes study area is defined by the distance over which impacts from all the offshore infrastructure (i.e. Offshore Export Cable Corridor, Offshore Substation Platform, Landfall) may occur and by the location of any receptors that may be affected by those potential impacts.

14. The study area for marine geology, oceanography and physical processes comprises the southern part of the Outer Bristol Channel west of the Devon coast (**Figure 8.1**). This study area accounts for the potential local and regional effects on physical and sedimentary processes, and includes a tide-parallel 10km wide buffer around the Offshore Development Area.



Legend:
- Windfarm Site
- Area of Search
- Marine geology, oceanography Study Area
- Offshore Development Area

Client:	Project:
Offshore Wind Ltd.	White Cross Offshore Windfarm

Title:

Marine geology, oceanography and physical processes study area

Figure: 8.1 | Drawing No: PC2978-RHD-ZZ-XX-DR-Z-0460

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P02	03/03/2023	AB	DB	A3	1:400,000
P01	20/12/2022	JT	DB	A3	1:400,000

Co-ordinate system: WGS 1984 UTM Zone 30N

WHITE CROSS

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8.3.2 Approach to Assessment

15. **Chapter 6: EIA Methodology** provides a summary of the general impact assessment methodology applied to the Offshore Project. The following sections confirm the methodology used to assess the potential impacts on marine geology, oceanography and physical processes.

16. The assessment of effects on marine geology, oceanography and physical processes are predicated on a Source-Pathway-Receptor (S-P-R) conceptual model, whereby the source is the initiator event, the pathway is the link between the source and the receptor impacted by the effect, and the receptor is the receiving entity. An example of the S-P-R conceptual model is provided by cable installation which disturbs sediment on the seabed (source). This sediment is then transported by tidal currents until it settles back to the seabed (pathway). The deposited sediment could change the composition and elevation of the seabed (receptor). Numerical modelling of these processes effects of the Offshore Project would be disproportionate to the potential impact and a conceptual evidence-based assessment is preferred.

17. Consideration of the potential effects of the Offshore Project on the marine geology, oceanography and physical processes is carried out over the following spatial scales:

    - near-field: the area within the immediate vicinity (tens or hundreds of metres) of the wind farm site and along the offshore export cable corridor
    - far-field: the wider area that might also be affected indirectly by the Offshore Project (e.g. due to disruption of waves, tidal currents or sediment pathways passing through the Offshore Development Area).

18. For the effects on marine geology, oceanography and physical processes, the assessment follows two approaches. The first type of assessment is impacts on marine geology, oceanography and physical processes whereby several discrete direct receptors can be identified. These include certain morphological features with ascribed inherent values, such as chalk reef and other MCZ features, and beaches and sea cliffs at the coast.

19. The impact assessment incorporates a combination of the sensitivity of the receptor, its value (if applicable) and the magnitude of the change to determine a significance of impact.

20. In addition to identifiable receptors, the second type of assessment covers changes to marine geology, oceanography and physical processes which in themselves are not necessarily impacts to which significance can be ascribed. Rather, these changes (such as a change in the wave climate, a change in the tidal regime or a change in

suspended sediment concentrations) represent effects which may manifest themselves as an impact upon other receptors, most notably marine water and sediment quality, benthic ecology, and fish and shellfish ecology (e.g. in terms of increased suspended sediment concentrations, or erosion or smothering of habitats on the seabed). Hence, the two approaches to the assessment of marine geology, oceanography and physical processes are:

- situations where potential impacts can be defined as directly affecting receptors which possess their own intrinsic morphological value. In this case, the significance of the impact is based on an assessment of the sensitivity of the receptor and magnitude of effect by means of an impact significance matrix.
- situations where effects (or changes) in the baseline marine geology, oceanography and physical processes may occur which could manifest as impacts upon receptors other than marine geology, oceanography and physical processes. In this case, the magnitude of effect is determined in a similar manner to the first assessment method but the significance of impacts on other receptors is made within the relevant chapters of the ES pertaining to those receptors.

8.3.2.1 Definitions of Sensitivity, Value and Magnitude

21. For each effect, the assessment identifies receptors sensitive to that effect and implements a systematic approach to understanding the impact pathways and the level of impacts on given receptors. The sensitivity of a receptor is dependent upon its:

- Tolerance to an effect (i.e. the extent to which the receptor is adversely affected by an effect)
- Adaptability (i.e. the ability of the receptor to avoid adverse impacts that would otherwise arise from an effect)
- Recoverability (i.e. a measure of a receptor's ability to return to a state at, or close to, that which existed before the effect caused a change).

22. In addition, a value component may also be considered when assessing a receptor. This ascribes whether the receptor is rare, protected or threatened. The magnitude of an effect is dependent upon its:

- Scale (i.e. size, extent or intensity)
- Duration
- Frequency of occurrence

- Reversibility (i.e. the capability of the environment to return to a condition equivalent to the baseline after the effect ceases).

23. The sensitivity and value of discrete morphological receptors and the magnitude of effect will be assessed using evidence-based judgement. The definitions of sensitivity, value and magnitude for the purpose of the marine geology, oceanography and physical processes assessment are provided in **Table 8.3**, **Table 8.4** and **Table 8.5**, respectively. These evidence-based judgements of receptor sensitivity, value and magnitude of effect will be closely guided by the conceptual understanding of baseline conditions.

Table 8.3 Definition of sensitivity for a morphological receptor

Sensitivity	Definition
High	Tolerance: Receptor has very limited tolerance of effect. Adaptability: Receptor unable to adapt to effect. Recoverability: Receptor unable to recover resulting in permanent or long-term (>10 years) change.
Medium	Tolerance: Receptor has limited tolerance of effect Adaptability: Receptor has limited ability to adapt to effect. Recoverability: Receptor able to recover to an acceptable status over the medium term (5-10 years).
Low	Tolerance: Receptor has some tolerance of effect. Adaptability: Receptor has some ability to adapt to effect. Recoverability: Receptor able to recover to an acceptable status over the short term (1-5 years).
Negligible	Tolerance: Receptor generally tolerant of effect. Adaptability: Receptor can completely adapt to effect with no detectable changes. Recoverability: Receptor able to recover to an acceptable status near instantaneously (<1 year).

Table 8.4 Definition of value for a morphological receptor

Source	Summary
High	Value: Receptor is designated and / or of national or international importance for marine geology, oceanography or physical processes. Likely to be rare with minimal potential for substitution. May also be of significant wider-scale, functional or strategic importance.
Medium	Value: Receptor is not designated but is of local to regional importance for marine geology, oceanography or physical processes.
Low	Value: Receptor is not designated but is of local importance for marine geology, oceanography or physical processes.
Negligible	Value: Receptor is not designated and is not deemed of importance for marine geology, oceanography or physical processes.

Table 8.5 Definition of magnitude for a morphological receptor

Sensitivity	Definition
High	Scale: A change which would extend beyond the natural variations in background conditions Duration: Change persists for more than ten years Frequency: The effect would always occur Reversibility: The effect is irreversible
Medium	Scale: A change which would be noticeable from monitoring but remains within the range of natural variations in background conditions Duration: Change persists for 5-10 years Frequency: The effect would occur regularly but not all the time Reversibility: The effect is very slowly reversible (5-10 years)
Low	Scale: A change which would barely be noticeable from monitoring and is small compared to natural variations in background conditions Duration: Change persists for 1-5 years Frequency: The effect would occur occasionally but not all the time Reversibility: The effect is slowly reversible (1-5 years)
Negligible	Scale: A change which would not be noticeable from monitoring and is extremely small compared to natural variations in background conditions Duration: Change persists for less than one year Frequency: The effect would occur highly infrequently Reversibility: The effect is quickly reversible (less than one year)

8.3.2.2 Effect Significance

24. In basic terms, the potential significance of an effect is a function of the sensitivity of the receptor and the magnitude of the impact (see **Chapter 6: EIA Methodology** for further details). The determination of significance is guided by the use of an effect significance matrix, as shown in **Table 8.6**. Definitions of each level of significance are provided in **Table 8.7**.

25. Potential effects identified within the assessment as major or moderate are regarded as significant in terms of the EIA regulations. Potential effects are described using effect significance, followed by a statement of whether the effect significance is significant in terms of the EIA regulations, e.g. "*minor adverse effect, not significant in EIA terms / moderate adverse effect, significant in EIA terms*". Appropriate mitigation is identified, where possible, in consultation with the regulatory authorities and relevant stakeholders. The aim of mitigation measures is to avoid or reduce the overall effect in order to determine a residual effect upon a given receptor.

Table 8.6 Significance of an effect resulting from each combination of receptor sensitivity and the magnitude of the impact upon it

		Negative Magnitude				Beneficial Magnitude			
		High	Medium	Low	Negligible	Negligible	Low	Medium	High
Sensitivity	High	Major	Major	Moderate	Minor	Minor	Moderate	Major	Major
	Medium	Major	Moderate	Minor	Minor	Minor	Minor	Moderate	Major
	Low	Moderate	Minor	Minor	Negligible	Negligible	Minor	Minor	Moderate
	Negligible	Minor	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Minor

Table 8.7 Definition of effect significance

Sensitivity	Definition
Major	Very large or large change in receptor condition, both adverse or beneficial, which are likely to be important considerations at a regional or district level because they contribute to achieving national, regional or local objectives, or could result in exceedance of statutory objectives and / or breaches of legislation.
Moderate	Intermediate change in receptor condition, which are likely to be important considerations at a local level.
Minor	Small change in receptor condition, which may be raised as local issues but are unlikely to be important in the decision making process.
Negligible	No discernible change in receptor condition.
No change	No effect, therefore, no change in receptor condition.

8.3.3 Worst Case-Scenario

26. In accordance with the assessment approach to the Project Design Envelope, or 'Rochdale Envelope', set out in **Chapter 6: EIA Methodology**, the impact assessment for marine geology, oceanography and physical processes has been undertaken based on a realistic worst case scenario of predicted effects. The Project Design Envelope for the Offshore Project is detailed in **Chapter 5: Project Description**.

27. The worst case scenarios with regard to marine geology, oceanography and physical processes within the study area are presented by impact in **Table 8.8**.

Table 8.8 Worst-case assumptions

Impact Construction	Worst case parameter
Impact 1: Impacts on the form and function of the coast due to buried cable installation	The two cables would be buried in a trench across the northern end of Saunton Sands and into the subtidal. The trench dimensions across the beach would be 0.5m wide and 270m long, = 135m^2 (plan area for two cables). The cable trench would be 1.2m deep, = 162m^3 (volume for two cables).
Impact 2: Impacts on the form and function of the subtidal seabed due to buried cable, mooring system, and Offshore Substation Platform installation	Export cable burial (single cable) would disturb the subtidal seabed 25m wide, up to about 93.6km long = 4,680,000m^2 (plan area for two cables). Cable burial for two cables would displace a volume of 1,684,800m^3 assuming 3m wide, 3m deep excavation for each. Jetting/ploughing considered the worst case. Sand wave removal for a single export cable would disturb about 2.8km of the seabed (assumed to be 3% of the total cable length) up to 50m wide = 280,800m^2 (plan area for two cables). Assuming an average sand wave height of 3m = 842,400m^3 (volume for two cables). Inter-array cable burial would disturb the subtidal seabed 20m wide, up to about 29.76km long = plan area of 480,000m^2. Cable burial for two cables would displace a volume of 216,000m^3 assuming 3m wide, 3m deep excavation for each. Jetting/ploughing considered the worst case. Sand wave removal for inter-array cables would disturb about 1.5km of the seabed (assumed to be 5% of the total cable length) up to 10m wide = plan area of 14,880m^2. Assuming an average sand wave height of 2m = 29,760m^3. Seabed preparation for mooring system = 9,914m^3. This is based on a total disturbance area of 4,957m^2 and a 2m depth of preparation. Seabed preparation for one Offshore Substation Platform = 1,256.64m^3. This is based on a disturbance area of 1,256.64m^2 and a 1m depth of preparation)

Impact	Worst case parameter
Impact 3: Impacts on suspended sediment concentrations and deposition due to buried cable, mooring system, and Offshore Substation Platform installation	As for Construction Impact 2
Impact 4: Indentations on the seabed due to installation vessels	Jack up vessels installing foundations for one Offshore Substation Platform = total footprint of 315m^2. This is based on a four-legged jack up with spud cans of 10m diameter.
Operation and Maintenance	
Impact 1: Impacts on waves and tidal currents due to the physical presence of the infrastructure	Eight floating substructures (supporting turbines) and one Offshore Substation Platform supported by a jacket foundation. The floating substructure for each will be of the semi-submersible type and will feature up to four buoyancy columns (up to 15m outer diameter) connected by pontoons and braces. The jacket foundation comprises four columns connected by beam and braces.
Impact 2: Impacts on bedload sediment transport and seabed morphological change due to the physical presence of the infrastructure	The catenary mooring and anchor footprint per turbine would be the sum of the drag anchor footprint (10m x 10m) and mooring seabed footprint (length of 600m x 0.5m chain width) multiplied by the maximum number of mooring lines (six) = 2,424m^2. For eight turbines = 19,392m^2. The chain will have an open structure allowing sediment throughput and the chain will have a maximum height above seabed of 0.5m.
Impact 3: Impacts on bedload sediment transport and seabed morphological change due to cable protection	The total length of unburied export cable (for two cables) is estimated at 34.08km. This is 18% of the total export cable length. This length would require protection using approximately 136,320m^3 of rock along the two cables. About 14,400m^3 of rock is estimated to be required to facilitate crossing of eight cables and pipelines. The total length of unburied inter-array cable (cable crossings, entry to substation/turbine and unburied due to soil uncertainties) is estimated at 3.2km. This length would require protection using approximately 23,040m^3 of rock.
Impact 4: Impacts on suspended sediment concentrations and transport due to the physical presence of the infrastructure	As for Operational Impact 2.

Impact	Worst case parameter
Decommissioning	
Impact 1: Impacts on the form and function of the coast due to buried cable decommissioning	As for Construction Impact 1.
Impact 2: Impacts on the form and function of the subtidal seabed due to buried cable, mooring system, and Offshore Substation Platform decommissioning	As for Construction Impact 2.
Impact 3: Impacts on suspended sediment concentrations and deposition due to buried cable, mooring system, and Offshore Substation Platform decommissioning	As for Construction Impact 3.
Impact 4: Indentations on the seabed due to decommissioning vessels	As for Construction Impact 4.

8.3.4 Impact receptors

28. The principal receptors with respect to marine physical processes are those features with an inherent geological or geomorphological value or function which may potentially be affected by the Offshore Project. The specific features defined within these receptors as requiring further assessment at the EIA stage for the Offshore Project are listed in **Table 8.9**.

Table 8.9 Marine geology, oceanography and physical processes receptors relevant to the Offshore Project

Receptor	Extent of coverage	Description of relevant features	Distance from the Offshore Project
Lundy MCZ	Marine areas around Lundy Island	Annex I Reefs Annex I Sandbanks which are slightly covered by sea water all the time Annex I Submerged or partially submerged sea caves	2km north from the Offshore Export Cable Corridor
Lundy SAC			3km north from the Offshore Export Cable Corridor
Bideford to Foreland Point MCZ	Bideford to Foreland Point	Protects a wide range of habitats, from beaches of intertidal sand to subtidal sediment and rock habitats, which are permanently submerged. This site is important for creating connectivity between sites along the north coast of Devon and Cornwall.	0km. Overlaps the Offshore Export Cable Corridor
Braunton Burrows SAC	Braunton Burrows	Annex I Shifting dunes along the shoreline with *Ammophila arenaria* ('white dunes') Annex I Fixed dunes with herbaceous vegetation ('grey dunes') Annex I Dunes with Salix repens ssp. argentea (*Salicion arenariae*) Annex I Humid dune slacks Annex I Mudflats and sandflats not covered by seawater at low tide	0km. Overlaps the Offshore Export Cable Corridor
Braunton Burrows SSSI		Braunton Burrows is a key site for coastal geomorphology. It is one of the largest dune systems in Britain, about 5km long north-south and 1.5km wide, with lime-rich dunes up to 30m high, and an extensive system of variably-flooded slacks, grassland and scrub, inland of a wide sandy foreshore, rich in lime from broken seashells, with some intertidal shingle grading to silt in the Taw-Torridge Estuary	0km. Overlaps the Offshore Export Cable Corridor

Receptor	Extent of coverage	Description of relevant features	Distance from the Offshore Project
Taw-Torridge Estuary SSSI	Taw-Torridge Estuary	The Taw-Torridge Estuary's wide tidal range is reflected by the very large areas of mudflats and sandbanks together with beaches and saltmarshes. Habitats include low energy intertidal rock, intertidal coarse sediment, intertidal sand and muddy sand, coastal saltmarsh and saline reedbed, subtidal sand, and subtidal mud	0km. Overlaps the Offshore Export Cable Corridor
Northam Burrows SSSI Westward Ho! Cliffs SSSI	Northam Burrows to Westward Ho!	Northam Burrows is of interest for its wide range of coastal habitats including dunes, intertidal sand and a cobble ridge. The cobble ridge is a classic coastal feature noted in particular for the large size of the sediments present. Few spits in Britain are formed of large cobbles at the back of an extensive sandy intertidal zone. Part of the site is listed in the Geological Conservation Review	Approximately 1.9km

8.3.5 Embedded Mitigation

29. This section outlines the embedded mitigation relevant to the marine geology, oceanography and physical processes assessment, which has been incorporated into the design of the Offshore Project (**Table 8.10**). Where other mitigation measures are proposed, these are detailed in the impact assessment.

Table 8.10 Embedded mitigation measures relevant to the marine geology, oceanography and physical processes assessment

Component/Activity	Mitigation embedded into the design of the Offshore Project
Cables	The Applicant will make reasonable endeavours to bury cables, minimising the requirement for cable protection measures and thus effects on sediment transport. Use of external cable protection would be minimised in all cases and no cable protection would be located in the nearshore including at the trenchless technique exit point.
	Route selection and micro-siting of the cables will be used to avoid areas of seabed that pose a significant challenge to their installation, including for example, areas of sand waves and megaripples. This will minimise the requirement for seabed preparation (levelling) and the associated seabed disturbance. This is reflected in the allowances that have been made for these works as described in **Table 8.8**, based on the information from the geophysical surveys conducted to date.
Landfall	Either open trenching or trenchless technique will be used to install the cables at the landfall (up to MHWS). Cables will be buried at sufficient depth to have no effect on coastal processes. Sediment transport would continue as a natural phenomenon driven by waves, which would not be affected by the Offshore Project.

8.3.6 Baseline Data Sources

8.3.6.1 Desktop Study

30. A desk study was undertaken to obtain information on marine geology, oceanography and physical processes. Data were acquired within the study area through a detailed desktop review of existing studies and datasets. Agreement was reached with all consultees that the data collected, and the sources used to define the baseline characterisation for marine geology, oceanography and physical processes are fit for the purpose of the EIA (agreed at the Marine Geology ETG held on 26th May 2022).

31. The sources of information presented in **Table 8.11** were consulted to inform the marine geology, oceanography and physical processes assessment.

Table 8.11 Existing data sources used to inform the marine geology, oceanography and physical processes assessment

Source	Summary
European Marine Observation and Data Network (EMODnet) data from European seas	Bathymetry and bedforms
British Geological Survey 1:250,000 Quaternary geology and bedrock geology mapping, Futurecoast and Shoreline Management Plans	Offshore and coastal geology
Admiralty Tide Tables (2022) and Environment Agency (2018)	Water levels
UK Atlas of Marine Renewable Energy (BERR, 2008)	Tidal currents
UK Atlas of Marine Renewable Energy (BERR, 2008)	Waves
UK Climate Projections (UKCP18) user interface for the model grid cell that covers the Landfall	Climate change and sea-level rise
British Geological Survey 1:250,000 seabed sediment mapping	Seabed sediment distribution
Cefas (2016) satellite suspended particulate material (SPM) covering UK waters and UK continental shelf between 1998 and 2015	Suspended sediment concentration

8.3.6.2 Site Specific Surveys

32. To inform the EIA, site-specific surveys were undertaken, as agreed with the statutory consultees. A summary of the completed surveys is outlined in **Table 8.12**.

Table 8.12 Summary of site-specific survey data

Survey/study	Purpose	Spatial Coverage
Geophysical survey between June and August 2022 (multibeam echosounder and side-scan sonar) (N-Sea)	Bathymetry and seabed feature identification	Offshore Development Area
Sub-bottom profiling and single channel sparker between June and August 2022 (Windfarm Site only)	Shallow geology	Offshore Development Area (sub-bottom) and Windfarm Site only (sparker)

Survey/study	Purpose	Spatial Coverage
Grab samples and drop-down camera and video samples in July and August 2022 (25 stations, 22 offshore and three nearshore of which 24 samples were analysed for particle size) (Ocean Ecology)	Seabed sediment characterisation	Offshore Development Area
Metocean data collection using floating lidar between August 2022 and January 2023	Waves heights and directions	Windfarm Site

8.3.6.1 Numerical Modelling of Swell Waves

33. To investigate swell waves and provide a baseline for prediction of changes due to the Offshore Project across the North Devon World Surfing Reserve, a wave model was run. Wave conditions were simulated using the spectral model MIKE21-SW. The model simulates the growth, decay and transformation of wind-generated waves and swell in offshore and coastal areas. MIKE21-SW is a state-of-the-art numerical tool for prediction and analysis of wave climates in offshore and coastal areas (**Appendix 8.A**).

34. A range of wave conditions representing characteristic 'optimal' surfing waves for the North Devon region were input into the model. The default model parameters and settings were adopted, and no wave model calibration was carried out. This approach is reasonable because the purpose of the wave modelling was to quantify the difference in nearshore wave conditions with and without the Offshore Project.

35. The potential effect of the Offshore Project on significant wave height, peak period and mean wave direction was assessed at seven coastal sites: Saunton Sands, Downend Point, Croyde Beach, Putsborough, Woolacombe, Combesgate, and Lynmouth.

8.3.7 Data Limitations

36. The key data limitations with the baseline data and their ability to materially influence the outcome of the EIA are:

- Due to the large amount of data that has been collected during the bespoke geophysical and benthic surveys, as well as other available data (**Table 8.11** and **Table 8.12**), there is a good understanding of the existing marine physical processes environment in the Offshore Development Area and its adjacent areas.

- Regional tidal current conditions have been extracted from BERR (2008). Bespoke tidal current data have not been collected as part of the assessment. The regional current data is considered appropriate as a baseline for the ES due to the likelihood of temporal consistency in conditions across the area. The data used is also proportionate to both the approach to assessment (conceptual evidence-based, **Section 8.3.2**) and the potential effects.
- Data on ambient suspended sediment concentrations for the Offshore Project are not available, and this assessment is solely based on the spatial distribution data of Cefas (2016) between 1998 and 2015. This long-term average data is considered proportionate to the potential effects of physical processes.

8.3.8 Scope

37. Upon consideration of the baseline environment, the project description outlined in **Chapter 5: Project Description**, and Scoping Opinion (Case reference: EIA/2022/00002), potential construction and operational effects upon marine geology, oceanography and physical processes are "Scoped in" or "Scoped out". These effects are outlined, together with a justification for why they are, or are not, considered further, in **Table 8.13** and **Table 8.14**, respectively.

Table 8.13 Summary of effects scoped in relating to marine geology, oceanography and physical processes

Potential Impact	Justification for scoping in
Construction impacts on the form and function of the coast due to buried cable installation	The presence of a trench (or trenchless technology infrastructure) at the landfall (up to MHWS) could cause changes in longshore beach sediment transport, and potentially trap sediment.
Construction impacts on the form and function of the subtidal seabed due to buried cable, mooring system, and Offshore Substation Platform installation	Excavating sediment to create the trenches for cable burial and seabed preparation for the mooring system and Offshore Substation Platform foundations could result in changes to sediment transport processes. Sand wave removal could potentially disturb the natural form and function of the sand waves, and interfere with sediment transport pathways that supply sediment to other areas of the seabed.
Construction impacts on suspended sediment concentrations and deposition due to buried cable, mooring	Disturbance of the seabed due to the installation activities for the buried cables, mooring system and Offshore Substation Platform could potentially release sediment into the water column resulting in increased

Potential Impact	Justification for scoping in
system, and Offshore Substation Platform installation	suspended sediment concentrations and changes to seabed levels from deposition.
Construction impacts caused by indentations on the seabed due to installation vessels	Vessels that utilise jack-up legs or several anchors to hold station during installation of the anchors and cable infrastructure could directly impact the seabed through creation of indentations.
Operational impacts on waves and tidal currents due to the physical presence of the infrastructure	The physical presence of offshore infrastructure and substructure above the seabed could result in changes to waves and tidal currents due to physical blockage effects.
Operational impacts on bedload sediment transport and seabed morphological change due to the physical presence of the infrastructure	The physical presence of offshore infrastructure and substructure on the seabed could result in changes to bedload sediment transport due to changes in waves and tidal currents.
Operational impacts on bedload sediment transport and seabed morphological change due to cable protection	Cable protection could interrupt bedload sediment transport processes across the seabed.
Operational impacts on suspended sediment concentrations and transport due to the physical presence of the infrastructure	The scouring effects of the catenary action of the mooring lines and around the foundations of the mooring anchors could re-suspend seabed sediments into the water column resulting in increased suspended sediment concentrations.

Table 8.14 Summary of effects relating to marine geology, oceanography and physical processes that are scoped out

Potential Effect	Justification for scoping out
Construction (and decommissioning) impacts on the physical processes regime (waves and tidal currents)	Whilst there is potential for the physical presence of construction plant and offshore infrastructure to influence the hydrodynamic regime, this effect would increase incrementally as the Windfarm is constructed with the greatest potential effects resulting from the physical presence of the completed windfarm. This effect is therefore covered under 'Potential effects during operation and maintenance', below, and is scoped out of further consideration in relation to the construction phase.
Operational impacts caused by indentations on the seabed	Operation of the Windfarm will not entail works operating from the seabed and so this potential impact only relates to construction and decommissioning. Hence, these effects are scoped out of further consideration in relation to the operational phase.

8.3.9 Consultation

38. Consultation has been a key part of the development of the Offshore Project. Consultation regarding marine geology, oceanography and physical processes has been conducted throughout the EIA. An overview of the project consultation process is presented within **Chapter 7: Consultation**.

39. A summary of the key issues raised during consultation specific to marine geology, oceanography and physical processes is outlined below in **Table 8.15**, together with how these issues have been considered in the production of this ES.

Table 8.15 Consultation responses

Consultee	Date, Document, Forum	Comment	Where addressed in the ES
MMO	Scoping Opinion	Scoping Report Para 197. Applicant's proposed matter to scope out: Effects on hydrodynamic regime (waves and tidal currents) during construction and decommissioning. The Applicant states "Whilst there is potential for the physical presence of construction plant and offshore infrastructure to impact upon the hydrodynamic regime, this impact would increase incrementally as the Windfarm is constructed with the greatest potential impacts resulting from the physical presence of the completed windfarm. This impact is therefore covered under 'Potential impacts during operation and maintenance'. On the basis that this potential impact is assessed within the operation and maintenance phase the MMO is satisfied that this matter can be scoped out for construction.	**Section 8.3.3** and **Table 8.12**. Construction and decommissioning impacts on the physical processes regime (waves and tidal currents) have been scoped out.
MMO	Scoping Opinion	Scoping Report Para 198 and Table 2.4. Applicant's proposed matter to scope out: Effects on bedload sediment transport and sea-bed morphological change - construction phase and decommissioning. The Applicant states "Construction of the Windfarm will not change the geology of the site other than in the case of localised effects associated with anchor and cable installation. Due to the localised nature of these effects, it is not anticipated that such changes would give rise to significant impacts on sea-bed features, and neither would there be any changes in coastal morphology. Hence, these impacts are scoped out of further consideration in relation to the construction phase. However, further consideration will be given to the potential effects on the form and function of the bedload sediment transport processes due to cable installation. The effect arises as a result of the presence of anchors and chains and so is assessed in the operational phase." On the basis that this potential impact is assessed within the operation and maintenance phase the MMO is satisfied that this matter can be scoped out for construction.	**Section 8.3.4** and **Table 8.12**. Construction (and decommissioning) impacts on bedload sediment transport and seabed morphological change related to construction of the windfarm array have been scoped out.

Consultee	Date, Document, Forum	Comment	Where addressed in the ES
MMO	Scoping Opinion	Scoping Report Para 200. Applicant's proposed matter to scope out: Indentations on the Sea bed due to installation and decommissioning vessels - Operational Phase. On the basis that this matter applies only to construction and decommissioning and will be assessed within the construction phase assessment, the MMO is satisfied that this matter can be scoped out for operation. The MMO is content that this can be scoped out for the operational phase.	**Section 8.3.2** and **Table 8.12**. Operational impacts caused by indentations on the seabed have been scoped out.
MMO	Scoping Opinion	Scoping Report Para 209. Applicant's proposed matter to scope out: Potential transboundary impacts. The Applicant states - "The Project is approximately 130km from any international territory boundary. Given that the likely marine geology, oceanography and physical processes impacts will be restricted to near-field change, coupled with its remote location from any international territory boundary, there would be no pathway for transboundary impacts. It is therefore proposed to scope out transboundary effects on marine geology, oceanography and physical processes." The MMO agrees that this matter can be scoped out of the ES.	**Section 8.9**. Potential transboundary impacts have been scoped out.
MMO	Scoping Opinion	Study area and assessment. The MMO notes that the Scoping Study Area is very large to account for uncertainty surrounding the exact routes of onshore elements of the Proposed Development. The ES should ensure that it is clear where the ongoing assessment work has refined the options and addressed potentially significant effects through design.	The study area is discussed in **Section 8.3.1**.
MMO	Scoping Opinion	Para 194-195 and Table 2.4. Designated Sites. The ES should therefore identify the location of any other relevant statutory or non-statutory sites protected for their geological interest as part of the baseline studies and assess any likely significant effects on all sites identified.	The potential offshore receptors to morphological change are Lundy Island and the Devon coast. The potential to affect their integrity is assessed with respect to changes

Consultee	Date, Document, Forum	Comment	Where addressed in the ES
			in seabed level caused by cable installation (**Section 8.5.1**, **Section 8.5.2**, and **Section 8.5.3**) and interruption to bedload sediment transport by cable protection (**Section 8.6.3**).
MMO	Scoping Opinion	Coastal change and flood risk. Coastal change should be considered with respect to any works in this proposed area (specifically for the siting of the cable landfall, cable route and associated infrastructure). The assessment should include geomorphological uncertainties about the future evolution of the coastline and estuary, as well as any development or future development of intertidal habitats and flood defences, with consideration of the Shoreline Management Plan.	Baseline coastal processes at the landfall (up to MHWS) including historic morphological changes to the beach are considered in **Section 8.4.1**. Potential construction impacts at the landfall (up to MHWS) are considered in **Section 8.5.1**. Potential flood risk impacts are considered in the separate Onshore Project EIA.
MMO	Scoping Opinion	Cable landfall and coastal processes. There is need to consider the potential for cable landfall (and the associated engineering works) to interfere with long-shore and near-shore coastal processes and we recommend that an assessment is made of the potential to temporarily, or	Potential construction impacts at the landfall (up to MHWS) are considered in **Section 8.5.1**.

Consultee	Date, Document, Forum	Comment	Where addressed in the ES
		potentially permanently, disrupt sediment movements and hydrodynamics during the works.	
MMO	Scoping Opinion	Offshore assessment. Offshore Assessments need to consider the potential changes to the hydrodynamics and sedimentary processes and the potential resultant changes to geomorphological processes acting to maintain the coastline. Impact types to be considered include changes to flows and implications for sediment transport, and changes to the wave regime.	Potential operational impacts on waves, tidal currents and sediment transport are presented in **Section 8.6.1**, **Section 8.6.3** and **Section 8.6.4**.
North Devon Surfing Reserve and the local surfing community	Meeting, December 2022	A strong sentiment from all in attendance that renewable energy is essential to combat climate change and support energy security. However, questions were raised in relation to: • “Why is the chosen route preferred? Wouldn’t it make more sense to route up the estuary, which is closer to the substation location? • What work has been done to provide assurances that the project will not significantly impact wave environment? • How will the cable to brought to shore?”	**Chapter 4: Site Selection and Assessment of Alternatives** details the process that was undertaken to identify the preferred Landfall location. Wave modelling has been undertaken and found there to be no impact to key surfing locations along the Devon coast (see **Appendix 8.A: Wave Modelling Report**). **Chapter 5: Project Description** outlines the trenchless or open trenching techniques used to make landfall.

8.4 Existing Environment

40. This section describes the existing environment in relation to marine geology, oceanography and physical processes associated with the Offshore Project.

8.4.1 Current baseline

8.4.1.1 Bathymetry and bedforms

41. For bathymetry, Wood (2022) divided the Offshore Development Area into six areas for interpretation purposes (**Figure 8.2**).

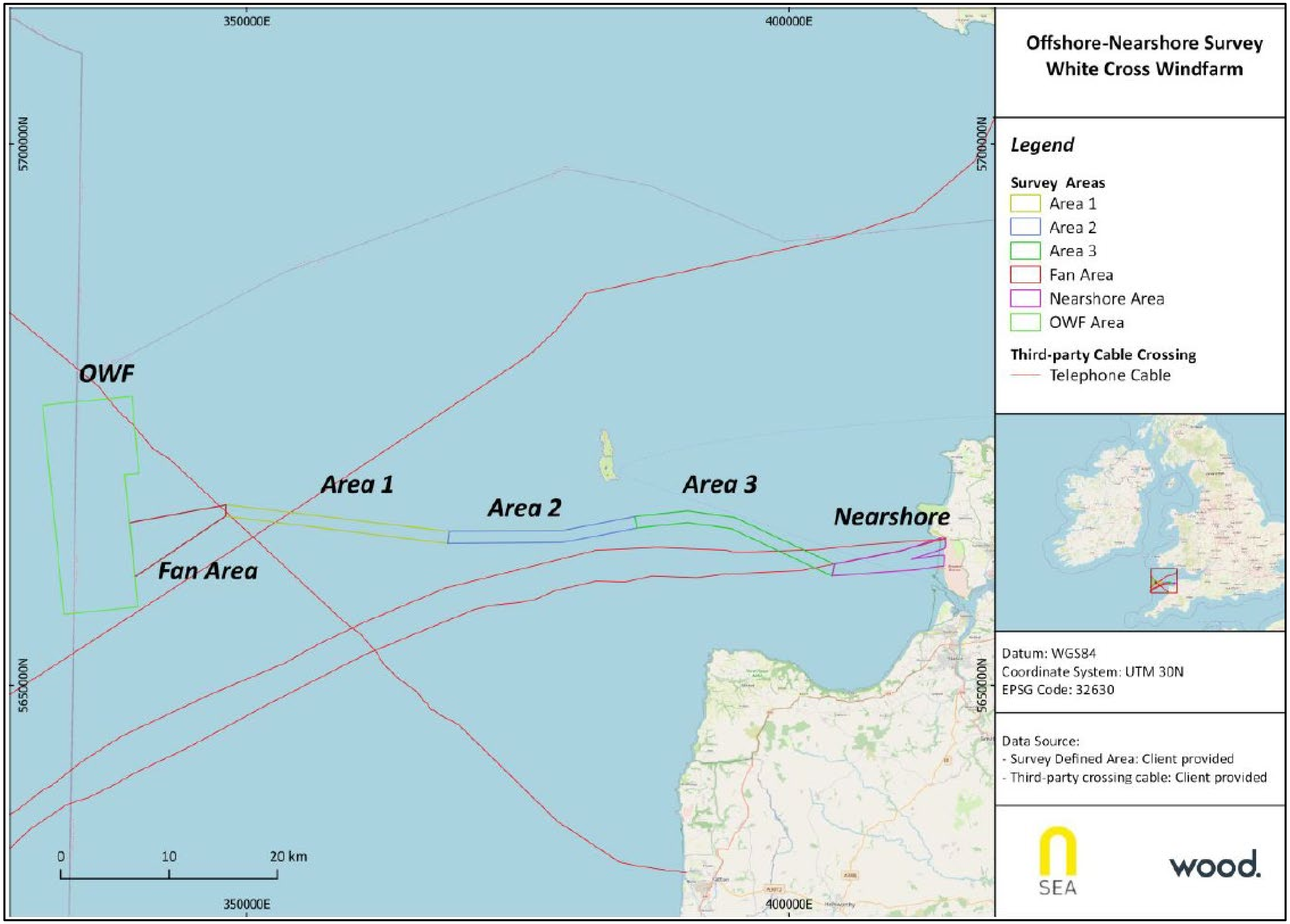
42. The minimum and maximum depths across each of these areas are summarised in **Table 8.16**. Details of the bathymetry in each area can be found in **Appendix 8.A**.

Table 8.16 Summary of bathymetries across the six areas defined by Wood (2022)

Area	Maximum depth (m LAT)	Minimum depth (m LAT)	Average depth (m LAT)
Nearshore	-25.1	+3.7	-13.1
Area 3	-52.6	-21.0	-42.7
Area 2	-59.2	-50.4	-54.6
Area 1	-68.9	-58.8	-64.7
Fan Area	-75.2	-67.6	-70.1
OWF	-78.1	-69.1	-71.9

43. The primary bedforms as defined by Wood (2022) are in the sand areas and comprise sand ripples (36.7% or 90km^2 of the surveyed area) and megaripples (2.7% or 7km^2 of the surveyed area).

Figure 8.2 Division of the Offshore Development Area (Wood, 2022)

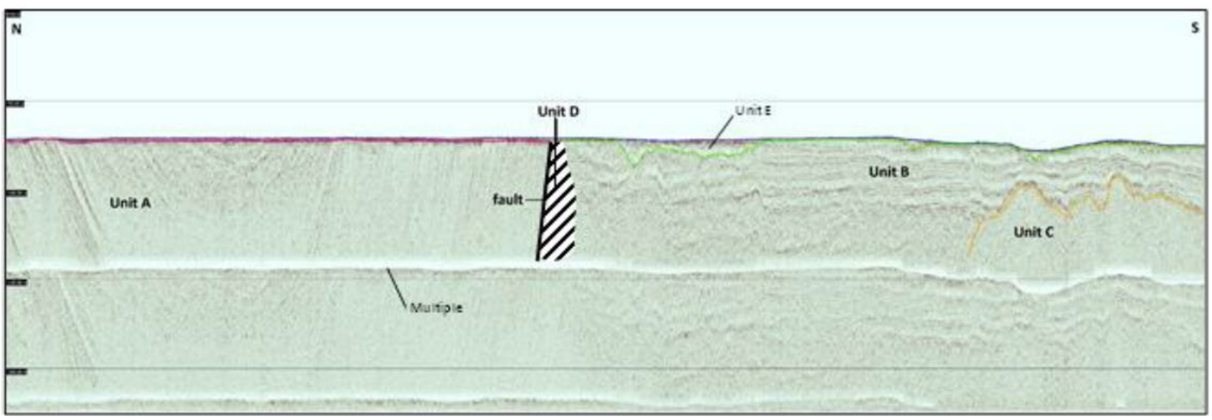


8.4.1.2 Geology

44. Wood (2022) identified five geological units under the Windfarm Site. These are (**Figure 8.3**):

- Unit A: The top of a major west plunging syncline which makes up the northern part of the Windfarm Site. The top of Unit A is an erosional surface, overlain by the Holocene sediments of Unit E
- Unit B: Sub-horizontal deposits which increase in thickness towards the west underlain by Unit C. This unit is covered by the Holocene sediments of Unit E.
- Unit C: Underlies Unit B and could be related to Unit A, although this is not proven by the profiles
- Unit D: Represents a high deformation zone probably related to faulting. No clear strata can be defined, and it separates the northern Unit A from the southern Units B and C. Unit D is covered by the Holocene sediments of Unit E
- Unit E: Represents the Holocene deposits, which cover the whole of the Windfarm Site

Figure 8.3 North-south schematic of the main geological units across the Windfarm Site (profile length is 20km) (Wood, 2022)



45. Beneath the Offshore Export Cable Corridor, Wood (2022) identified two of the geological units that occur beneath the Windfarm Site. These are Unit B overlain by Unit E, which varies from 0 to 10m thick. Because of limited penetration it was not possible to get a continuous interpretation of the boundary between the two units along the whole Offshore Export Cable Corridor.

46. Details of the shallow geology in each area can be found in **Appendix 8.A**.

8.4.1.3 Water levels

47. The Landfall (up to MHWS) is in an area subject to a macrotidal regime, with a mean spring tidal range of about 8.3m at Ilfracombe (the nearest point of analysis to the Landfall).

48. The Outer Bristol Channel can be susceptible to storm surges, and water levels across the Offshore Development Area could become elevated several metres by these meteorological effects. The coast can also be subject to significant surge activity which may raise water levels above those of the predicted tide. Predicted extreme water levels can exceed predicted mean high-water spring levels. Environment Agency (2018) calculated one in one-year water levels of 5.43m at Ilfracombe, about 0.9m above MHWS. The 1 in 50-year water levels are predicted to be 5.85m, about 1.3m above MHWS.

8.4.1.4 Tidal Currents

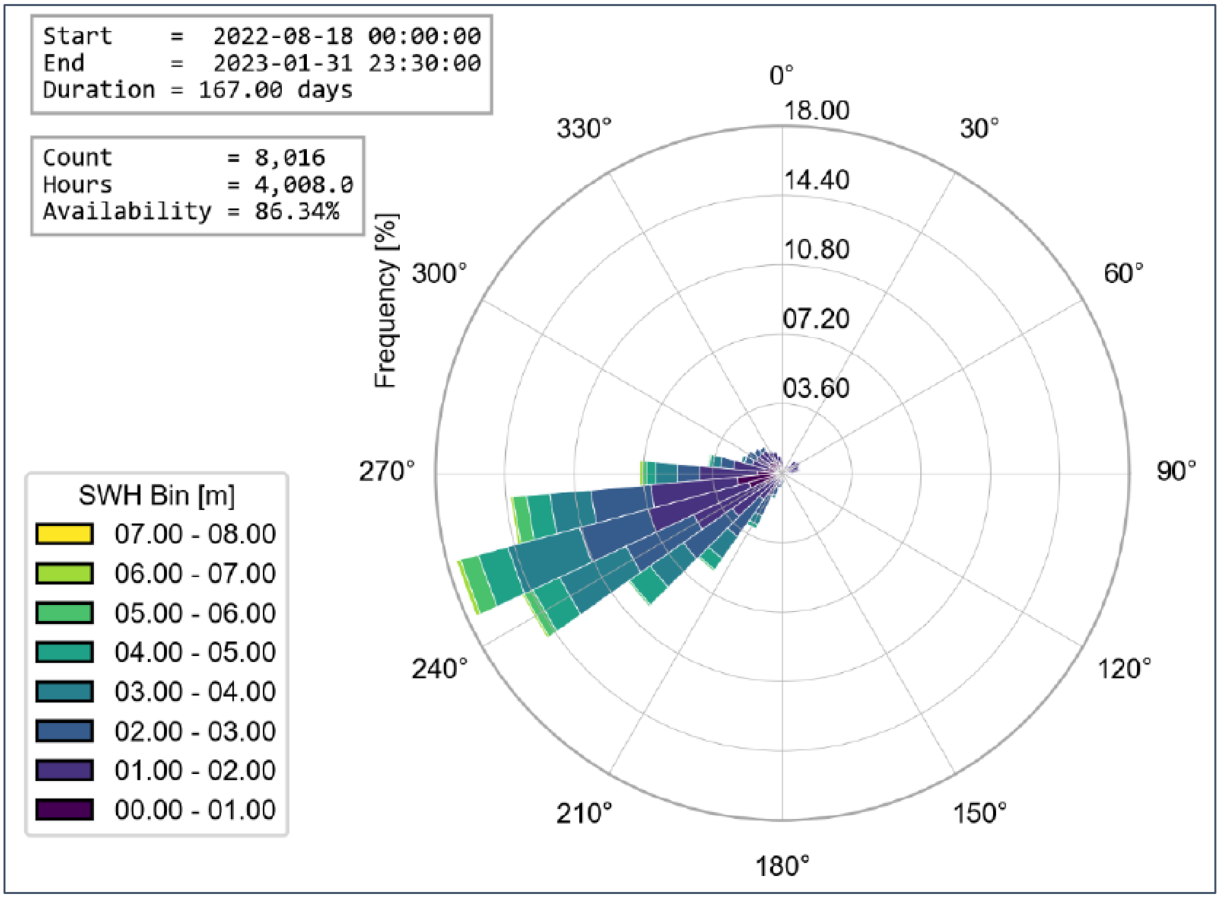
49. Spring tide current flows across the Windfarm Site are directed approximately east-northeast on a flood tide and west-southwest on an ebb tide. BERR (2008) modelled peak flows for mean spring tides of between approximately 0.6m/s and 0.65m/s at the Windfarm Site. Higher velocities (1.3-1.4m/s) occur across the Offshore Export Cable Corridor where the tidal currents pass between Lundy Island and Hartland Point. Closer to the coast, current velocities reduce again and are approximately parallel to the shore.

8.4.1.5 Waves

50. The most frequent waves across the Windfarm Site are from the southwest to south-southwest sector. BERR (2008) described annual mean significant wave heights of 1.9m to 2.0m. Along the Offshore Export Cable Corridor, annual mean significant wave heights reduce to around 1.2m about 10km from the Landfall (up to MHWS).

51. Wood (2023) reported wave data collected by floating lidar at the Windfarm Site between 18th August 2022 and 31st January 2023. The data describes a mean significant wave height of 2.28m, with a minimum of 0.37m and a maximum of 7.33m (**Figure 8.4**). The predominant direction of wave approach is from the west-southwest.

Figure 8.4 Wave rose of significant wave heights at the Windfarm Site between 18th August 2022 and 31st January 2023 (Wood, 2023)



52. Baseline swell conditions across the North Devon World Surfing Reserve can be represented by five scenarios. These are (**Appendix 8.A**):

- average surfing swell from the west
- very clean swell from the west (low directional spread)
- reasonable surfing swell from the west (high directional spread)
- very clean swell from the west-southwest (low directional spread)
- very clean swell from the west-northwest (low directional spread).

53. The modelled average surfing swell from the west is shown in **Figure 8.5** and **Figure 8.6**. Details of the other four scenarios are provided in **Appendix 8.A**).

Figure 8.5 Average surfing swell from the west at mean high water spring tides

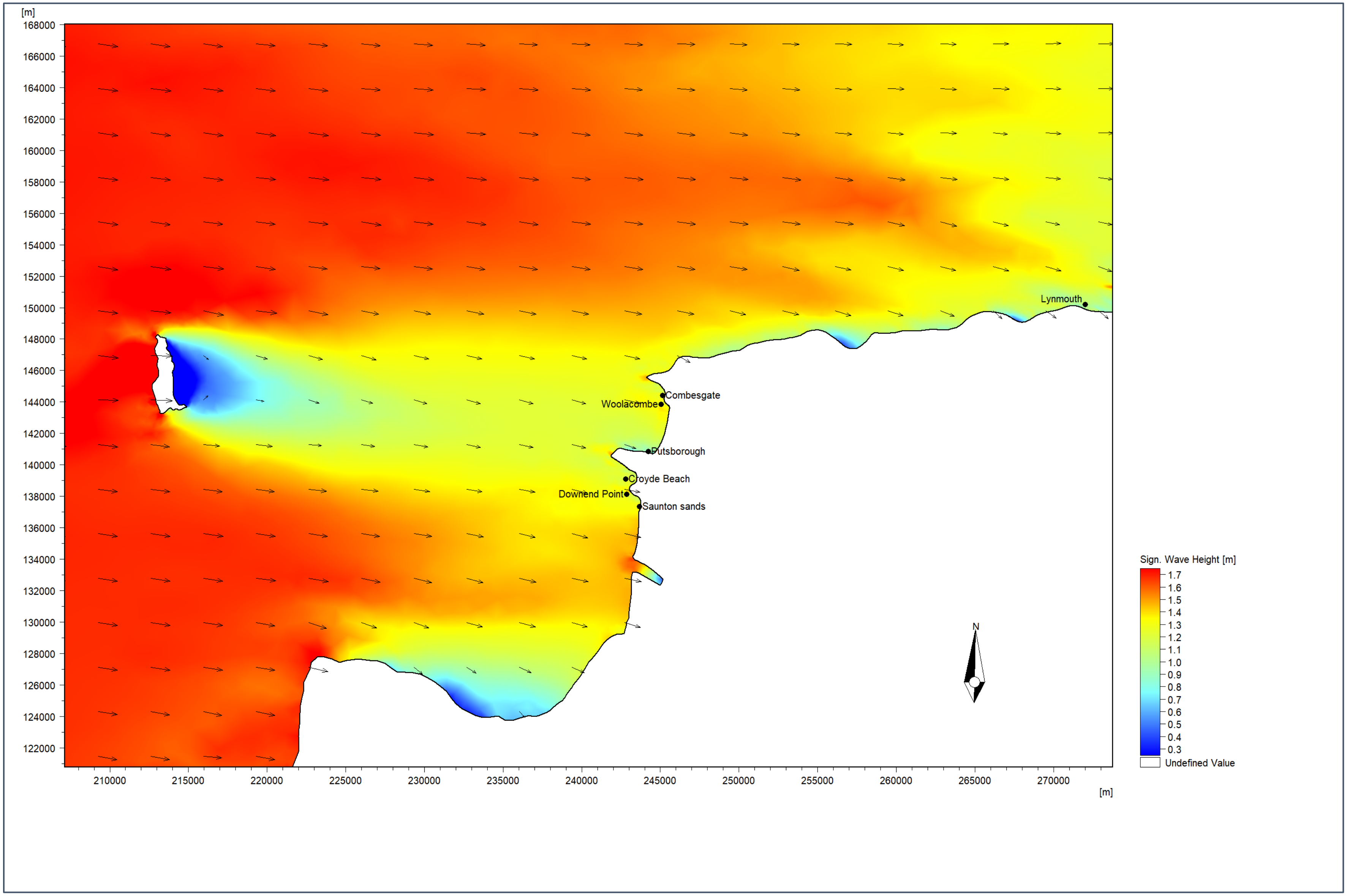
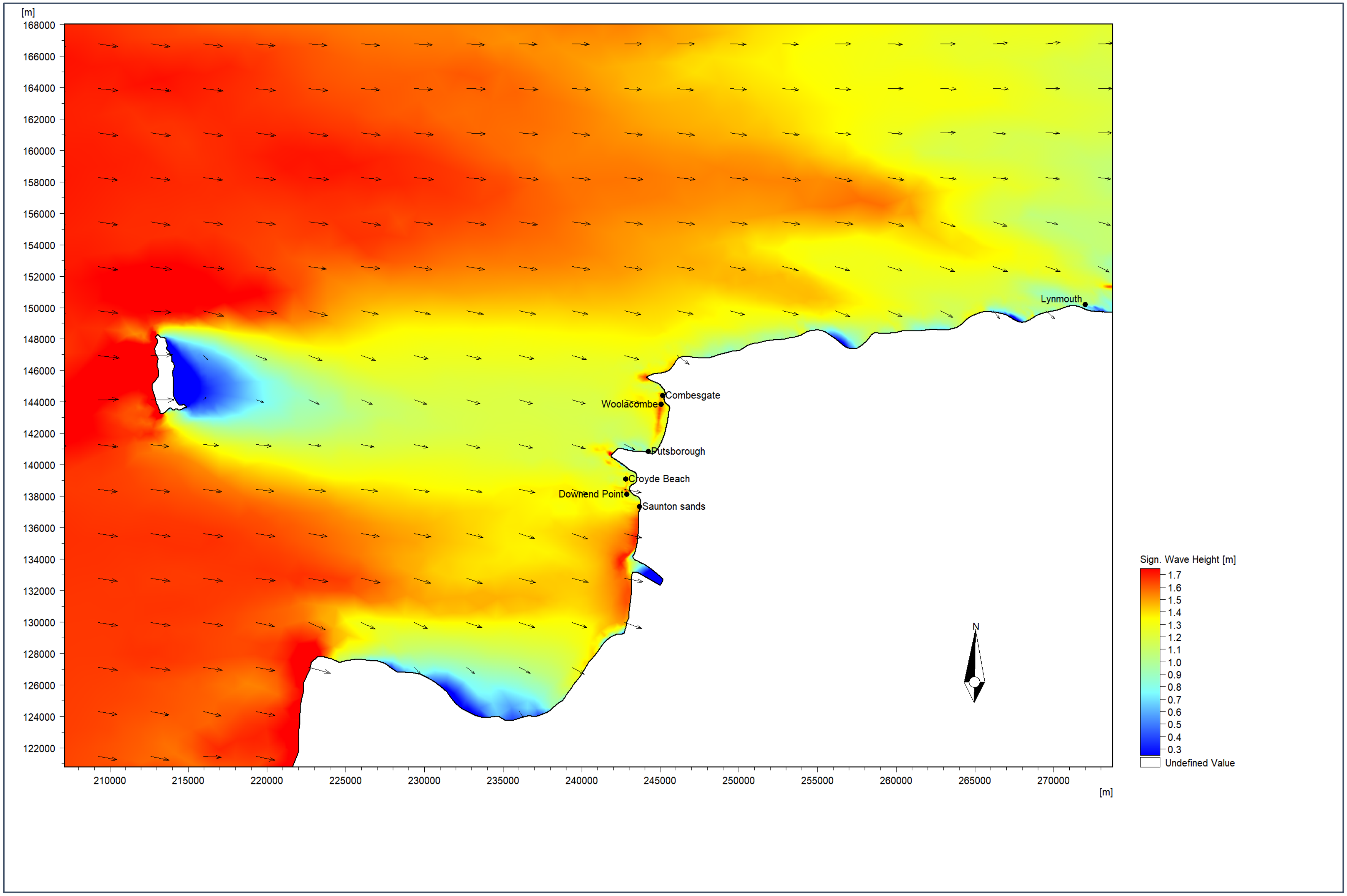


Figure 8.6 Average surfing swell from the west at mean low water spring tides



8.4.1.6 Climate Change and Sea-level Rise

54. Historical data show that the global temperature has risen significantly due to anthropogenic influences since the beginning of the 20th Century, and predictions are for an accelerated rise, the magnitude of which is dependent on the magnitude of future emissions of greenhouse gases and aerosols.

55. According to UKCP18 which draws on the Intergovernmental Panel on Climate Change (IPCCs) Fifth Assessment of Climate Change (Church *et al.*, 2013), it is likely (IPCC terminology meaning greater than 66% probability) that the rate of global sea-level rise has increased since the early 20th Century. It is very likely (IPCC terminology meaning greater than 90% probability) that the global mean rate was 1.7mm/year (1.5 to 1.9mm/year) between 1901 and 2010 for a total sea-level rise of 0.19m (0.17 to 0.21m). The average long-term trend for the UK is estimated as 1.4mm/year which is slightly lower than the global 1.7mm/year. Between 1993 and 2010, the rate was very likely (IPCC terminology) higher at 3.2 mm/year (2.8 to 3.6mm/year), and this is the historic rate used in this analysis.

56. The rate of global mean sea-level rise during the 21st Century is likely to exceed the rate observed between 1993 and 2010. Church *et al*. (2013) developed projections of global sea-level rise for four emissions scenarios of future climate change, called the Representative Concentration Pathways (RCP). In this analysis, the median projection of the worst case emissions scenario (RCP8.5) is used. For RCP8.5, the rise by 2100 is 0.74m (range 0.52 to 0.98m) with a predicted sea-level rise rate during 2081–2100 of 8 to 16mm/year.

57. Although the indicative design lifetime of the Offshore Project is a minimum of 25 years, the offshore infrastructure is set far enough away from the coast, that this rise in sea level will not change significantly through the design lifetime of the Offshore Project.

58. One of the most important long-term implications of climate change is the physical response of the coast to future sea-level rise. Predicting coastal erosion rates is critical to forecasting future problem areas. It is likely that the future erosion rate of the coast at the Landfall (up to MHWS) will be affected by the higher rates of sea-level rise than historically. Higher baseline water levels would result in a greater occurrence of waves impacting the dunes of Braunton Burrows, increasing their susceptibility to erosion.

8.4.1.7 Seabed Sediment Distribution

59. Mapping of sediment types was completed by Institute of Geological Sciences (1983). The data shows that the Windfarm Site is dominated by sand. Across the Offshore Export Cable Corridor, seabed sediments are predominantly gravelly sand and sandy gravel with sand closer to the coast. Areas of exposed bedrock appear south of Lundy Island.

60. Wood (2022) presented the results of a geophysical survey describing the seabed sediments and features in the six defined areas (**Figure 8.2**), along the Offshore Export Cable Corridor and across the Windfarm Site. Further details of seabed sediment distribution in each area can be found in **Appendix 8.B**:

- Nearshore. Here the seabed is flat and featureless and composed of sand
- Area 3. In the eastern part, the seabed continues from the nearshore as flat and featureless and composed of sand. Further west, the sand forms a shallow veneer covering sub-cropping bedrock, and can be sculpted into bedforms of various sizes. Local parts are covered in megaripples with wavelengths of 5m to 12m and crests oriented north-northwest to south-southeast. In places the megaripples are superimposed on larger-scale, similarly oriented, sand waves (wavelengths between 60m and 120m). Towards the western edge of Area 3, the sand thins to be replaced by exposures of bedrock or bedrock with a thin sand veneer
- Area 2. The eastern part is a continuation of the western edge of Area 3; bedrock or bedrock with a thin sand veneer. Further west, the bedrock is covered by sand, which is generally flat and featureless, with occasional megaripple patches. The megaripples are generally smaller than in Area 3, with wavelengths between 1m and 3m and crests oriented north-northwest to south-southeast
- Area 1. Most of Area 1 is covered with sand. In the eastern half, the sand is megarippled and the Offshore Export Cable Corridor contains occasional patches of clay and coarser sediments, while megarippled sand dominates the western half. These megaripples have wavelengths between 4m and 16m, with crests oriented north-northwest to south-southeast and north-south
- Fan Area. The majority of the area is covered with sand with occasional patches of coarse sediment. The seabed is generally flat and featureless except for a section of megaripples that continue from Area 1, at the eastern boundary of this area, with wavelengths 6m and 13m, and crests north-northwest to south-southeast

- OWF (Windfarm Site). Most of the site is sand with local variations. The northern part is mostly covered with megaripples with wavelengths approximately 15m to 20m and crests oriented north-south. Elsewhere the sand is featureless.

61. Ocean Ecology (2022) presented the results of a benthic survey characterising the seabed sediments across the Offshore Development Area. Particle size analyses were completed on 134 samples (**Figure 8.7**). Details of the analyses are provided in **Appendix 8.C**.

62. The results show that despite some variation in sediment types between locations, the dominant sediment type is sand. Mud content was highest closer to Landfall (up to MHWS) at ST01 and also high at ST38. Gravel content was low overall but variable along the Offshore Export Cable Corridor with a few locations containing greater than 50% gravel (ST03, ST07, ST09, ST10, ST102, ST118, and ST123). Most locations are classified as sand and muddy sand, with some sandy gravel or gravelly sand (coarse sediment) and occasional muddy sandy gravel and gravelly muddy sand (mixed sediment) (**Figure 8.7**).

63. The percentage contribution of gravel (greater than 2mm), sand (0.063mm to 2mm), and mud (less than 0.063mmm) at each location are presented in **Figure 8.8**. Sand is the main sediment fraction present at most locations. The mean proportion of sand across all locations is 85%, with the mean mud and gravel contents of 6% and 9%, respectively. Sand content was greatest at ST078 and lowest at ST09.

64. The mean particle size at the sampling locations ranged from 0.035mm at ST01 to 5.6mm at ST123 (**Figure 8.9**). Approximately 63% of samples had a mean particle size in the fine sand range (0.125-0.25mm) with 12% in the medium sand range (0.25-0.5mm). Only 2% of the samples had a mean particle size less than 0.125mm (very fine sand and finer) whereas 23% were greater than 0.55m (coarse sand and coarser).

8.4.1.8 Suspended Sediment Concentrations

65. Cefas (2016) mapped the spatial distribution of average annual suspended sediment concentrations across the UK continental shelf between 1998 and 2015 and found that the Windfarm Site is characterised by values lower than 5mg/l. Towards the coast, along the Offshore Export Cable Corridor, concentrations increase to less than 15mg/l.

Figure 8.7 Textural group classification at each sampling location across the Offshore Development Area (Ocean Ecology, 2022)

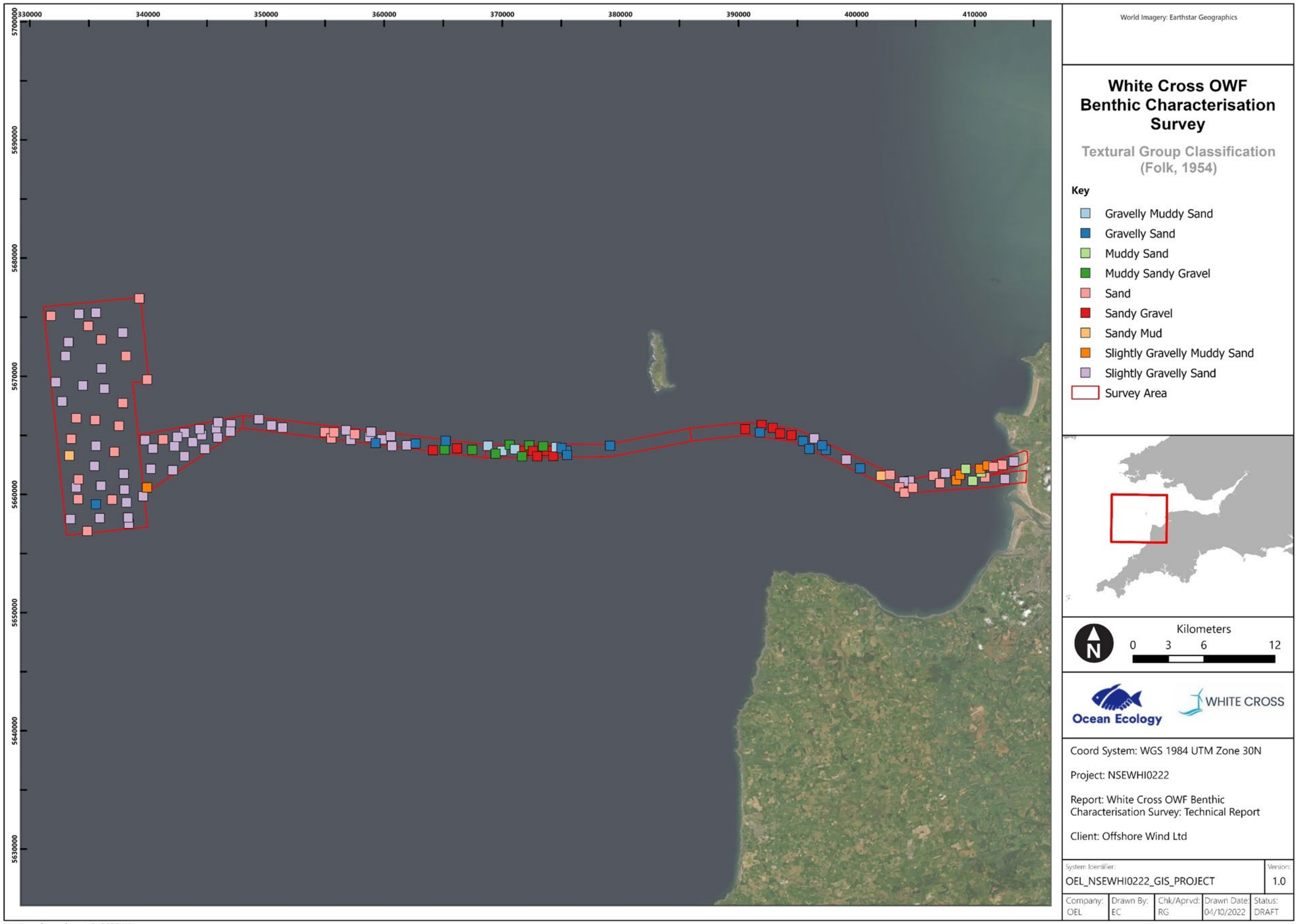


Figure 8.8 Percentage volume of sand, gravel and mud at each sampling location across the Offshore Development Area (Ocean Ecology, 2022)

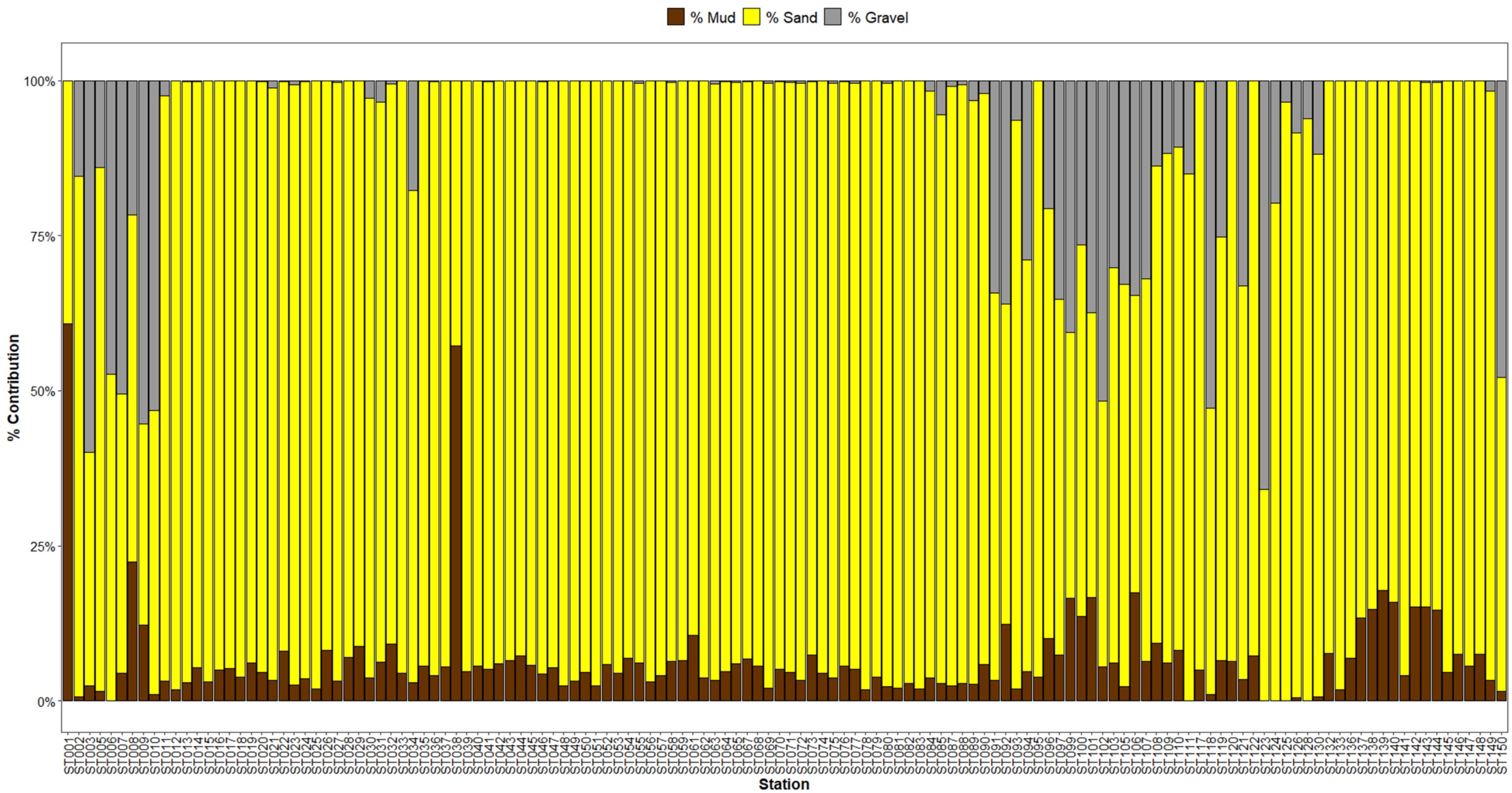
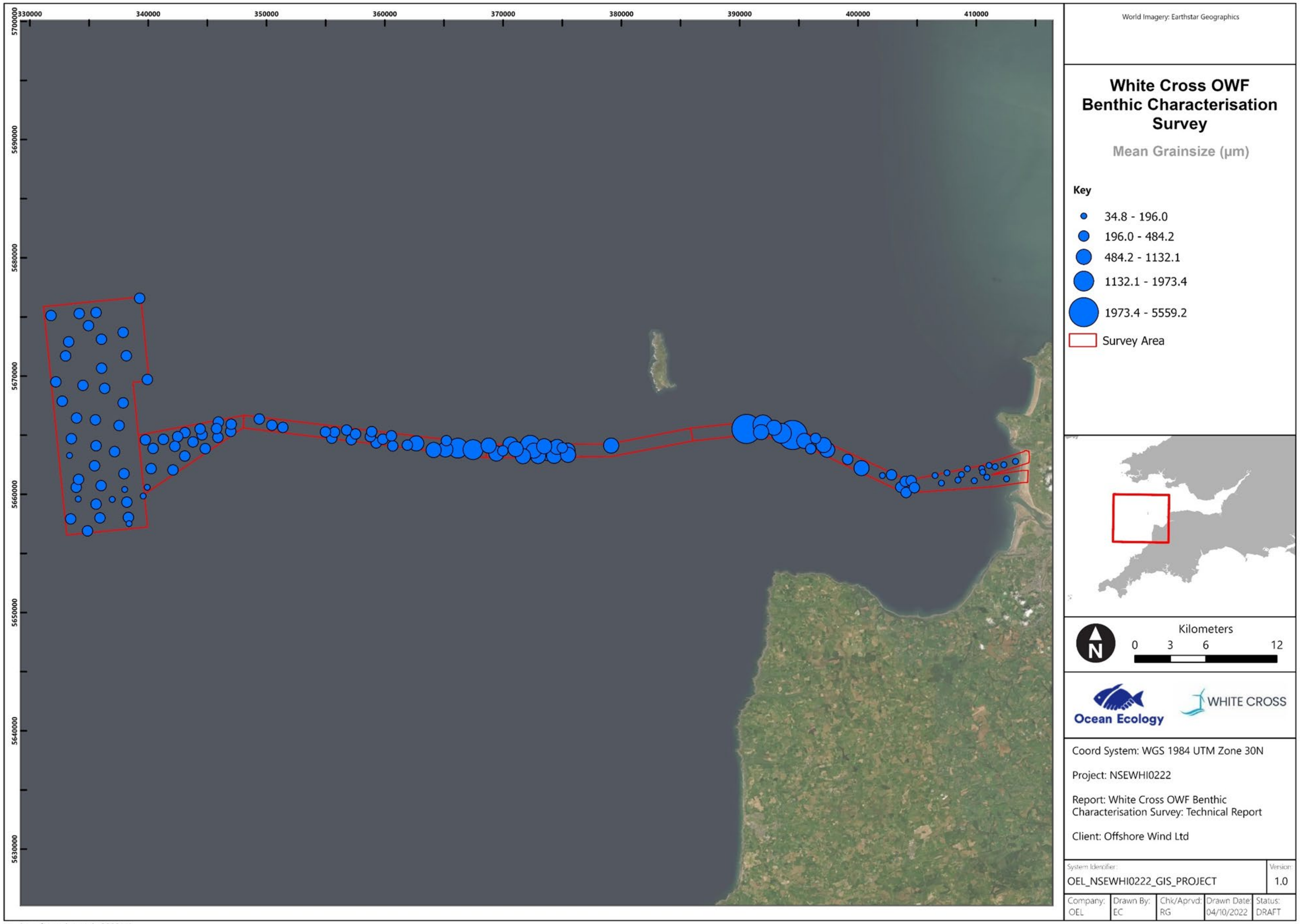


Figure 8.9 Mean particle size (in micrometres) at each sampling location across the Offshore Development Area (Ocean Ecology, 2022)



8.4.1.9 Coastal Processes at the Landfall (up to MHWS)

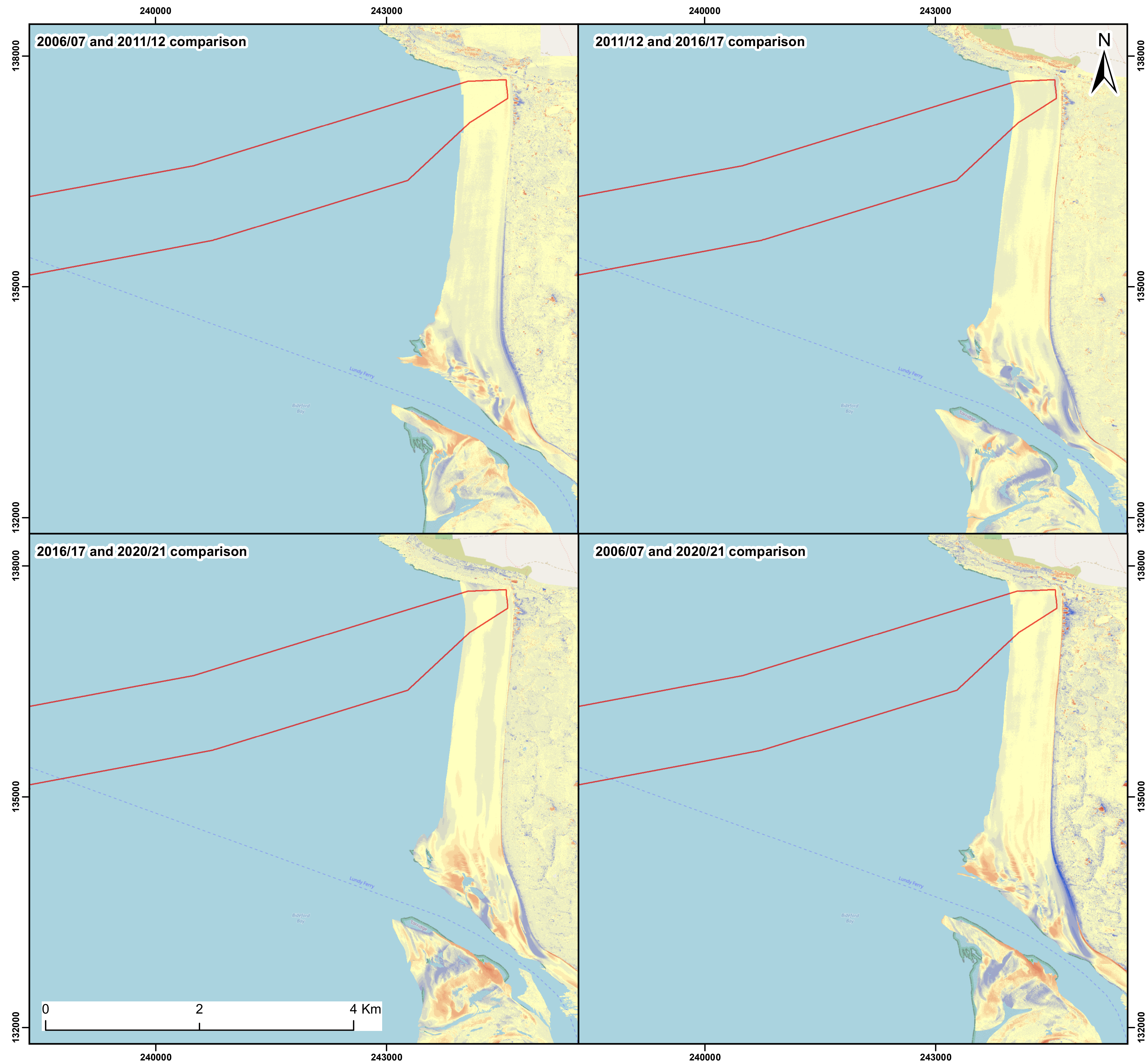
66. The export cable will make Landfall (up to MHWS) at the northern end of Saunton Sands fronting the car park where the coast is dominated by a wide sand beach and the extensive dune system of Braunton Burrows. The beach-dune system extends southwards approximately 5km from the resistant cliff headland of Saunton Down (immediately north of the Landfall) into the mouth of the Taw-Torridge Estuary.

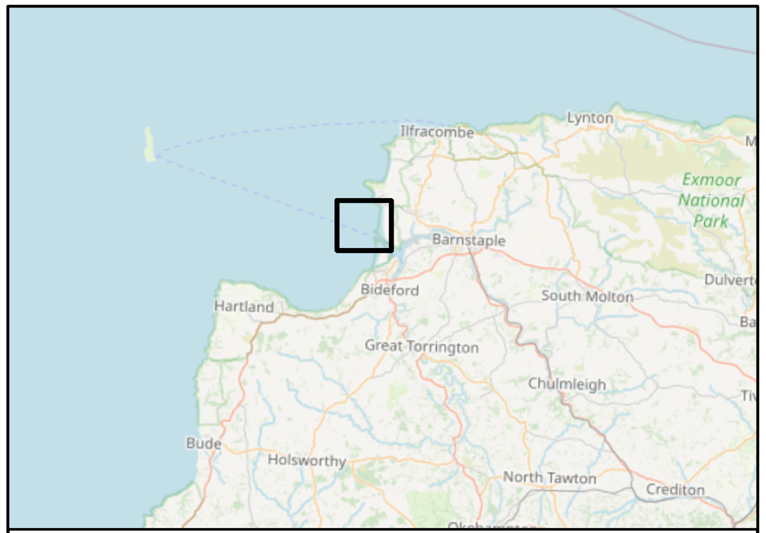
67. Lidar elevation data captured in 2006/07, 2011/12, 2016/17 and 2020/21 provides a time series that is analysed here for historic changes to Saunton Sands over the past 14 years. Comparisons of the 2006/07 and 2011/12 data, 2011/12 and 2016/17 data, 2016/17 and 2020/21 data, and 2006/07 and 2020/21 data are presented in **Figure 8.10**. Comparisons of the same data at the Landfall (up to MHWS) are presented in **Figure 8.11**.

68. Between 2006/07 and 2011/12, Saunton Sands was predominantly erosional (up to 0.5m over the five-year period), with a higher rate (up to 0.75m) at the top of the beach at the Landfall (up to MHWS) (**Figure 8.10** and **Figure 8.11**). Between 2011/12 and 2016/17, the beach was predominantly accretional, up to 0.5m (0.5m - 0.75m at the Landfall) with small areas of erosion. A mix of accretion and erosion took place between 2016/17 and 2020/21, with the greatest erosion at the southern end adjacent to the Taw-Torridge Estuary. Overall, between 2006/07 and 2020/21, Saunton Sands, including the Landfall (up to MHWS) has eroded between 0m and 0.5m over the 14-year period (0-36mm/year).

8.4.2 Do Nothing Scenario

69. The Marine Works (EIA) (Amendment) Regulations 2017 require that "*an outline of the likely evolution thereof without implementation of the development as far as natural changes from the baseline scenario can be assessed with reasonable effort on the basis of the availability of environmental information and scientific knowledge*" is included within the ES (EIA Regulations, Schedule 4, Paragraph 3). From the point of assessment, over the course of the development and operational lifetime of the Offshore Project (operational lifetime anticipated to be a minimum of 25 years), long-term trends mean that the condition of the baseline environment is expected to evolve. This section provides a qualitative description of the evolution of the baseline environment, on the assumption that the Offshore Project is not constructed, using available information and scientific knowledge of marine geology, oceanography and physical processes.





Legend:

Offshore Development Area

LiDAR comparison - Change in elevation (m)

Gain
- > 6
- 5.01 - 6
- 4.01 - 5
- 3.01 - 4
- 2.01 - 3
- 1.01 - 2
- 0.76 - 1
- 0.51 - 0.75
- 0.26 - 0.5
- 0.01 - 0.25

Loss
- -0.24 - 0
- -0.49 - -0.25
- -0.74 - -0.5
- -0.99 - -0.75
- -1.99 - -1
- -2.99 - -2
- -3.99 - -3
- -4.99 - -4
- -5.99 - -5
- -6.99 - -6
- < -7

Client: Offshore Wind Ltd.

Project: White Cross Offshore Windfarm

Title:

Historic changes to Saunton Sands between 2006/07, 2011/12, 2016/17 and 2020/21

Figure: 8.10 | Drawing No: PC2978-RHD-ZZ-XX-DR-Z-0462

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P03	09/03/2023	GC	DB	A3	1:50,000
P02	03/03/2022	AB	DB	A3	1:50,000

Co-ordinate system: British National Grid

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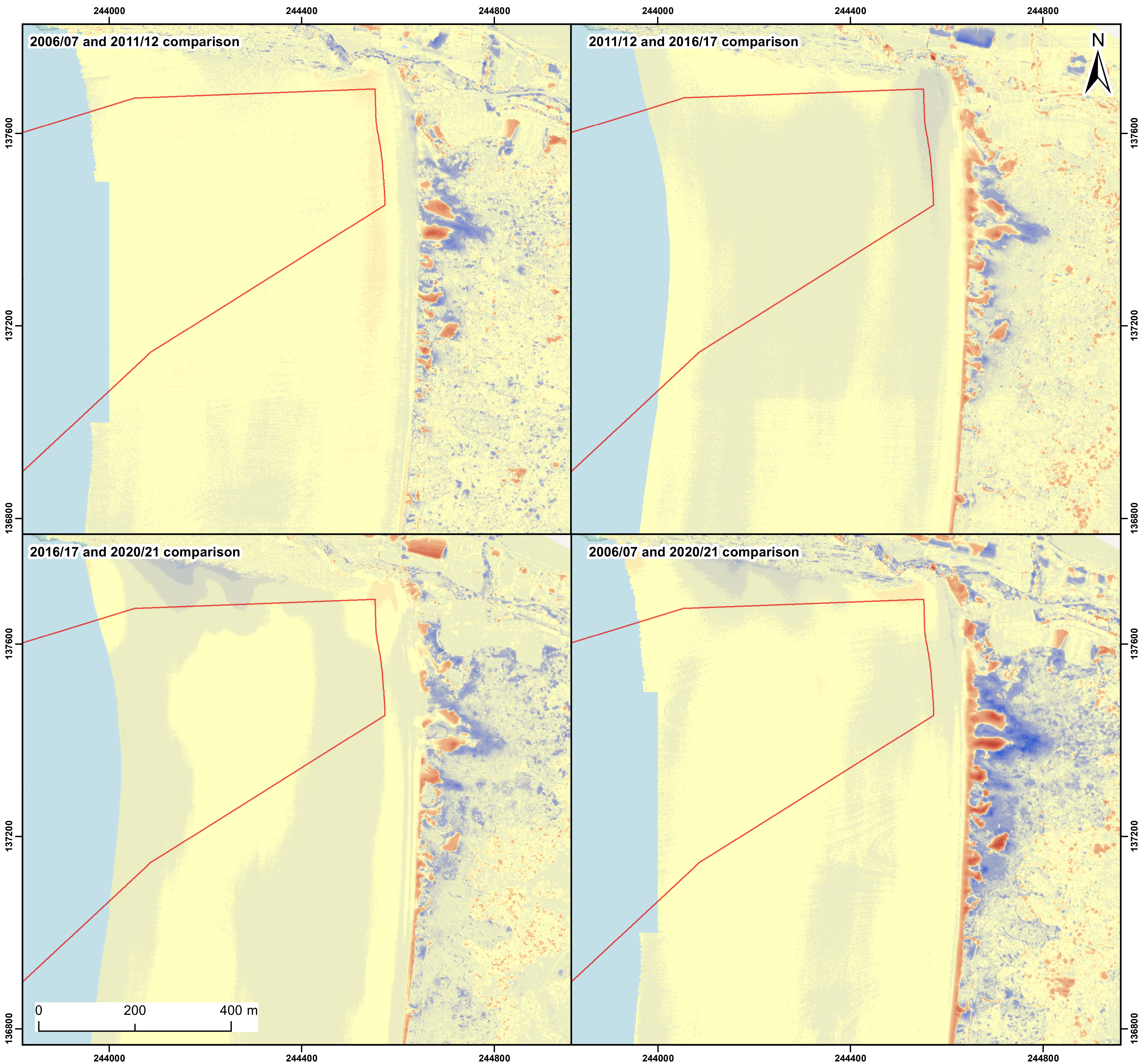

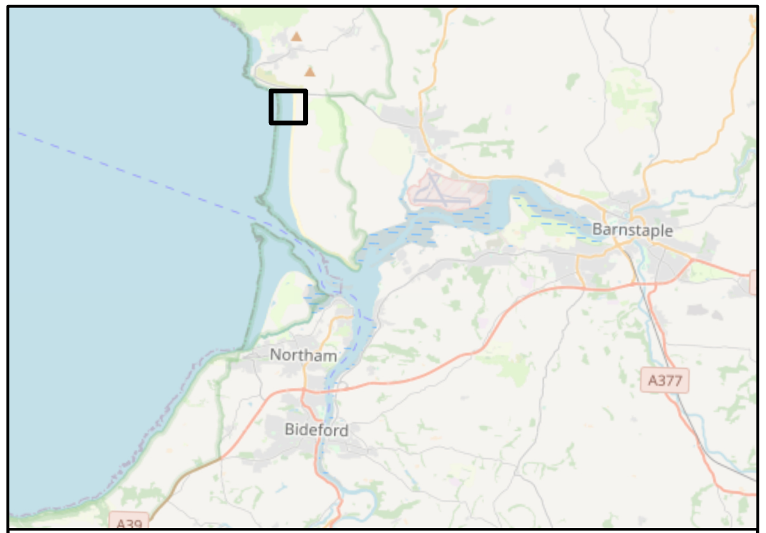

Legend:

Offshore Development Area

LiDAR comparison - Change in elevation (m)

Gain
- > 6
- 5.01 - 6
- 4.01 - 5
- 3.01 - 4
- 2.01 - 3
- 1.01 - 2
- 0.76 - 1
- 0.51 - 0.75
- 0.26 - 0.5
- 0.01 - 0.25

Loss
- -0.24 - 0
- -0.49 - -0.25
- -0.74 - -0.5
- -0.99 - -0.75
- -1.99 - -1
- -2.99 - -2
- -3.99 - -3
- -4.99 - -4
- -5.99 - -5
- -6.99 - -6
- < -7

Client:	Project:
Offshore Wind Ltd.	White Cross Offshore Windfarm

Title:

Historic changes of the beach at the Landfall between 2006/07, 2011/12, 2016/17 and 2020/21

Figure: 8.11 Drawing No: PC2978-RHD-ZZ-XX-DR-Z-0461

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P03	09/03/2023	GC	DB	A3	1:8,000
P02	03/03/2022	AB	DB	A3	1:8,000

Co-ordinate system: British National Grid

WHITE CROSS

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70. The baseline conditions for marine geology, oceanography and physical processes will continue to be controlled by waves and tidal currents driving changes in sediment transport and then seabed morphology. However, the long-term established performance of these drivers may be affected by environmental changes including climate change driven sea-level rise (see Climate Change and Sea-level Rise section). This will have the greatest effect at the coast where more waves will impinge on the cliffs, potentially increasing their rate of erosion. Climate change will have little impact offshore where landscape-scale changes in water levels (water depths) far outweigh the effect of minor changes due to sea-level rise.

8.5 Potential effects during construction

71. The potential effects to marine geology, oceanography and physical processes within the Offshore Export Cable Corridor during the construction phase, may arise due to direct physical disturbance of the seabed during installation of the cables (or placement of any required rock armour or concrete mattress protection to installed cables or at cable/pipeline crossings). This could be manifest as changes to the form and function of the seabed (geological or geomorphological impact) or increase in suspended sediment concentration in the water column due to trenching/backfilling or placing rock armour or concrete mattress protection onto the seabed. Installation of anchors within the Windfarm Site during the construction phase could disturb seabed sediments that may become entrained within the water column and potentially transported in suspension and ultimately deposited onto the seabed.

8.5.1 Impact 1: Impacts on the form and function of the coast due to buried cable installation

72. As part of the Offshore Export Cable installation process at Landfall (up to MHWS), the worst case is open trenching to bury two cables across the entire width of Saunton Sands. The indicative length and width of the trench across the beach would be 270m and 0.5m, respectively (plan area for two cables of 135m^2). The trench would be excavated to a depth of 1.2m (volume of 162m^3 for two cables) with a mechanical digger over an indicative period of up to 24 hours. This excavated sediment would be backfilled into the trench by mechanical means to re-instate the beach to its original morphology. The landfall activities would cause a temporary short-term cessation of longshore beach sediment transport, due to the presence of the trench and its potential to trap sediment.

73. Assuming the worst case scenario, a trench would be cut across the beach providing an almost continuous barrier to sediment transport for a period of up to two days. The rate of net annual longshore transport specifically at the Landfall (up to MHWS)

has not been established. However, given its location in the immediate lee of Saunton Down and the absence of any distinct longshore-transport driven morphological features, indicates that actual longshore sediment transport rates are low in this area, and so the presence of the trench for such a short period of time would have little effect on beach morphology.

74. One of the main uncertainties in the landfall construction methodology is the depth to which the cables should be buried across the beach. At the landfall (up to MHWS), the beach sand overlies bedrock, but the depth to the bedrock is not known. It is important to define the depth of burial, so that over the design lifetime of the cables (minimum 25 year), the risk of exposure is reduced if beach levels lower (potentially because of sea-level rise) into the future. A Cable Burial Risk Assessment will be completed to accurately define the preferred burial depth to mitigate future exposure.

8.5.1.1 Sensitivity, magnitude of impact and significance of the effect

75. Due to the short-term nature of the construction programme and the long-term (14 years) low rates of vertical change of the beach at the Landfall (up to MHWS) (0-36mm/year) means that changes to the beach would be low and temporary. After installation of the cables, the trench would be backfilled, returning the beach to its original morphology. The magnitude of impact is therefore considered **negligible**.

76. Importantly, the Devon coast overlaps the route for the Offshore Export Cable Corridor and the Landfall (up to MHWS). The sensitivity and value of this receptor is presented in **Table 8.17**.

Table 8.17 Sensitivity and value assessment of the Devon coast

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Devon coast	Negligible	Negligible	Negligible	High	Negligible

77. The return of the beach to its pre-construction morphology means that short-term changes in the form and function of the coast arising from cable installation would not be significant. Hence, the overall significance of the effect under a worst case scenario on the identified morphological receptor is deemed **negligible adverse**. This effect reduces to **no significant effect** upon cessation of the works and the restoration of the beach to its former profile.

8.5.2 Impact 2: Impacts on the form and function of the subtidal seabed due to buried cable, mooring system, and Offshore Substation Platform installation

78. Offshore from the Landfall (up to MHWS) into the subtidal zone, the Offshore Export Cable Corridor predominantly passes through areas of sand (with megaripples in many places and some sand waves) and the cables would continue to be mainly buried in trenches. Here, cable burial would disturb a 25m-width of seabed over a maximum length of 93.6km. Burial of two cables would displace a volume of 1,684,800m^3 of sediment assuming 3m-wide, 3m-deep excavations. Burial of the inter-array cables would displace a volume of 267,840m^3 of sediment (from a 29.8km long, 3m deep, and 3m wide trench).

79. Like the landfall (up to MHWS), the excavated sediment would be backfilled into the trenches to re-instate the seabed close to its original morphology. This activity would result in some localised and short-term disturbance, but there would be no long-term effect on sediment transport processes.

80. Additional seabed preparation of 11,171m^3 would be required for construction of the mooring system and the Offshore Substation Platform.

81. In some areas, the cables would pass through sand wave fields that require (partial) levelling before installation. Sand wave removal could potentially disturb the natural form and function of the sand waves and interfere with sediment transport pathways that supply sediment to other areas of the seabed. Within the Offshore Export Cable Corridor, sand wave levelling is estimated to require 5.6km of excavation along two cables, across an area of 280,000m^2 (volume of 842,400m^3 for two cables assuming an average sand wave height of 3m). Along the inter-array cables, excavation of 29,760m^3 of sand is anticipated (across an area of 14,880m^2).

82. The total area of sand waves defined by Wood (2022) along the Offshore Export Cable Corridor and inter-array cables is 7.62km^2, so the area of sand wave levelling (294,880m^2) equates to only 3.9% of the total area of sand waves in the corridor. Hence, the effects on the surrounding environment are anticipated to be small because it is likely that the natural changes to the sand waves, through the active physical processes, are far greater than the quantities of sand that would be extracted. Also, the sediment arising from sand wave removal would be disposed back to the seabed local to its extraction and so there would be no net loss of sediment within the area.

8.5.2.1 Sensitivity, magnitude of impact and significance of the effect

83. Upon completion of the sand wave removal, excavation of the trench, installation of the cables and backfilling, the mobility of the sediment would reconfigure the subtidal seabed close to its original morphology before installation (including re-formation of sand waves).

84. Importantly, the Offshore Export Cable Corridor passes through the Bideford to Foreland Point MCZ. It will also be 2km from Lundy Island to the north. The sensitivity and value of these receptors are presented in **Table 8.18**.

Table 8.18 Sensitivity and value assessment of the identified morphological receptors

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Bideford to Foreland Point MCZ	Negligible	Negligible	Negligible	High	Negligible
Lundy Island	Negligible	Negligible	Negligible	High	Negligible

85. Based on the conceptual evidence-based assessment, changes in seabed elevation will be small in magnitude, meaning that the effect on the identified morphological receptors is **not significant**. Hence, the overall significance of the effect of cable installation activities under a worst case scenario on form and function of the subtidal seabed for the identified morphological receptors is **negligible adverse**.

8.5.3 Impact 3: Impacts on suspended sediment concentrations and deposition due to buried cable, mooring system, and Offshore Substation Platform installation

86. The detail of the export and inter-array cabling is dependent upon the final project design, but present estimates are that the maximum length of export and inter-array cable could be up to 93.6km and 29.8km, respectively, seaward of the Landfall (up to MHWS). A potential impact during construction (trenching and sand wave levelling) would be temporary disturbance of the seabed due to the installation activities for the buried cables which would potentially release sediment into the water column resulting in increased suspended sediment concentrations and changes to seabed levels from deposition.

87. The worst case of jetting/ploughing or trenching/cutting for both export cable and inter-array cable installation would displace a volume of 1,952,6400m^3 of sediment assuming 3m-wide, 3m-deep excavations. The potential requirement for sand wave levelling across the Offshore Development Area is estimated to be 872,160m^3

(842,400m^3 for the export cables and 29,760m^3 for the inter-array cables). Additional seabed preparation of 11,171m^3 would be required for construction of the mooring system and the Offshore Substation Platform.

88. In areas, where the cable is buried up to 3m, the cable would be installed mainly in sand (or coarser). Sand wave levelling and seabed preparation and would also be through mainly sand. The amount of fine sediment recorded from samples along the corridor and across the Offshore Development Area is on average less than 7%. Therefore, dispersion of fine sediment from the areas of burial and sand wave levelling would be very low.

89. The increases in suspended sediment concentrations would be short in duration (lasting the maximum duration of cable installation – 6 months for inter array cables and 12 months for the offshore export cables) and, over time, the suspended sediment would disperse, either through settling of coarser sediments rapidly to the seabed close to the point of disturbance or, for finer sediments, as they become entrained within a plume within the water column and widely dispersed by tidal and wave action.

90. The increase in suspended sediment concentrations is not likely to be high in magnitude for prolonged periods of time and is most likely to be within the range of natural variability in the system (e.g. during storms, suspended sediment concentrations will naturally be higher than during calm periods). Furthermore, with the construction affecting different sections of the corridor progressively over time (rather than being instantaneous along the whole corridor at a single point in time) the impact is localised, although this will be most concentrated in areas where sand wave levelling is undertaken (mainly in Area 3 as defined by Wood, 2022, **Figure 8.2**).

8.5.3.1 Sensitivity, magnitude of impact and significance of the effect

91. The magnitude of impact is considered **negligible**. The disturbance effects along the cable are likely to persist in the water column for hours to a few days, before depositing to form a thin layer on the seabed. However, it is anticipated that under the prevailing hydrodynamic conditions, this sediment would be readily re-mobilised, especially in the shallow inshore area where waves would regularly agitate the bed. Accordingly, outside the immediate vicinity of the offshore export cable trench, bed level changes and any changes to seabed character are expected to be not measurable in practice.

92. Importantly, the Offshore Export Cable Corridor passes through the Bideford to Foreland Point MCZ. It will also be 2km from the Lundy Island receptor to the north. The sensitivity and value of these receptors are presented in **Table 8.19**.

Table 8.19 Sensitivity and value assessment of the identified morphological receptors

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Bideford to Foreland Point MCZ	Negligible	Negligible	Negligible	High	Negligible
Lundy Island	Negligible	Negligible	Negligible	High	Negligible

93. Based on the conceptual evidence-based assessment of deposition from the plume generated from cable installation indicates that the changes in seabed elevation are effectively immeasurable within the accuracy of any bathymetric survey. This means that given these very small magnitude changes in seabed level arising from cable installation, the effects on the identified morphological receptors would be **not significant**. Hence, the overall significance of the effect of offshore export cable installation activities under a worst case scenario on bed level changes for the identified morphological receptors is **negligible adverse**.

8.5.4 Impact 4: Indentations on the seabed due to installation vessels

94. There is potential for certain vessels used during installation of the foundations for the Offshore Substation Platform to directly impact the seabed. This applies for those vessels that utilise jack-up legs or several anchors to hold station and to provide stability for a working platform. Where legs or anchors (and associated chains) have been inserted into the seabed and then removed, there is potential for an indentation to remain, proportional to the dimensions of the object. The worst case scenario corresponds to the use of jack-up vessels.

95. A six-legged jack-up barge used for the installation of the foundations for the Offshore Substation Platform would have a footprint of 302m^2. This is based on a six-legged jack up with spud cans of 10m diameter. Each leg could penetrate into the seabed and may be cylindrical, triangular, truss leg or lattice.

96. As the leg is inserted, the seabed sediments would primarily be compressed vertically downwards and displaced laterally. This may cause the seabed around the inserted leg to be raised in a series of concentric pressure ridges. As the leg is retracted, some of the sediment would return to the hole via mass slumping under

gravity until a stable slope angle is achieved. Over the longer term, the hole would become shallower and less distinct due to infilling with mobile seabed sediments.

8.5.4.1 Magnitude of impact and significance of the effect

97. The footprint of jack-ups used during the installation of anchors would not extend beyond the direct footprint. Therefore, there is no impact from these activities in the near-field, beyond the immediate vicinity of the legs, or in the far-field. In the immediate vicinity of the legs there is potential for indentations to occur. However, any disturbance footprint would be limited in scale and any effects would be temporary in nature with indentations infilling through natural processes. Therefore, the magnitude of impact is considered **negligible**. There would be **no significant effect** on the identified morphological receptors as they are remote from the footprints of the jack-up legs.

8.6 Potential effects during operation and maintenance

98. During the operation and maintenance phase, the export cable will be mostly buried and therefore the only interaction with marine geology, oceanography and physical processes will be in areas where rock armour or concrete mattress protect the cable, or at cable/pipeline crossings, both standing proud of the seabed. Depending on its length and height above the seabed, the upstanding cable protection could potentially affect waves, tidal currents, and sediment transport. Other infrastructure, including the Offshore Substation Platform, anchors, chains, and mooring lines could also potentially have an impact.

8.6.1 Impact 1: Impacts on waves and tidal currents due to the physical presence of the infrastructure

99. Potential impacts on waves and tidal currents during operation could occur due to the physical presence of infrastructure (i.e. the single Offshore Substation Platform, floating substructures, and mooring system, in the water column), which may result in localised changes to waves and tidal currents due to physical blockage effects.

100. The infrastructure would present only small obstacles to the passage of waves and currents locally, causing a small modification to the wave heights and/or directions, and current flows as they pass. Generally, this would cause a small wave shadow effect to be created by each piece of infrastructure and currents would decelerate immediately upstream and downstream of each obstacle and accelerate around its sides. Wave heights and current speeds would return to baseline conditions a short distance downstream and would not interact with changes from adjacent infrastructure due to the separation distances.

101. The bespoke modelling of swell waves considered five characteristic wave scenarios (**Appendix 8.A)** to assess the potential impact of the Offshore Project on waves at the coast. The results were analysed to predict changes in nearshore wave climate due to the presence of the infrastructure, using a conservative representation of the eight floating substructures and a jacket structure. **Figure 8.12** and **Figure 8.13** show the difference in significant wave height between the baseline condition and the Offshore Project foundation layouts for surfing swell from the west for mean high water spring tides and mean low water spring tides respectively. Results from the other four scenarios are presented in **Appendix 8.A**.

102. The presence of the Offshore Project is predicted to result in a slight reduction in significant wave height, up to 0.015m (15mm) local to each substructure element. With distance towards the coast, the effect gradually reduces until there is no impact on the nearshore wave conditions (significant wave height, peak period and mean wave direction) along the North Devon coast, and at each of the seven coastal locations analysed.

103. There is also a strong evidence base which demonstrates that changes in the wave and current regimes due to the presence of large fixed foundation structures, even under a worst case scenario of the largest diameter Gravity Base Structure, are relatively small in magnitude.

104. Evidence for the absence of an impact on waves at the coast has been demonstrated recently in a wave modelling exercise carried out for two wind farms off the coast of East Anglia; Dudgeon and Sheringham Shoal (Equinor, 2022). The results predict the potential impact of a wind farm array on an adjacent coast, that can be used as a very conservative analogy for the Offshore Project. The results of the exercise are conservative compared to the Offshore Project, because:

- the nearest point of the wind farms to the coast is 16km (about three times less than the Offshore Project)
- the number of turbines modelled was 208, significantly more (by 26 times) than the Offshore Project
- the foundations are fixed to the seabed, providing a much larger barrier to waves than the floating foundations at the Offshore Project.

Figure 8.12 Differences in significant wave height for surfing swell from the west at mean high water spring tides

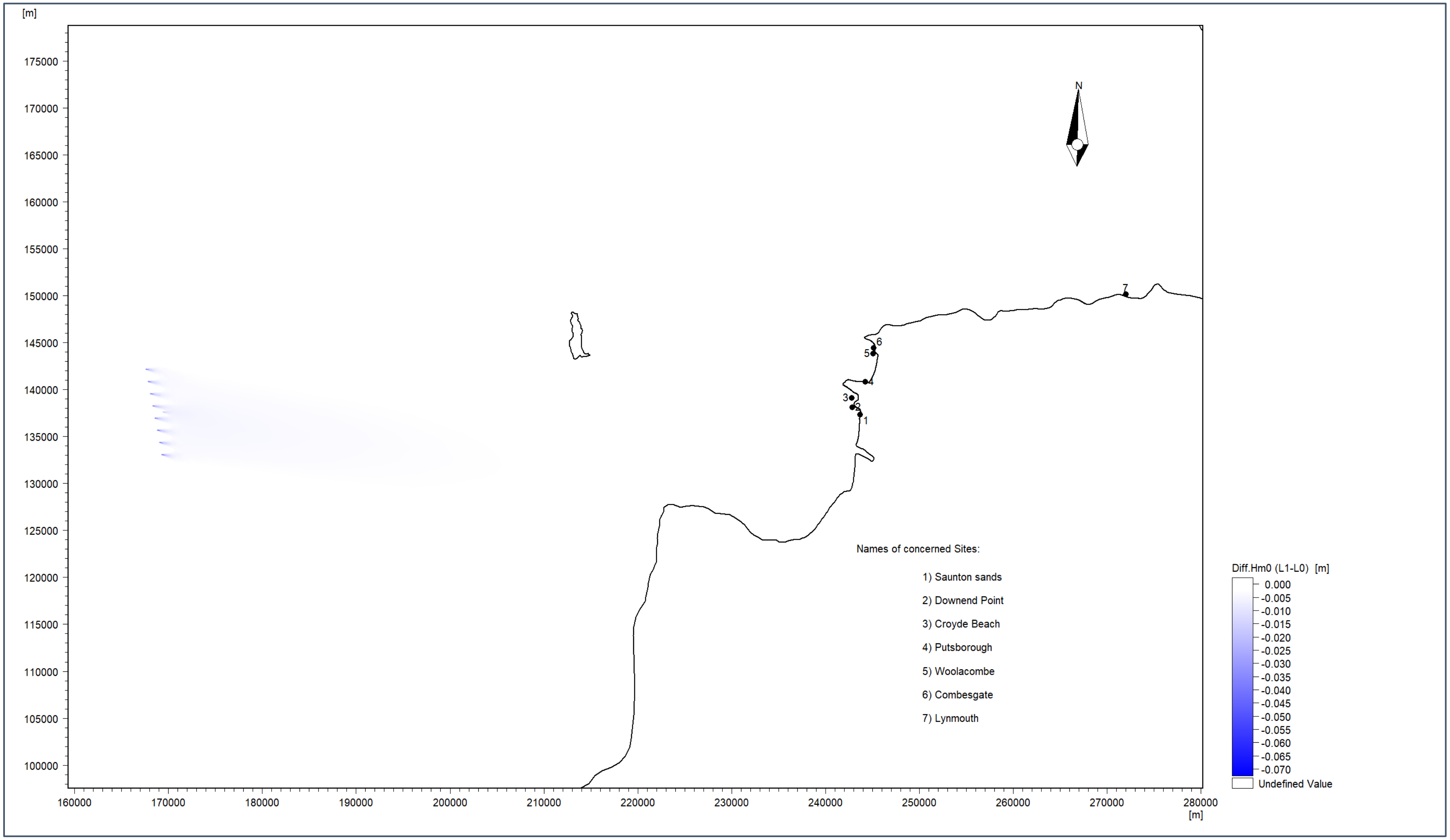
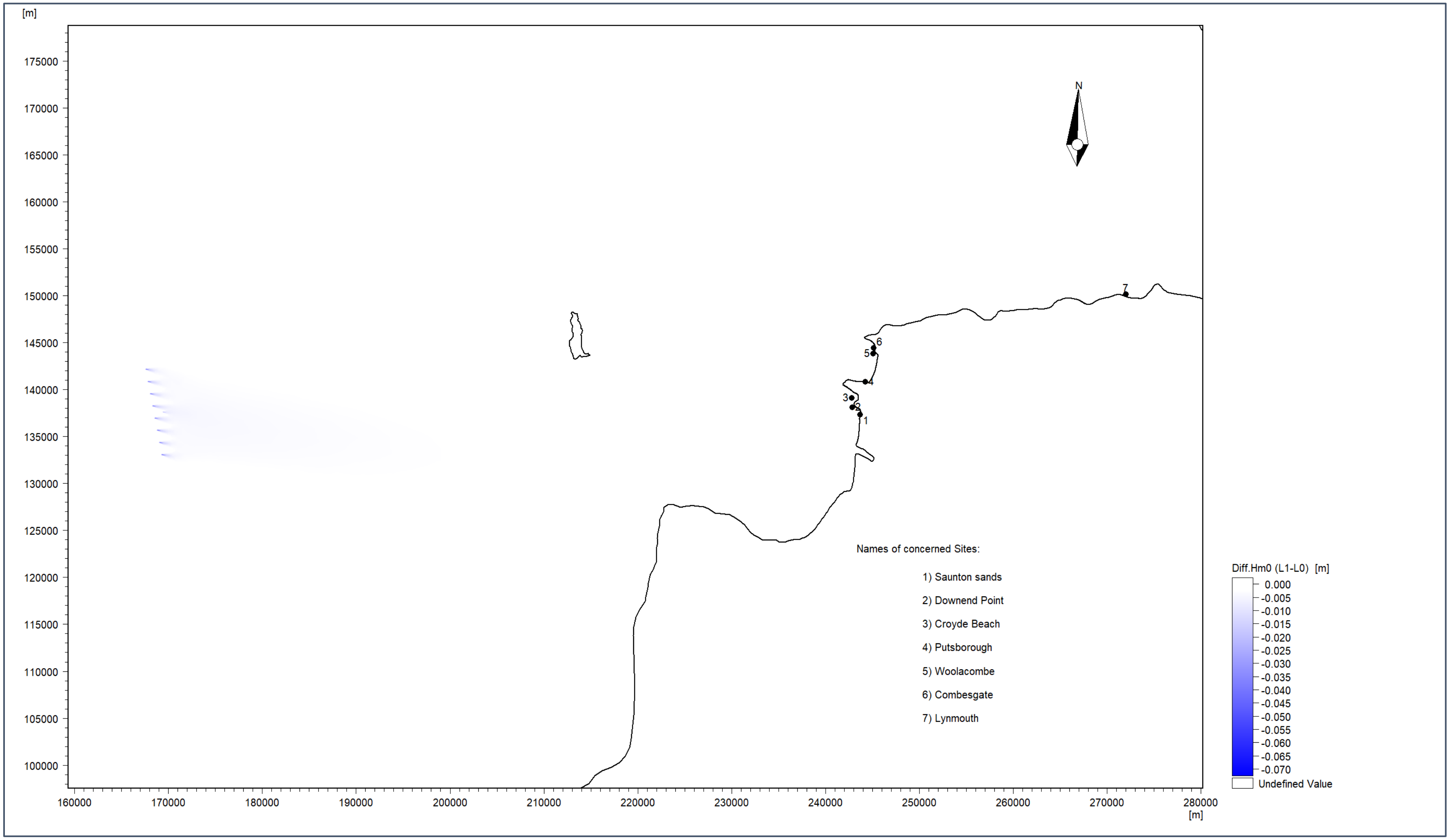


Figure 8.13 Differences in significant wave height for surfing swell from the west at mean low water spring tides



105. The wave modelling at Dudgeon and Sheringham Shoal considered a number of wave and wind directions to determine the worst case direction, that is the direction that results in the worst case nearshore wave conditions along the East Anglian coast. Two return period events were assessed; the 1 in 1 year and 1 in 50 year events. The simulations showed that waves approaching from the 0ºN directional sector (i.e. directly towards the coast) resulted in the worst case nearshore wave conditions for both return period events. This directional sector was therefore used in the assessment of effects.

106. The results were analysed to predict changes in nearshore wave climate because of the proposed offshore wind farms. They show that the wind farms would have only a localised impact on wave climate, where reflection from the wind turbines results in a slight reduction in wave conditions. They show that there is no impact on the nearshore wave conditions along the East Anglian coast.

107. These results demonstrate that for an offshore wind farm that is significantly bigger than and closer to the coast than the Offshore Project has no impact on waves at the coast. Hence, impacts at the Windfarm Site would be relatively localised in spatial extent, extending as a shadow zone typically up to several kilometres from along the axis of approach, but with low magnitudes (only a few percent change across this wider area). This is confirmed by a review of modelling studies from around 30 wind farms in the UK and European waters (Seagreen, 2012) and existing guidance documents (ETSU, 2000; ETSU, 2002; Lambkin et al., 2009).

108. The closest distance to the coast of the Windfarm Site is 52.5km. This means that waves and tidal currents will have returned to baseline heights and velocities, respectively, tens of kilometres from the coast. Hence, there will be no impact on waves and tidal currents at the coast during operation.

8.6.1.1 Magnitude of impact and significance of the effect

109. The operational infrastructure at the Windfarm Site is a small obstacle to wave and tidal current passage and hence the magnitude of impact is **negligible**. The Devon coast and Lundy Island are remote from the zone of potential influence on the wave and tidal regimes. Due to this, no pathway exists between the source and these receptors, and so in terms of effects on these receptors the effect is deemed **not significant**.

8.6.2 Impact 2: Impacts on bedload sediment transport and seabed morphological change due to the physical presence of the infrastructure

110. Modifications to the wave regime and/or the tidal regime due to the physical presence of infrastructure during the operational phase may affect bedload sediment transport across the seabed. The predicted reductions in the wave regime and tidal regime associated with the presence of the structures on the seabed (foundations of the Offshore Substation Platform and mooring system) would result in a reduction in the sediment transport potential across the areas where such changes are observed. Conversely, areas of increased tidal flow around each wind turbine would result in increased sediment transport potential.

111. These changes would be both low in magnitude and largely confined to local wave shadow or wake effects attributable to individual foundations and chains, and therefore, would be small in geographical extent. In the case of wave effects, there would also be reductions due to a shadow effect across a greater seabed area, but the changes in wave heights across this wider area are very low (a few percent) compared to the changes local to each wind turbine (tens of percent).

8.6.2.1 Magnitude of impact and significance of the effect

112. The operational infrastructure at the Windfarm Site is a small obstacle to wave and tidal current passage, and the knock-on effects on bedload sediment transport, and hence the magnitude of impact is **negligible**. The Devon coast and Lundy Island are remote from the zone of potential influence on bedload sediment transport. Due to this, no pathway exists between the source and these receptors, and so in terms of effects on these receptors the effect is deemed **not significant**.

8.6.3 Impact 3: Impacts on bedload sediment transport and seabed morphological change due to export and inter-array cable protection

113. As a worst case scenario for the Offshore Export Cable Corridor and the inter-array cables, it is assumed that cable burial would not practicably be achievable within some areas. These would include parts of the corridor and Windfarm Site occupied by bedrock or other hard substrate and at cable/pipeline crossing locations. Instead, cable protection measures would need to be provided to surface-laid cables in these areas. The preferred methods for cable protection would be rock armour or concrete mattress, although other methods may be used.

114. The total length of unburied export cable (for two cables) along the Offshore Export Cable Corridor is estimated at 34.1km. This length would require protection using approximately 136,320m^3 of rock along the two cables. About 14,400m^3 of rock is estimated to be required to facilitate crossing of eight cables and pipelines. The total length of unburied inter-array cable (cable crossings, entry to substation/turbine and unburied due to soil uncertainties) is estimated at 3.8km. This length would require protection using approximately 27,187m^3 of rock.

115. The impacts that cable protection may have on processes primarily relate to the potential for interruption of sediment transport. The potential magnitude of the impact will depend on the local sediment transport rates; a lower rate would reduce the potential impact on sediment supply to wider areas. There would be a range of sediment transport potentials across the cables. If bedrock is exposed at the seabed or covered by a thin lag, then the seabed is likely to be static and have zero transport potential (i.e. no mobile sediment). If the cable protection is laid in these areas, then sediment transport is not an issue as no sediment is being transported.

116. Where the seabed is composed of mobile sand, it can be transported under existing tidal conditions. If the protection does present an obstruction to this bedload transport the sediment would first accumulate one side or both sides of the obstacle (depending on the gross and net transports at that location) to the height of the protrusion (up to 1m in most cases). With continued build-up, it would then form a 'ramp' over which sediment transport would eventually occur by bedload processes, thereby bypassing the protection. The gross patterns of bedload transport across the cables would therefore not be affected significantly.

117. Where the cables are buried, there would be no protrusions from the seabed associated with cable protection measures. There would be no impact on bedload sediments and sediment transport, and hence geomorphological change (erosion and accretion). This would be achieved along most of the Offshore Export Cable Corridor.

8.6.3.1 Sensitivity, magnitude of impact and significance of the effect

118. The worst case changes to the seabed morphology and sediment transport due to cable protection measures could potentially affect the Devon coast as the export cables pass through the Bideford to Foreland Point MCZ. Given this, the sensitivity and value of this receptor are presented in **Table 8.20**.

119. It is considered that the small areas associated with cable protection would have no significant effect on the sediment transport processes in the MCZ. Therefore, there would be **negligible adverse effect** on the Bideford to Foreland Point MCZ.

Table 8.20 Sensitivity and value assessment of the Devon coast

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Devon coast	Medium	Low	Negligible	High	Medium

120. The Lundy Island receptor is remote from the zone of potential influence on sediment transport. Due to this, no pathway exists between the source and this receptor, and so in terms of effects on this receptor there is deemed to be **no significant effect**.

8.6.4 Impact 4: Impacts on suspended sediment concentrations and transport due to the physical presence of the infrastructure

121. There is potential for sediments to be re-suspended by the scouring effects of the catenary action of the mooring lines and around the foundations of the mooring anchors.

122. The seabed in the vicinity of the turbines will be swept by the catenary action of the mooring lines for each turbine. If there is sediment present on the seabed (rather than exposed bedrock) then this will be entrained into suspension in the water column. However, the sediment is sand or slightly gravelly sand across the Windfarm Site and so much of this will fall to the seabed shortly after disturbance. Only the finest fractions will reside in the water column and in these cases for short durations and in the lower layers of the water column. The mean mud content across the site is 6%.

123. The total volume of sediment that could be disturbed is relatively low. Even the fullest swept area of 19,200m^2 for eight turbines, affecting only a thin layer of surface sediment, equates to a few tens or, at most, a few hundred cubic metres of sediment per turbine, although this could be a frequent disturbance through the operation and maintenance phase. Hence, the increase in suspended sediment concentrations is most likely to be within the range of natural variability in the system, with ambient concentrations at the Windfarm Site of up to 5mg/l on average. Also, during storms, suspended sediment concentrations will naturally be higher (by several magnitudes) than during calmer periods.

124. Considering the physical separation between anchors at each turbine, and the relatively deep water depths of 69-78m below LAT, there is unlikely to be sufficient current energy acting on the seabed, during both calm and storm conditions, to generate significant quantities of scour (if any) around each of the mooring anchors

in the Windfarm Site. With up to eight turbines, each with a maximum of six anchors, there will be a maximum of 48 anchors on the seabed.

8.6.4.1 Magnitude of impact and significance of the effect

125. The impact on suspended sediment concentrations of catenary action will be localised and small in magnitude, and hence the magnitude of impact is negligible. Although it will persist throughout the operation and maintenance phase it is deemed to have a **no effect** on the identified receptors. This is because they are located remotely from the zone of potential impact.

126. Seabed scour around the anchor foundations is likely to be minimal in these relatively deep waters. Hence, this impact is deemed to be negligible throughout the operation and maintenance phase, with **no effect** on the identified receptors, because of their remoteness from the zone of potential impact.

8.7 Potential effects during decommissioning

127. No decision has been made regarding the final decommissioning policy for the cables in the nearshore/intertidal zone, as it is recognised that industry best practice, rules and legislation change over time. It is likely that the cables would be pulled through the ducts and removed, with the ducts themselves left in situ.

128. The decommissioning methodology would need to be finalised nearer to the end of the lifetime of the Offshore Project so as to be in line with current guidance, policy and legalisation at that point. Any such methodology would be agreed with the relevant authorities and statutory consultees. The decommissioning works could be subject to a separate licencing and consenting approach.

129. The anticipated decommissioning activities are outlined in **Section 5.10** of **Chapter 5: Project Description**. The potential impacts of the decommissioning of the Offshore Project have been assessed for marine geology, oceanography and physical process on the assumption that decommissioning methods will be similar or of a lesser scale than those deployed for construction. During the decommissioning phase, it is anticipated that they may be caused by removal of the cable and any rock armour or concrete mattress protection that has been placed.

8.7.1 Impact 1: Impacts on the form and function of the coast due to buried cable decommissioning

130. Decommissioning effects on the form and function of the coast will be like to those experienced during the construction phase. This means there will be **negligible adverse effect** on the identified morphological receptors. Upon completion of

decommissioning, the effect remaining from the Offshore Project will be **not significant**.

8.7.2 Impact 2: Impacts on the form and function of the seabed due to buried cable, mooring system, and Offshore Substation Platform decommissioning

131. Decommissioning effects on the form and function of the seabed will be like those experienced during the construction phase. This means there will be **negligible adverse effect** on the identified morphological receptors. Upon completion of decommissioning, the effect remaining from the Offshore Project will be **not significant**.

8.7.3 Impact 3: Impacts on suspended sediment concentrations and deposition due to buried cable, mooring system, and Offshore Substation Platform decommissioning

132. Decommissioning effects upon suspended sediment concentrations will be like those experienced during the construction phase. This means there will be **negligible adverse effect** on the identified morphological receptors. Upon completion of decommissioning, there will be no notable impact remaining from the Offshore Project.

8.7.4 Impact 4: Indentations on the seabed due to decommissioning vessels

133. The effects of indentations caused by decommissioning vessels will be like those experienced during the construction phase. This means the effects on the identified morphological receptors is deemed **not significant**.

8.8 Potential Cumulative Effects

134. The approach to Cumulative Effect Assessment (CEA) is set out in **Chapter 6: EIA Methodology**. Only projects which are reasonably well described and sufficiently advanced to provide information on which to base a meaningful and robust assessment have been included in the CEA. Projects which are sufficiently implemented during the site characterisation for the Offshore Project have been considered as part of the baseline for the EIA. Where possible OWL has sought to agree with stakeholders the use of as-built project parameter information (if available) as opposed to consented parameters to reduce over-precaution in the

cumulative assessment. The scope of the CEA was therefore be established on a topic-by-topic basis with the relevant consultees.

135. The CEA for marine geology, oceanography and physical processes was undertaken in two stages. The first stage was to consider the potential for the impacts assessed as part of the Offshore Project to lead to cumulative effects in conjunction with other projects. The first stage of the assessment is detailed in **Table 8.21**. Only potential impacts assessed in **Section 8.5** as negligible adverse or above are included in the CEA (i.e. those assessed as 'no impact' are not taken forward as there is no potential for them to contribute to a cumulative effect).

Table 8.21 Potential cumulative effects considered for marine geology, oceanography and physical processes

Impact	Potential for cumulative effect	Rationale
Construction phase effects impacts		
Impact 1: Impacts on the form and function of the coast due to buried cable installation	Yes	There is potential for temporal overlap of offshore export cable construction
Impact 2: Impacts on the form and function of the subtidal seabed due to buried cable, mooring system, and Offshore Substation Platform installation	No	There is no potential for temporal overlap of cable and other infrastructure construction
Impact 3: Impacts on suspended sediment concentrations and deposition due to buried cable, mooring system, and Offshore Substation Platform installation	No	There is no potential for temporal overlap of cable and other infrastructure construction
Operational and maintenance phase cumulative effects		
Impact 1: Impacts on bedload sediment transport and seabed morphological change due to cable protection	Yes	Effects could potentially coalesce with those arising from other projects and disturb sediment transport pathways, particularly if protection measures are near to the coast
Decommissioning phase cumulative effects		
Impact 1: Impacts on the form and function of the seabed due to cable decommissioning	No	Effects would occur at discrete locations for a time-limited duration and negligible adverse in magnitude

Impact	Potential for cumulative effect	Rationale
Impact 2: Impacts on suspended sediment concentrations and deposition due to buried cable, mooring system, and Offshore Substation Platform decommissioning	No	Effects would occur at discrete locations for a time-limited duration and negligible adverse in magnitude

136. The second stage of the CEA is to evaluate the projects considered for the CEA to determine whether a cumulative effect is likely to arise. The list of considered projects (identified in **Chapter 6: EIA Methodology**) and their anticipated potential for cumulative effects are summarised in **Table 8.22**). A rationale for inclusion in the CEA for marine and physical processes has been provided and is predominately based on distance or the tiering approach described in **Chapter 6: EIA Methodology**.

Table 8.22 Projects considered in the cumulative effect assessment on marine geology, oceanography and physical processes

Project	Status	Distance from Offshore Development Areay (km)	Included in the CEA?	Rationale
White Cross Onshore Project	Planned	0 (Landfall)	Yes	Potential for temporal overlap of export cable installation activities close to and at the coast

137. In all cases but one, the projects are several 10s of km's away from the Offshore Project and there is therefore no potential for cumulative effect on the identified receptors.

138. It is noted that the only project listed is the Town and Country Planning Application for the White Cross Onshore Project which is separate to the offshore Section 36 consent and Marine Licences applications for which this ES is prepared. The specific combined project elements are assessed cumulatively first and then cumulatively with all other projects.

8.8.1 Impact 1: White Cross Onshore Project

139. There is potential for temporal overlap of offshore export cable construction across the landfall zone (up to MHWS) of northern Saunton Sands and the onshore installation of the cables across Braunton Burrows dune complex.

8.8.1.1 Magnitude of impact and significance of the effect

140. Based on an assumption that the installation of the landfall cable across Saunton Sands would take place over a period of up to two days, a temporal overlap in cable construction activities is unlikely. The installation of the export cable in the subtidal zone and the installation of the onshore cable landwards beneath Braunton Burrows would have no interaction. The magnitude of impact is therefore considered negligible to no impact. The overall significance of the effect under a worst case scenario on the identified morphological receptors is deemed **negligible adverse**. This effect reduces to **no effect** upon cessation of the works. Also, if the installation uses trenchless technology (e.g. Horizontal Directional Drilling) then there would be no interaction.

8.8.1.2 Further Mitigation

141. No further mitigation is required.

8.9 Potential transboundary effects

142. The Scoping Report identified that there was no potential for significant transboundary impacts regarding marine geology, oceanography and physical processes from the Offshore Project upon the interests of other EEA States. This is because the nearest EEA is at a distance from the Offshore Project such that impacts would not extend that far. Hence, potential transboundary effects are not discussed further.

8.10 Inter-relationships

143. Inter-relationship effects are covered as part of the assessment and consider effects from the construction, operation or decommissioning of the Offshore Project on the same receptor (or group). A description of the process to identify and assess these impacts is presented in **Chapter 6: EIA Methodology**. The potential inter-relationship impacts that could arise in relation to marine geology, oceanography and physical processes include both:

- **Project lifetime impacts:** Impacts arising throughout more than one phase of the Offshore Project (construction, operation, and decommissioning) to interact to potentially create a more significant impact on a receptor than if just one phase were assessed in isolation
- **Receptor led impacts:** Assessment of the scope for all relevant impacts to interact, spatially and temporally, to create inter-related impacts on a receptor (or group). Receptor-led impacts might be short term, temporary or transient impacts, or incorporate longer term impacts.

144. **Table 8.23** serves as a sign-posting for inter-relationships.

8.11 Interactions

145. The effects identified and assessed in this chapter have the potential to interact with each other, which could give rise to synergistic effects as a result of that interaction. The areas of interaction between effects are presented in **Table 8.24**, **Table 8.25** and **Table 8.26**, along with an indication as to whether the interaction may give rise to synergistic effects. This provides a screening tool for which effects have the potential to interact.

146. **Table 8.27** then provides an assessment for each receptor related to these effects in two ways. Firstly, the effects are considered within a development phase (i.e. construction, operation, maintenance or decommissioning) to see if, for example, multiple construction effects could combine. Secondly, a lifetime assessment is undertaken which considers the potential for effects to affect receptors across development phases. The significance of each individual effect is determined by the sensitivity of the receptor and the magnitude of impact; the sensitivity is constant whereas the magnitude may differ. Therefore, when considering the potential for effects to be additive it is the magnitude of impact which is important – the magnitudes of the different impacts are combined upon the same sensitivity receptor. If minor effect and minor effect were added this would effectively double count the sensitivity.

8.1 Summary

147. This chapter has provided a characterisation of the existing environment for marine geology, oceanography and physical processes based on both existing and site specific survey data. It then investigated the potential effects on marine geology, oceanography and physical processes receptors arising from the Offshore Project. The specific receptors that have been identified in relation to this topic are Lundy Island and the sensitive Devon coast. The range of potential impacts and associated effects considered has been informed by the Scoping Opinion, consultation, and agreed through ETG Meetings, as well as reference to existing policy and guidance. The impacts considered include those brought about directly as well as indirectly.

Table 8.23 Marine geology, oceanography and physical processes inter-relationships

Topic and description	Related chapter	Where addressed in this Chapter	Rationale
Construction impacts on coastal morphology	Chapter 10: Benthic and Intertidal Ecology Chapter 19: Offshore Seascape, Landscape and Visual Amenity	**Section 8.5.1** (cable installation)	Disruption to coastal morphology could potentially impact on these chapters through a change to the existing shoreline environment which could have implications for the receptors associated with these chapters
Construction impacts on seabed morphology	Chapter 10: Benthic and Intertidal Ecology Chapter 11: Fish and Shellfish Ecology Chapter 14: Commercial Fisheries Chapter 15: Shipping and Navigation Chapter 16: Marine Archaeology and Cultural Heritage	**Section 8.5.1** (cable installation) **Section 8.5.2** (installation vessels)	Disruption to seabed morphology and sediment composition could affect these receptors by altering the existing sedimentary environment. However, this is unlikely to be to levels which are significant
Construction impacts on suspended sediment concentrations and deposition	Chapter 9: Marine Water and Sediment Quality Chapter 10: Benthic and Intertidal Ecology Chapter 11: Fish and Shellfish Ecology Chapter 14: Commercial Fisheries Chapter 19: Offshore Seascape, Landscape and Visual Amenity	**Section 8.5.3** (cable installation)	Suspended sediment could be contaminated and could cause disturbance to fish and benthic species through smothering

Topic and description	Related chapter	Where addressed in this Chapter	Rationale
Operational impacts on waves, tidal currents, bedload sediment transport and seabed morphological change	Chapter 10: Benthic and Intertidal Ecology Chapter 11: Fish and Shellfish Ecology Chapter 14: Commercial Fisheries Chapter 13: Shipping and Navigation Chapter 16: Marine Archaeology and Cultural Heritage	**Section 8.6.1** (infrastructure - waves and tidal currents) **Section 8.6.3 and Section 8.6.4** (infrastructure - sediment transport)	Disruption to seabed morphology and sediment composition could affect these receptors by altering the existing sedimentary environment. However, this is unlikely to be to levels which are significant
Operational impacts on suspended sediment concentrations and transport	Chapter 9: Marine Water and Sediment Quality Chapter 10: Benthic and Intertidal Ecology Chapter 11: Fish and Shellfish Ecology Chapter 14: Commercial Fisheries Chapter 19: Offshore Seascape, Landscape and Visual Amenity	**Section 8.6.4** (scour)	Suspended sediment could be contaminated and could cause disturbance to fish and benthic species through smothering
Inter-relationships for effects during the decommissioning phase will be the same as those outlined above for the construction phase.			

Table 8.24 Interaction between impacts during construction

Construction	Impact 1: Impacts on the form and function of the coast due to buried cable installation	Impact 2: Impacts on the form and function of the subtidal seabed due to buried cable, mooring system, and Offshore Substation Platform installation	Impact 3: Impacts on suspended sediment concentrations and deposition due to buried cable, mooring system, and Offshore Substation Platform installation	Impact 4: Indentations on the seabed due to installation vessels
Impact 1: Impacts on the form and function of the coast due to buried cable installation		Yes	Yes	No
Impact 2: Impacts on the form and function of the subtidal seabed due to buried cable, mooring system, and Offshore Substation Platform installation	Yes		Yes	No
Impact 3: Impacts on suspended sediment concentrations and deposition due to buried cable, mooring system, and Offshore Substation Platform installation	Yes	Yes		No
Impact 4: Indentations on the seabed due to installation vessels	No	No	No	

Table 8.25 Interaction between impacts during operation and maintenance

Operation and maintenance	Impact 1: Impacts on waves and tidal currents due to the physical presence of the infrastructure	Impact 2: Impacts on bedload sediment transport and seabed morphological change due to the physical presence of the infrastructure	Impact 3: Impacts on bedload sediment transport and seabed morphological change due to cable protection	Impact 4: Impacts on suspended sediment concentrations and transport due to the physical presence of the infrastructure
Impact 1: Impacts on waves and tidal currents due to the physical presence of the infrastructure		Yes	No	Yes
Impact 2: Impacts on bedload sediment transport and seabed morphological change due to the physical presence of the infrastructure	Yes		No	Yes
Impact 3: Impacts on bedload sediment transport and seabed morphological change due to cable protection	No	No		No
Impact 4: Impacts on suspended sediment concentrations and transport due to the physical presence of the infrastructure	Yes	Yes	No	

Table 8.26 Interaction between impacts during decommissioning

Decommissioning	Impact 1: Impacts on the form and function of the seabed due to cable decommissioning	Impact 2: Impacts on the form and function of the subtidal seabed due to buried cable, mooring system, and Offshore Substation Platform decommissioning	Impact 3: Impacts on suspended sediment concentrations and deposition due to buried cable, mooring system, and Offshore Substation Platform decommissioning	Impact 4: Indentations on the seabed due to decommissioning vessels
Impact 1: Impacts on the form and function of the seabed due to cable decommissioning		Yes	Yes	No
Impact 2: Impacts on the form and function of the subtidal seabed due to buried cable, mooring system, and Offshore Substation Platform decommissioning	Yes		Yes	N0

Decommissioning	Impact 1: Impacts on the form and function of the seabed due to cable decommissioning	Impact 2: Impacts on the form and function of the subtidal seabed due to buried cable, mooring system, and Offshore Substation Platform decommissioning	Impact 3: Impacts on suspended sediment concentrations and deposition due to buried cable, mooring system, and Offshore Substation Platform decommissioning	Impact 4: Indentations on the seabed due to decommissioning vessels
Impact 3: Impacts on suspended sediment concentrations and deposition due to buried cable, mooring system, and Offshore Substation Platform decommissioning	Yes	Yes		No
Impact 4: Indentations on the seabed due to decommissioning vessels	No	No	No	

Table 8.27 Interaction between impacts – phase and lifetime assessment

Highest level significance					
Receptor	**Construction**	**Operation and Maintenance**	**Decommissioning**	**Phase Assessment**	**Lifetime Assessment**
Lundy Island	Negligible Adverse	Negligible Adverse	Negligible Adverse	No greater than individually assessed effect. The effects are no effect to negligible adverse effect on the receptors. Given that each effect will be managed with standard and best practice methodologies it is considered that there would either be no interactions or that these would not result in greater effect than assessed individually.	No greater than individually assessed effect
Devon coast	Negligible Adverse	Negligible Adverse	Negligible Adverse		

148. The effects on the identified receptors during construction, operation and decommissioning phases of the Offshore Project are considered negligible adverse or no effect. **Table 8.28** presents a summary of the impacts assessed within this ES chapter, any commitments made, and mitigation required and the residual effects. The impacts that result in no effect to the above-mentioned receptors are because they are located remotely from the zones of influence and no pathway has been identified that can link the source to the receptor. Where there is a pathway for effect, the assessment has concluded that effects would be of no greater than negligible adverse significance.

149. The assessment of cumulative effects from the Offshore Project and other developments and activities concluded that only one activity has the potential for interaction; the White Cross Onshore Project. However, the effects would be of no greater than negligible adverse significance.

150. The screening of transboundary impacts identified that there was no potential for significant transboundary impacts regarding marine geology, oceanography and physical processes from the Offshore Project.

Table 8.28 Summary of potential effects for marine geology, oceanography and physical processes during construction, operation, maintenance and decommission of the Offshore Project

Potential impact	Receptor	Sensitivity	Magnitude of impact	Significance of effect	Potential mitigation measure	Residual effects
Construction						
Impact 1: Impacts on the form and function of the coast due to buried cable installation	Devon coast	N/A	Negligible	Negligible adverse to no effect	N/A	Negligible Adverse to no effect
Impact 2: Impacts on the form and function of the subtidal seabed due to buried cable, mooring system, and Offshore Substation Platform installation	Bideford to Foreland Point MCZ (Devon coast)	N/A	Negligible	Negligible adverse	N/A	Negligible adverse
	Lundy Island	N/A	Negligible	Negligible adverse	N/A	Negligible adverse
Impact 3: Impacts on suspended sediment concentrations and deposition due to buried cable, mooring system, and Offshore Substation Platform installation	Bideford to Foreland Point MCZ (Devon coast)	N/A	Negligible	Negligible adverse	N/A	Negligible adverse
	Lundy Island	N/A	Negligible	Negligible adverse	N/A	Negligible adverse
Impact 4: Indentations on the seabed due to installation vessels	Devon coast and Lundy Island	N/A	Negligible to no impact	No effect	N/A	No effect

Potential impact	Receptor	Sensitivity	Magnitude of impact	Significance of effect	Potential mitigation measure	Residual effects
Operation and Maintenance						
Impact 1: Impacts on waves and tidal currents due to the physical presence of the infrastructure	Devon coast and Lundy Island	N/A	No impact	No effect	N/A	No effect
Impact 2: Impacts on bedload sediment transport and seabed morphological change due to the physical presence of the infrastructure	Devon coast and Lundy Island	N/A	No impact	No effect	N/A	No effect
Impact 3: Impacts on bedload sediment transport and seabed morphological change due to cable protection	Bideford to Foreland Point MCZ (Devon coast)	N/A	Negligible	Negligible adverse	N/A	Negligible adverse
	Lundy Island	N/A	Negligible	No effect	N/A	No effect
Impact 4: Impacts on suspended sediment concentrations and transport due to the physical presence of the infrastructure	Devon coast and Lundy Island	N/A	Negligible	No effect	N/A	No effect

Potential impact	Receptor	Sensitivity	Magnitude of impact	Significance of effect	Potential mitigation measure	Residual effects
Decommissioning						
Impact 1: Impacts on the form and function of the seabed due to cable decommissioning	Devon coast and Lundy Island	N/A	Negligible	Negligible adverse	N/A	Negligible adverse
Impact 2: Impacts on the form and function of the subtidal seabed due to buried cable, mooring system, and Offshore Substation Platform decommissioning	Lundy Island	N/A	Negligible	Negligible adverse	N/A	Negligible adverse
Impact 3: Impacts on suspended sediment concentrations and deposition due to buried cable, mooring system, and Offshore Substation Platform decommissioning	Devon coast and Lundy Island	N/A	Negligible	Negligible adverse	N/A	Negligible adverse
Impact 4: Indentations on the seabed due to decommissioning vessels	Devon coast and Lundy Island	N/A	Negligible to no impact	No effect	N/A	No effect

Potential impact	Receptor	Sensitivity	Magnitude of impact	Significance of effect	Potential mitigation measure	Residual effects
Cumulative						
Impact 1: Impacts on the form and function of the coast due to buried cable installation	Devon coast	N/A	Negligible to no impact	Negligible adverse to no effect	N/A	Negligible Adverse to no effect
Impact 2: Impacts on bedload sediment transport and seabed morphological change due to cable protection	Devon coast	N/A	No impact	No effect	N/A	No effect

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White Cross Offshore Windfarm Environmental Statement

Appendix 8.A: Wave Modelling Report

REPORT

White Cross Offshore Wind Farm

Wave Modelling

Client: Offshore Wind Limited

Reference: FLO-WHI-REP-0045

Status: A1/C01

Date: 7 March 2023

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Document title:	White Cross Offshore Wind Farm
Subtitle:	Wave Modelling
Reference:	FLO-WHI-REP-0045
Status:	C01/A1
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Project name:	PC2978
Project number:	PC2989
Author(s):	Keming Hu

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Date / initials:	01/03/2023 PT

Classification
Internal use only

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Figure 24: Differences in significant wave heigh (L1 - L0) for Swell 01 at MLWS 33

Figure 25: Differences in significant wave heigh (L1 - L0) for Swell 02 at MLWS 34

Figure 26: Differences in significant wave heigh (L1 - L0) for Swell 03 at MLWS 35

Figure 27: Differences in significant wave heigh (L1 - L0) for Swell 04 at MLWS 36

Figure 28: Differences in significant wave height (L1 - L0) for Swell 05 at MLWS 37

1 Introduction

1.1 The Project and this Report

1.1.1 White Cross Offshore Windfarm is a proposed floating offshore windfarm located in the Celtic Sea with a capacity of up to 100MW. The Project is being developed by Offshore Wind Ltd (OWL) a joint venture between Cobra Instalaciones Servicios, S.A., and Flotation Energy Ltd.

1.1.2 An Environmental Statement (ES) for the offshore aspects (below Mean High Water Springs (MHWS)) of the White Cross Offshore Windfarm (hereafter referred to as 'the Offshore Project)) is currently being prepared. The ES will be submitted as part of an application for a consent under Section 36 of the Electricity Act 1989 and relevant Marine Licenses under the Marine and Coastal Access Act 2009. A separate application under the Town and Country Planning Act 1990 will be submitted at a later date for the onshore aspects of the Project (the 'Onshore Project').

1.1.3 The ES describes the potential environmental impacts associated with the Offshore Project which may arise from construction, operation (including maintenance activities), and decommissioning of the Offshore Project. Under best practice guidance and requirements under the relevant consent legislation (i.e. the 'Electricity Works (Environmental Impact Assessment) (England and Wales) Regulations 2017' and the Marine Works (EIA) (Amendments) Regulations 2017 (herein 'the EIA Regulations')) consultation has been carried out on the proposal prior to submission of the consent application. Consultation with the North Devon World Surfing Reserve and other surfing stakeholders identified the need to provide quantitative evidence that surfing receptors would not be adversely affected by the proposed Project.

1.1.4 This report therefore presents the results of a wave modelling study to understand the potential impact of the proposed Offshore Project on wave conditions at the North Devon World Surfing Reserve.

2 Project Description

2.1 Floating Substructures and Offshore Substation

2.1.1 The proposed offshore wind farm proposes to install between 6 and 8 floating substructures (supporting turbines) and potentially 1 offshore sub-station supported by a (fixed) jacket foundation. The need for the offshore substation will be decided post-consent when further detailed design and engineering studies have been undertaken, though it is included in the worst case scenario. Furthermore, for the purposes of a worse case scenario the model includes 8 turbines, though it may be lower. This will also be decided post-consent, again once detailed design and engineering studies have been undertaken. Indicative drawings of each foundation type are shown in **Figure 1** and **Figure 2** respectively.

Figure 1: WTG floating substructure and jacket foundation for offshore substation (isometric view)

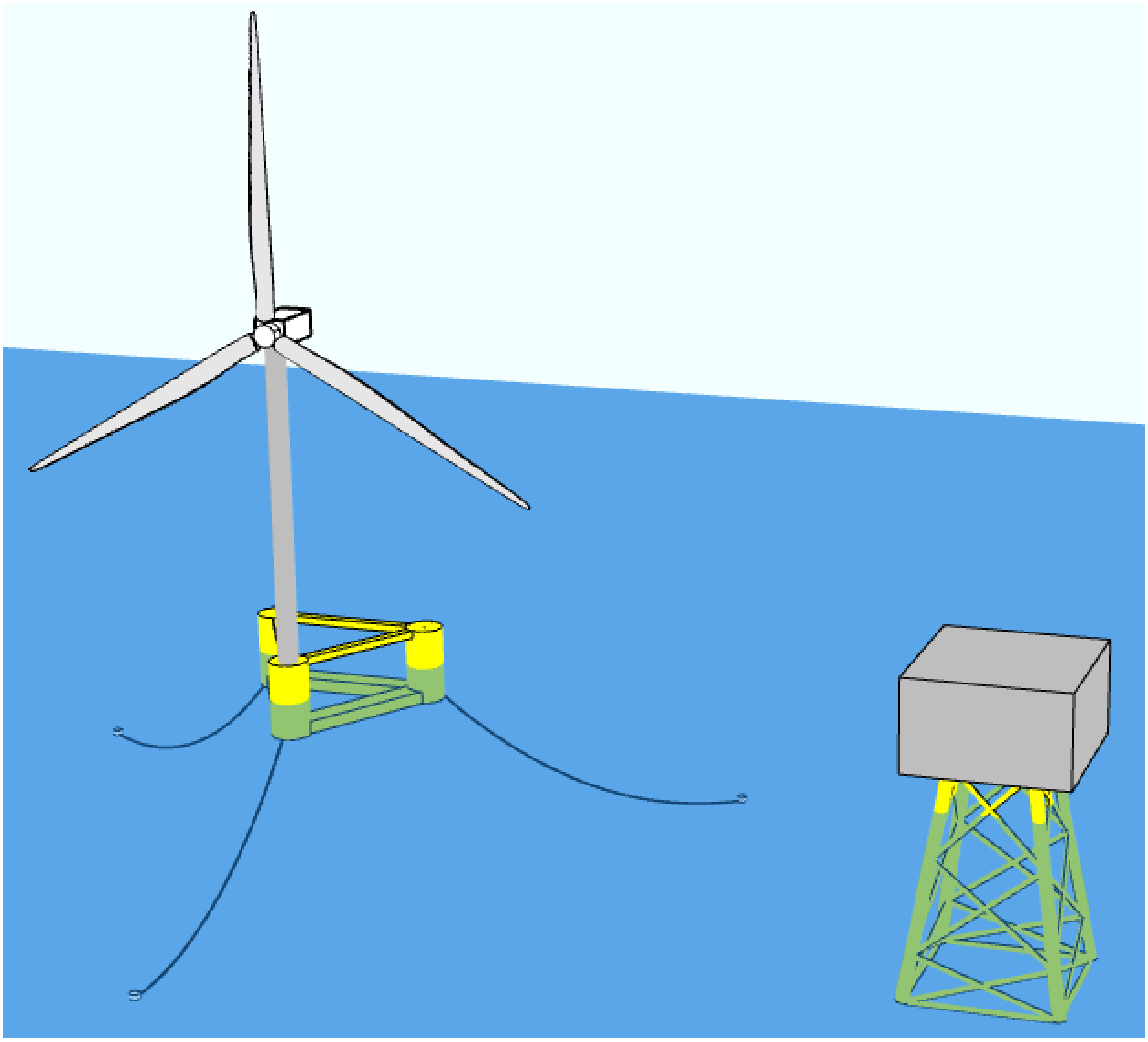
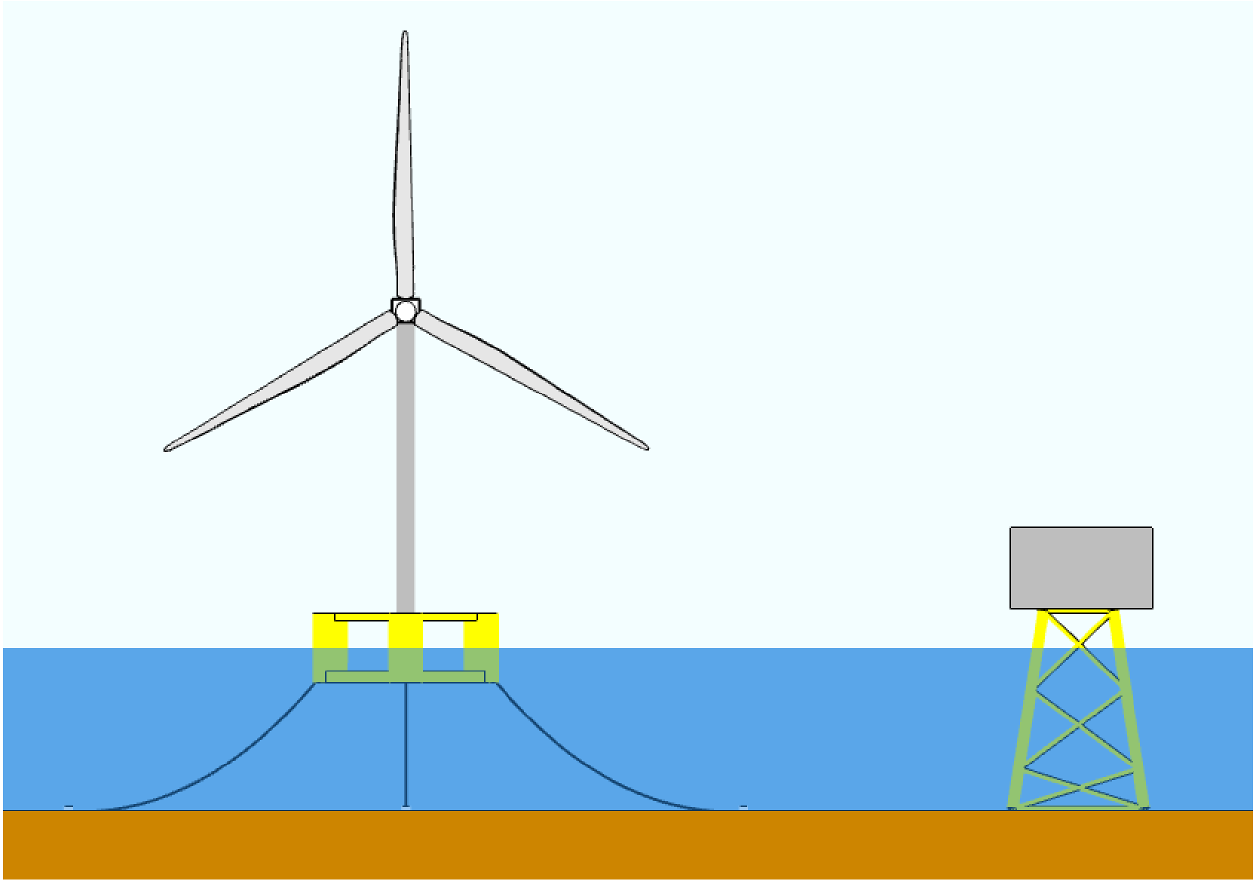


Figure 2: WTG floating substructure and jacket foundation for offshore substation (2D view)



2.1.2 The Wind Turbine Generators (WTGs) will be supported by floating substructures, the specific concept for which has not yet been selected. With many substructure concepts currently available on the market, each at varying stages of development, the Offshore Project has completed a selection process and feasibility studies to understand which substructure categories and concepts will be most suitable for the Offshore Project. Through this selection process the number of substructure categories has been reduced to one, semi-submersibles. The final selection of which semi-submersible concept will be utilised on the Offshore Project will be made post-consent application, as such some conservative assumptions have been made for the purposes of this study detailed in **Section 3.1**.

2.1.3 A semi-submersible substructure is a buoyancy stabilised platform which floats semi-submerged on the surface of the ocean whilst anchored to the seabed through its mooring system. The structure gains its stability through the buoyancy force associated with its large footprint and geometry which ensures the wind loadings on the structure and WTG are countered / dampened by the equivalent buoyancy force on the opposite side of the structure. These can be constructed in various configuration (varying number of columns arranged in varying layouts) but are typically comprised of several buoyancy columns interconnected by either pontoons, beams or braces.

2.1.4 The offshore substation would be supported by a jacket foundation. This would be permanently fixed to the seabed and would be comprised of 4 primary columns that extend from the seabed to the waterline which are interconnected by beams and braces. The decision for the need of an offshore substation platform has not been made yet. Therefore, where needed, conservative assumptions have been made for this study. As a result, the jacket foundation has been conservatively sized for the purposes of this study as detailed in **Section 3.2**.

3 Modelling Approach

3.1 Introduction

3.1.1 This section presents the development of the model and the various parameters used in the model run.

3.2 Spectral Wave Modelling

3.2.1 The spectral wave modelling software MIKE21-SW developed by DHI was selected for this study.

3.2.2 Bathymetry data were downloaded from Admiralty Marine Data Portal and the latest dataset was used to build this wave model.

3.2.3 The default model parameters and settings were adopted, and no wave model calibration has been carried out. This approach is reasonable because the purpose of this study is to quantify the difference in nearshore wave conditions with and without the proposed offshore wind farm project.

3.2.4 After consultation with Plymouth University, a highly conservative approach was adopted to represent the floating substructure and jacket in MIKE21-SW, which is detailed in the following sub-sections.

3.3 Wave conditions and wave heights for assessment

3.3.1 Following consultation with the North Devon World Surfing Reserve and experts at Plymouth University a range of wave conditions representing characteristic ‘optimal’ surfing waves for the North Devon region were agreed, for use in this wave shadowing model assessment. These wave conditions are presented in **Table 1**.

Table 1: Swell conditions used for the assessment

No.	Scenario	Hs (m)	Tp (s)	Tz (s)	MWD (°N)	DSD (°)	n
1	Average surfing swell from west	1.7	12	7	275	11	53
2	Very clean swell from west (low directional spread)	1.7	12	7	275	8	101
3	Reasonable surfing swell from west (high directional spread)	1.7	12	7	275	17	22
4	Very clean swell from WSW (low directional spread)	1.7	12	7	260	11	53

No.	Scenario	Hs (m)	Tp (s)	Tz (s)	MWD (°N)	DSD (°)	n
5	Very clean swell from WNW (low directional spread)	1.7	12	7	290	11	53

Key:

Hs(m) is the significant wave height in metres

Tp(s) is the peak wave frequency in seconds

Tz(s) is the mean time interval between waves

MWD (°N) is the Mean Wave Direction

DSD (°N) is Directional Standard Deviation

n is the equivalent cosine power of the DSD.

3.3.2 In this study, the wave conditions given in **Table 1** are tested with for two water levels:

- Mean High Water Springs (MHWS) = 9.2 mCD
- Mean Low Water Springs (MLWS) = 1.0 mCD

3.3.3 The above tide levels were obtained from the Admiralty Tide Table for Ilfracombe.

3.4 Floating Substructures

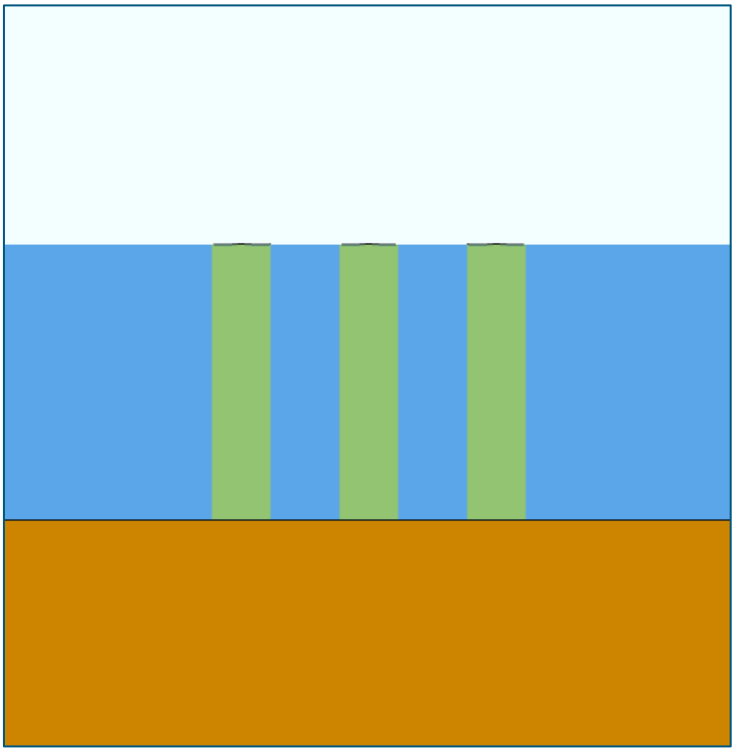
3.4.1 A conventional 3 columned semi-submersible substructure (as shown in **Figure 1** and **Figure 2**) has been assumed for the study, the primary parameters for which are shown in **Table 2**. These parameters have been determined from past project experience in semi-submersible substructure sizing.

Table 2: Floating Substructure Parameters

Parameter	Value
Number of Columns per Substructure	3
Column Outer Diameter	15m
Column Centre-to-Centre Distance	63m
Substructure Orientation	WTG column facing South-West
WTG Spacing	~1320m

3.4.2 A floating substructure of this type would typically have a draft in operation (the depth the columns extend below the sea surface) of 12-20m. For the purpose of this study a conservative approach has been taken whereby the columns have been modelled to extend from the sea surface to the seabed (column height of ~70m) as shown in **Figure 3**, effectively modelling them as fixed foundations instead of floating. As a result, it is expected that the model would exaggerate the effect of the substructures and produce conservative results.

Figure 3 - Floating Substructure Modelling Approach



3.5 Offshore Substation

3.5.1 The jacket foundation for the potential offshore substation has been modelled using the parameters in **Table 3**. These parameters have been determined from past project experience in jacket foundation sizing.

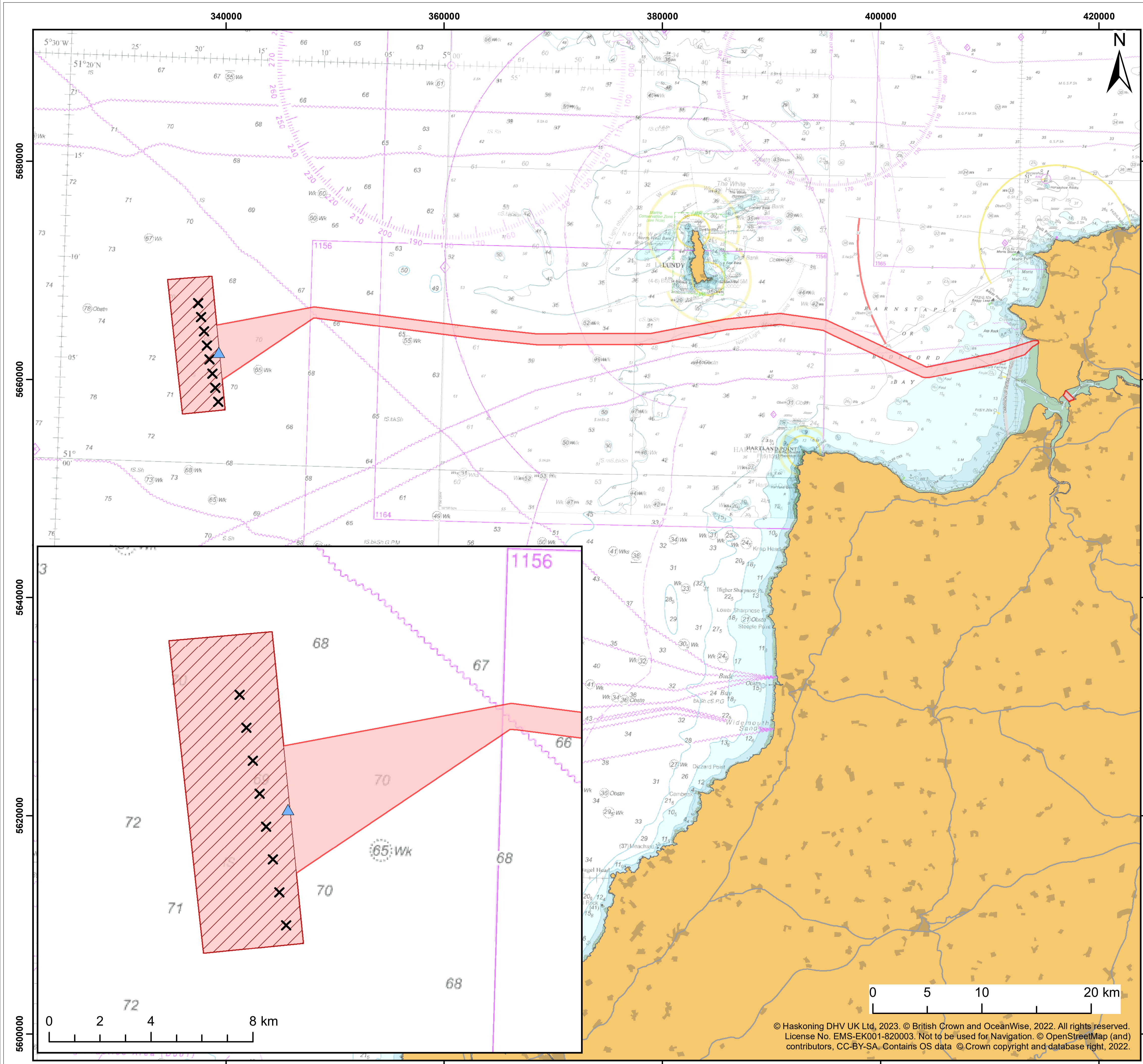
Table 3: Offshore Substation Jacket Foundation Modelling Parameters

Parameter	Value
Number of Columns	4
Column Outer Diameter	5m
Column Centre-to-Centre Distance	40m

3.5.2 The 4 columns of the offshore substation have been modelled extending from the seabed to the sea surface. The brace members have been excluded to avoid analysis complications. Due to their small outer diameter (~2m) they would produce only a negligible impact on waves.

3.6 Windfarm Layout

3.6.1 The windfarm layout as modelled in the study is shown in **Figure 4**.



Legend:

- Windfarm Site
- Offshore Development Area
- Wind Turbine Locations
- Offshore Substation Platform

Client:	Project:
Offshore Wind Ltd.	White Cross Offshore Windfarm

Title:

Indicative Locations of the Infrastructure in the Windfarm Site

Figure:	4	Drawing No:	PC2978-RHD-ZZ-XX-DR-Z-0562

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P01	07/03/2023	GC	SF	A3	1:350,000

Co-ordinate system: WGS 1984 UTM Zone 30N

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4 Model Set-up

4.1 Introduction

4.1.1 The geographical extent of the model, the bathymetry, the location of the wind farm, and key nearshore locations are shown on **Figure 5** and nearshore elements on **Figure 6**.

4.1.2 The model mesh was set at 30m around the wind farm and the concerned nearshore areas, and this is shown on **Figure 7** and **Figure 8**.

4.1.3 The default settings which were used for this MIKE21-SW model are presented in **Table 4**.

Table 4: MIKE21 SW model settings

Spectral formulation	Fully Spectral Formulation
Time formulation	Quasi Stationary
Water level conditions	Constant over domain
Currents	No
Wind Forcing	Constant in Domain No winds forcing for swell runs
Diffraction	Excluded
Wave breaking	constant gamma = 0.8
Bottom friction	Nikuradse roughness, kn = 0.2mm

4.2 Receptor Result Locations

4.2.1 Consultation with the North Devon Surfing Reserve and other stakeholders identified a number of surfing locations where there was interest in understanding the potential changes to waves that could arise as a result of the Offshore Project. Therefore, the model specifically identified seven concerned sites (as listed in **Table 5**) where model outputs would be extracted. These seven concerned sites are illustrated in **Figure 6**.

Table 5: List of concerned sites

Concerned site	Latitude (degree)	Longitude (degree)
Saunton sands	51.114346	-4.233549
Downend Point	51.121130	-4.245628
Croyde Beach	51.129726	-4.246661

Concerned site	Latitude (degree)	Longitude (degree)
Putsborough	51.145856	-4.227417
Woolacombe	51.172898	-4.216849
Combsegate	51.178316	-4.215722
Lynmouth	51.236571	-3.833678

Figure 5: Model Domain and the concerned locations

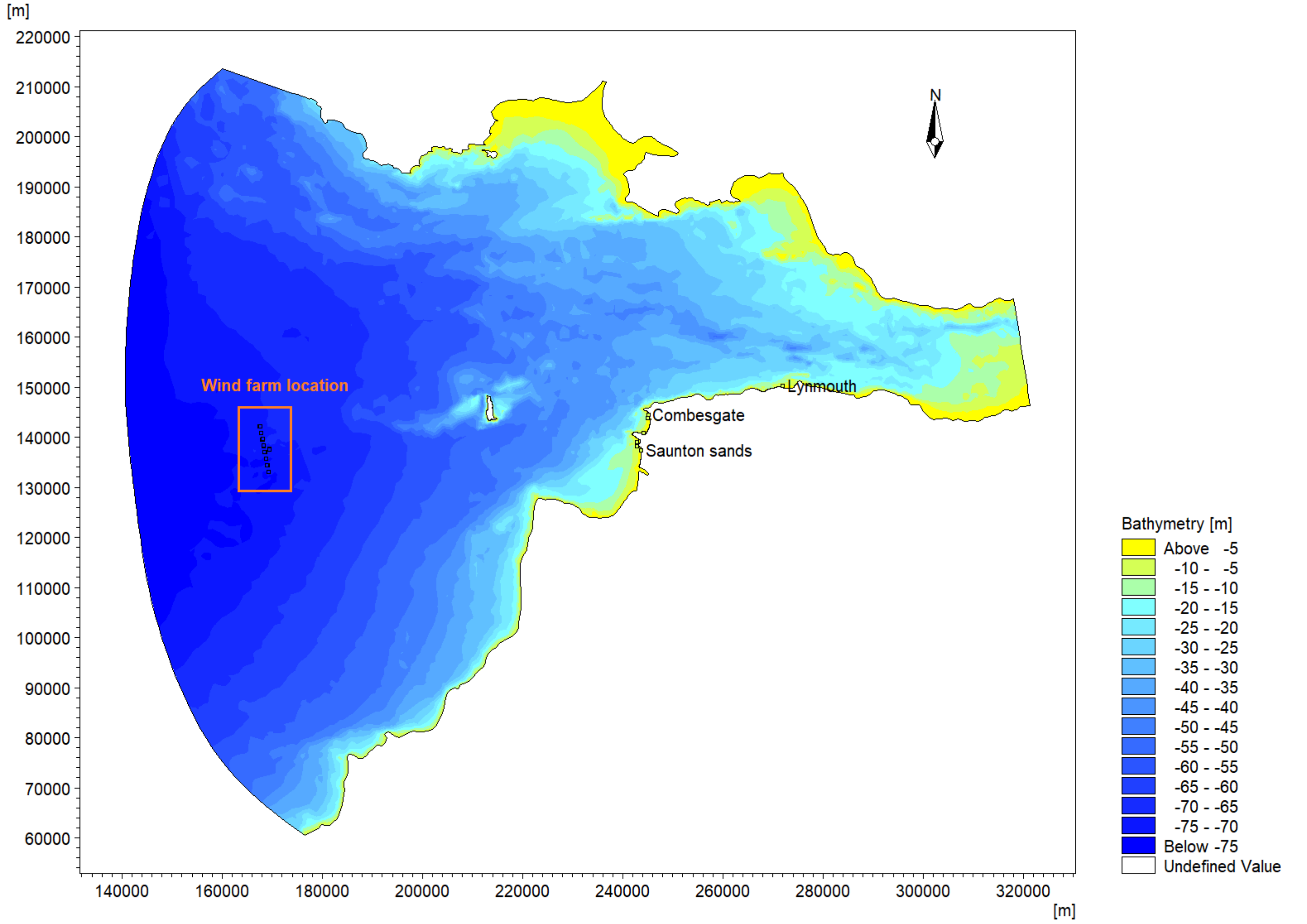


Figure 6: The concerned locations

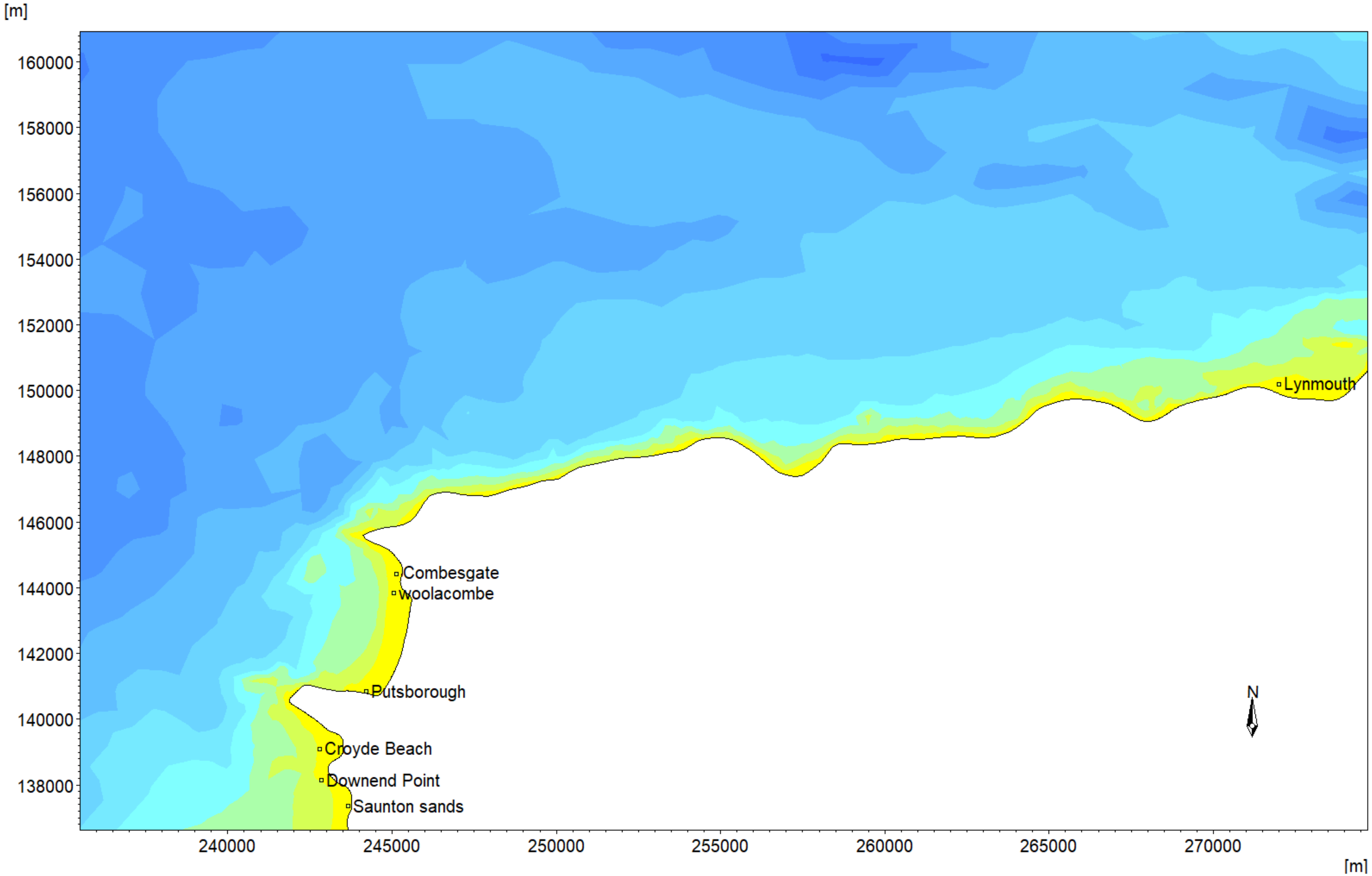


Figure 7: Computation mesh

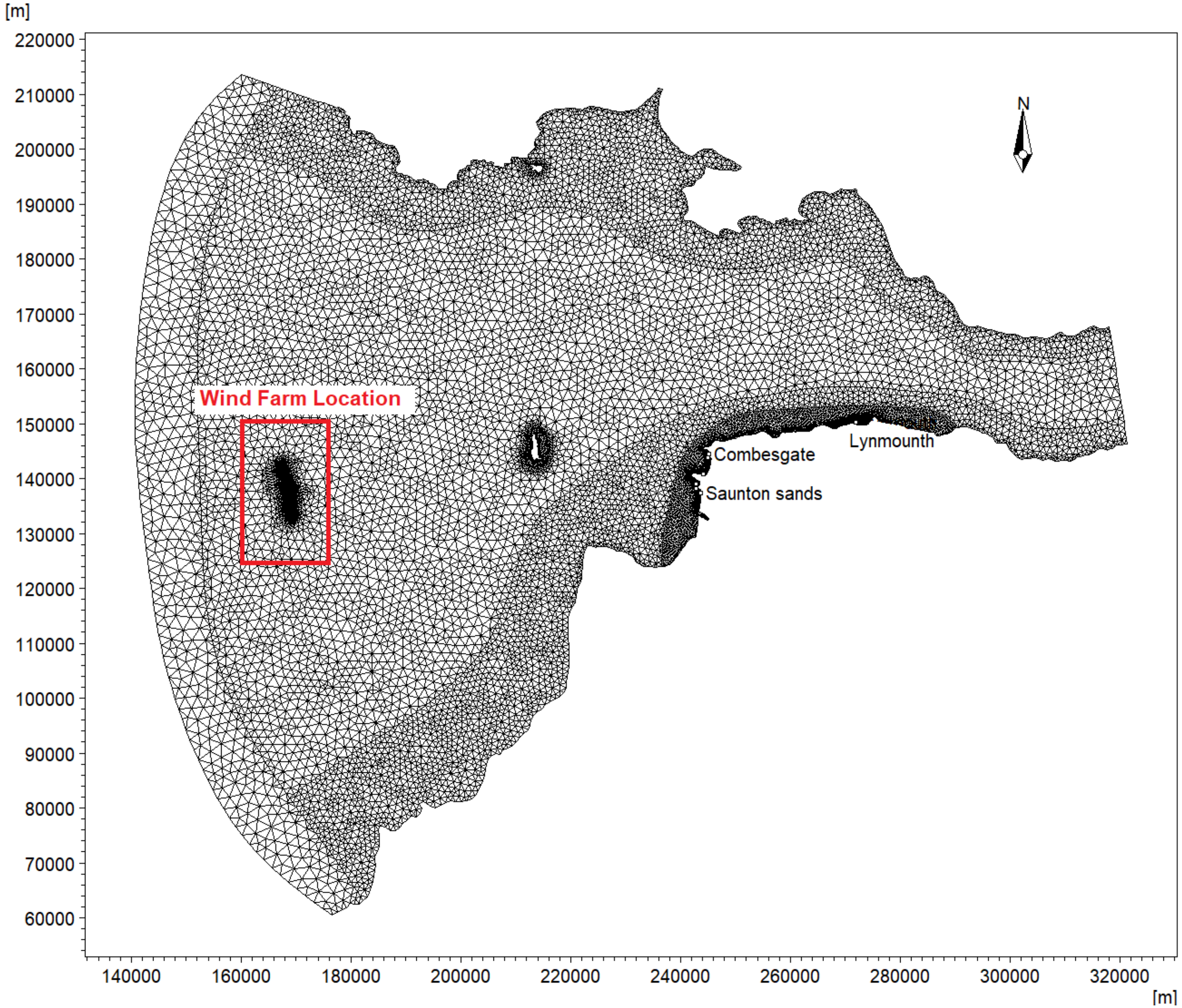
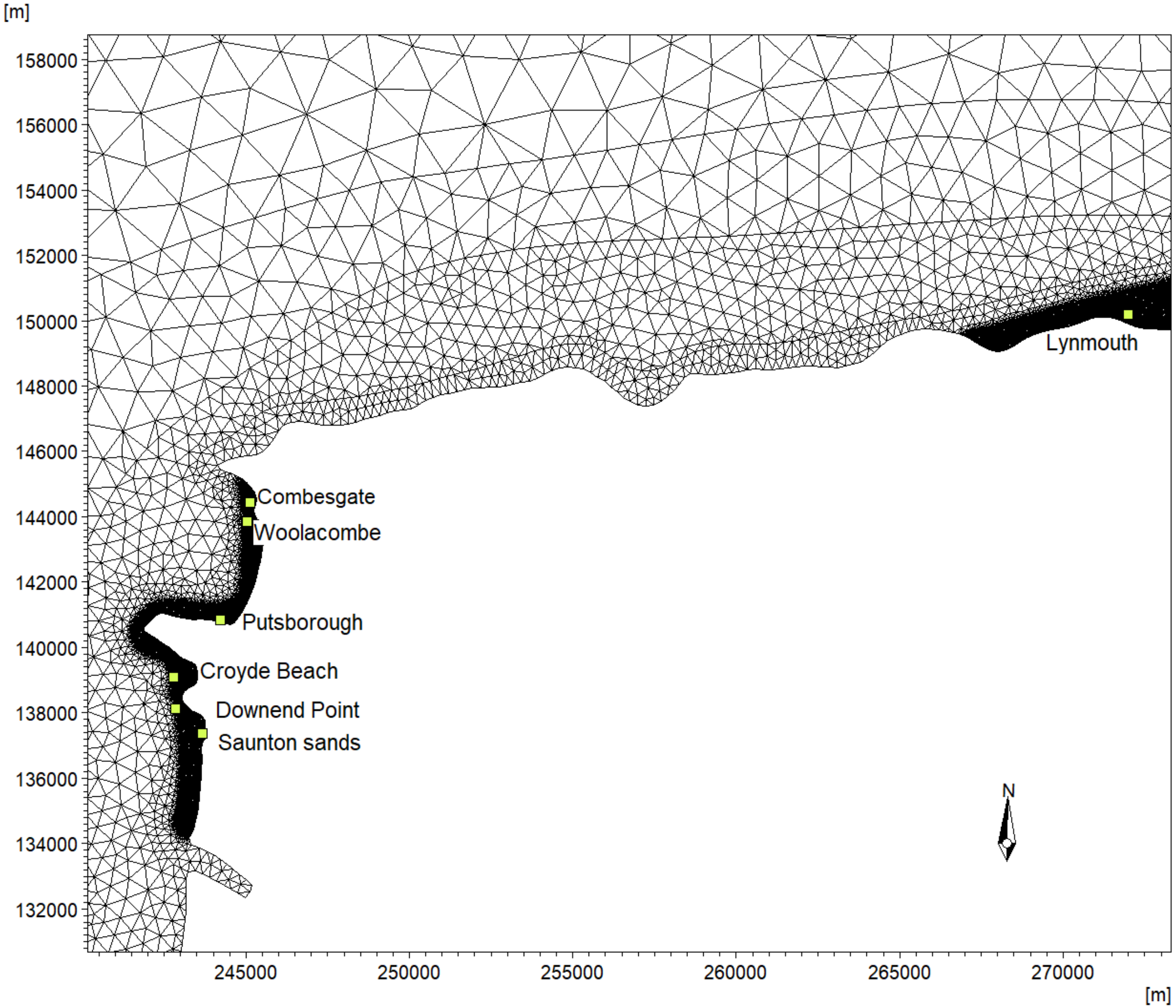


Figure 8: Computation mesh at concerned sites



5 Model Results

5.1 Wave Height

5.1.1 The significant wave heights for existing conditions and conditions with the proposed offshore wind farm were extracted at the concerned sites and are presented in **Table 6**. The changes to significant wave height were a decrease of less than 1.2mm for all scenarios and swell states. The swell state 4 (West-South-West) had the highest decrease, with an average across all concerned sites of 0.9mm decrease. The greatest decrease (of 1.2mm) was at Croyde and Woolacombe. The site where change was greater on more swell states was at Saunton Sands, with an average decrease of 0.8mm on the swell states modelled.

5.1.2 Model results indicate that the differences in wave heights due to the proposed offshore wind farm are very small (in order of millimetres) therefore 2D wave height plots for each wave condition are only presented for the existing conditions in **Figure 9** to **Figure 18**. These figures show the significant wave height (in 10cm height bands) and the direction of swell of these waves from the West, West-South-West, and west-North-West for tides at MHWS (**Figure 9** to **Figure 13**) and MLWS (**Figure 14** to **Figure 18**).

5.1.3 **Figure 19** to **Figure 28** present the contour plots of differences in wave height between with and without the proposed offshore windfarm. The difference is calculated by “wave height of with the proposed offshore wind farm” minus “wave height of without the proposed offshore wind farm”.

5.1.4 The figures show that changes of 5mm in significant wave height or higher at all tide states from various directions and at MHWS or MLWS do not appear to extend beyond a line between Lundy Island and Hartland Point. The wave direction and swell type that showed this extent of change was Swell 02 a very clean swell (low directional spread) from the West at MHWS. Changes for other wave conditions (and ones that resulted in higher waves at the concerned sites) were smaller and did not extend as far.

Table 6: Significant wave height (H_{m0}) at the concerned sites

Layout	Water level	Wave conditions	H_{m0} (m)						
			Saunton Sands	Downend Point	Croyde Beach	Puts-borough	Woola-combe	Comb-segate	Lyn-mouth
Existing (L0)	MHWS	Swell 1	1.30	1.25	1.22	0.89	1.34	1.29	1.05
		Swell 2	1.30	1.24	1.19	0.85	1.30	1.26	1.08
		Swell 3	1.32	1.27	1.26	0.93	1.37	1.32	0.99
		Swell 4	1.47	1.41	1.43	0.82	1.37	1.36	0.80
		Swell 5	1.17	1.18	1.22	1.12	1.46	1.35	0.96
	MLWS	Swell 1	1.43	1.24	1.29	0.96	1.52	1.39	1.03
		Swell 2	1.42	1.22	1.27	0.93	1.49	1.37	1.05
		Swell 3	1.44	1.25	1.33	0.99	1.55	1.40	0.98
		Swell 4	1.60	1.43	1.51	0.88	1.57	1.44	0.86
		Swell 5	1.26	1.11	1.24	1.15	1.60	1.40	0.92
Wind Farm (L1)	MHWS	Swell 1	1.30	1.25	1.22	0.89	1.34	1.29	1.05
		Swell 2	1.30	1.23	1.19	0.85	1.30	1.26	1.08
		Swell 3	1.32	1.27	1.26	0.93	1.37	1.32	0.99
		Swell 4	1.47	1.41	1.43	0.82	1.37	1.36	0.80
		Swell 5	1.17	1.18	1.22	1.12	1.46	1.35	0.96
	MLWS	Swell 1	1.43	1.23	1.29	0.96	1.52	1.39	1.03
		Swell 2	1.42	1.22	1.27	0.93	1.49	1.37	1.05
		Swell 3	1.44	1.25	1.33	0.98	1.55	1.40	0.98
		Swell 4	1.60	1.43	1.51	0.88	1.56	1.44	0.86
		Swell 5	1.26	1.11	1.24	1.15	1.60	1.40	0.92

Layout	Water level	Wave conditions	H_{m0} (m)						
			Saunton Sands	Downend Point	Croyde Beach	Puts-borough	Woola-combe	Comb-segate	Lyn-mouth
Change with the Wind Farm	MHWS	Swell 1	-0.0009	-0.0009	-0.0008	-0.0002	-0.0004	-0.0003	-0.0003
		Swell 2	-0.0010	-0.0009	-0.0008	-0.0002	-0.0002	-0.0002	-0.0003
		Swell 3	-0.0008	-0.0008	-0.0008	-0.0003	-0.0005	-0.0004	-0.0003
		Swell 4	-0.0011	-0.0011	-0.0012	-0.0007	-0.0012	-0.0011	-0.0003
		Swell 5	-0.0001	-0.0001	-0.0001	0.0000	0.0000	0.0000	-0.0005
	MLWS	Swell 1	-0.0008	-0.0007	-0.0007	-0.0002	-0.0003	-0.0002	0.0000
		Swell 2	-0.0008	-0.0007	-0.0006	-0.0001	-0.0002	-0.0001	0.0000
		Swell 3	-0.0007	-0.0007	-0.0006	-0.0002	-0.0004	-0.0002	0.0000
		Swell 4	-0.0007	-0.0009	-0.0010	-0.0005	-0.0009	-0.0004	-0.0001
		Swell 5	-0.0001	-0.0001	-0.0001	0.0000	0.0000	0.0000	0.0000

Figure 9: Swell 01 - Average surfing swell from West at MHWS

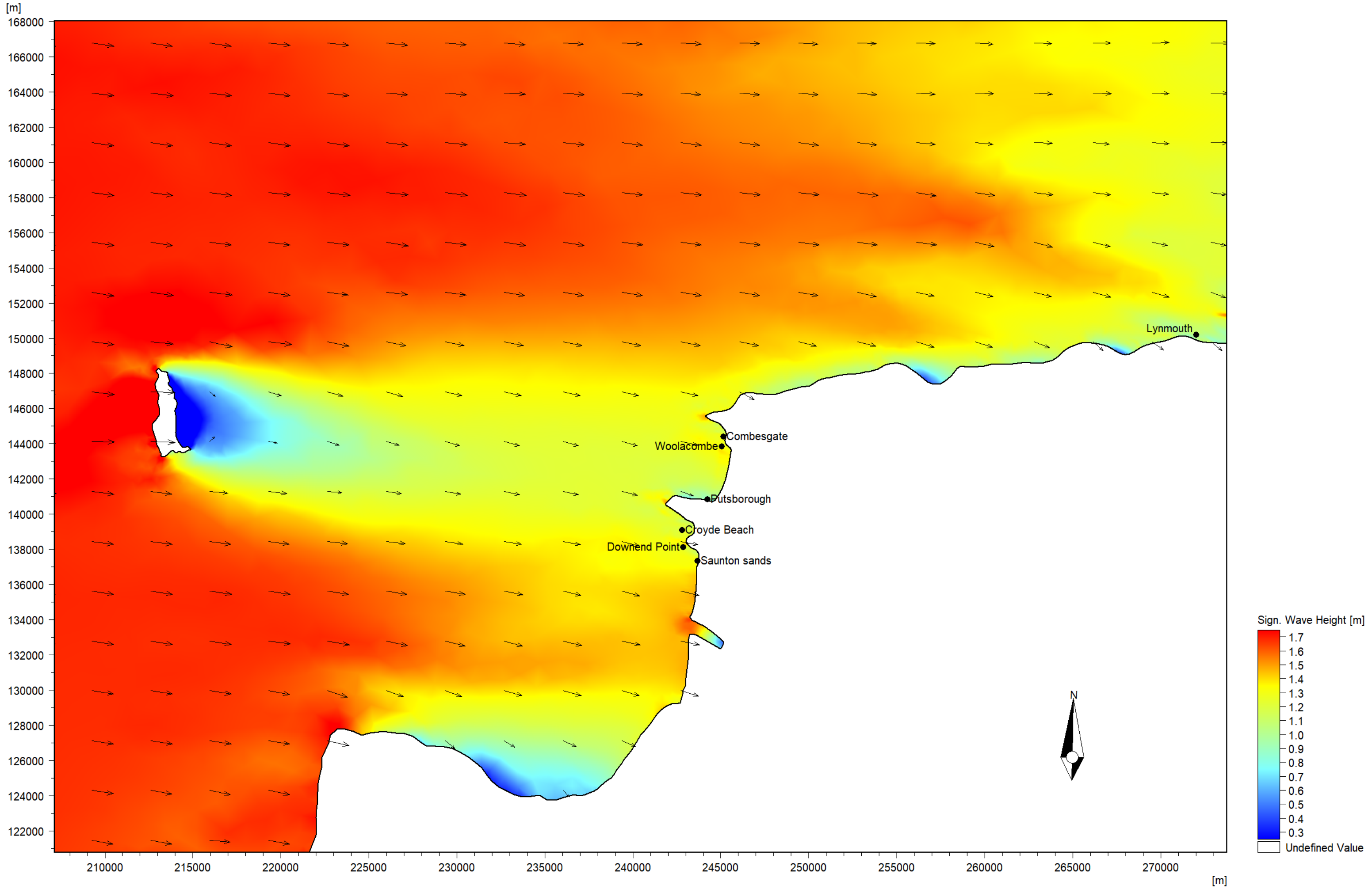


Figure 10: Swell 02 - Very clean swell (low directional spread) from West at MHWS

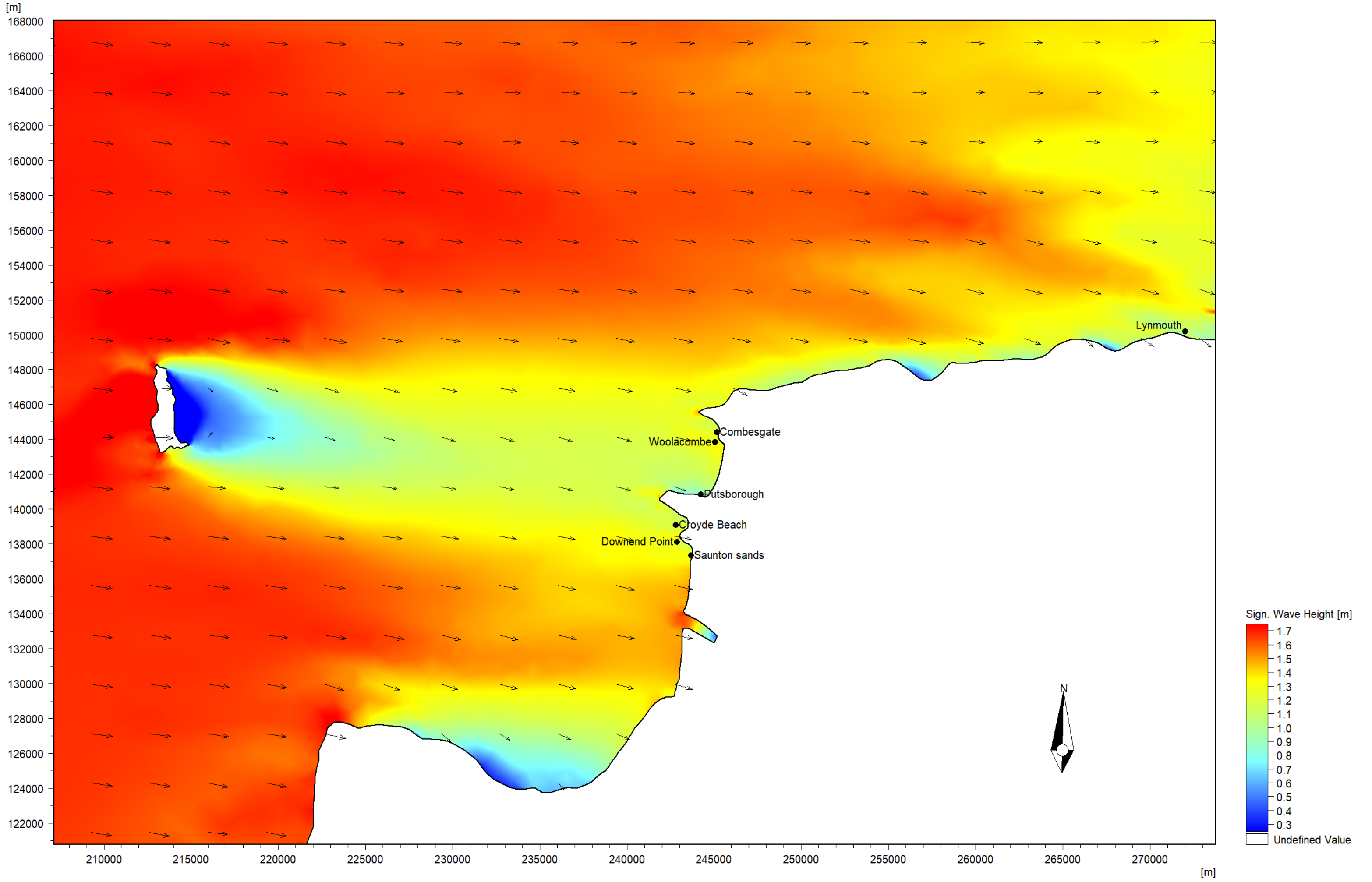


Figure 11: Swell 03 - Reasonable surfing swell (high directional spread), from West at MHWS

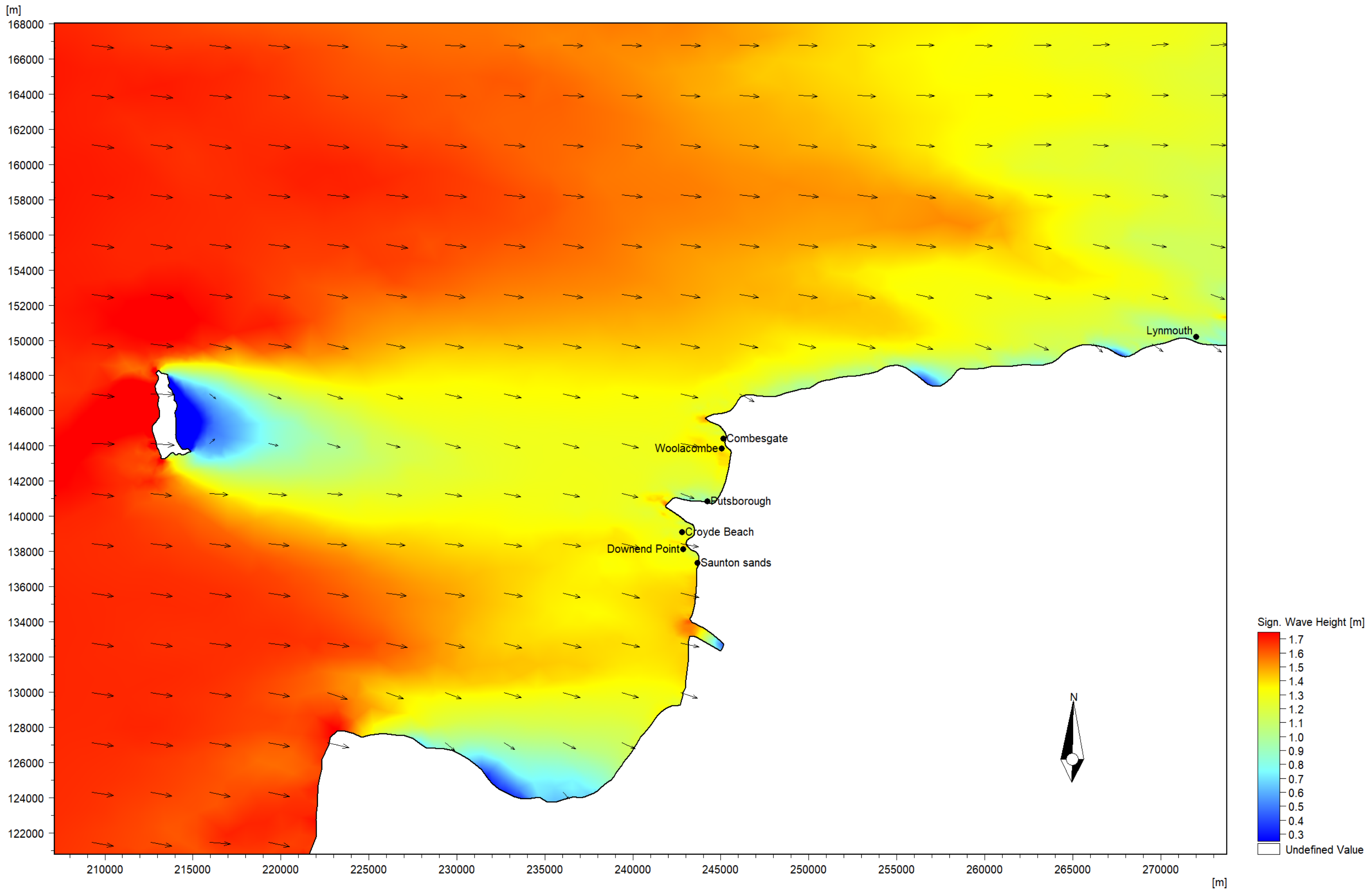


Figure 12: Swell 04 -Very clean swell (low directional spread), from WSW at MHWS

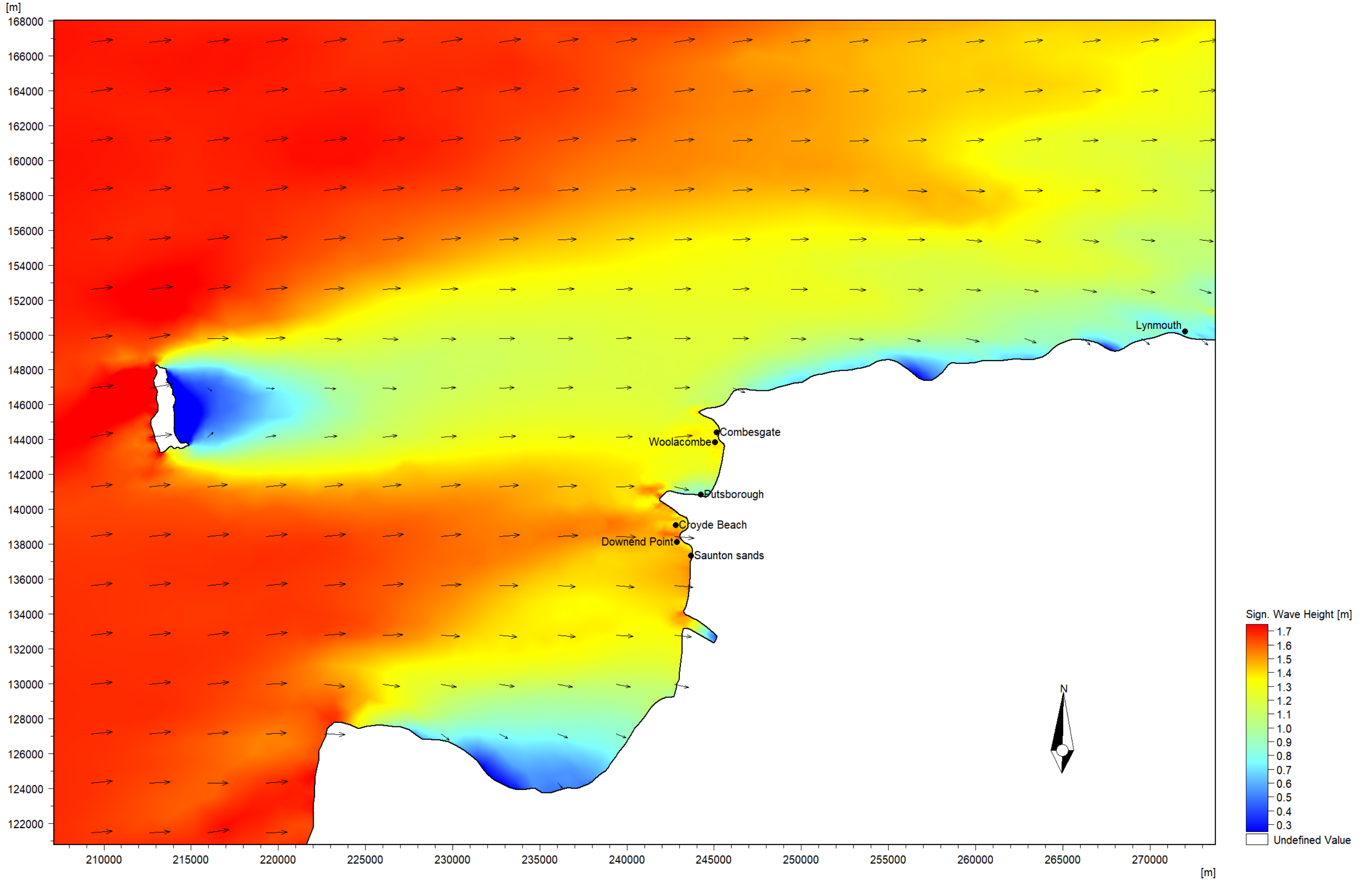


Figure 13: Swell 05 -Very clean swell (low directional spread), from WNW at MHWS

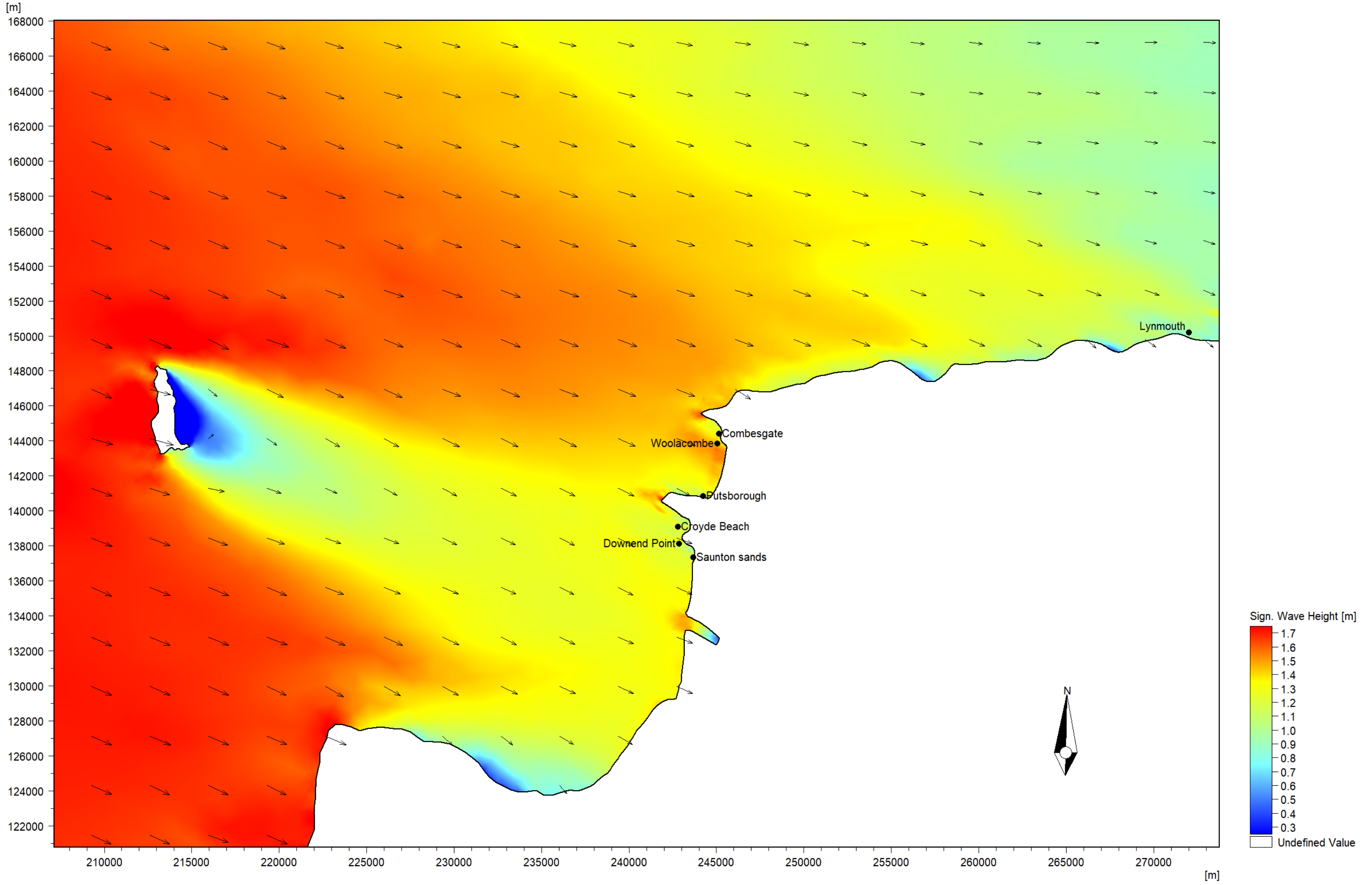


Figure 14: Swell 01 - Average surfing swell from West at MLWS

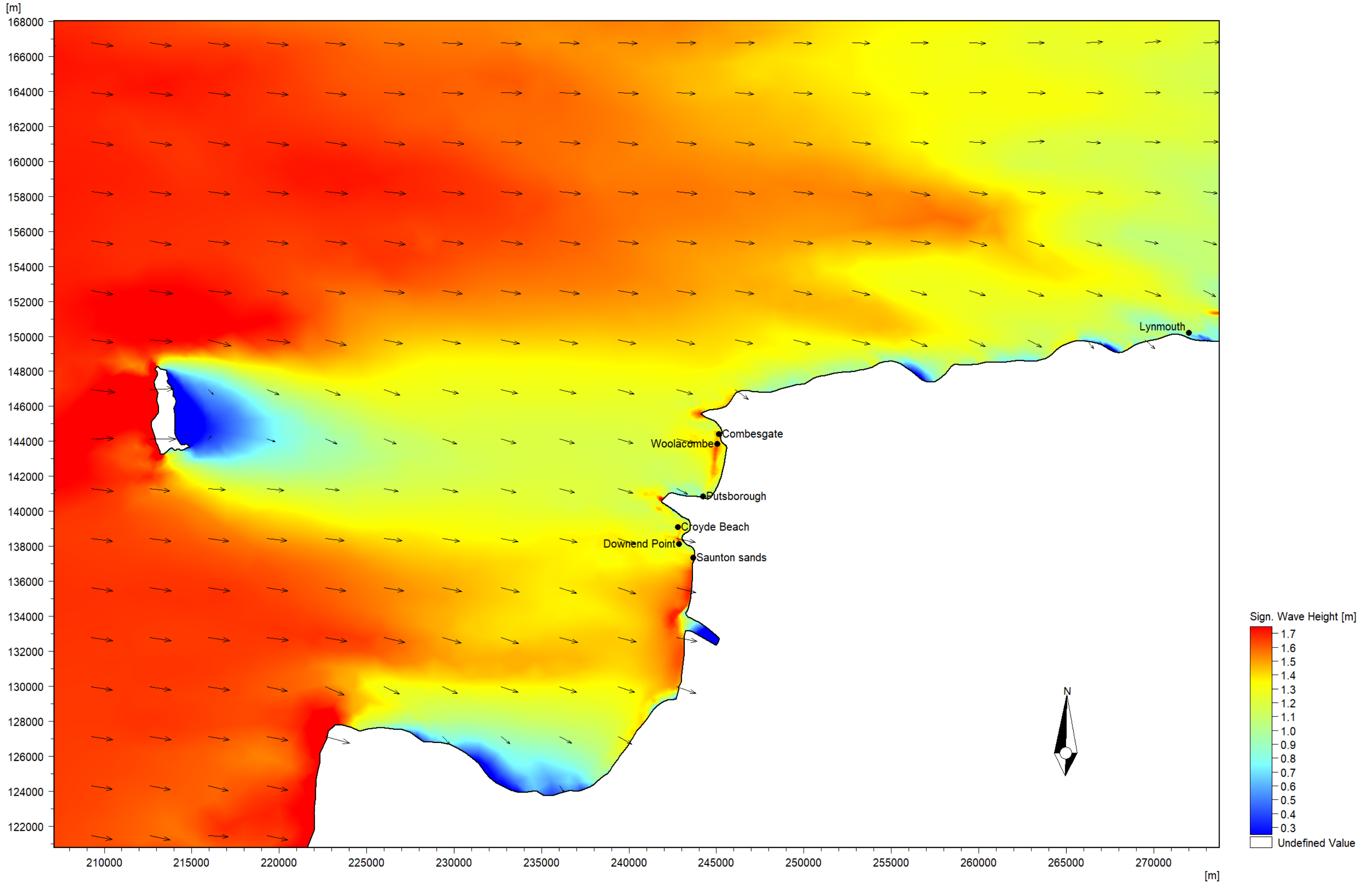


Figure 15: Swell 02 - Very clean swell (low directional spread) from West at MLWS

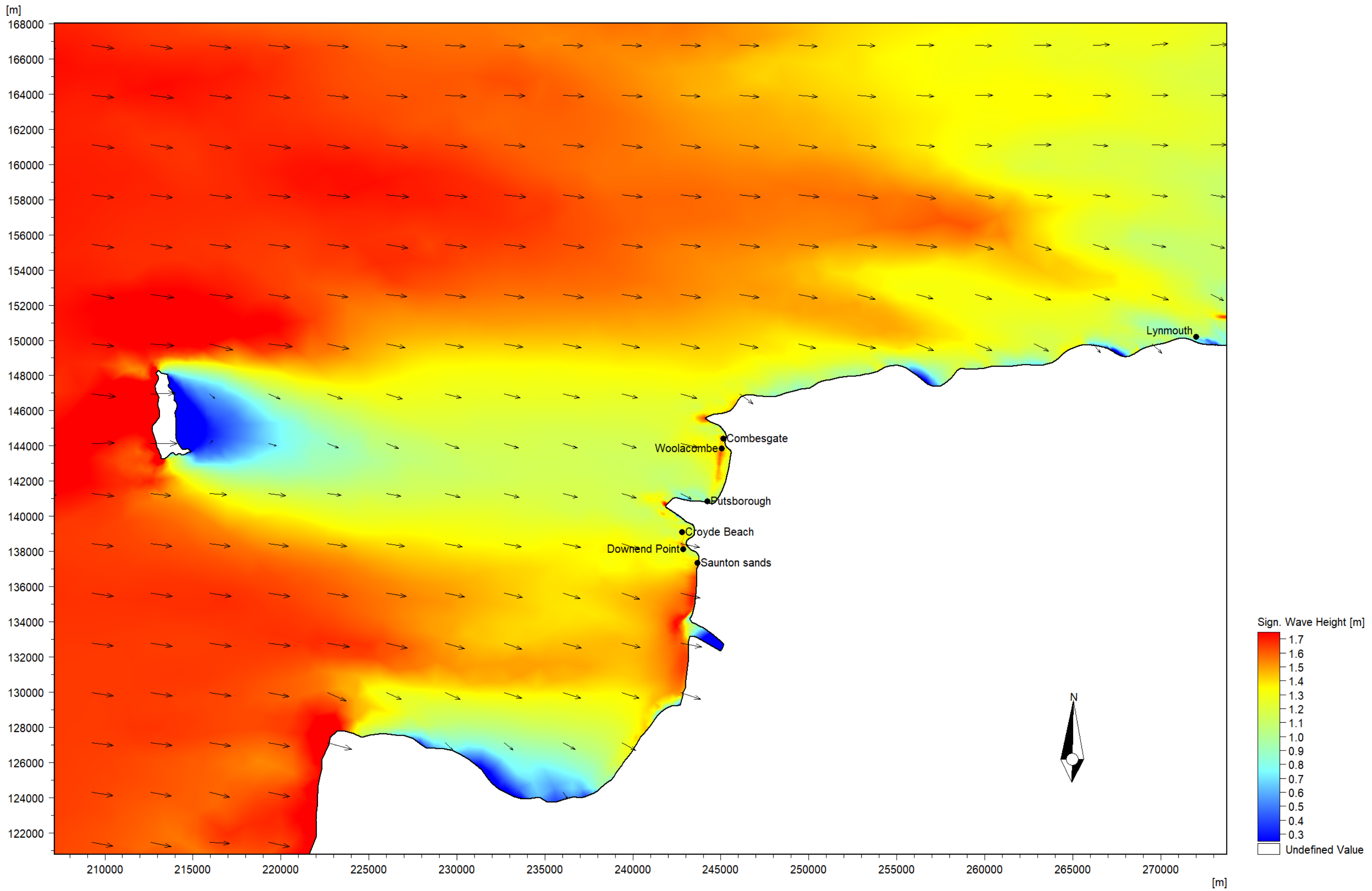


Figure 16: Swell 03 - Reasonable surfing swell (high directional spread), from West at MLWS

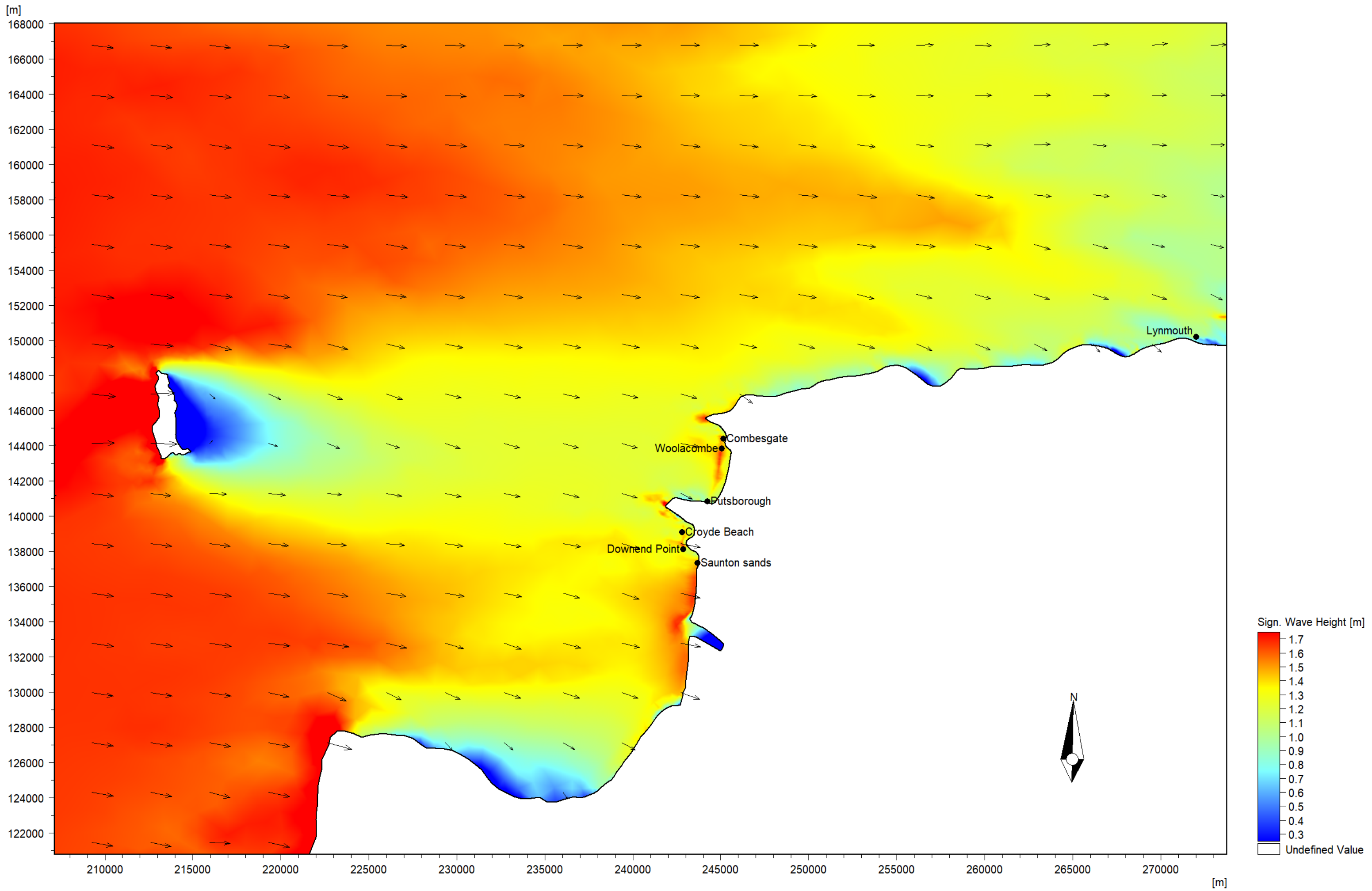


Figure 17: Swell 04 -Very clean swell (low directional spread), from WSW at MLWS

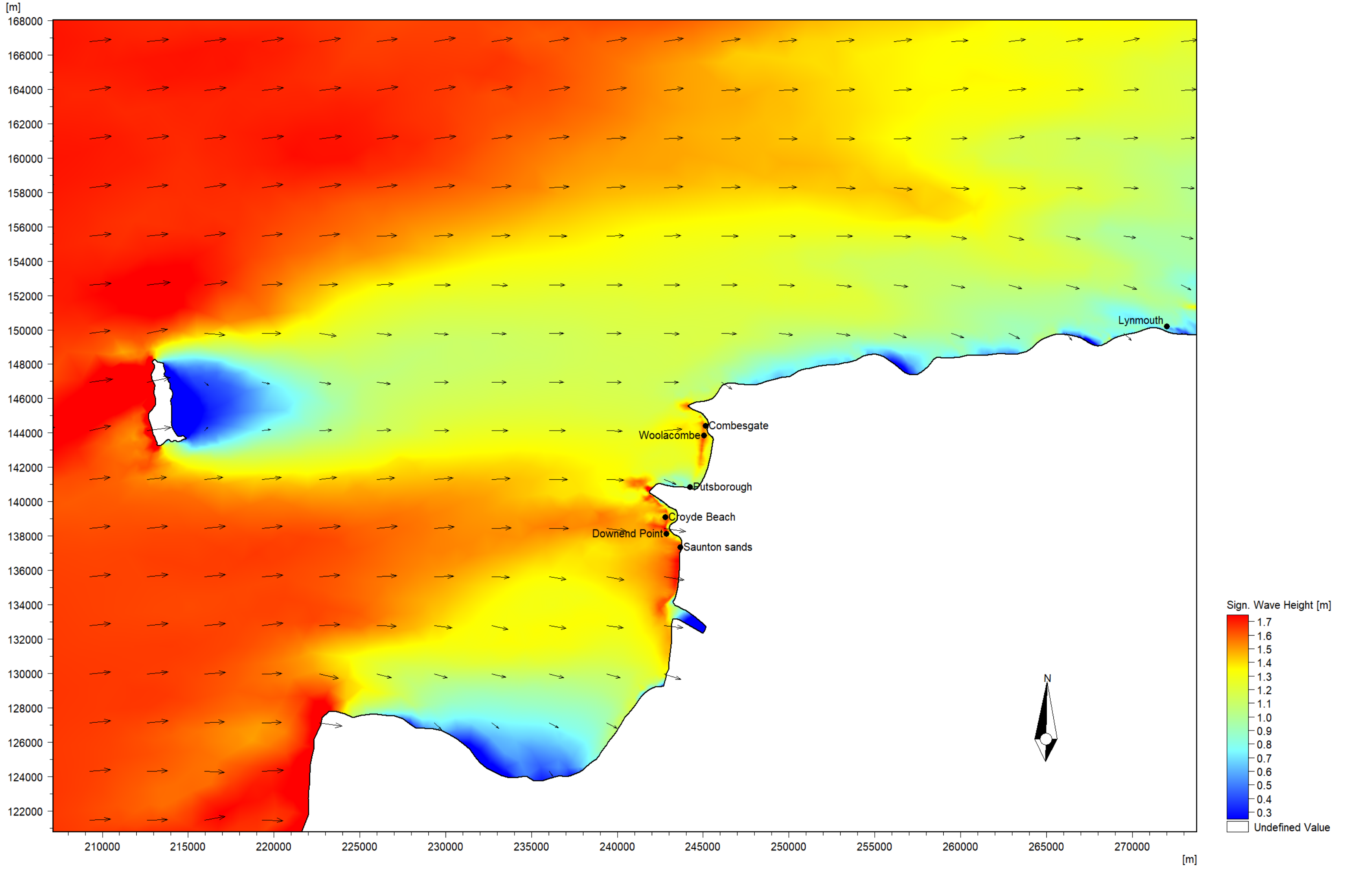


Figure 18: Swell 05 -Very clean swell (low directional spread), from WNW at MLWS

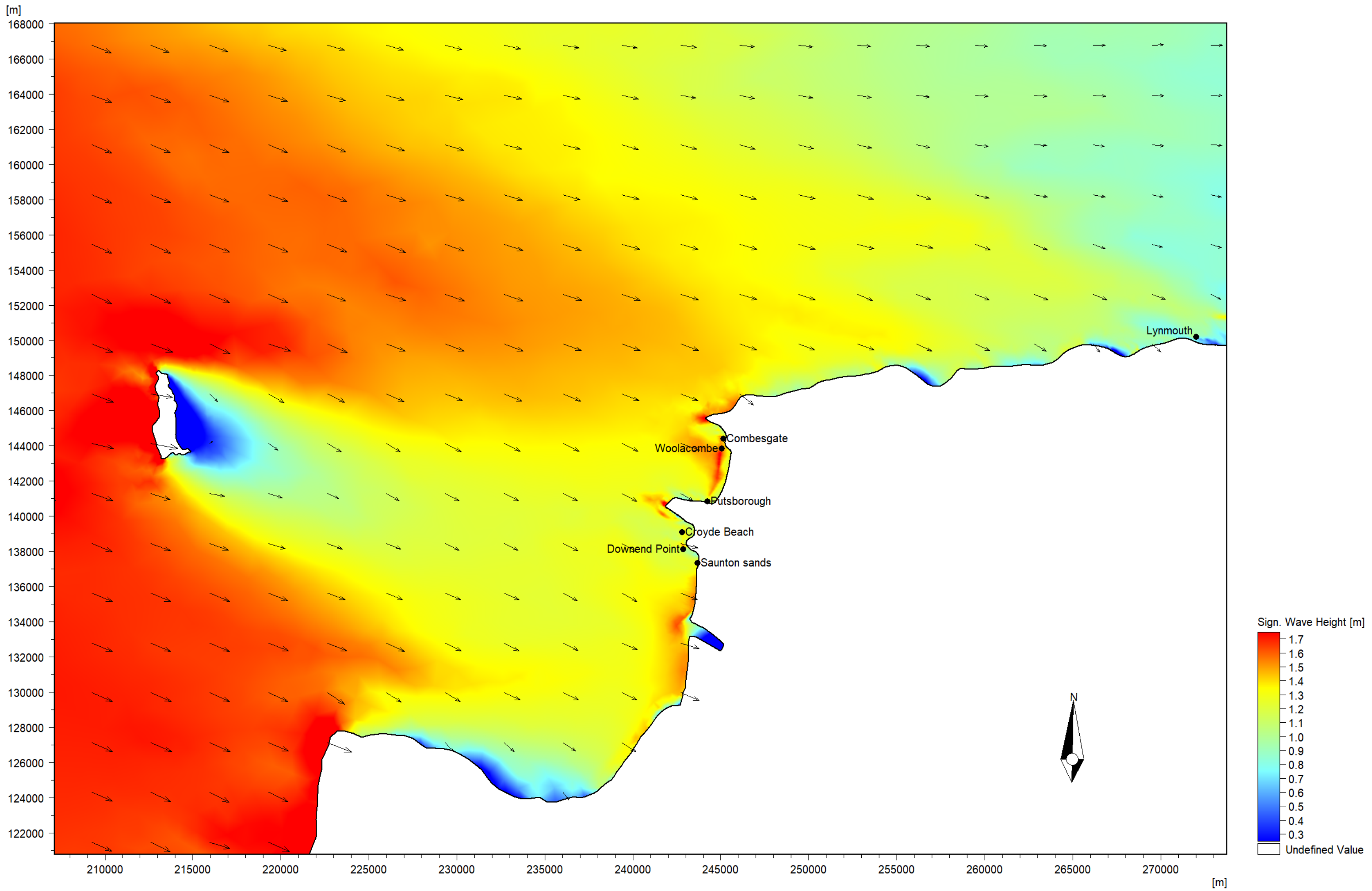


Figure 19: Differences in significant wave heigh (L1 - L0) for Swell 01 at MHWS

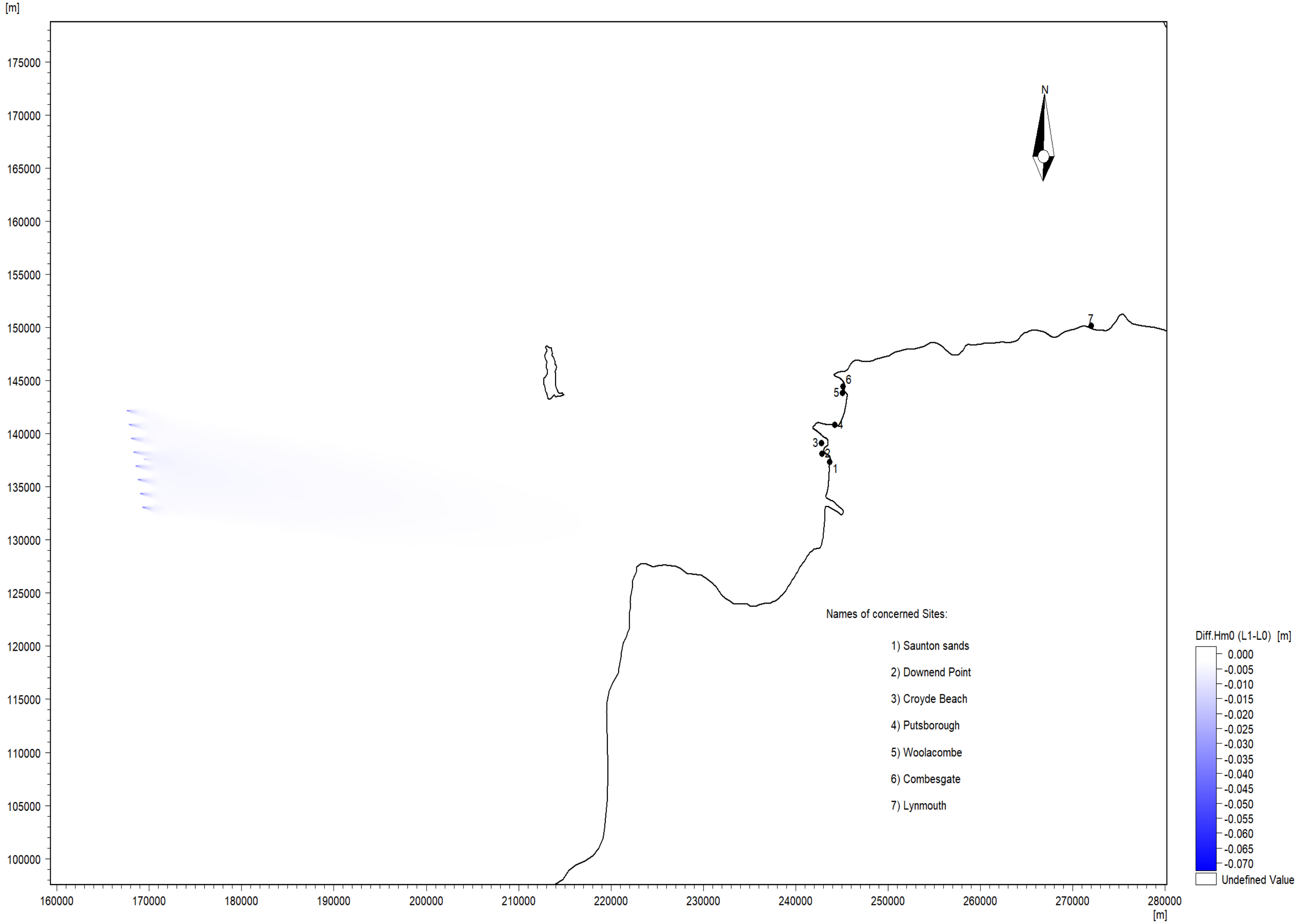


Figure 20: Differences in significant wave heigh (L1 - L0) for Swell 02 at MHWS

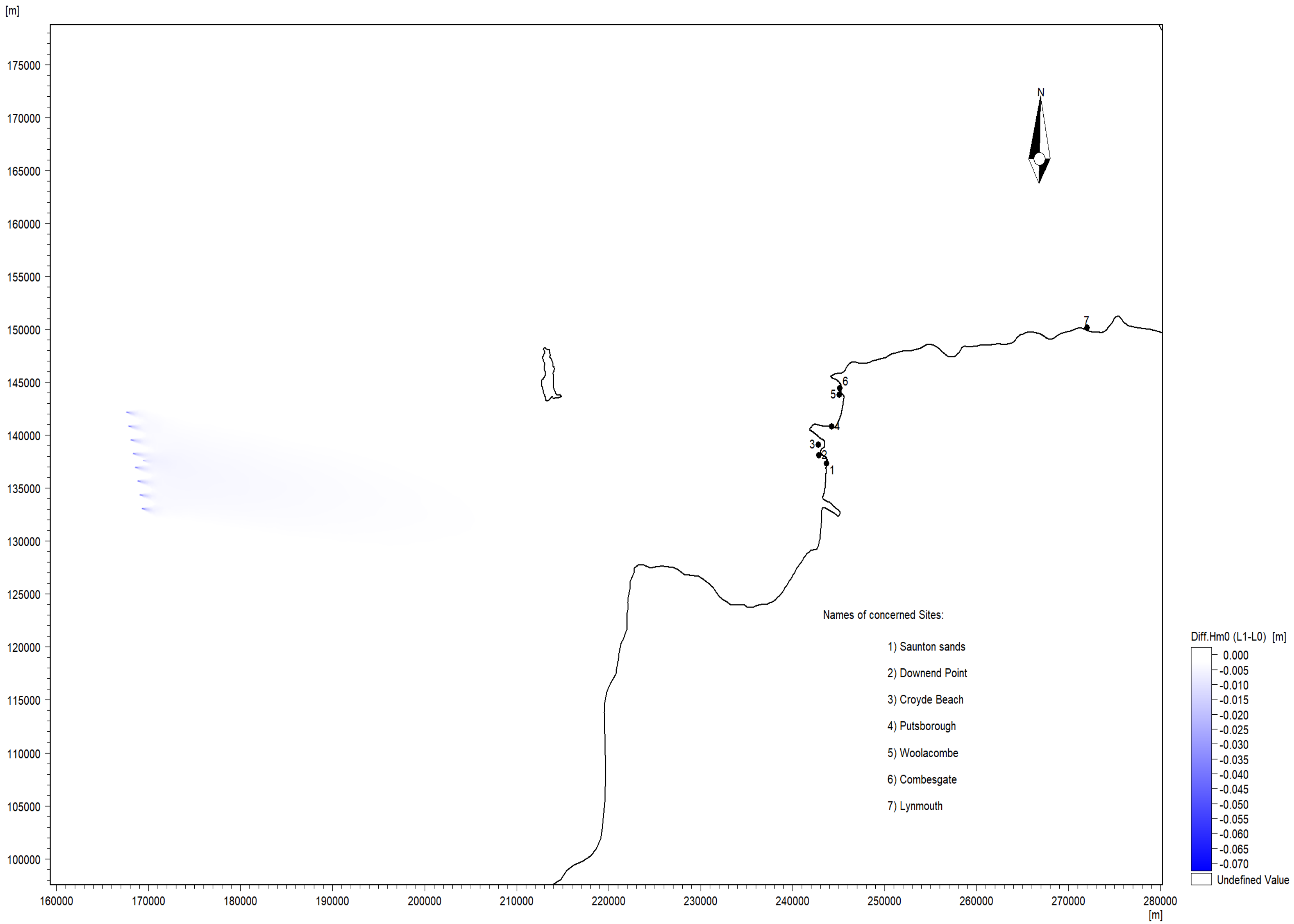


Figure 21: Differences in significant wave heigh (L1 - L0) for Swell 03 at MHWS

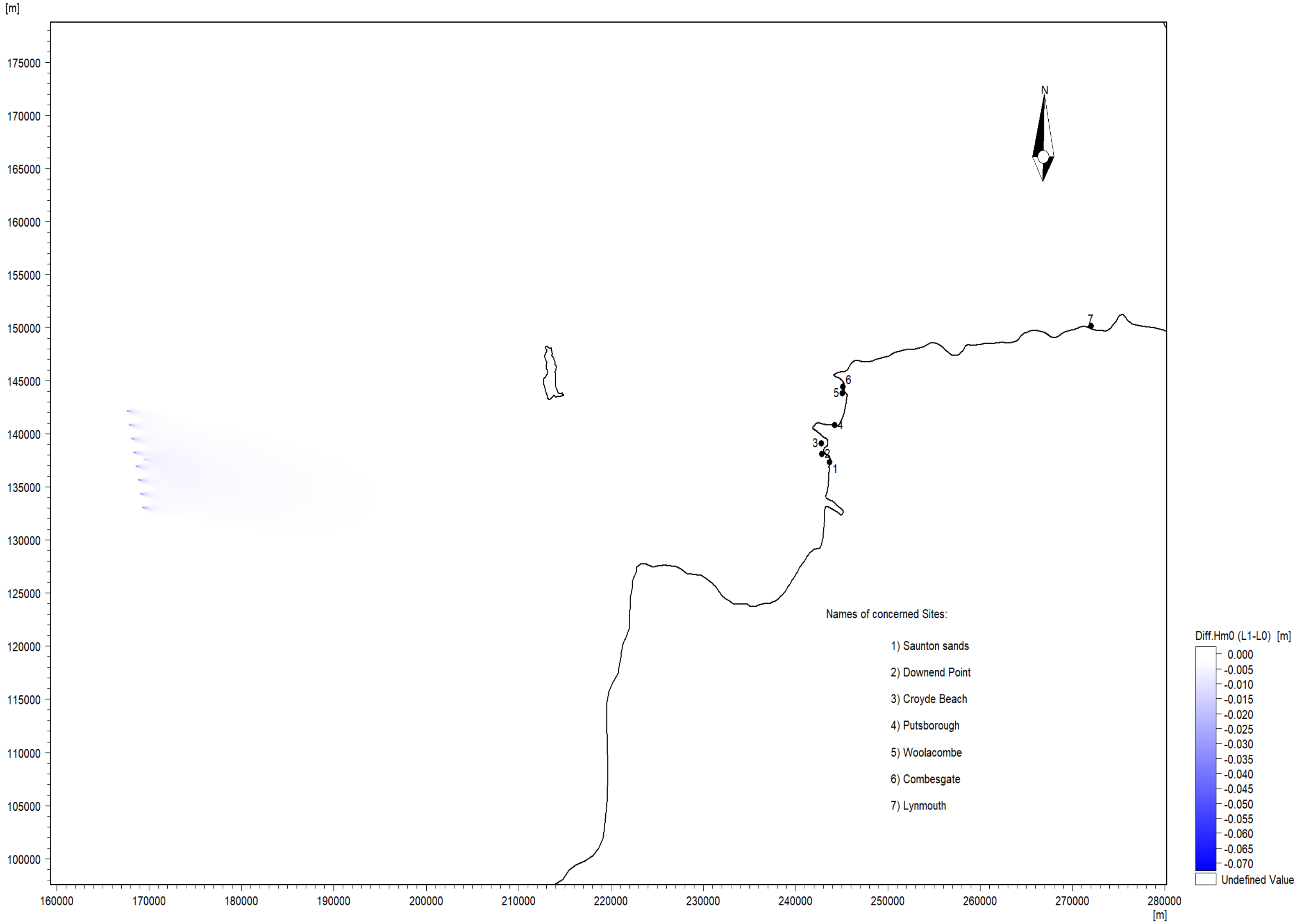


Figure 22: Differences in significant wave heigh (L1 - L0) for Swell 04 at MHWS

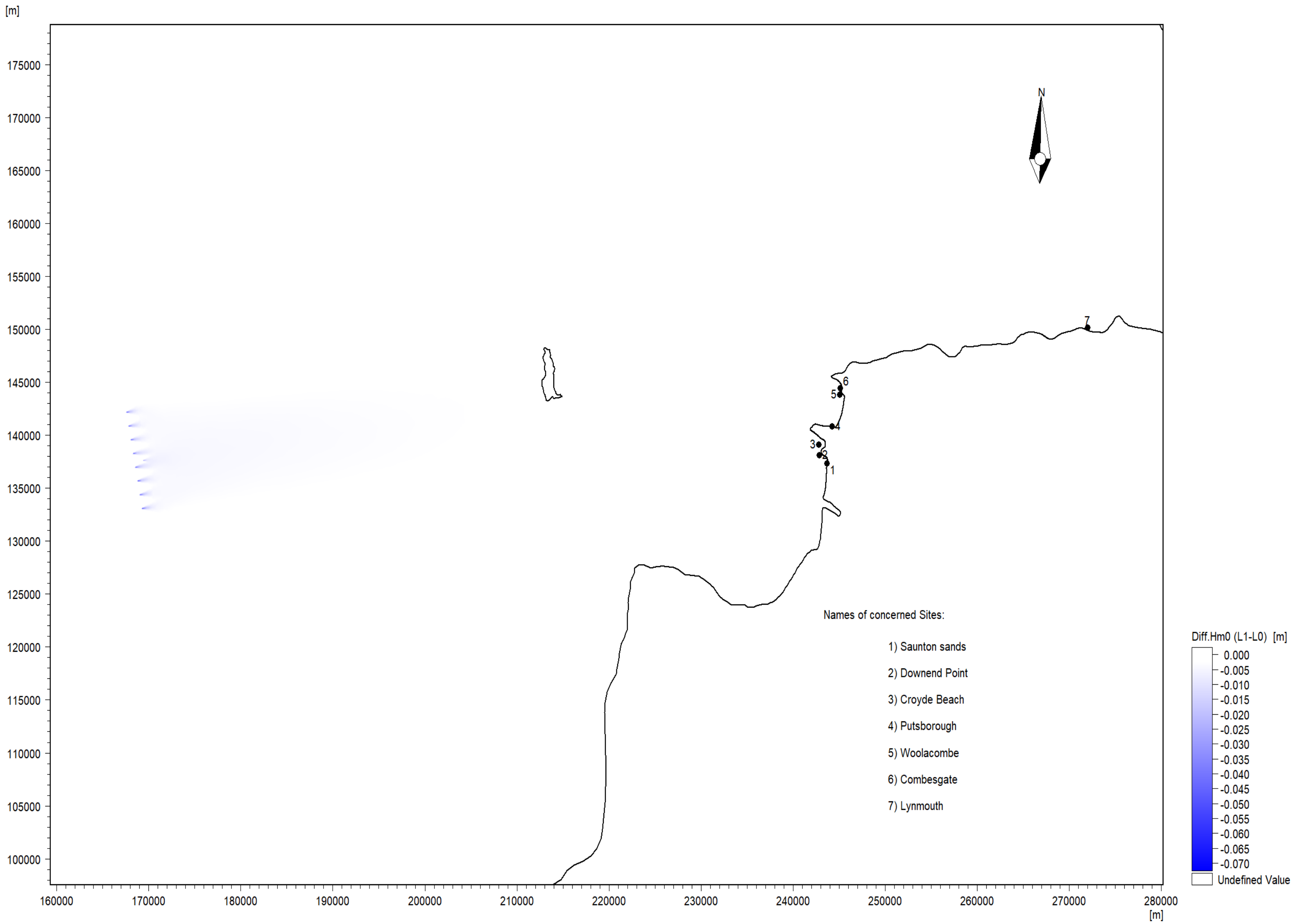


Figure 23: Differences in significant wave heigh (L1 - L0) for Swell 05 at MHWS

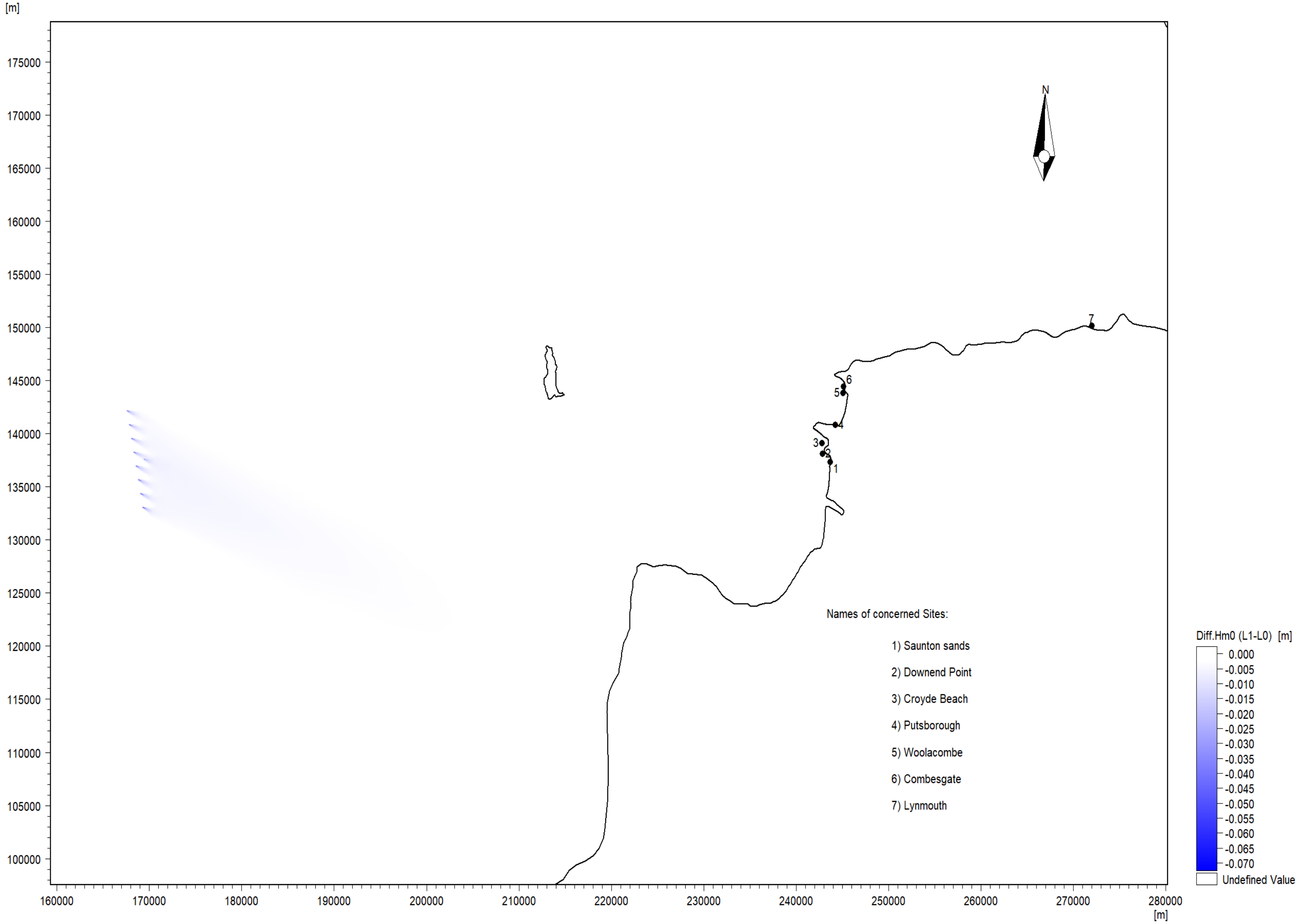


Figure 24: Differences in significant wave heigh (L1 - L0) for Swell 01 at MLWS

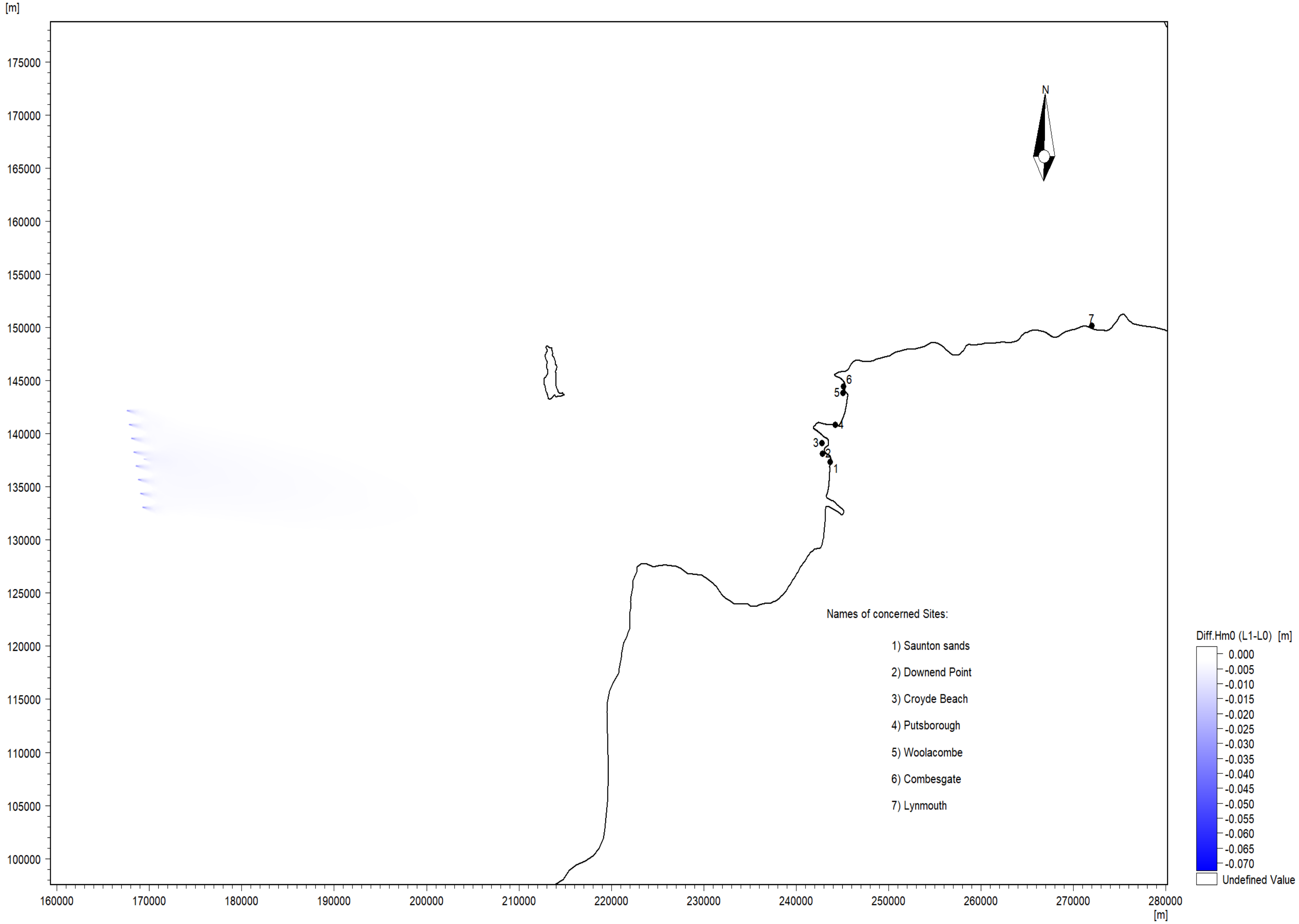


Figure 25: Differences in significant wave heigh (L1 - L0) for Swell 02 at MLWS

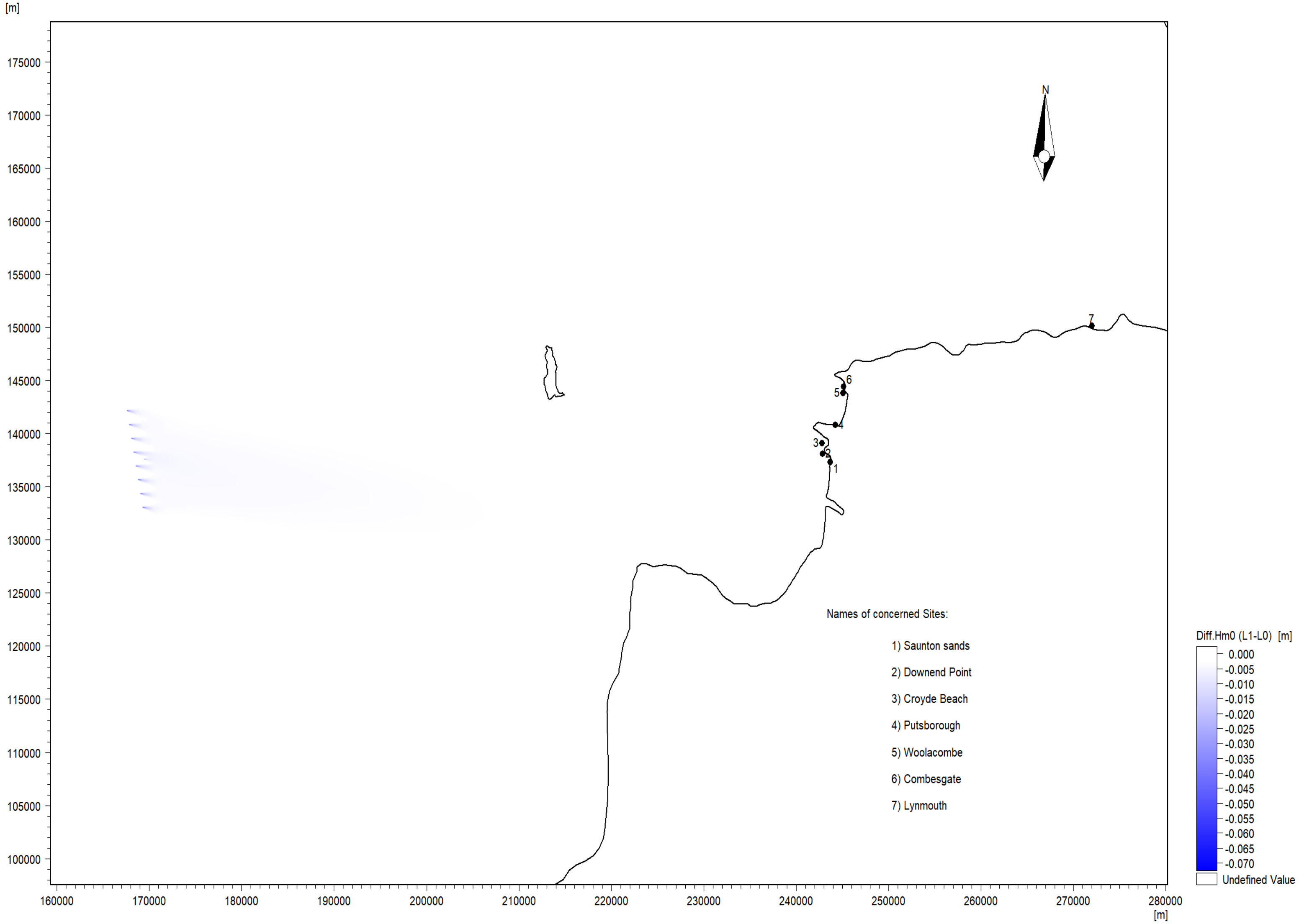


Figure 26: Differences in significant wave heigh (L1 - L0) for Swell 03 at MLWS

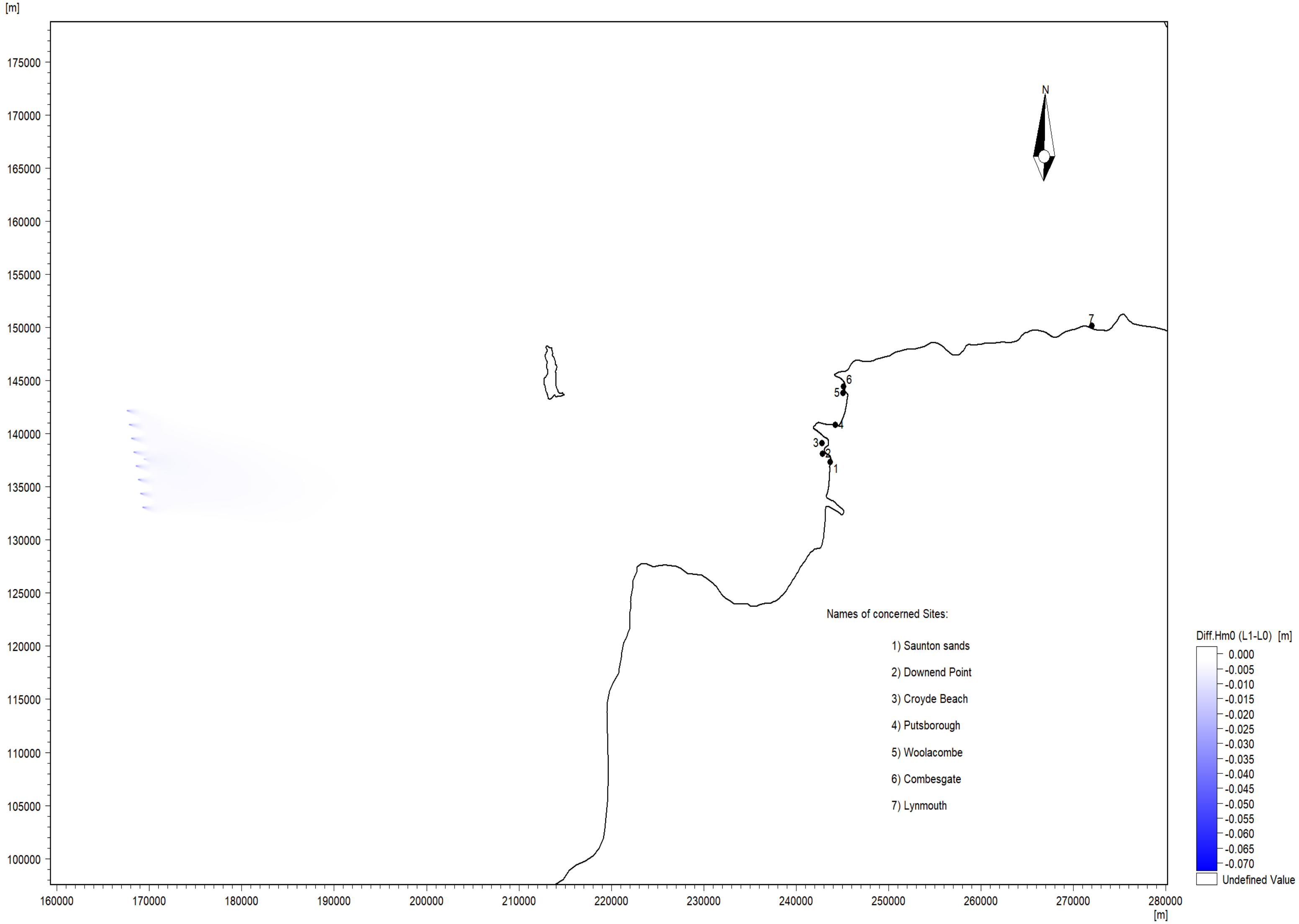


Figure 27: Differences in significant wave heigh (L1 - L0) for Swell 04 at MLWS

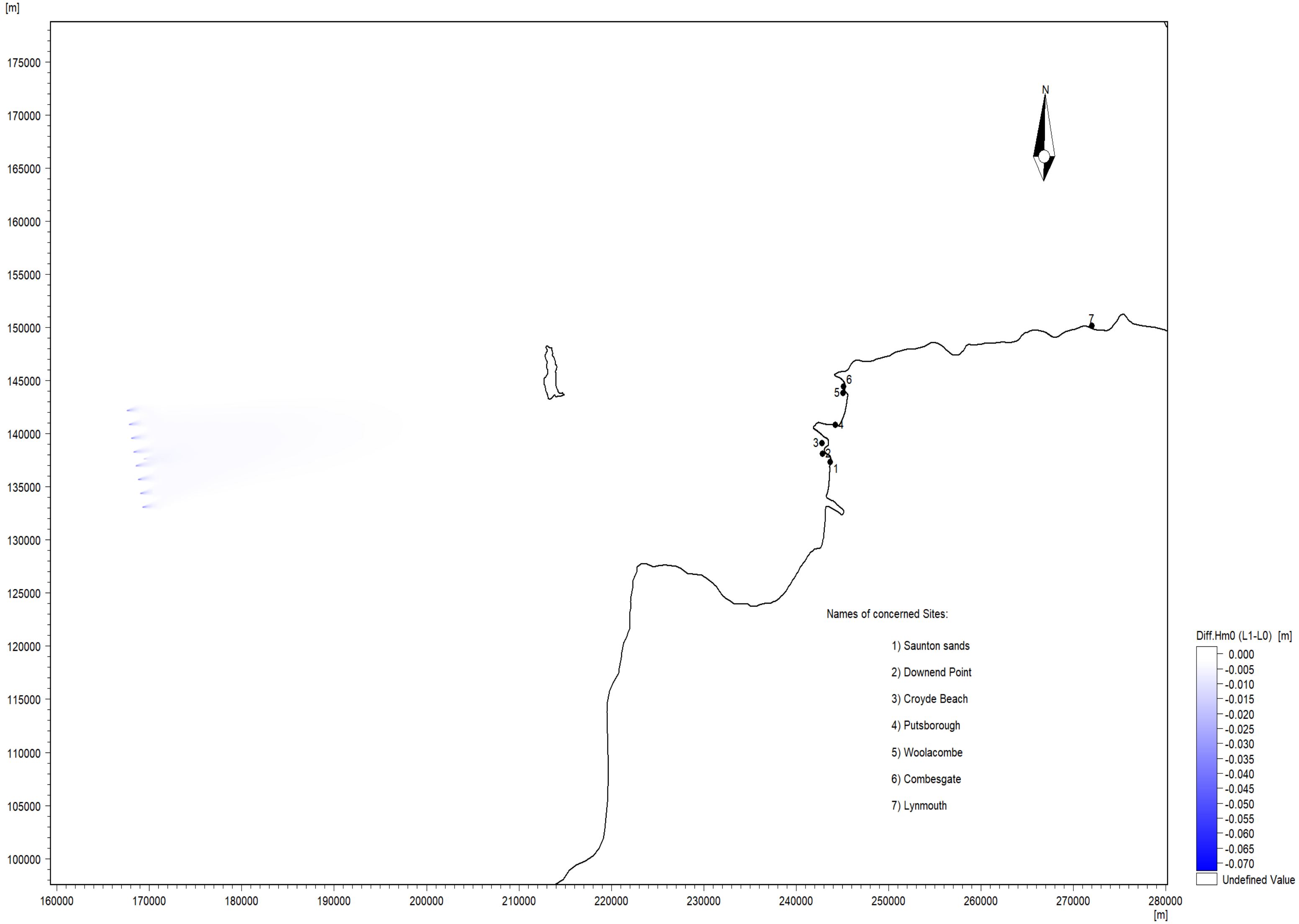
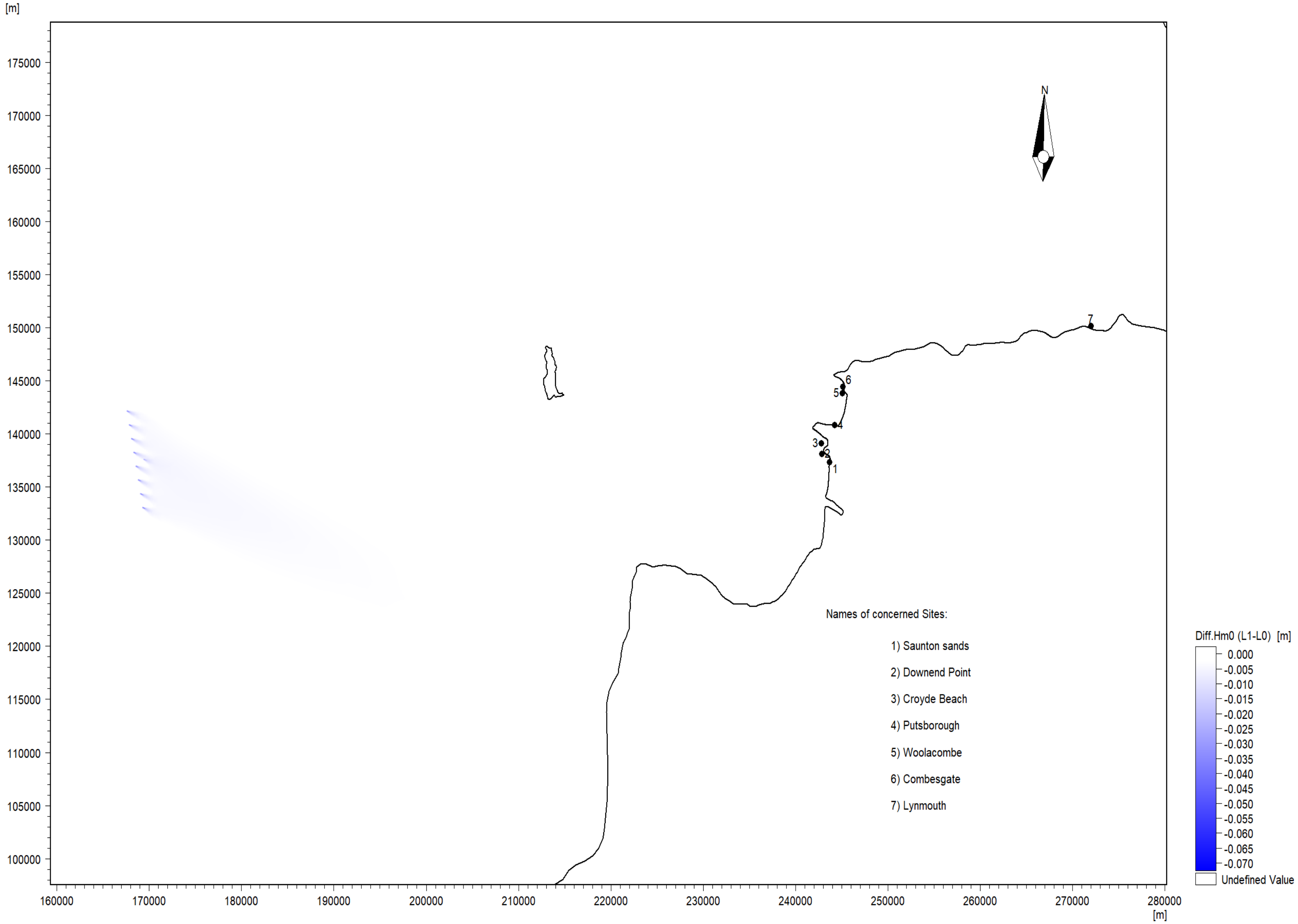


Figure 28: Differences in significant wave height (L1 - L0) for Swell 05 at MLWS



5.2 Peak Wave Period

5.2.1 The peak wave period for existing conditions and conditions with the proposed offshore wind farm were extracted at the concerned sites and are presented in **Table 7**. Any changes to the peak wave period recorded in the model were smaller than one hundredth of a second (the highest being 4 thousandths of a second).

Table 7: Peak wave period (Tp) at the concerned sites for existing conditions and after wind farm

Layout	Water level	Wave conditions	T_p (s)						
			Saunton Sands	Downend Point	Croyde Beach	Puts-borough	Woola-combe	Comb-segate	Lyn-mouth
Existing (L0)	MHWS	Swell 1	11.80	11.80	11.81	11.83	11.81	11.80	11.76
		Swell 2	11.80	11.80	11.82	11.85	11.82	11.81	11.76
		Swell 3	11.79	11.79	11.79	11.80	11.79	11.79	11.78
		Swell 4	11.78	11.78	11.77	11.81	11.79	11.77	11.87
		Swell 5	11.79	11.78	11.77	11.74	11.76	11.76	11.74
	MLWS	Swell 1	11.82	11.81	11.83	11.85	11.82	11.82	11.76
		Swell 2	11.82	11.82	11.84	11.87	11.83	11.83	11.75
		Swell 3	11.81	11.80	11.81	11.83	11.81	11.80	11.77
		Swell 4	11.79	11.78	11.78	11.84	11.80	11.79	11.82
		Swell 5	11.82	11.81	11.80	11.77	11.78	11.78	11.76
Wind Farm (L1)	MHWS	Swell 1	11.80	11.80	11.81	11.83	11.81	11.80	11.77
		Swell 2	11.80	11.80	11.82	11.85	11.82	11.81	11.76
		Swell 3	11.79	11.79	11.79	11.80	11.79	11.79	11.78
		Swell 4	11.78	11.78	11.77	11.81	11.79	11.77	11.87
		Swell 5	11.79	11.78	11.77	11.74	11.76	11.76	11.74
	MLWS	Swell 1	11.82	11.81	11.83	11.85	11.82	11.82	11.76
		Swell 2	11.82	11.82	11.84	11.87	11.83	11.83	11.75
		Swell 3	11.81	11.80	11.81	11.83	11.81	11.80	11.77
		Swell 4	11.79	11.78	11.78	11.84	11.80	11.79	11.82
		Swell 5	11.82	11.81	11.80	11.77	11.78	11.78	11.76

Layout	Water level	Wave conditions	T_p (s)						
			Saunton Sands	Downend Point	Croyde Beach	Puts-borough	Woola-combe	Comb-segate	Lyn-mouth
Change with the Wind Farm	MHWS	Swell 1	0.0004	0.0004	0.0003	0.0002	0.0002	0.0001	0.0002
		Swell 2	0.0003	0.0003	0.0003	0.0001	0.0001	0.0001	0.0002
		Swell 3	0.0003	0.0003	0.0003	0.0002	0.0001	0.0002	0.0002
		Swell 4	0.0004	0.0004	0.0003	0.0004	0.0004	0.0004	0.0004
		Swell 5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003
	MLWS	Swell 1	0.0004	0.0003	0.0003	0.0002	0.0001	0.0001	0.0000
		Swell 2	0.0004	0.0004	0.0004	0.0002	0.0001	0.0001	0.0000
		Swell 3	0.0003	0.0004	0.0003	0.0001	0.0001	0.0001	0.0000
		Swell 4	0.0003	0.0004	0.0004	0.0004	0.0003	0.0003	0.0001
		Swell 5	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000

5.3 Mean Wave Direction

5.3.1 The mean wave direction for existing conditions and conditions with the proposed offshore wind farm were extracted at the concerned sites and are presented in **Table 8**. Any changes recorded in the model were less than 0.011 degree for mean wave direction at any swell state at any concerned site.

Table 8: Mean Wave Direction (MWD) at the concerned sites for existing conditions and after wind farm

Layout	Water level	Wave conditions	MWD						
			Saunton Sands	Downend Point	Croyde Beach	Puts-borough	Woola-combe	Comb-segate	Lyn-mouth
Existing (L0)	MHWS	Swell 1	279	277	276	298	280	275	308
		Swell 2	279	277	276	298	280	275	308
		Swell 3	278	277	276	298	279	274	308
		Swell 4	272	270	267	294	269	265	309
		Swell 5	287	285	286	301	286	281	309
	MLWS	Swell 1	277	270	271	304	278	269	320
		Swell 2	277	270	271	304	279	269	320
		Swell 3	276	270	271	304	278	269	320
		Swell 4	274	267	266	302	272	264	320

Layout	Water level	Wave conditions	MWD						
			Saunton Sands	Downend Point	Croyde Beach	Puts-borough	Woola-combe	Comb-segate	Lyn-mouth
		Swell 5	280	274	278	305	281	272	320
Wind Farm (L1)	MHWS	Swell 1	279	277	276	298	280	275	308
		Swell 2	279	277	276	298	280	275	308
		Swell 3	278	277	276	298	279	274	308
		Swell 4	272	270	267	294	269	265	309
		Swell 5	287	285	286	301	286	281	309
	MLWS	Swell 1	277	270	271	304	278	269	320
		Swell 2	277	270	271	304	279	269	320
		Swell 3	276	270	271	304	278	269	320
		Swell 4	274	267	266	302	272	264	320
		Swell 5	280	274	278	305	281	272	320
Change with the Wind Farm	MHWS	Swell 1	0.006	0.008	0.009	0.003	0.008	0.006	-0.007
		Swell 2	0.006	0.007	0.007	0.003	0.004	0.005	-0.007
		Swell 3	0.006	0.008	0.009	0.003	0.009	0.008	-0.007
		Swell 4	-0.001	0.001	0.000	0.005	0.005	0.002	-0.002
		Swell 5	0.002	0.002	0.002	0.000	0.000	0.000	-0.011
	MLWS	Swell 1	0.003	0.004	0.006	0.002	0.004	0.003	0.000
		Swell 2	0.004	0.003	0.006	0.002	0.002	0.002	0.000
		Swell 3	0.002	0.003	0.005	0.002	0.005	0.004	0.000
		Swell 4	0.000	0.000	0.001	0.003	0.003	0.001	0.000
		Swell 5	0.001	0.001	0.002	0.000	0.000	0.000	0.000

6 Findings

6.1.1 The approach to wave modelling was highly "conservative" as we included 8 floating substructures (whereas there may be less) and a jacket structure for the Offshore Substation Platform (when this may not be required) and as such the obstruction to wave energy is likely to be less in the event of future structures and no OSP (if that is the case). Furthermore, the modelling assumed fixed / solid structures from the seabed to above the sea surface for the floating substructures. Fixed / solid structures would reflect all of the wave energy. In reality because of the submersible nature of the structures not all the wave energy would be reflected and thus a lower level of change will occur at the concerned sites.

6.1.2 The model results and the greatest change in wave parameters at the concerned sites (see **Table 9**) show that the proposed offshore wind farm would result in negligible impact on wave conditions (height, period, and direction) at the concerned locations in the North Devon Surfing Reserve. The levels of change are extremely small (millimetres, less than a hundredth of a second, or less than one degree) such that these variations would be immeasurable from the natural variation within waves particularly at the concerned sites.

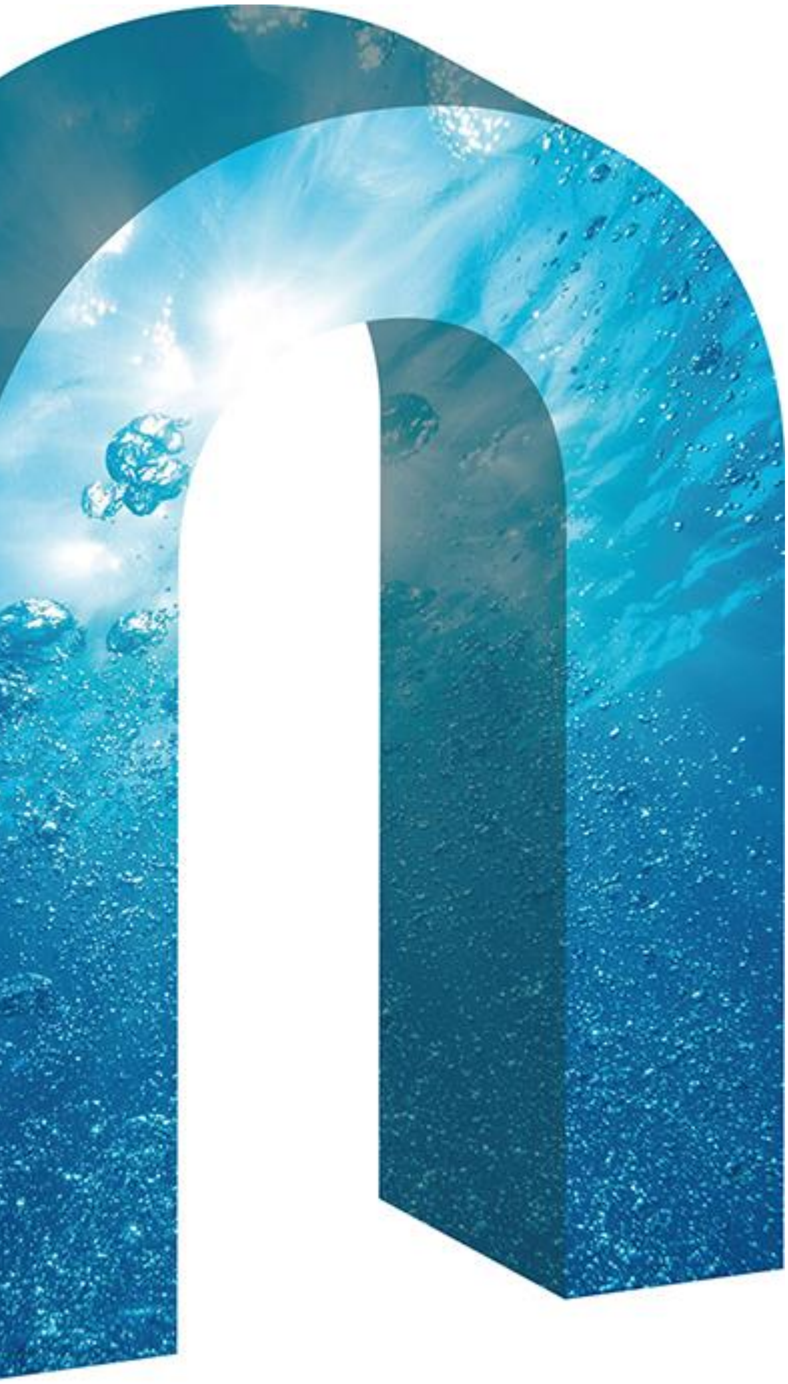
Table 9: Summary of greatest change in significant wave parameters at concerned sites

Concerned site	Maximum change in significant wave height (m)	Maximum change in Peak wave period (s)	Maximum change in Mean Wave Direction (°N)
Saunton sands	-0.0011	0.004	0.006
Downend Point	-0.0011	0.004	0.008
Croyde Beach	-0.0012	0.003	0.009
Putsborough	-0.0007	0.004	0.005
Woolacombe	-0.0012	0.004	0.009
Combsegate	-0.0011	0.004	0.008
Lynmouth	-0.0003	0.004	-0.011

6.1.3 It is important to highlight that the effect of the proposed offshore wind farm is exaggerated by the highly conservative representation of the floating substructure and jacket structure, particularly the size of the "shallow" area behind the structures. Therefore, this report should be only used for assessing potential impact from the Windfarm Site to the concerned sites in the North Devon Surfing Reserve.

White Cross Offshore Windfarm Environmental Statement

Appendix 8.B: Geophysical Survey Results Report



SEA

WOOD PLC

OFFSHORE AND NEARSHORE SURVEY-WHITE CROSS WINDFARM

GEOPHYSICAL RESULTS REPORT

DOC NO: NSW-PJ00285-RR-DC-SUR-001

WE LISTEN THEN DELIVER

Rev	Date	Originator	Reviewed	Approved	Client Approved
1.2	17-01-2023	Wouter Wester	David Ollivier	Mark Gerhards	Charles Grose
Signature	n/a				

Revision index		Abbreviation
1.x	Issued for Review	IFR
2.x	Approved / As Built	APR / ASB

REVISION HISTORY

Revision	Date	Chapters	Description of changes
1.0	03-10-2022	All	First issue to Client
1.1	23-12-2022	All	Client comments addressed
1.2	17-01-2023	Figures	OWF extent adjusted

EXECUTIVE SUMMARY

WORK SCOPE

Objectives

Geophysical investigation comprised multibeam echo sounder (MBES bathymetry and backscatter), side scan sonar (SSS), sub-bottom profiler (SBP), single channel sparker (SCS) (OWF only) and magnetometer (MAG) surveys.

The objective of the geophysical survey for both areas (ECR and OWF) was to provide all necessary geophysical data to the Client following specific requirements. The main objectives were:

- Supplement existing survey data from various sources to provide Client with a broad understanding of the geophysical conditions within the survey area.
- Obtain accurate bathymetry, locate all obstructions and identify other seabed factors which may affect the installation of the wind turbines, offshore substation, subsea cables and any other associated equipment.
- Establish digital terrain models with specified resolution for basic and detailed engineering purposes.
- Establish vertical route profiles for engineering purposes. Produce a contour plan and map the location of seabed features, particularly any rock outcrops or obstructions.
- Carry out a geophysical survey within the survey area to define the shallow sub-seabed geology across the area and export cable route corridor sufficient for basic foundations design.
- Carry out a gradiometer survey to:
  - Establish the distribution and magnitude of ferrous metal UXO threats on the sailed survey lines.
  - Validate existing and identify any new marine archaeological features.
  - Positively locate all existing pipelines and cables, both operational and redundant, within the survey corridor.

In addition of the geophysical scope, an environmental survey was required. Objectives were:

- Carry out a benthic survey to create benthic baseline habitat reports and biotope maps

OPERATION SUMMARY

Phase		Offshore vessel *Geo Focus*		Nearshore vessel *Elysse*		Environmental vessel *Argyll Explorer*	
		Start	End	Start	End	Start	End
Geophysical	Mobilisation	27-05-2022	05-06-2022	30-07-2022	06-08-2022	N/A	N/A
	Operations	06-06-2022	06-08-2022	06-08-2022	14-08-2022	N/A	N/A
	Demobilisation	06-08-2022	07-08-2022	15-08-2022	15-08-2022	N/A	N/A
Environmental	Mobilisation	08-08-2022	09-08-2022	N/A	N/A	06-07-2022	17-07-2022
	Operations	09-08-2022	16-08-2022	N/A	N/A	18-07-2022	30-07-2022
	Demobilisation	16-08-2022	16-08-2022	N/A	N/A	31-07-2022	31-07-2022

MAIN SURVEY EQUIPMENT SUMMARY

Item	Offshore vessel – *Geo Focus*	Nearshore vessel - *Elysse*
DGNSS receiver (primary)	Trimble SPS852	Applanix POS MV Wavemaster II
MRU/Gyro Compass 1	iXblue Hydrins	Applanix POS MV Wavemaster II
Subsea positioning (USBL)	Kongsberg HiPAP 501	N/A
Multibeam echo sounder (MBES)	Kongsberg EM 2040 MKII dual swath	Norbit 24003 WBMS Narrow
Magnetometer	2x Geometrics G-882	2x Geometrics G-882
SSS	EdgeTech 4205FS 300/600kHz	EdgeTech 4205 MP
SBP	Innomar SES 2000 Medium	Geoacoustics GeoPulse 5430A
Sparker	GSO-360	N/A
Streamer	8 elements mini streamer	N/A

RESULTS SUMMARY

Bathymetry Summary

Area	Maximum depth [m] (LAT)	Minimum depth [m] (LAT)	Average depth [m] (LAT)
Nearshore	-25.07	+3.67	-13.12
Area 3	-52.59	-21.00	-42.73
Area 2	-59.18	-50.37	-54.64
Area 1	-68.86	-58.76	-64.67
Area Fan	-75.16	-67.62	-70.07
OWF	-78.12	-69.07	-71.92

Seabed Sediments Summary

The sediment classification within the survey area was performed based on the side scan sonar data and sediments reflectivity and appearance. The seabed in the survey area shows some variety in different seabed surficial sediment and morphology. Analysis was done in line with SSDM / IOGP standard classification

Class	IOGP Code	Area in km2	% of the survey area
Sediment (Primary)			
Sand	IOGP3102	235.87	96.3%
Clayey Sand	IOGP3202	2.01	0.8%
Rocky	IOGP3205	7.09	2.9%
Sediment (Secondary)			
Coarse Sediment	IOGP3093	38.94	15.9%
Seabed Features			
Sand Ripples	IOGP3004	89.81	36.7%
Mega Ripples	IOGP3052	6.71	2.7%
Area with Occasional boulders		2.92	1.2%
Area of Bedrock	IOGP3079	7.09	2.9%

Side Scan Sonar Contact Summary

Contact type	Nearshore	Area 3	Area 2	Area 1	FAN	OWF	Total
Unknown	45	30	6	34	52	124	**291**
Boulder	1	217	145	123	440	1685	**2611**
Other	2	5	6	4	4	4	**25**
Linear Feature	1	2	0	1	2	0	**6**
Wreck	0	2	0	0	0	1	**3**
Debris	0	0	0	0	1	3	**4**
Total	**49**	**256**	**157**	**162**	**499**	**1817**	**2940**

Magnetic Anomalies Summary

Anomaly type	Nearshore	Area 3	Area 2	Area 1	FAN	OWF	Total
Other	364	214	91	29	39	253	990
Linear Feature	0	5	79	0	0	0	84
Wreck	0	2	0	0	0	1	3
Cable	32	32	0	17	0	3	84
Total	396	253	170	46	39	257	1161

Shallow Stratigraphy Summary

OWF

- Unit A: major syncline (with axis dipping towards west) which makes up the northern part of the OWF. This syncline is extending beyond the penetration depth of +/- 60 m. The top of Unit A is an erosional surface. Between the top of Unit A and the seabed, Holocene sediments of Unit E are deposited and lie discordant on top of Unit A.
- Unit B: Sub horizontal deposits which increase in thickness towards the west and are bounded by the top of Unit C until it is beyond the penetration depth. The unit experienced some deformation, although not as much as Unit A and C. This unit is covered by Holocene sediments of Unit E.
- Unit C: Could be related to Unit A, however this cannot be seen in the seismic profiles. Parts of layering within this unit can be distinguished although it is not continuous. Because of the deformation zone of Unit D present between Unit A and C, Unit C is seen as a different unit. Unit C is covered by Unit B
- Unit D: Unit D represent a high deformation zone probably related to faulting. No clear strata can be defined, and it separates the northern Unit A from the southern Unit B and C. This Unit has been picked to visualise the deformation zone. Unit D is covered by sediments of Unit E.
- Unit E: Represents the Holocene deposits, which cover the whole of the OWF area.

ECR

- R1: Top of bedrock. Holocene sediments deposited on top, which vary between 0 and 10 m in thickness. No correlation could be made to tops of other units.
- R2: Top of bedrock. Partially correlates with the top of Unit B of the OWF. Because of limited penetration it was not possible to get a continuous interpretation of this top along the whole cable route which is the reason to categorised it as a separate reflector.
- Unit E. Represents the Holocene deposits, which cover the whole of the ECR area.

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DEFINITIONS AND ABBREVIATIONS

Throughout this report the following terminology is used:

OWL	Offshore Wind Ltd	(End Client)
Wood	John Wood Group plc	(Client's Consultant)
N-Sea	N-Sea Offshore Wind Ltd.	(Contractor)
OEL	Ocean Ecology Ltd.	(Environmental scope Subcontractor)
GSO	Geophysical Services Offshore B.V.	(UHRS sub-contractor)
Ultrabeam	Ultrabeam Hydrographic Ltd.	(Nearshore sub-contractor)

AGC	Automatic Gain Control
ASCII	American Standard Code for Information Interchange
BS	Backscatter
DGNSS	Differential Global Navigation Satellite System
DTM	Digital Terrain Model
ECR	Export Cable Route
EGN	Empirical Gain Normalization
GIS	Geographic Information System
Hz	Hertz
IOGP	International Association of Oil & Gas Producers
LAT	Lowest Astronomical Tide
MAG	Magnetic Data
MBES	Multibeam Echosounder
MRU	Motion Reference Unit
MW	Megawatt
nT	nano Tesla
OWF	Offshore Wind Farm
SBP	Sub bottom Profiler
SCS	Single Channel Sparker
SEGY	Society of Exploration Geophysicists 'Y' format
SSDM	Seabed Survey Data Model
SSS	Side Scan Sonar
TG	Transverse Gradient
TVG	Time Varying Gain
UK	United Kingdom
UTC	Coordinated Universal Time
UTM	Universal Transverse Mercator
UXO	Unexploded Ordnance
VORF	Vertical Offshore Reference Frame
WGS	World Geodetic System

Where abbreviations used in this document are neither part of the International System of Units nor included in this list, it may be assumed that they are either equipment brand names or company names.

1 INTRODUCTION

White Cross is a ~100 MW Test and Demonstration floating wind farm located in the Celtic Sea, United Kingdom. The Project is being developed by Offshore Wind Ltd (OWL). OWL is a joint venture partnership between Cobra Instalaciones y Servicios, S.A. and Flotation Energy plc. The wind farm is located 52.5 km off the Cornish Coast in England (Figure 1-1).

The White Cross project has a maximum capacity of 100 MW. The baseline layout consists of 8 x 12 MW wind turbines each mounted on top of a floating foundation, with an offshore substation located within the wind farm area. The export cable is to connect between the offshore and onshore substations.

N-Sea Offshore Wind Limited was contracted by OWL to undertake general inspection survey at the White Cross site and along the associated Export Cable Route (ECR) corridor.

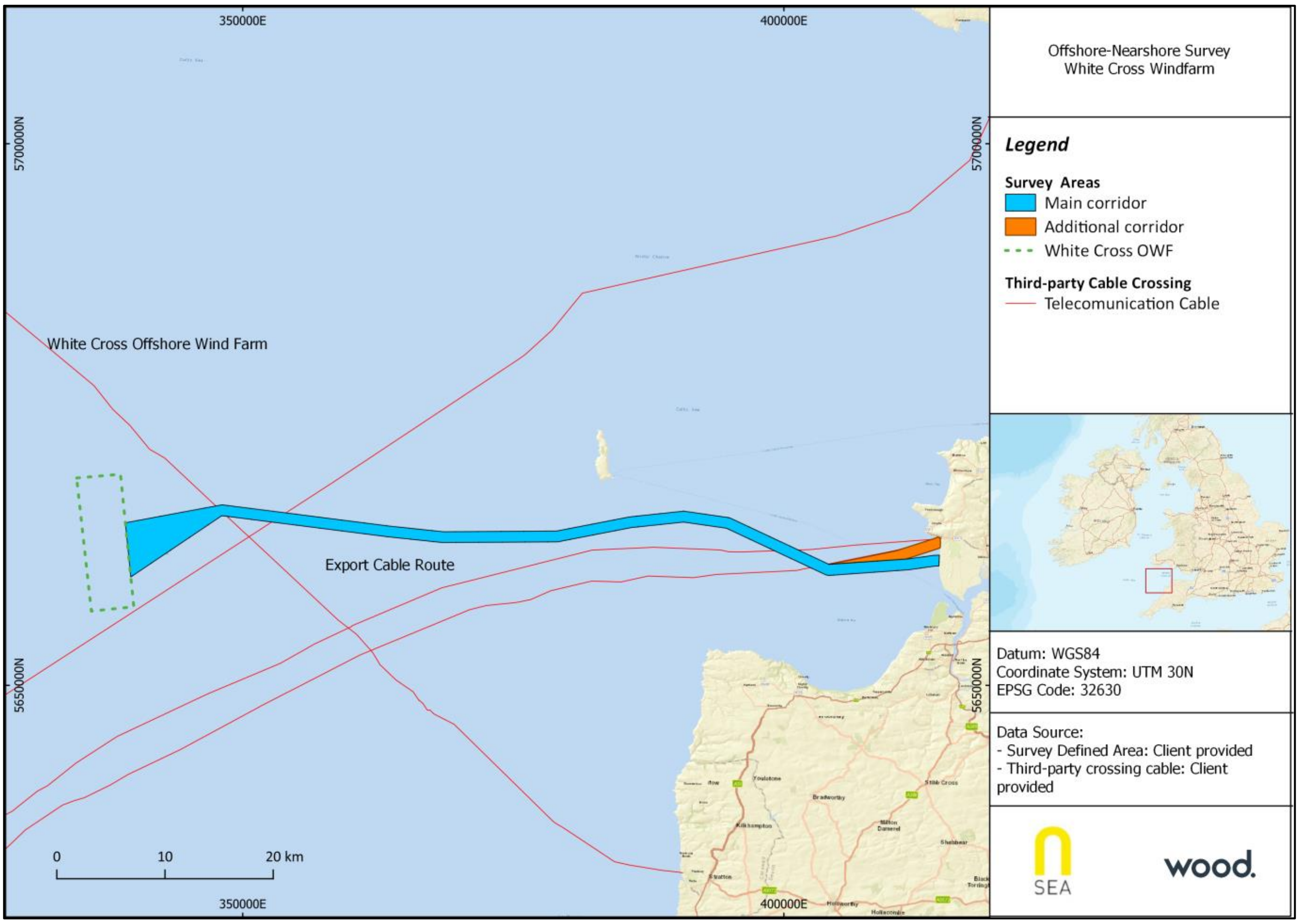

Figure 1-1: Project location

The geophysical scope area was divided in two parts:

- Export Cable Route (ECR): Multibeam Echo Sounder (MBES), Side Scan Sonar (SSS), High Resolution Sub-Bottom Profiler (HR SBP), Transverse Gradient (TG)
- OWF: MBES, SSS, HR SBP, TG and Single Channel (SC) Sparker

The environmental survey, consisting of grab sampling and video transects was completed upon completion of the geophysical survey. Results are provided as APPENDIX A.

The ECR was further split up in five blocks of near equal size: the 'fan out' zone (i.e., Fan), the ECR Areas 1, 2, 3 and the nearshore part as seen in Figure 1-2. This allows for a better presentation of the data.

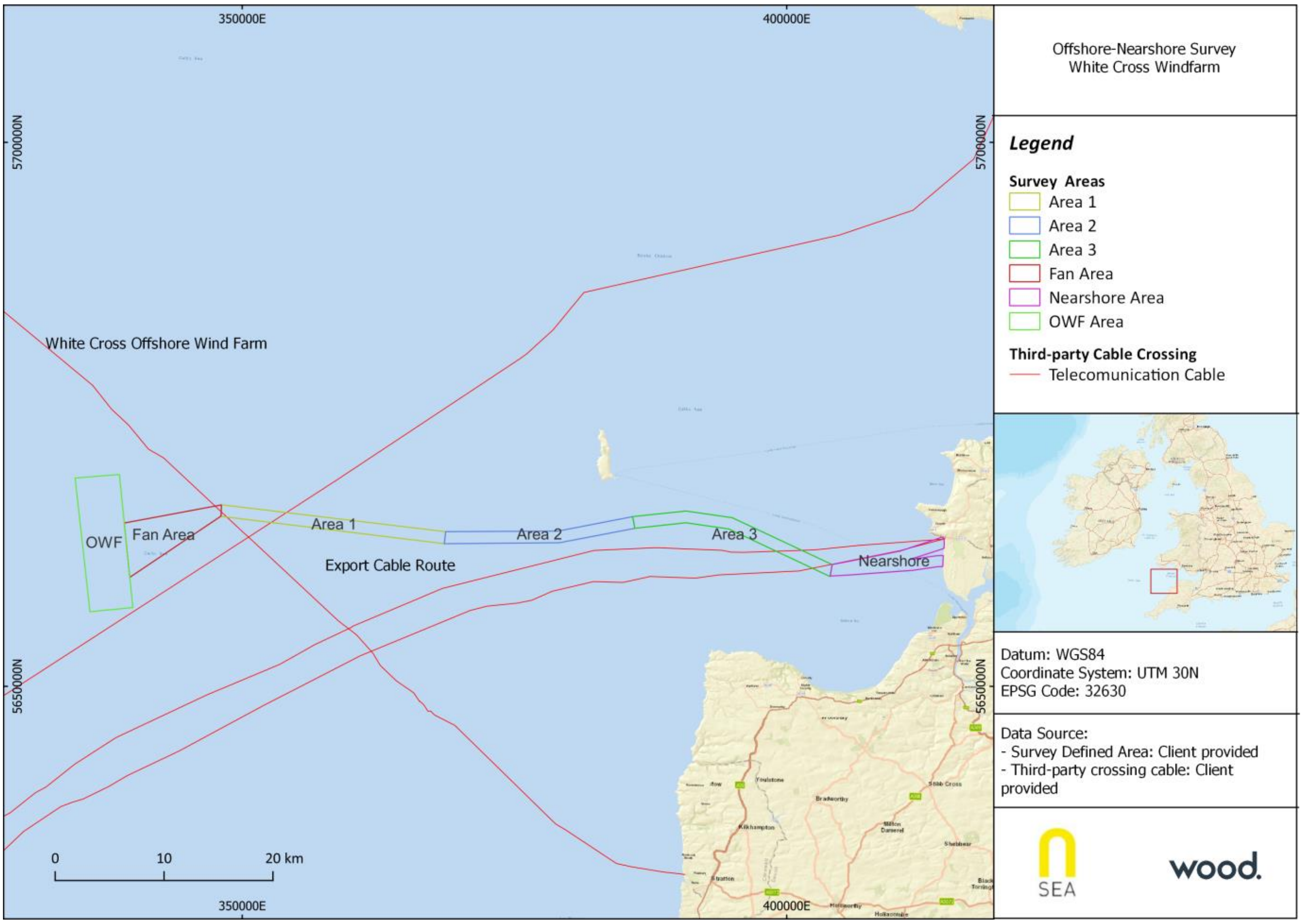

Figure 1-2: Area divisions

1.1 SCOPE OF DOCUMENT

This document presents the results of geophysical survey conducted between 27 May and 16 August 2022 from *Geo Focus* and *Elysse* vessels.

A *Field Operations Report* and *Mobilisation and Calibrations Report* were issued separately [Ref. 5].

This results report focuses on the geophysical campaign. Details about the environmental campaign are in a separated report enclosed as APPENDIX A of this document.

1.2 REFERENCE DOCUMENT

1.2.1 N-Sea

Table 1-1: N-Sea reference documents

#	Document number / filename	Title
1.	NSW-PJ00285-PEP-001	Project Execution Plan – Survey
2.	NSW-PJ00285-MCR-GFC-SUR-001	Mobilisation and Calibration Report
3.	NSW-PJ00285-MDR-01	Master Document Register
4.	NSW-PJ00285-SIT-GFC-SUR-001	Surrogate Item Trial Report
5.	NSW-PJ00285-FOR-GFC-SUR-001	Field Operations Report

#	Document number / filename	Title
6.	NSW-PJ00285-RR-DC-SUR-001	Geophysical Results Report
7.	BMS-OP-0510-PR-001	MBES Processing Procedure
8.	BMS-OP-0510-PR-002	Magnetometer and Gradiometer Processing Procedure
9.	BMS-OP-0510-PR-003	Side Scan Sonar Processing Procedure
10.	BMS-OP-0510-PR-004	Sub-Bottom Profiler Processing Procedure

1.2.2 Client

Table 1-2: Client reference documents

#	Document number / filename	Title
11.	808166-01-SR-SOW-0001 Rev 0	Offshore GI Survey Scope of Work – White Cross Offshore Windfarm
12.	808166-01-SR-SPE-0001 Rev 0	Offshore and Nearshore GI Survey Technical Specification – White Cross Offshore Wind Farm

1.2.3 Third Party

Table 1-3: Third party reference documents

#	Document number / filename	Title
13.	OP-0457 Geo Focus (Ocean Phoenix International Limited)	Gyro & MRU Calibration, DGNSS Verification and Offset Survey Report

1.3 SCOPE OF WORK

The objectives of both the geophysical surveys were to provide all necessary geophysical data to the Client following specific requirements. The main objectives were:

- Supplement existing survey data from various sources to provide Client with a broad understanding of the geophysical conditions within the survey area.
- Obtain accurate bathymetry, locate all obstructions and identify other seabed factors which may affect the installation of the wind turbines, offshore substation, subsea cables and any other associated equipment.
- Establish digital terrain models with specified resolution for basic and detailed engineering purposes.
- Establish vertical route profiles for engineering purposes. Produce a contour plan and map the location of seabed features, particularly any rock outcrops or obstructions.
- Carry out a geophysical survey within the survey area to define the shallow sub-seabed geology across the area and export cable route corridor sufficient for basic foundations design.
- Carry out a gradiometer survey to:
  - Establish the distribution and magnitude of ferrous metal UXO threats on the sailed survey lines.
  - Validate existing, and identify any new marine archaeological features.
  - Positively locate all existing pipelines and cables, both operational and redundant, within the survey corridor.
- Present data that has been acquired and processed during the survey in accordance with contractual requirements.

1.3.1 Work Elements

The contracted services were split into several work elements:

Work Element 2 (Offshore Hydrographic and Geophysical Survey)

- Survey work between 10 m LAT water depth and the limit of offshore safe working.
- Located in the ECR and OWF.
- MBES survey, complete coverage
- SSS survey, complete coverage.
- SBP survey, on all SSS lines.
- Drop-down video at selected sites

Work Element 3 (Offshore UXO Survey)

- Transverse gradiometer (TG) survey on all SSS survey lines and ECR centreline

Work Element 4 (Nearshore Hydrographic and Geophysical Survey)

- Survey work between 10 m LAT water depth and 3 m LAT (inshore safe working limit).
- Located at ECR.
- MBES survey, complete coverage.
- SSS survey, complete coverage.
- SBP survey, on all SSS lines.
- Quality control crosslines.
- Drop-down video at selected sites.

Work Element 5 (Nearshore UXO Survey)

- Transverse gradiometer (TG) survey on all SSS survey lines and ECR centreline

Work Element 6 (Offshore Benthic Survey)

- Located in the ECR (between 80 m LAT and 10 m LAT) and OWF.
- Drop-down camera transects at selected locations
- Drop down camera drops at selected locations
- Grab sampling at selected locations

Work Element 7 (Nearshore Benthic Survey)

- Located in the ECR (between 10 m LAT and 3 m LAT).
- Drop-down camera drops at selected locations
- Grab sampling at selected locations

Work element 1 was related to preparatory work.

2 SURVEY PARAMETERS

2.1 HORIZONTAL DATUM

The following horizontal datum parameters were used throughout survey operations:

Table 2-1: Datum parameters

Parameter	Details
Name	World Geodetic System 1984 (WGS84)
Ellipsoid	WGS 84
Semi-Major Axis (a)	6378137.000 m
Semi-Minor Axis (b)	6356752.314 m
Inverse Flattening	298.257 223 563
Geodetic parameters EPSG Code	4326

Table 2-2: Projection parameters

Parameter	Details
Projection	Universal Transverse Mercator (UTM)
Zone	30 North
Central Meridian	3° West
Latitude of Origin	0°
False Easting	500000.00m
False Northing	0.00m
Scale Factor at Central Meridian	0.9996
Projected coordinate system EPSG code	32630
Units	metres

2.2 VERTICAL DATUM

All elevations and depths used for vertical referencing in this project are relative to Lowest Astronomical Tide [LAT].

2.3 STANDARD NOMENCLATURE & UNITS

Throughout this report the following nomenclature and units apply unless otherwise stated.

- Linear units are expressed in international meters [m]
- Angular units are expressed in degrees (°)
- Frequency units are expressed in hertz (Hz)
- Magnetic field induction is expressed in nanoteslas (nT)

2.4 TIME KEEPING

All times referred to within this document and time used for record keeping during the project are in local time unless otherwise stated. Operations took place in UK waters where the local time was UTC + 1 hours also known as British Summer Time.

3 SURVEY EQUIPMENT

3.1.1 Vessel Equipment

For the acquisition of datasets required, the systems listed in Table 3-1 were used.

Table 3-1: Vessel survey equipment

Item	Offshore Vessel – *Geo Focus*	Nearshore Vessel - Elysse
DGNSS receiver (primary)	Trimble SPS852	Applanix POS MV Wavemaster II
MRU/Gyro Compass 1	iXblue Hydrins	Applanix POS MV Wavemaster II
Subsea positioning (USBL)	Kongsberg HiPAP 501	N/A
Sound velocity profiler	Valeport Swift	Valeport Swift
Sound velocity sensor	Valeport MiniSVS	AML SVS
Multibeam echo sounder (MBES)	Kongsberg EM 2040 MKII dual swath	Norbit 24003 WBMS Narrow
Magnetometer	2x Geometrics G-882 in a Transverse Gradient configuration	2x Geometrics G-882 in a Transverse Gradient configuration
SSS	EdgeTech 4205FS 300/600kHz	EdgeTech 4205 MP
SBP	Innomar SES 2000 Medium	Geoacoustics GeoPulse 5430A
Sparker	GSO-360	N/A
Streamer	8 elements mini streamer	N/A

3.1.2 Software

Table 3-2 shows the main software utilised for the interpretation.

Table 3-2: Software list

Software	Manufacturer / Model
MBES processing	BeamworX Autoclean
SSS processing	Moga Software/ SeaView 4.2
Magnetometer processing	Seequent / Oasis Montaj 2021.2
MBES backscatter processing	QPS FMGT / Geocoder
GIS – Data QC	Open source qgis.org / QGIS
GIS – Data presentation	ESRI / ArcGIS Pro
SBP / Sparker processing	Moga Software/ SeaView 4.2

4 PROCESSING AND INTERPRETATION METHOD STATEMENT

4.1 MBES

4.1.1 Processing

Data acquired by the offshore vessel were quality checked. The raw data was sent to shore and received by the onshore processing team and subsequently processed with in-house processing and coverage checked. The N-Sea MBES Processing Procedure document [Ref. 7], which contained detailed, step-by-step processing sequence, was used by project data processors as a guide. This document was always adhered to in respect of the bathymetric data processing. General overview of the processing workflow is summarised by diagram in Figure 4-1.

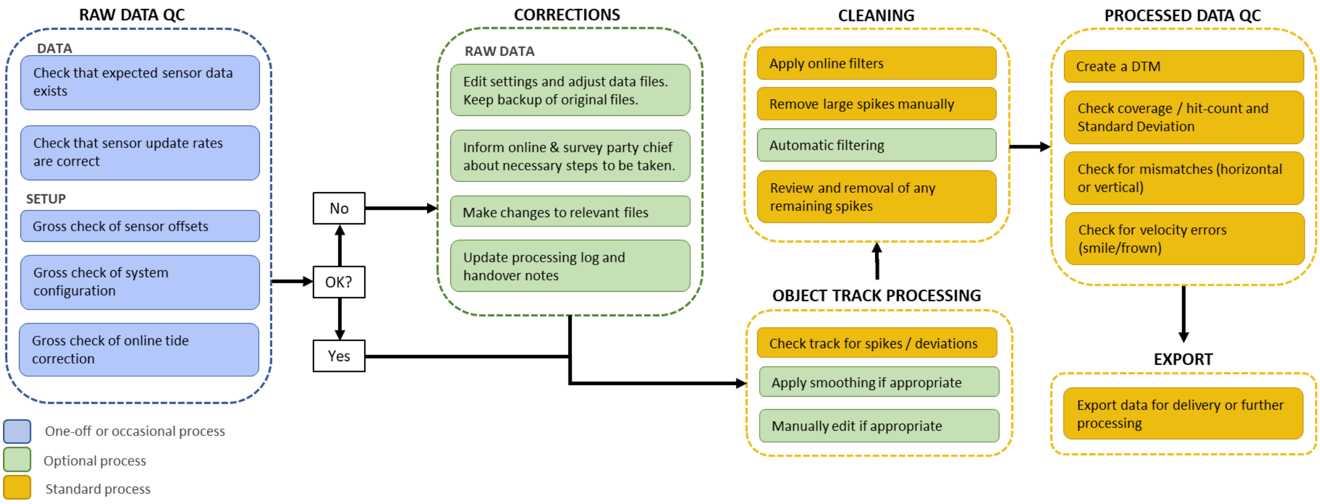

Figure 4-1: MBES processing flow

4.1.2 Interpretation

The MBES bathymetry dataset was used in conjunction with the MBES backscatter and SSS data in order to complete the seabed feature interpretation. MBES datasets was useful to accurately delineate large features such as sand megaripples, sand wave crests, or large man-made features. The MBES dataset was also used to quality check the SSS data positioning accuracy.

4.2 MBES BACKSCATTER

4.2.1 Processing

Backscatter data was acquired, processed and exported as mosaic at 1.0 m resolution. Data was exported from the online navigation software and converted in *FM Geocoder* to 8-bit colour coded Backscatter grids. General overview of the processing workflow is summarised by diagram in Figure 4-2. Mosaic was then produced and exported as GeoTIFF provided as part of the deliverable package.

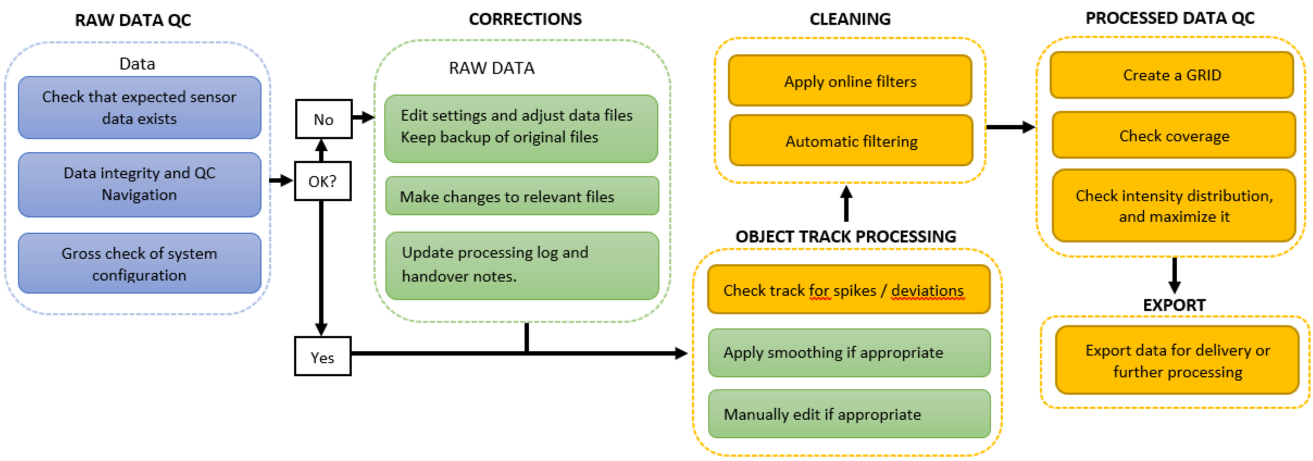

Figure 4-2: MBES backscatter processing flow

4.2.2 Interpretation

The BS dataset was used conjunction with the MBES-bathymetric and SSS data in order to complete the seabed feature interpretation.

4.3 SIDE SCAN SONAR

4.3.1 Processing

The Side Scan Sonar survey was used to identify items of debris and any significant seabed features and to draw surficial sediment unit boundaries. This was achieved at the N-Sea office and not offshore. The N-Sea *Side Scan Sonar Processing Procedure* document [Ref. 8] was used by project geophysicists as a processing guide. This document was always adhered to in respect of the side scan sonar data processing and interpretation.

The processing of the data consisted of the following steps:

- Copied data from online to the vessel network and then transferred the data ashore to N-Sea's office network
- QC the data and filled in the offline log sheet
- Tracked the seabed
- Applied gain (TVG or EGN)
- Applied corrected navigation provided by Data Processor
- Picked targets in line with picking criteria outlined in job specific documentation
- Aligned SSS to MBES /BS
- Exported target lists
- Exported mosaic images, imported them in GIS suite and interpreted seabed features

General overview of the processing workflow is summarised by diagram in Figure 4-3.

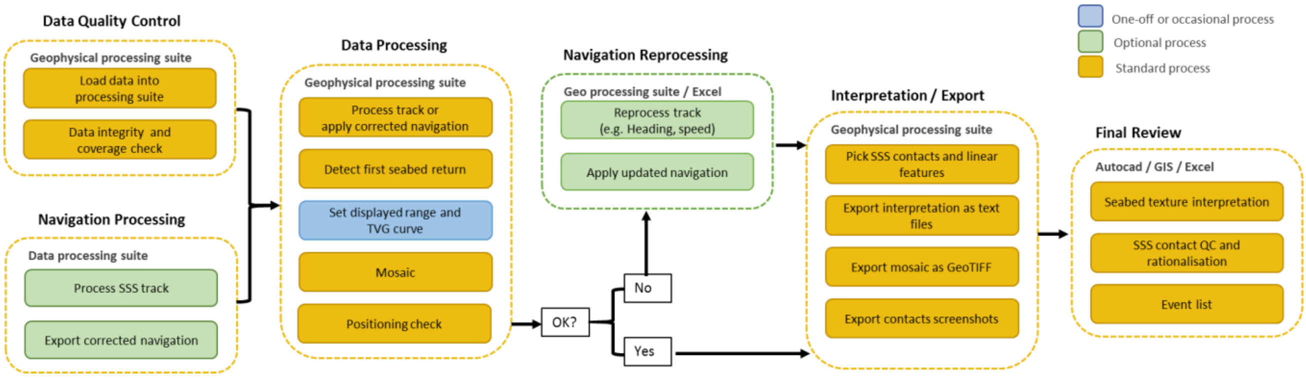

Figure 4-3: Side Scan Sonar processing workflow

4.3.2 Interpretation

Discrete Anomalies

Discrete features greater than 0.3 m were evented and compiled in a SSS contact list (up to a maximum of 3000 boulders), along with relevant attributes such as positions, size, and classification. The selected targets were also correlated with the MBES dataset/DTM to fine tune their positions. No meaningful correlation was possible between SSS targets and magnetometer anomalies due to the magnetometer line spacing and achieved data density.

Discrete anomalies were classified as per the following:

- Boulder
- Debris
- Other
- Unknown
- Wreck
- Linear Feature

Seabed Features

Seabed features were interpreted using the SSS high frequency data in conjunction with the MBES and BS dataset.

The following seabed feature categories were observed:

- Megaripples
- Ripples
- Boulder fields
- Areas of bedrock

Seabed Types

The surficial layer was interpreted based on the acoustic reflectivity recorded on SSS data across the survey site. MBES and BS dataset were used to aid the interpretation.

4.4 SUB-BOTTOM PROFILER

4.4.1 Processing

The SBP data processing was undertaken using the N-Sea SBP Processing Procedure document [Ref. 10].

The processing of the data consisted of the following steps:

- Copy the data from online to shore
- Check the data and fill in the offline log sheet
- Load data into software SESconvert, to convert .SES files into SEG-Y files
- Load data into processing software
- Reduce water-column noise
- Apply burst noise filter
- Track seabed return
- Restore the seabed shape
- Apply AGC
- Pick horizons and any other relevant features (boulder, palaeochannels, faults)
- Export interpretation and created isopach maps
- Review isopach
- Export processed data as per client requirement.

A general overview of the processing workflow is summarised by diagram in Figure 4-4.

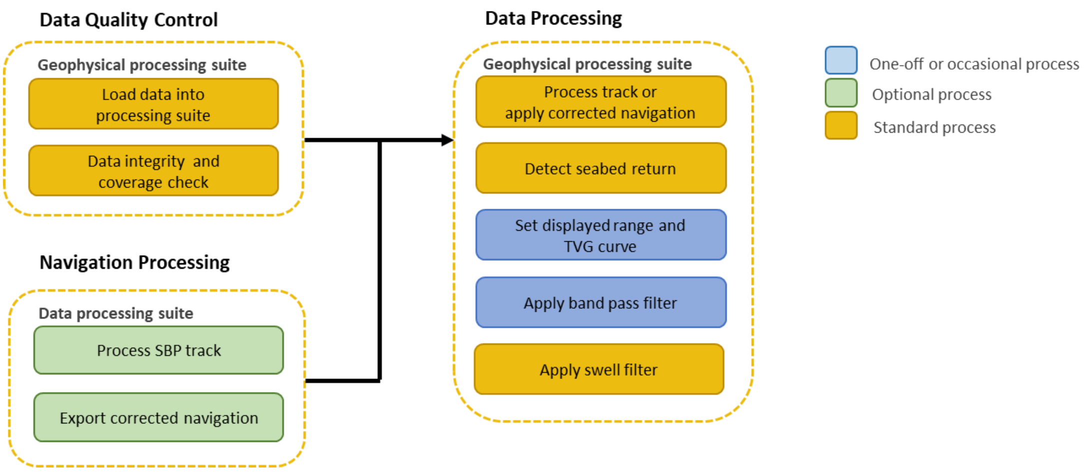

Figure 4-4: Bottom Profiler processing workflow

4.4.2 Interpretation

The shallow geology was interpreted by picking significant reflectors in the seismic profiles. In this dataset two main reflectors were picked: R1 in the Nearshore area and Area 3, and R2 in Area 2, 1, FAN area and OWF area. All picked horizons and features were exported and gridded for charting purposes. For the export, a sediment sound velocity of 1600 m/s was assumed, and the reflector depths kept relative to the picked seabed.

4.5 SINGLE CHANNEL SPARKER

4.5.1 Processing

Single channel sparker data was recorded in the OWF only. The SCS data processing was undertaken using the N-Sea processing procedure document [Ref. 10]. The processing of the data consisted of the following steps:

- Copy the data from online to shore
- Check the data and fill in the offline log sheet
- Load data into processing software
- Reduce water-column noise
- Apply burst noise filter/ IIR window filter
- Track seabed return
- Restore the seabed shape
- Apply AGC
- Pick horizons and any other relevant features (i.e., infilled channels, faults)
- Export interpretation and created isopach maps
- Review isopach
- Export processed data as per client requirement.

A general overview of the processing workflow is summarised by diagram in Figure 4-5.

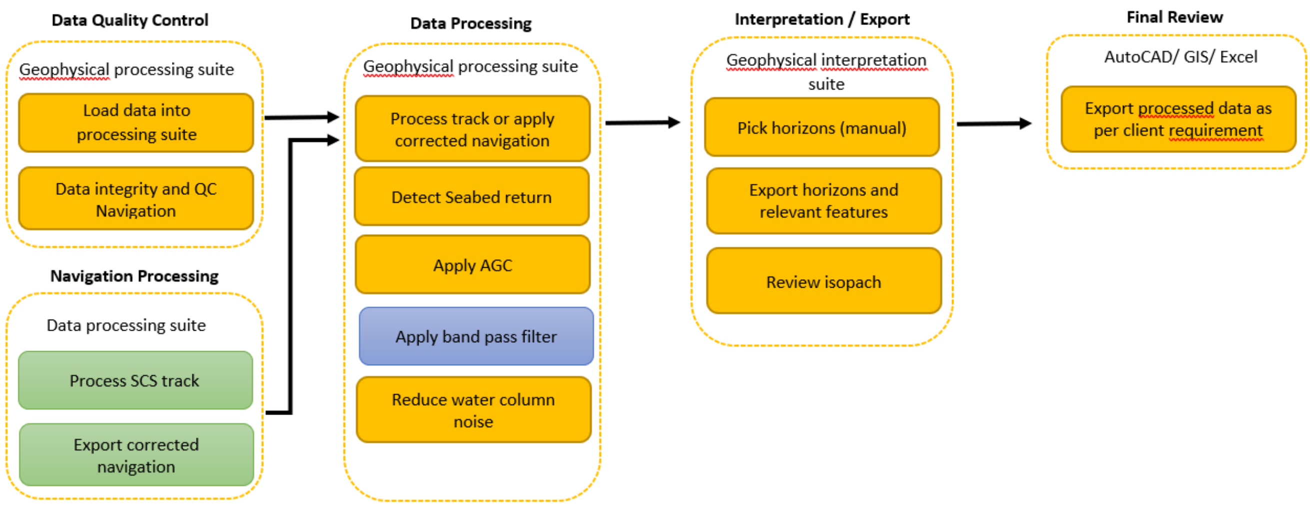

Figure 4-5: SCS processing flow

4.5.2 Interpretation

The shallow geology was interpreted by picking significant reflectors in the seismic profiles. In this dataset four horizons were picked, presenting the top of Unit A, B, C and D. All picked horizons and features were exported and gridded for charting purposes. For the export, a sediment sound velocity of 1600 m/s was assumed, and the reflector depth kept relative to the picked seabed.

4.6 MAGNETOMETER

4.6.1 Processing

The magnetometer data processing was undertaken using the N-Sea *Magnetometer and Gradiometer Processing Procedure* document [Ref. 9]. Background removal was applied to the data and targets picked. Existing infrastructures had some influence on the dataset. The data was recorded with a TG (transverse gradient – horizontal across track) frame with 2 magnetometers. However, the data were processed as 2 separate residual data sets.

Processing sequence is summarised below and in Figure 4-6.

- Data quality control and navigation smoothing
- Background removal (using an 80 fiducials long non-linear filter).
- The residual gridding was achieved using minimum curvature with a blanking distance of 2 m. This width was selected for display purpose only and does not represent the achieved coverage across track.
- Target picking (manual process). All significant anomalies with a peak to peak of 4 nT (-2 nT to +2 nT) were reported, subsequently the anomaly characteristics were determined.

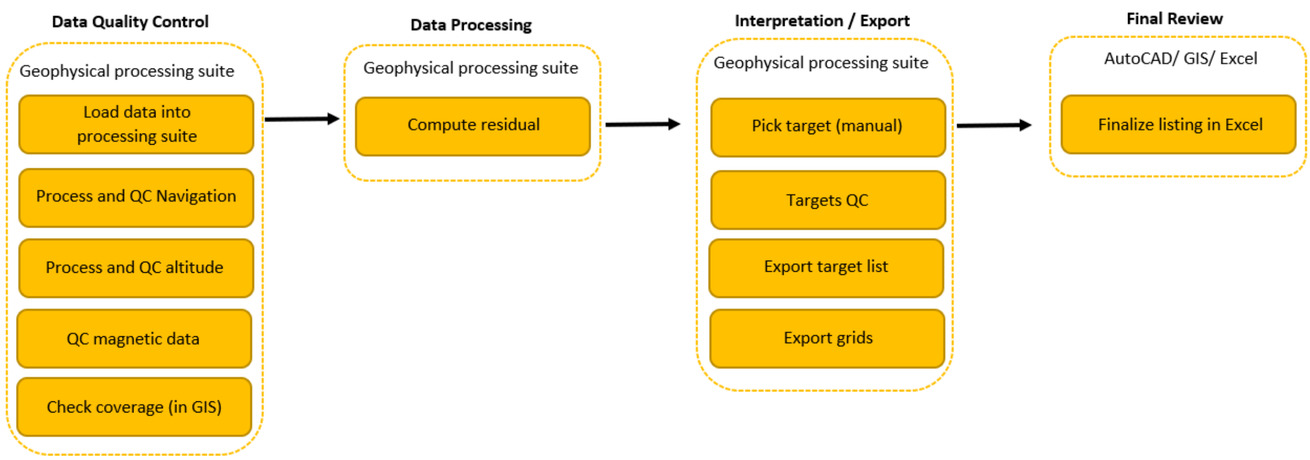

Figure 4-6: Magnetometer processing flow

4.6.2 Interpretation

For the main target picking, a short trend residual grid (80 fiducials) was created. Anomaly characteristics were determined i.e., dipole separation and amplitude. Where possible the anomalies have been correlated to known subsea infrastructure (i.e., subsea cables).

5 RESULTS

5.1 DELIVERABLES

This *Results Report* is part of a bundle of documents and data which may be considered to constitute the full *Survey Report*. The structure of this bundle is presented in Table 5-1 . The content of the deliverables package is as per the *Project Execution Plan* [Ref. 12] unless otherwise requested by, or agreed with the Client.

Table 5-1: Deliverables structure

Categories	Deliverables	Comments
Report	Daily Progress Report	
	Mobilisation and Calibration Report	
	Field Operation Report	
	Geophysical Survey Report	This report
	Benthic Survey Report	
Charts	Alignment Charts	
	Magnetometer Charts	
	MBES Charts	
	Track Charts	
Bathy data	Raw data	Databases
	Ungridded	ASCII
	Gridded (0.2m nearshore / 1m offshore)	ASCII
	Contours	shapefile
	Track plot	shapefile
	Image	GeoTIFF
	MBES backscatter mosaic (1m Resolution)	GeoTIFF
SSS	Raw data (Navigation corrected) Low & High frequency	xtf
	Processed data	xtf
	Track plot	shapefile
	SSS contact list	xlsx
	SSS contact images	GeoTIFF
	SSS Mosaic	GeoTIFF
MAG	Data (Raw and processed combined)	ASCII
	Track plot	shapefile
	Total Field, Residual, Analytic Signal Grid	GeoTIFF
	Target list	Excel
	As Found Cables	shapefile
SBP	Raw data	SEGY
	Processed data	SEGY
	Track plot	shapefile
	Isopach - Contours	shapefile

Categories	Deliverables	Comments
Sparker	Raw data	SEGY
	Processed data	SEGY
	Track plot	shapefile
	Isopach - Contours	shapefile
GIS	ESRI ArcGIS Geodatabase (Compatible ARCGIS 9.x) conforming to SSDM format, containing discrete layers for the following:	Geodatabase
	Slope maps (1m resolution)	Raster
	Bathymetric DTM (1m resolution)	Raster
	MBES backscatter mosaic (1m Resolution)	Raster
	SSS Mosaic (0.1m Resolution)	Raster
	Observed features: wrecks, boulders	Feature class
	Seabed characterisation	Feature class
	Anomaly magnetic gradient (1m resolution – 1 nT gradient interval)	Raster
	Isopachs depicting depth below seabed to all significant reflectors / soil units	Raster
	Interpreted 2D geophysical profile sections linked to survey line track plots	Feature class
Environmental	Stills, video	
	Biotope map	
	Geospatial Data	Shapefile

5.2 BATHYMETRY

5.2.1 Summary

Table 5-2 summarises the 2022 survey findings. The seabed levels range from +3.67 m recorded at the north-eastern side of the nearshore area, to -78.12 m, recorded in the southern section of the OWF area. The seabed morphology in the survey area can be characterised as relatively rich in features and somewhat uneven. The overall bathymetric trend shows a slight relatively regular slope resulting in increasing depth towards the West. A 1 m DTM was created for the offshore survey area and added to the alignment chart and GIS package. For the nearshore area, MBES data were gridded at 0.2 m.

Table 5-2: Bathymetry summary

Area	Maximum depth [m] (LAT)	Minimum depth [m] (LAT)	Average depth [m] (LAT)
Nearshore	-25.07	+3.67	-13.12
Area 3	-52.59	-21.00	-42.73
Area 2	-59.18	-50.37	-54.64
Area 1	-68.86	-58.76	-64.67
Area Fan	-75.16	-67.62	-70.07
OWF	-78.12	-69.07	-71.92

5.2.2 Nearshore

The depths at the Nearshore area ranged between +3.67 and -25.07 m; with an average depth of -13.12 m (Figure 5-1). The seabed profile (Figure 5-2) shows three distinct areas:

- First, at the landfall, a regular slope (0.5%), for 2.5 km
- Then in the centre part, the route reaches a plateau, approximately 13.5 m deep.
- Finally, the slope gradient increases again as the route moves towards the west, where the maximum water depth of 25 m is reached at the Area 3 boundary.

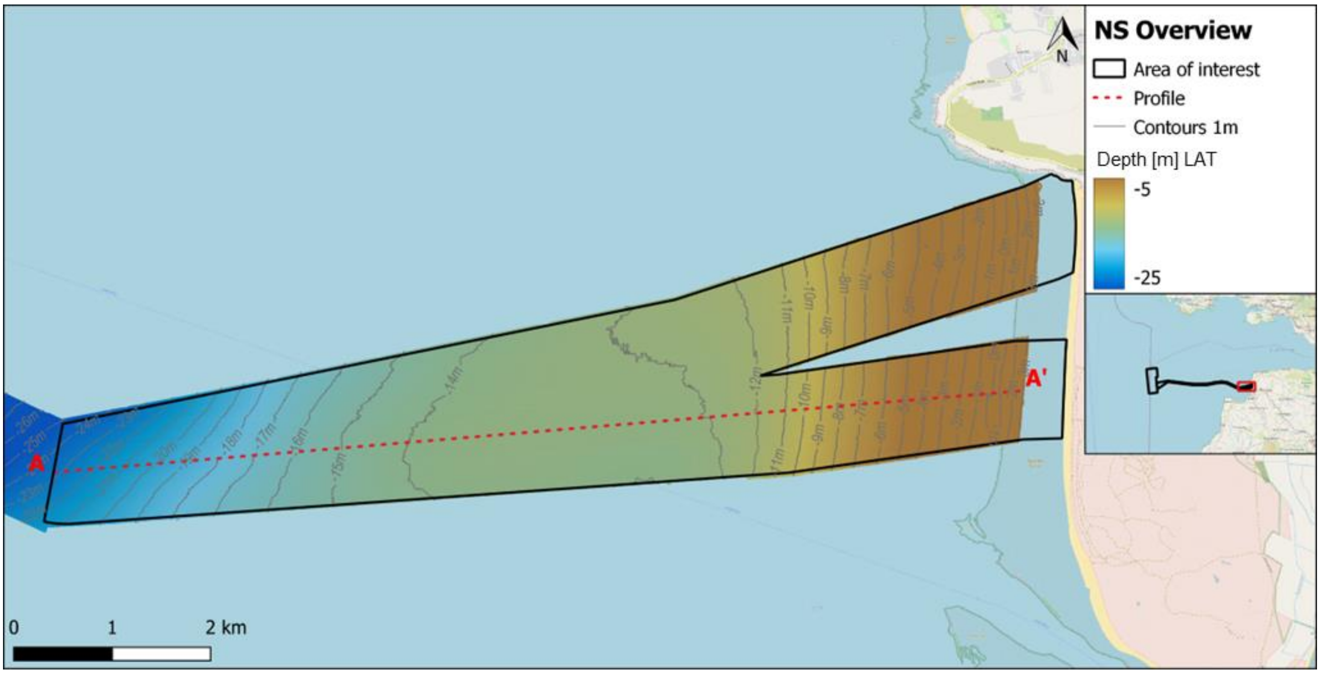

Figure 5-1: Bathymetry overview of Nearshore area

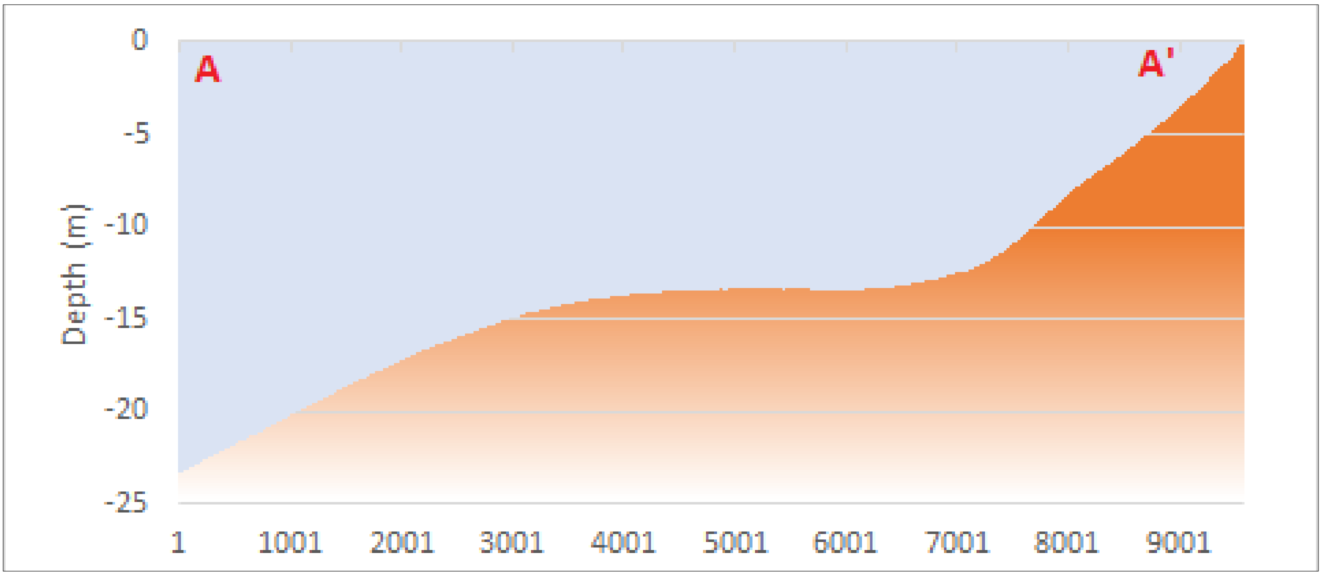

Figure 5-2: Bathymetry profile across Nearshore area

5.2.3 Area 3

The depths across Area 3 range between -21.00 m and -52.59 m; with an average depth of -42.73 m.

The seabed profile shows a general slope with increasing depths towards the west, although the slope gradient tends to decrease as the route moves away from the shore. From 2 to 9 km west of A', the route crosses an area of sand waves. Those features are generally 5 to 10 m high, and their crest are oriented NNE / SSW, crossing the route at an approximate angle of 30 degrees.

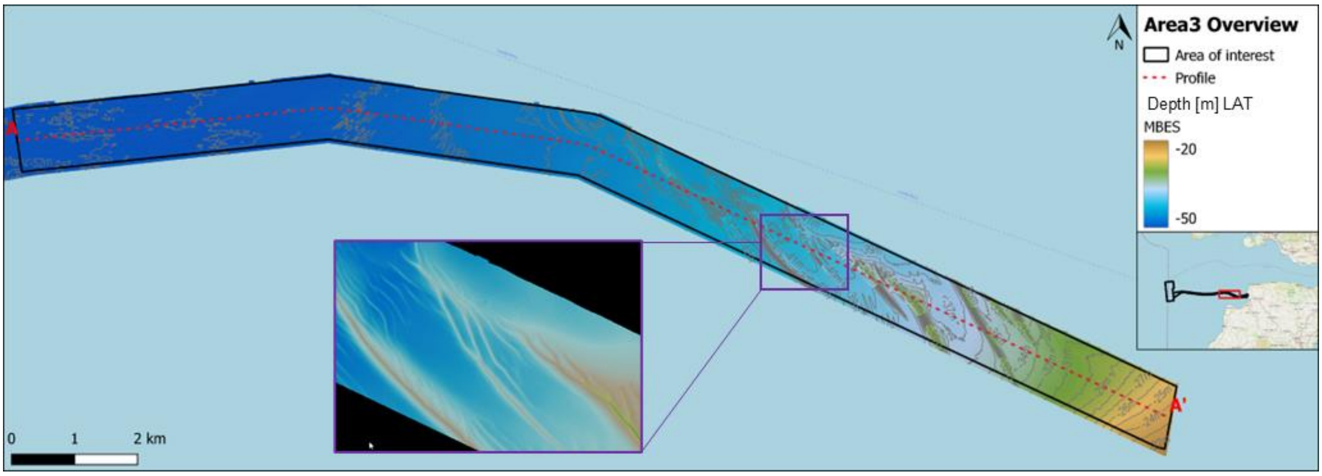

Figure 5-3: Bathymetry overview of Area 3

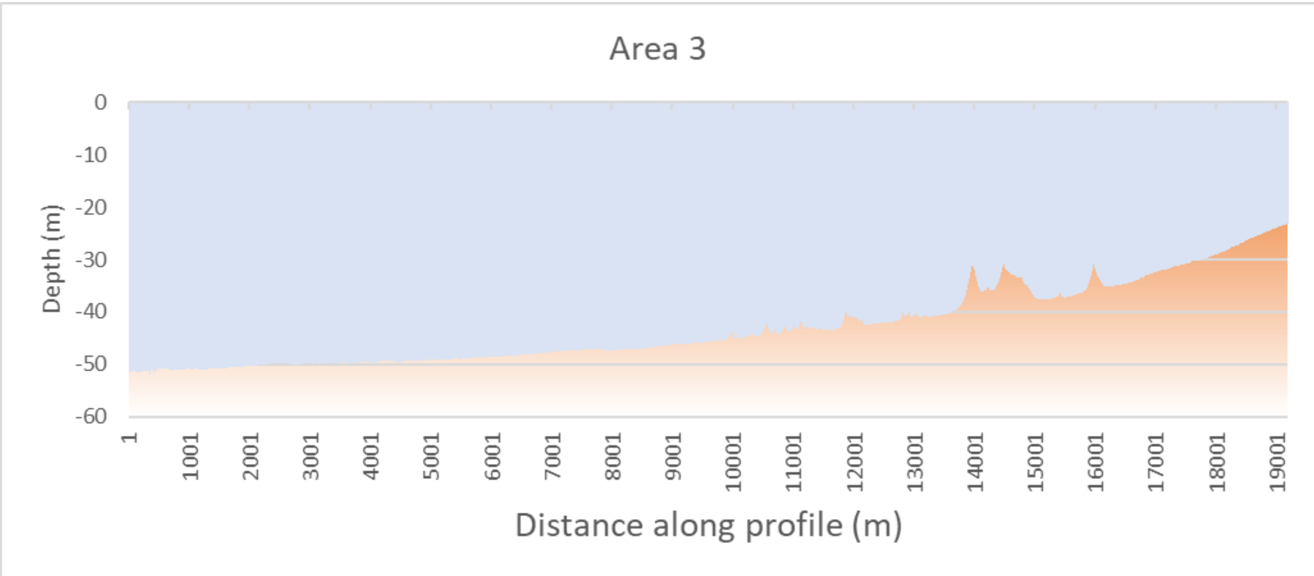

Figure 5-4: Bathymetry profile across Area 3

5.2.4 Area 2

The water depths at Area 2 range between -50.37 m and -59.18 m; with an average depth of -54.64 m. While the western half of the area shows a regular slope as reported within area 1, the centre and eastern parts are revealing an irregular seabed, as the route crosses a region of frequent rock outcrops. In the centre section, the seabed depths remain generally between -52 m and -55 m.

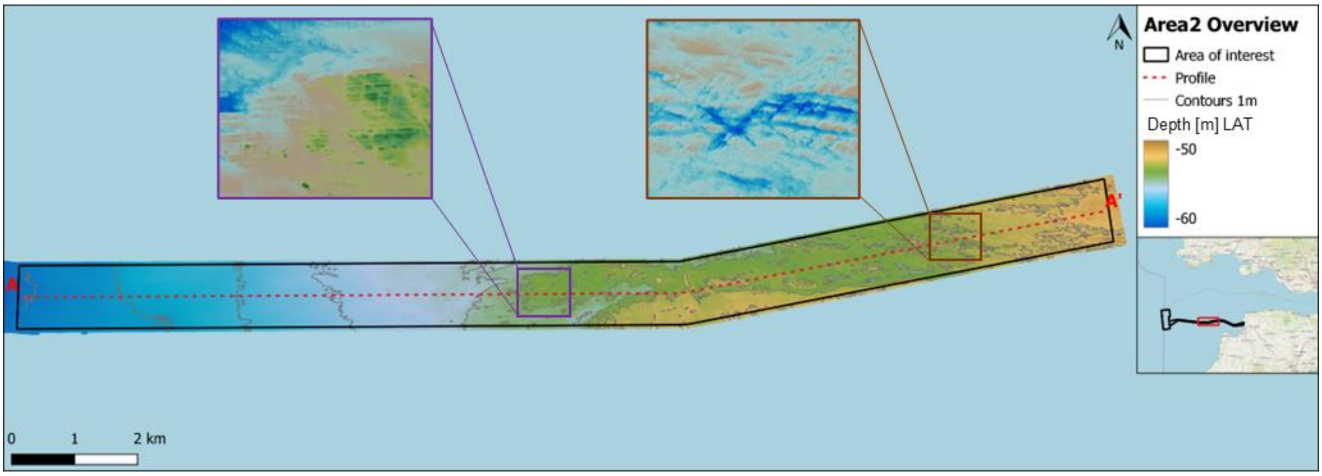

Figure 5-5: Bathymetry overview of Area 2

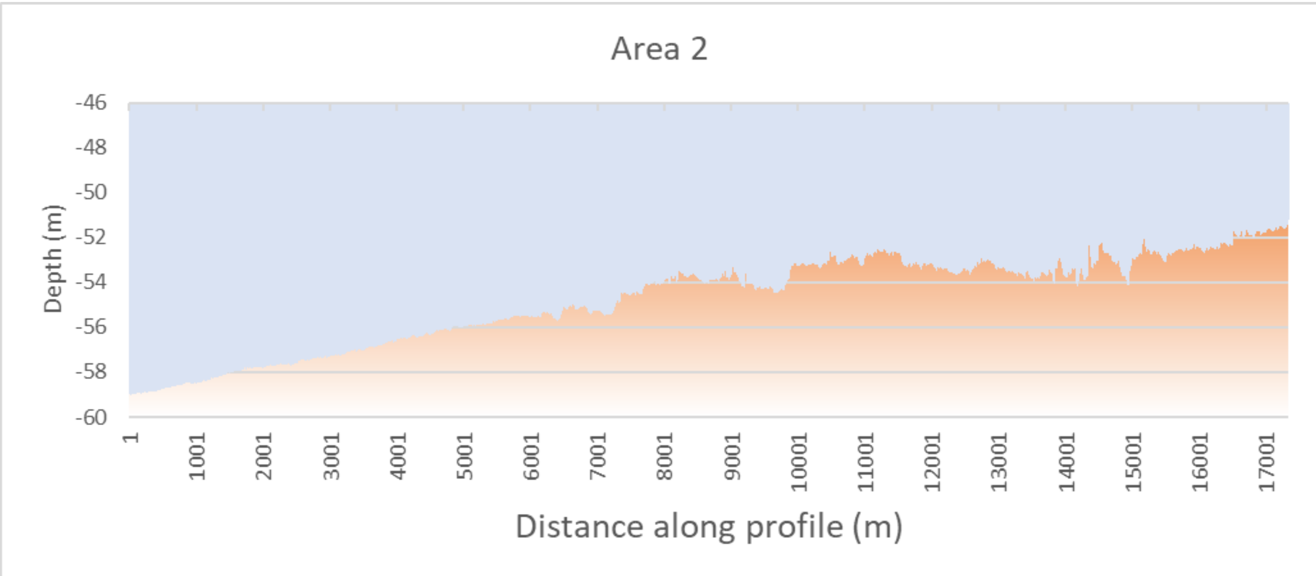

Figure 5-6: Bathymetry profile across Area 2

5.2.5 Area 1

The water depths at Area 1 range between -58.76 m and -68.86 m; with an average depth of -64.67 m. The seabed appears to be gently and regularly dipping towards the West Figure 5-7. One exception can be noted on the profile (Figure 5-8), approximately 1.5 km west of A' where the route crosses a 1 m deep depression.

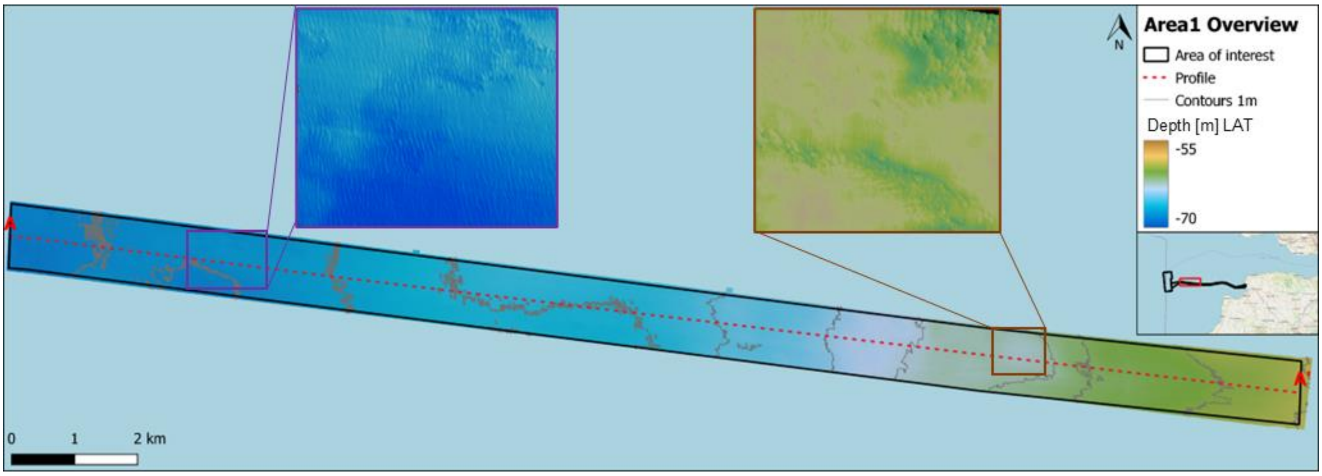

Figure 5-7: Bathymetry overview of Area 1

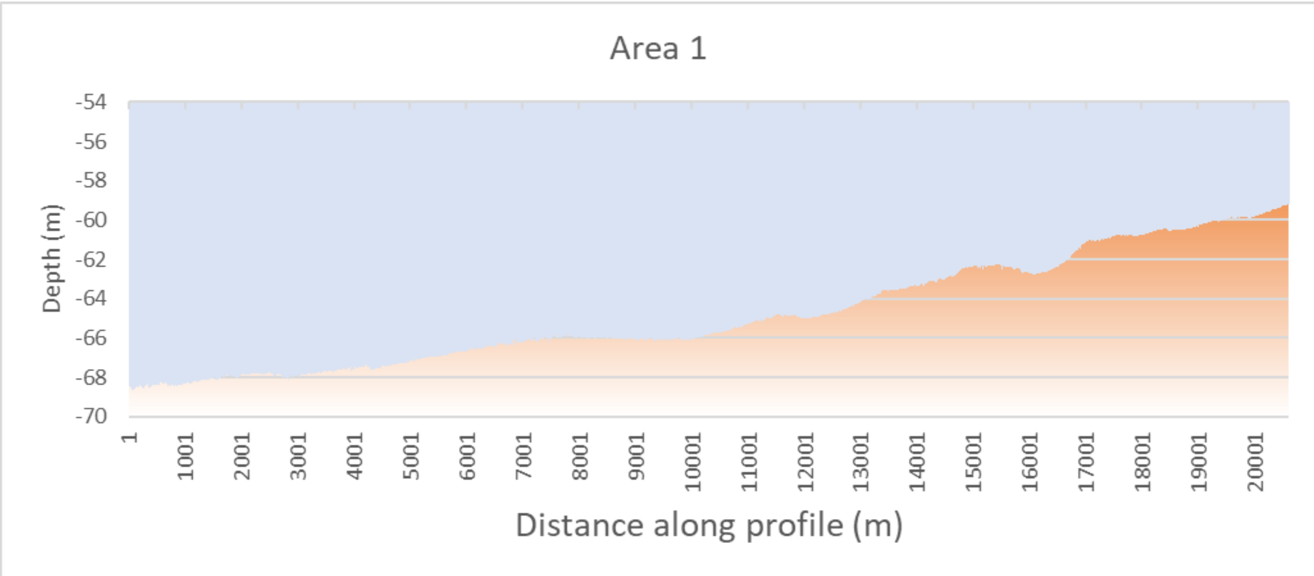

Figure 5-8: Bathymetry profile across Area 1

5.2.6 FAN Area

The MBES DTM of the Fan area reveals a gentle slope with water depth generally increasing towards the southwestern corner of the area. The seabed depths at the Fan area range from -67.62 m to -75.16 m; with an average depth of -70.07 m.

As seen on the profile (Figure 5-10), the seabed is slightly irregular with small sand ripples and small relief (<1 m) likely caused by the underlying geology.

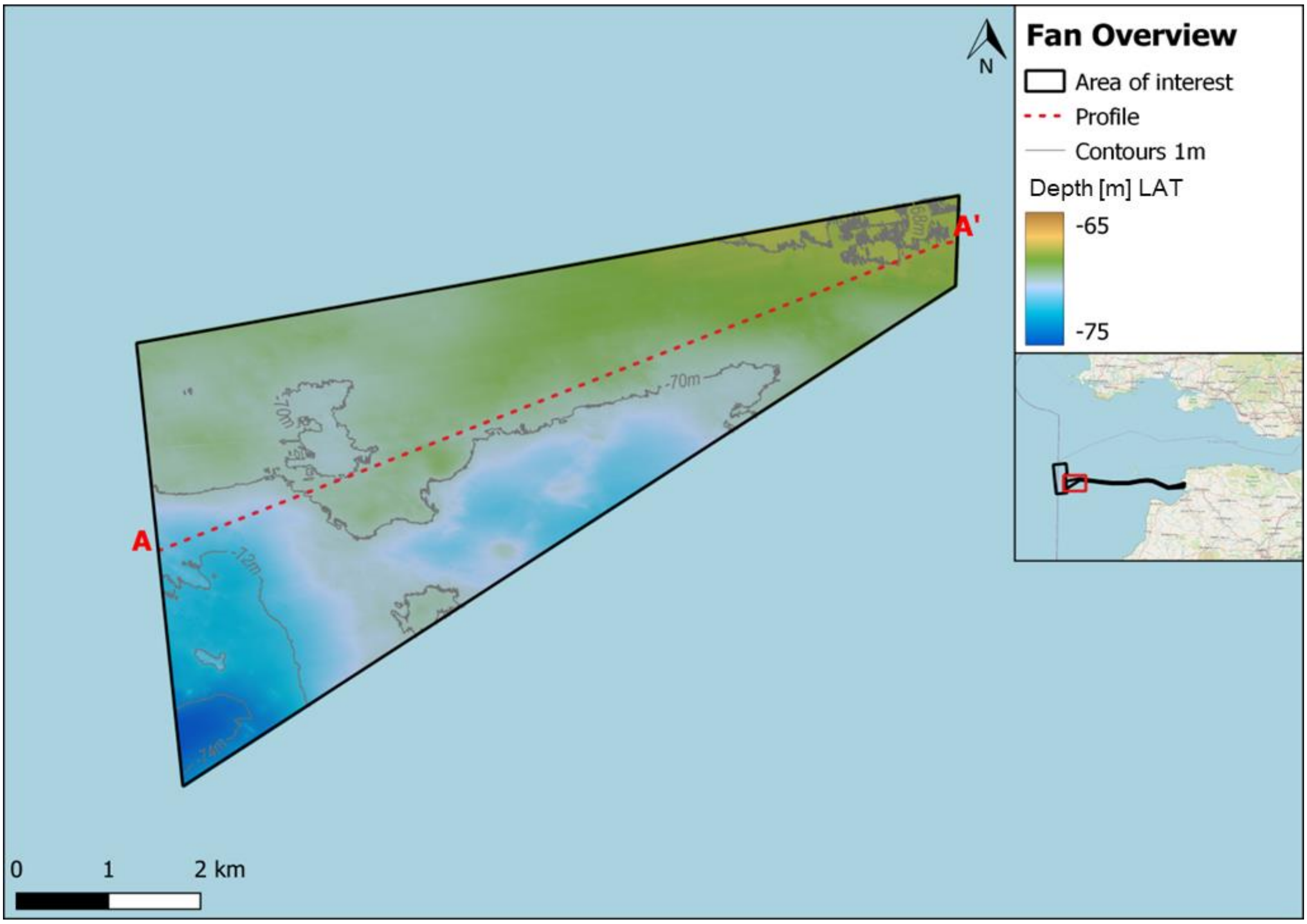

Figure 5-9: Bathymetry overview of the Fan area

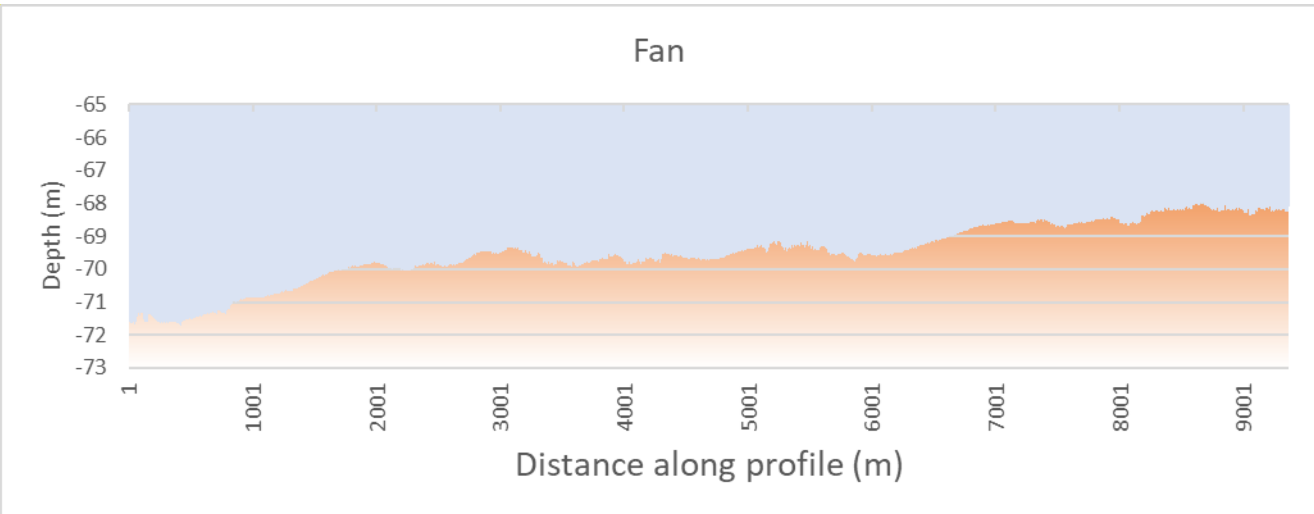

Figure 5-10: Bathymetry profile across Fan area

5.2.7 OWF

The water depths at the OWF range between -69.07 m and -78.12 m; with an average depth of -71.92 m. In the northern part, the seabed gently dips toward the western edge of the area. Small ripples are discernible, mostly in the north-eastern sector. Towards the southern end of the site, the DTM reveals a more irregular seabed with depressions, the most significant one being located about 2 km North of A' on Figure 5-11 where the deepest soundings were recorded.

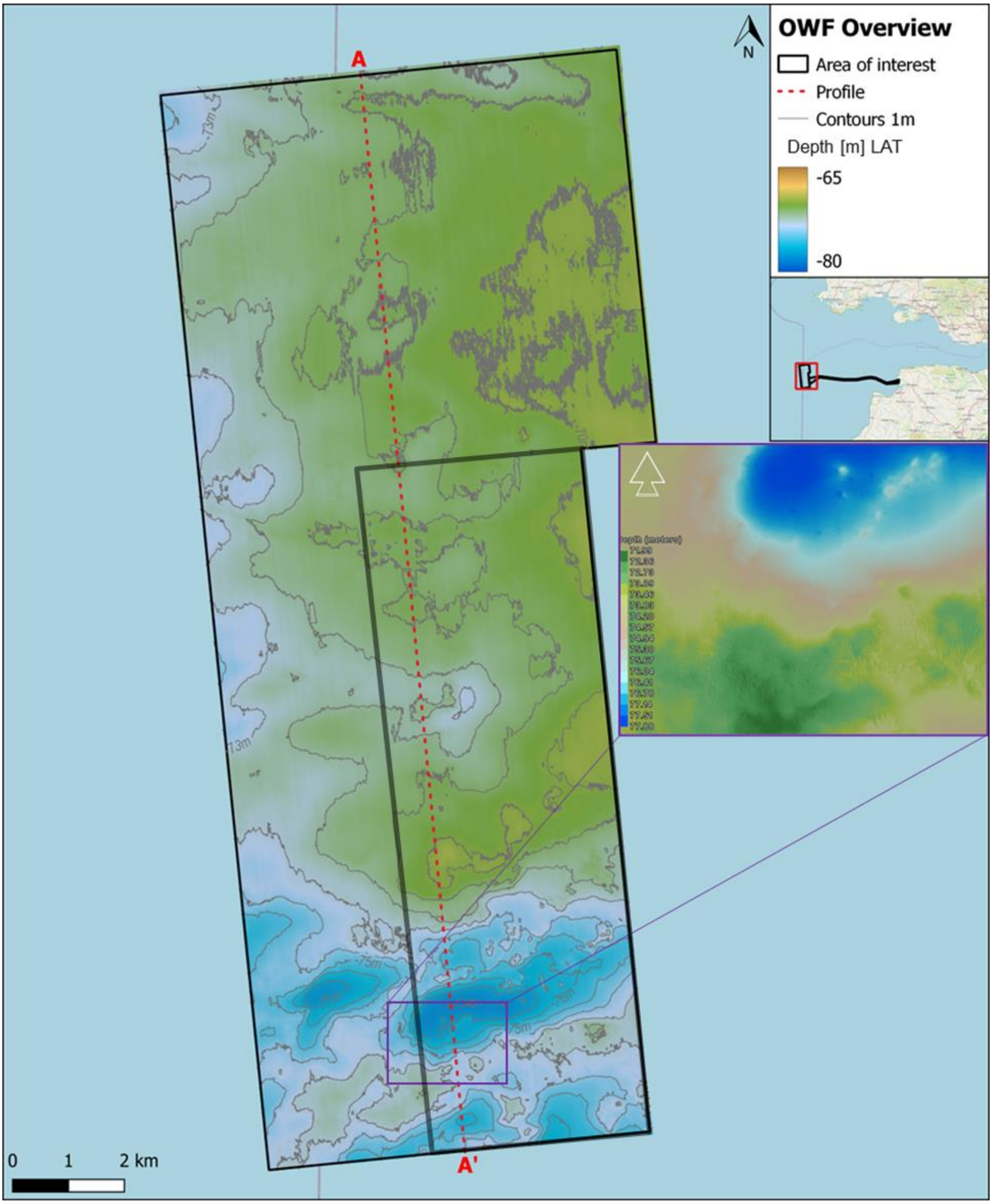

Figure 5-11: Bathymetry overview of the OWF

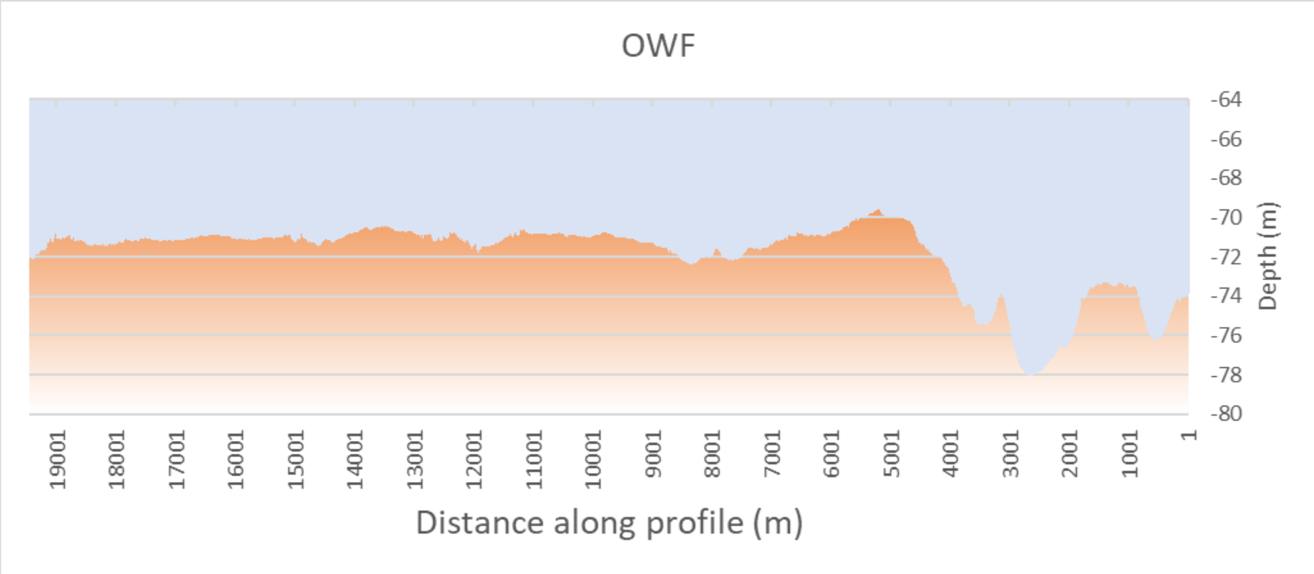

Figure 5-12: Bathymetry profile across OWF

5.3 SEABED FEATURES AND CONTACTS

The SSS records (in conjunction with MBES DTM and Backscatter mosaics) were interpreted to provide seabed information, which can be divided in three categories:

- seabed surficial sediments classification;
- seabed morphology and features;
- sonar contacts.

5.3.1 Seabed Sediments Classification and Morphology

The sediment classification within the survey area was performed based on the side scan sonar data and sediments reflectivity and appearance, with aid of MBES bathymetry and backscatter data. The seabed in the survey area shows some variety in different seabed surficial sediment and morphology. Classification was done in line with SSDM / IOGP standards.

Table 5-3: Seabed sediments classification and distribution

Class	IOGP Code	Area in km2	% of the survey area
Sediment (Primary)			
Sand	IOGP3102	235.87	96.3%
Clayey Sand	IOGP3202	2.01	0.8%
Rocky	IOGP3205	7.09	2.9%
Sediment (Secondary)			
Coarse Sediment (including boulders)	IOGP3093	38.94	15.9%
Seabed Features			
Sand Ripples	IOGP3004	89.81	36.7%
Mega Ripples	IOGP3052	6.71	2.7%
Area with Occasional boulders (1 to 25 per 50x50m)	IOGP3076	2.92	1.2%
Area of Bedrock	IOGP3079	7.09	2.9%

Nearshore Area

The nearshore area is located West of Saunton Sands, Devon, UK. The reconnaissance lines were completed until approximately 10 m LAT (Figure 5-13). With the exception of two small, isolated rocky outcrops, it reveals a flat and featureless sandy seabed over the entire section acquired.

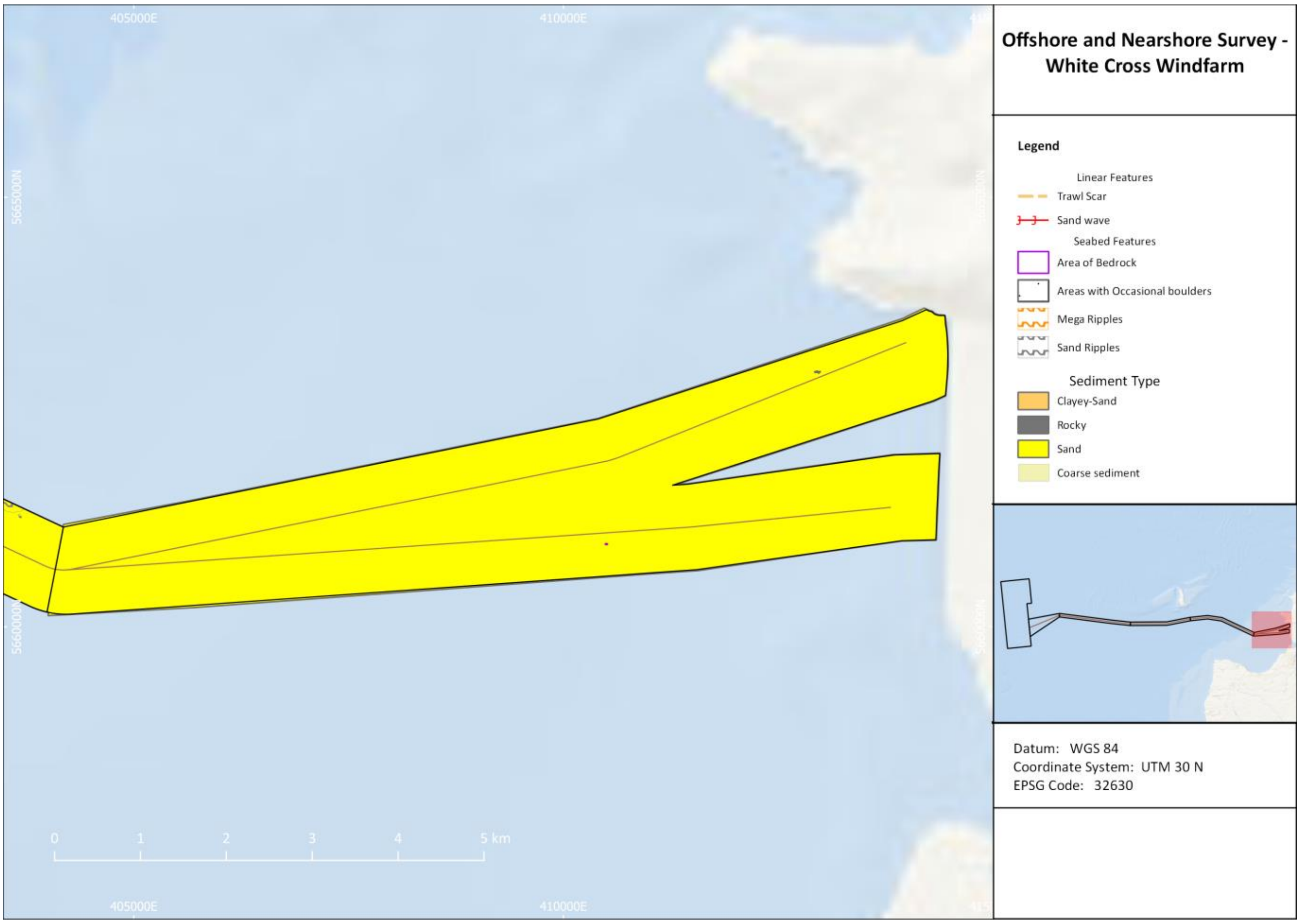

Figure 5-13: Nearshore area - seabed interpretation overview

Area 3

Area 3 is situated at the eastern edge of the offshore section of the ECR, adjacent to the nearshore area. Figure 5-14 shows an overview of the interpretation of the seabed in this area.

Majority of Area 3 is covered with uniform medium to medium-high reflectivity sediments, interpreted as sand (Figure 5-14). The sand is present from the eastern edge of the area, all the way to the western boundary, where it is forming only a shallow veneer covering sub-cropping bedrock.

In the eastern section of the area, for a distance of approximately 1100 m, the sandy seabed appears flat and featureless. Patches of sand ripples, generally localised, disconnected and of linguoid type, with height between 10 to 25 cm, wavelengths from 10 to 12 m and crests orientated NNW-SSE, appear within the section from 1100 to 2800 m from the eastern boundary of the area (Figure 5-15).

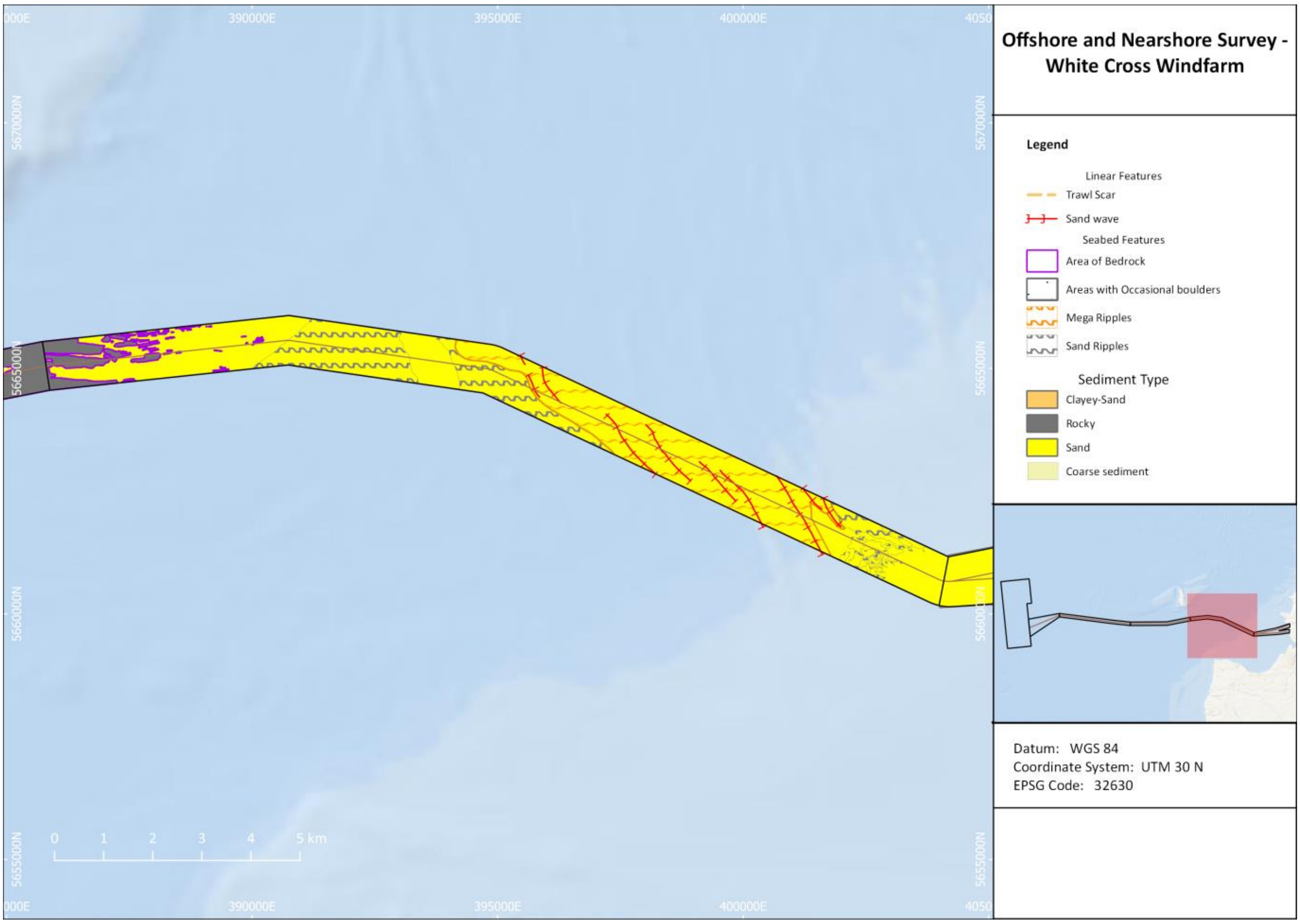

Figure 5-14: Area 3 - seabed interpretation overview

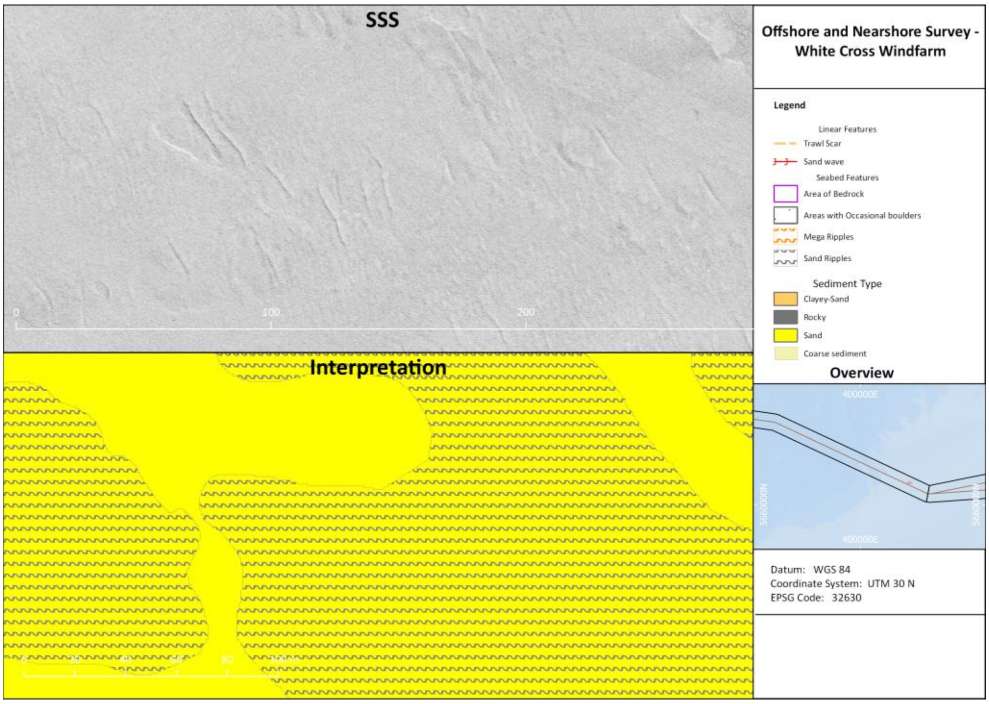

Figure 5-15: Area 3 – patches of sand ripples

At the point approximately 2800 m from the eastern boundary, the patches give way to megarippled seabed, fully covering the ECR corridor (Figure 5-16). The megaripples throughout most of this section are sinuous to straight in type, reaching heights between 10 and 20 cm, with wavelengths varying between 5 and 10 m and crests orientated NNW-SSE. These mid-size bedforms are overlaid on larger scale sand waves. The wavelengths of the megaripples are significantly shortened when observed on the slopes of larger forms, generally not exceeding 3 m.

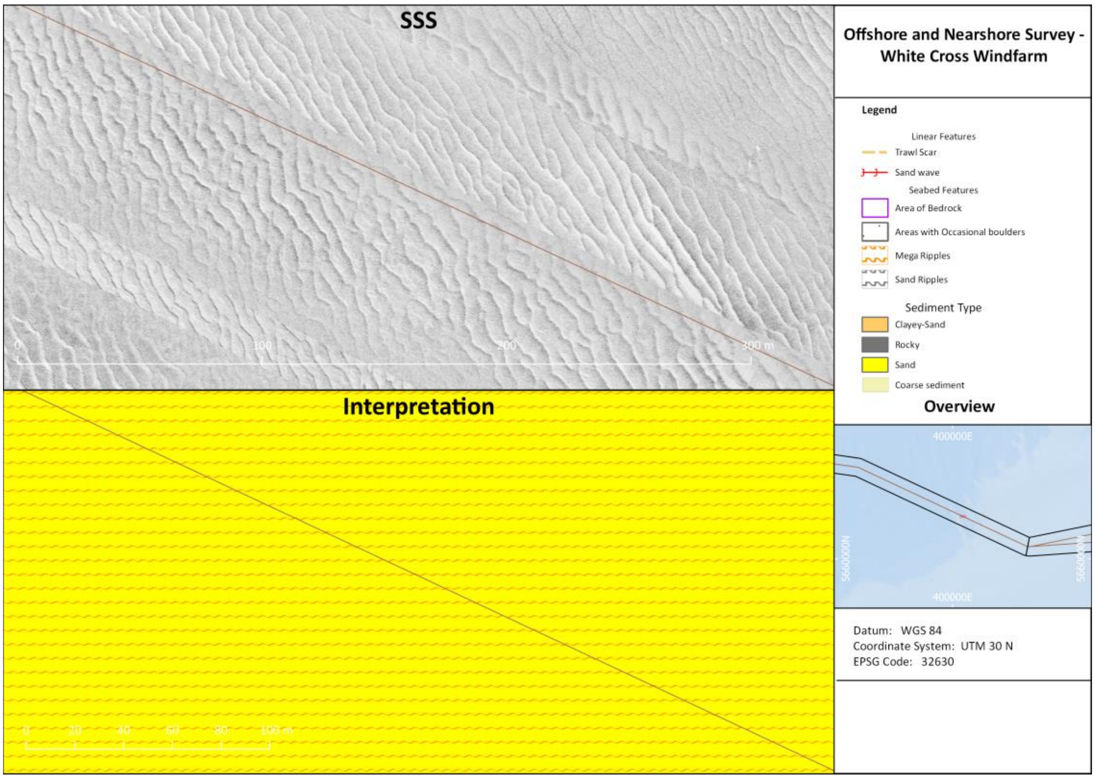

Figure 5-16: Area 3 – megarippled seabed

The large-scale sand waves are scattered irregularly over 7 km of Area 3. When appearing in groups, they have wavelengths between 60 to 120 m. General crest orientation of the sand waves follow the orientation of the megaripples. Heights of the sand waves vary between 1 m and 10 m.

At the point approximately 10 000 m along the ECR corridor in Area 3, the megaripples disappear and flat / slightly rippled sandy seabed is the dominating feature again. Sand ripples appears again in localised, elongated (NNE-SSW) patches. The ripples within the patches do not exceed 20 cm in height, have wavelengths up to 2 m and crests orientated NNW-SSE.

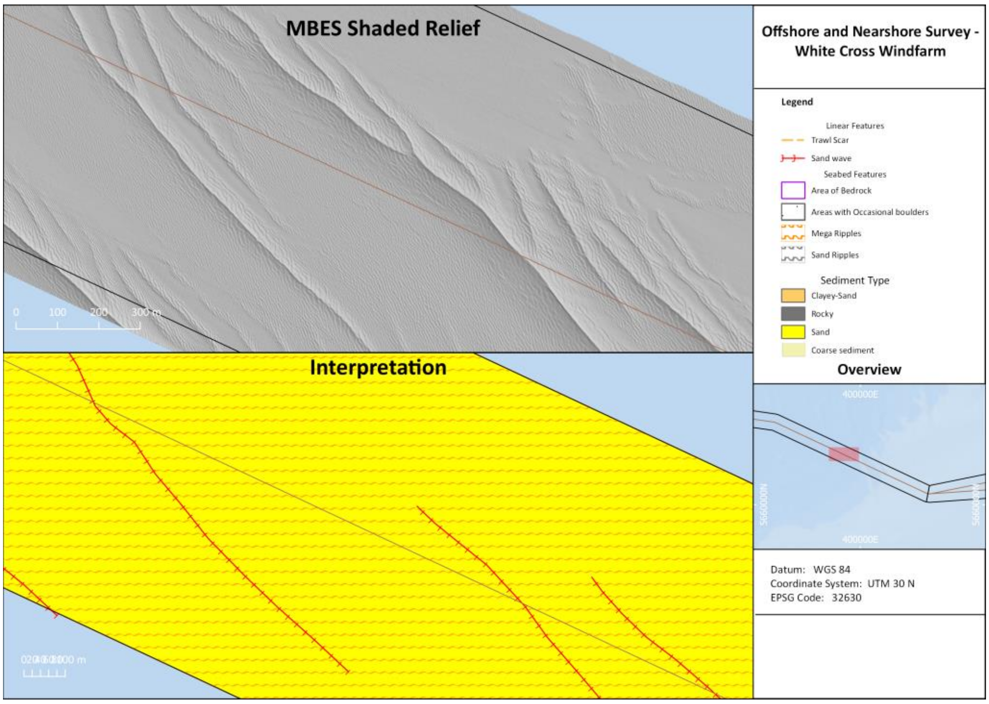

Figure 5-17: Area 3 – sand waves

From the point where these patches disappear, a new type of feature is observed, first occasionally and eventually becoming the main type at the western edge of Area 3. These are the exposures of bedrock. Firstly, observed as relatively small outcrops, the bedrock becomes dominant within the last 2600 m of the area (Figure 5-18). The exposures are elongated in the W-E direction. Internal bedding of the exposed rocks is clearly visible on SSS records. The abundance of rock outcrops suggests that in this section the sand is only present as shallow veneer covering sub-cropping bedrock.

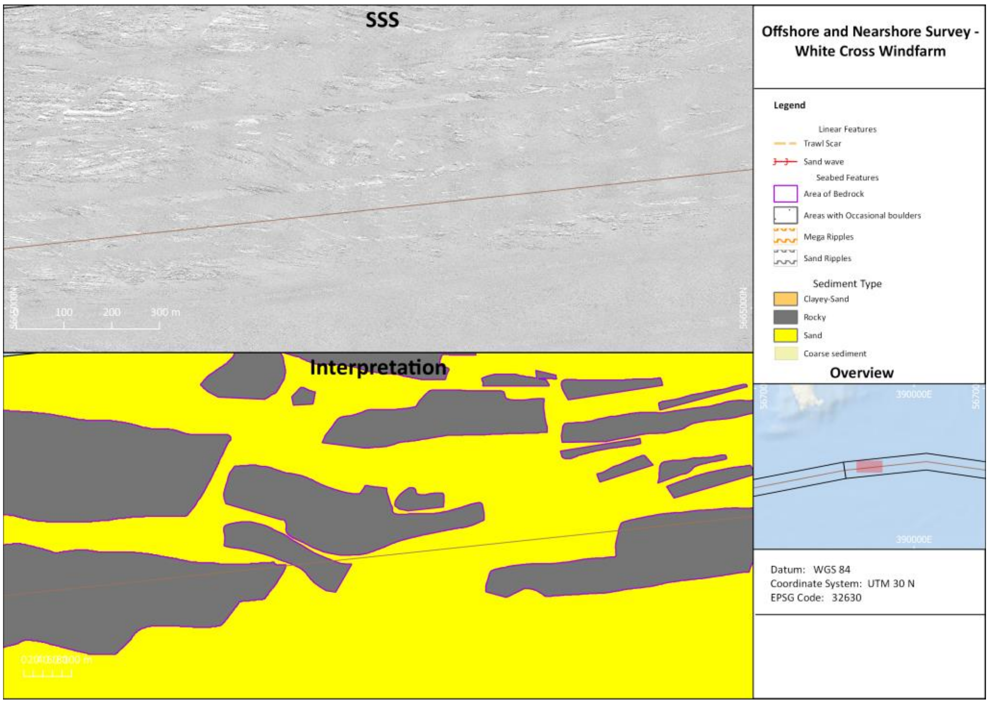

Figure 5-18: Area 3 – exposed bedrock

Area 2

Area 2 is situated within the offshore section of the ECR, to the west of Area 3. Figure 5-19 shows an overview of the interpretation of the seabed in this area.

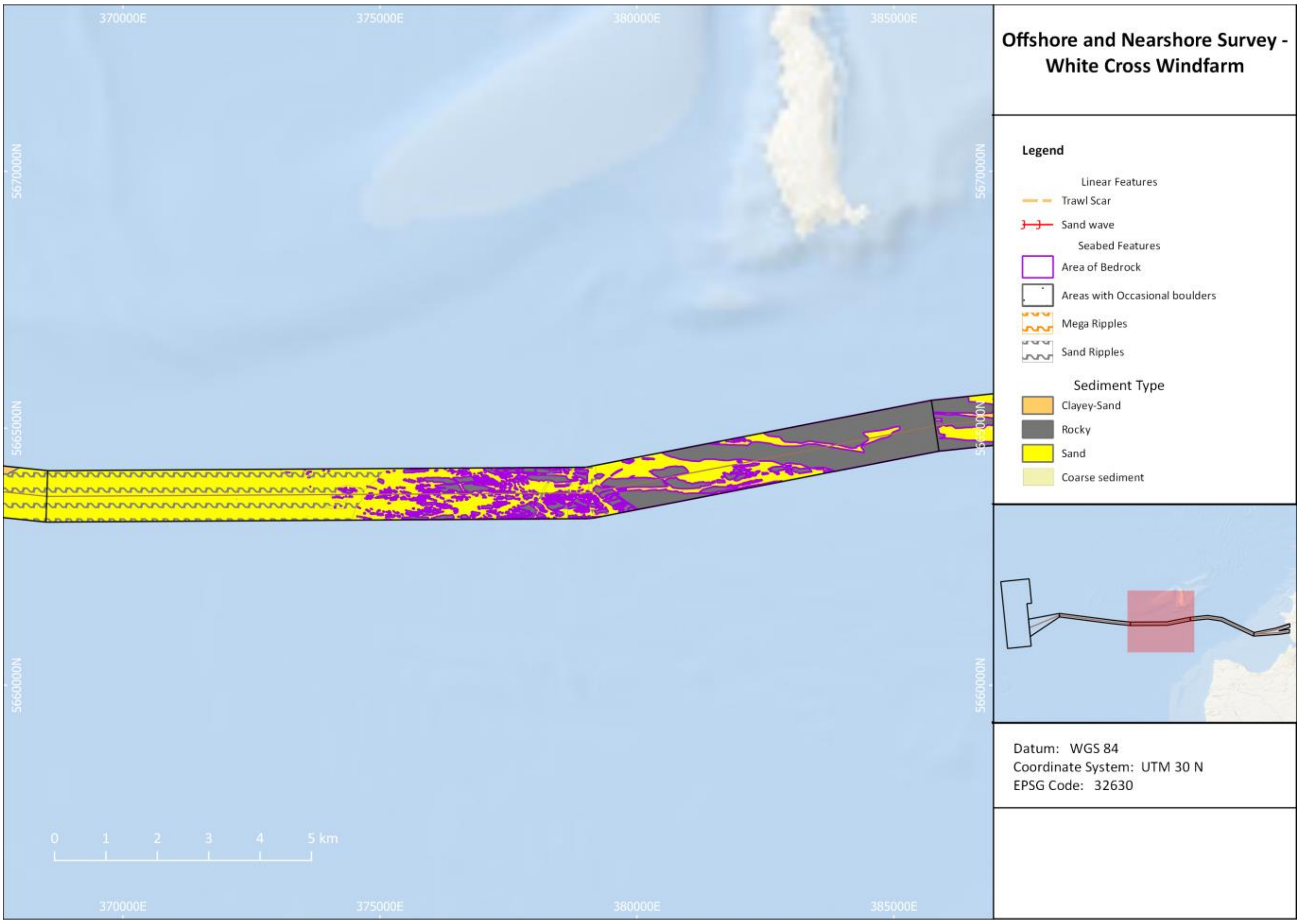

Figure 5-19: Area 2 - seabed interpretation overview

Large part of Area 2 is covered with sand, likely only shallow veneer overlaying a sub-cropping bedrock, also present as large exposures (Figure 5-19). The sand is characterised on SSS records by medium to medium-high reflectivity, while the rock exposures have medium-high to high reflectivity on SSS records. The sand is intersected by bands of lower reflectivity sediments, towards the western edge of the area.

From the eastern boundary up to a point approximately 11 400 m west, the frequent exposures of bedrock continue from Area 3 (Figure 5-20). Here, the exposures are also elongated in the W-E direction, with internal bedding clearly visible on SSS records. The large amount and size of rock outcrops also suggests that in this section the sand is only present as shallow veneer covering sub-cropping bedrock.

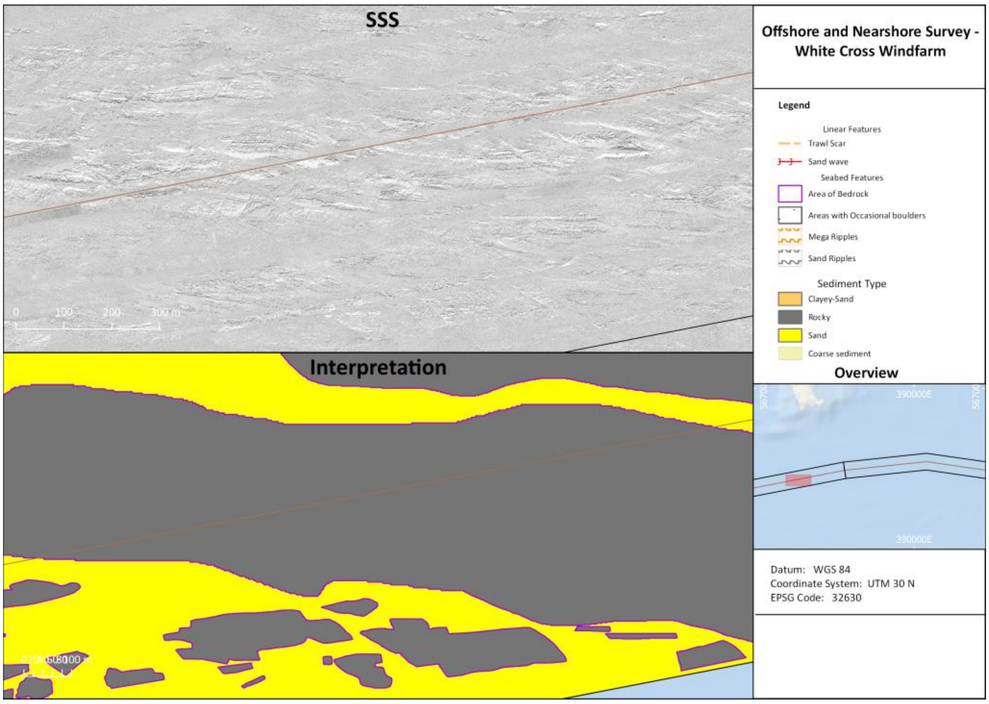

Figure 5-20: Area 2 – exposed bedrock

At the point 11 400 m to the west from the eastern edge of the area, the bedrock outcrops disappear, implying thicker cover of surficial sands (Figure 5-21).

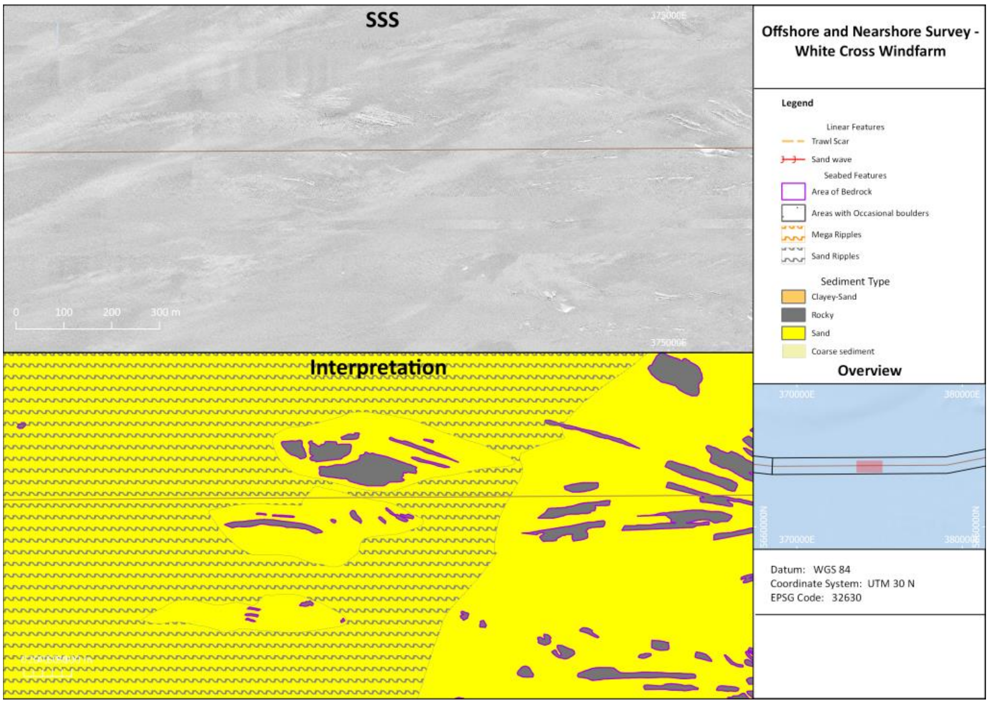

Figure 5-21: Area 2 – bedrock outcrops western limit

The surficial sand continues to the western boundary of Area 2. It is observed to be generally flat and featureless, with occasional rippled patches crossing the corridor. The ripples are generally smaller than in Area 3, with wavelengths between 1 and 3 m, heights up to 10 cm and straight crests orientated NNW-SSE (Figure 5-22).

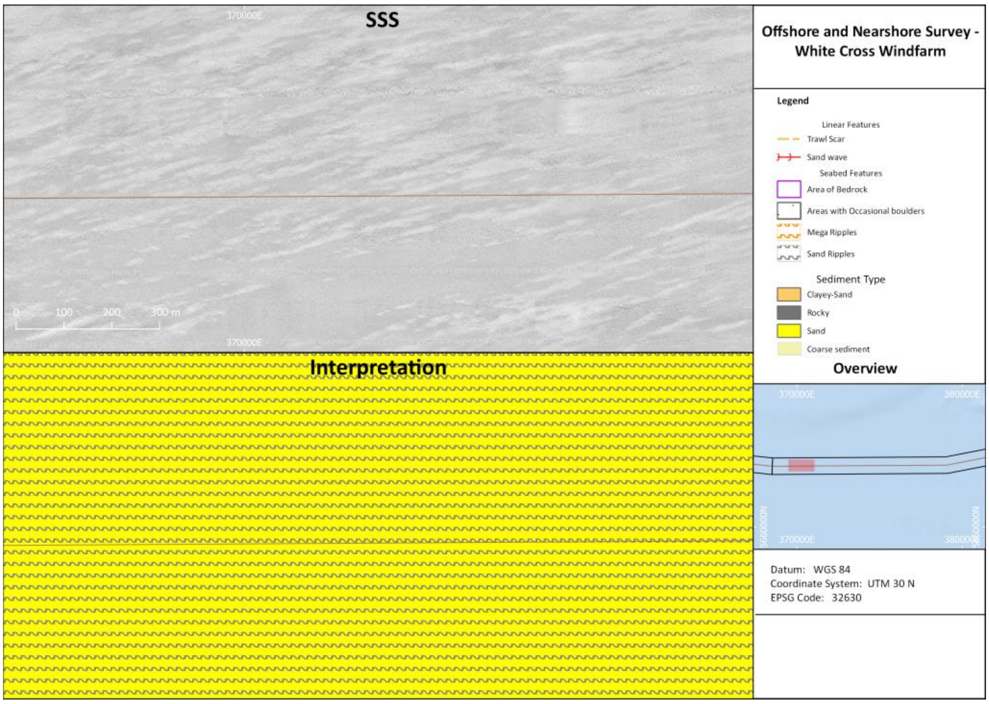

Figure 5-22: Area 2 – change in reflectivity along the route

The featureless sections of the seabed are characterised by elongated (NE-SW) patches of lower and higher reflectivity. These suggests change in sediment composition (Figure 5-22) with alternating fine and coarse sediments. These stretches of alternating reflectivity become more frequent towards the western boundary of Area 2 with small, remnant ripples visible on SSS records, under 10 cm in height and average wavelength of 10 m. Crests of these slight forms are oriented NNW-SSE.

Area 1

Area 1 is situated within the offshore section of the ECR, to the west of Area 2. Figure 5-23 shows an overview of the interpretation of the seabed in this area.

Most of Area 1 is covered with sand, with a E-W divide, where rippled, medium-high reflectivity sediments, with occasional patches of clay and coarser material dominate the eastern half of the area, while medium reflectivity megarippled sand is observed in the western half (Figure 5-23).

From the eastern boundary of Area 1, the alternating low/high reflectivity sections that were present in Area 2 as elongated patches, start to dominate the composition of surficial sediments.

Several areas of infrequent, larger scale megaripples were noted along the ECR within the easternmost 6000 m of Area 1. These were linguoid in character, with wavelengths 5 to 10 m, sub 10 cm heights and crests orientated NNW-SSE.

Figure 5-23: Area 1 - seabed interpretation overview

Occasional exposures of clay, usually developed in small, localised shallow depressions (Figure 5-24) were reported. In the remaining sections, the seabed was interpreted as poorly sorted silt, sand and coarser sediments, with occasional boulders.

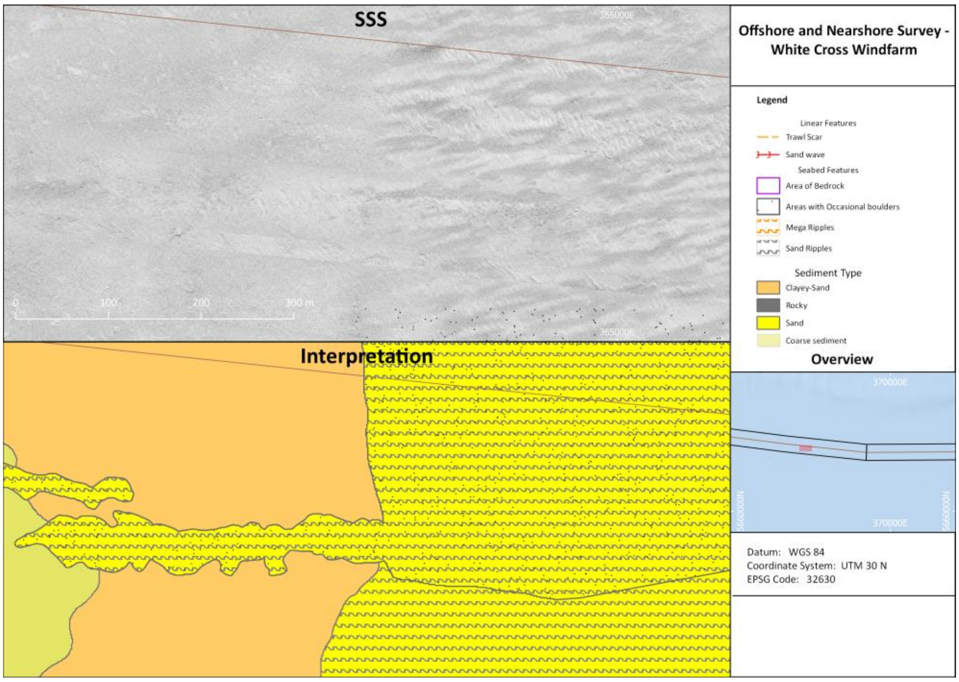

Figure 5-24: Area 1 - sand with clay patches (left) / Ripples and boulders (right)

At a point approximately 7000 m from the eastern boundary of the area, the seabed becomes covered with rippled sand that dominates the entire ECR corridor to the western limit of Area 1. These ripples are straight to sinuous in type and display wavelengths between 4 to 16 m, heights between 20 and 40 cm. Crests are generally orientated from NNW-SSE to N-S (Figure 5-25). These features gradually disappear towards the western edge of the area.

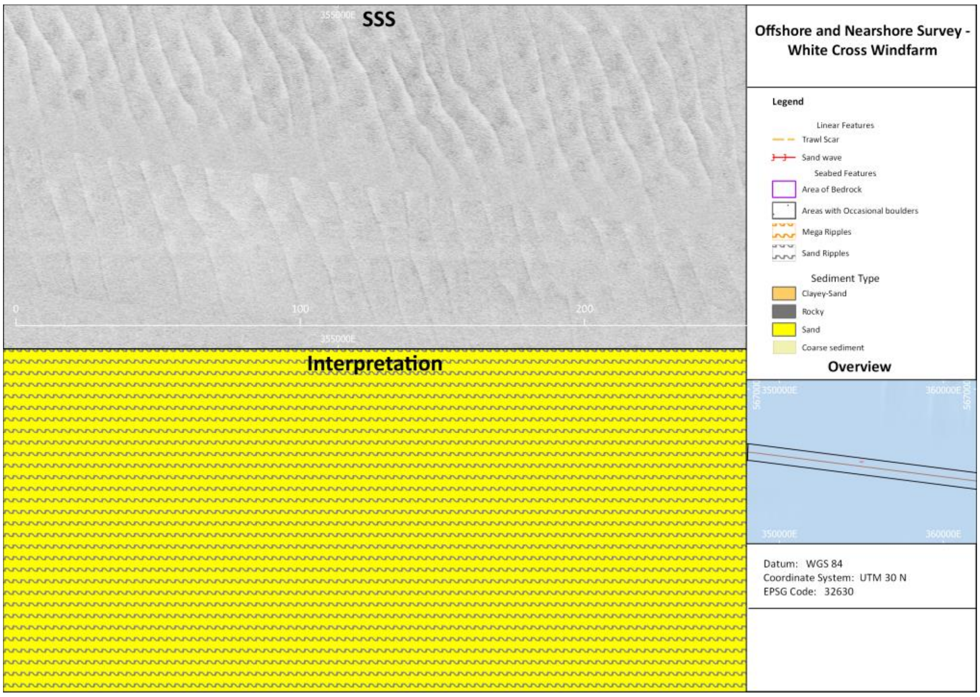

Figure 5-25: Area 1 – rippled sand

At the approaches to the western limits of Area 1, several patches of seabed were noted, where changeable reflectivity and presence of boulders exposed at seabed surface imply possibility of sub-cropping of coarser material (Figure 5-26). These sub-cropping patches continue to the end of Area 1, being also present across the Fan Area further west.

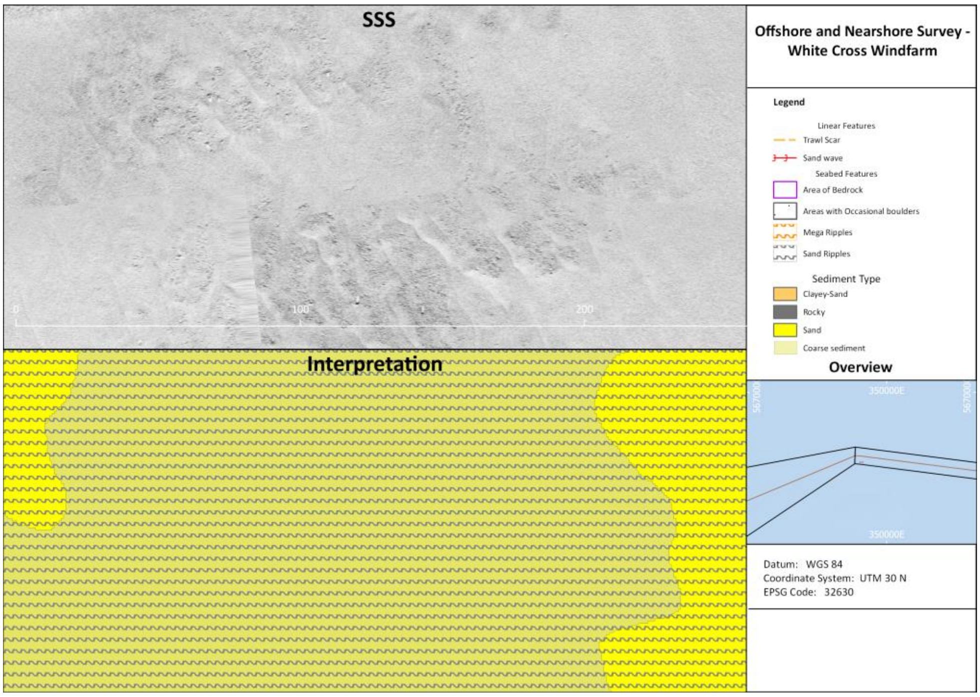

Figure 5-26: Area 1 – coarse sediments sub-cropping between ripples

Area "Fan"

Area Fan is situated within the offshore section of the ECR, to the west of Area 1 and to the east of the approaches to the OWF. Figure 5-27 shows an overview of the interpretation of the seabed in this area.

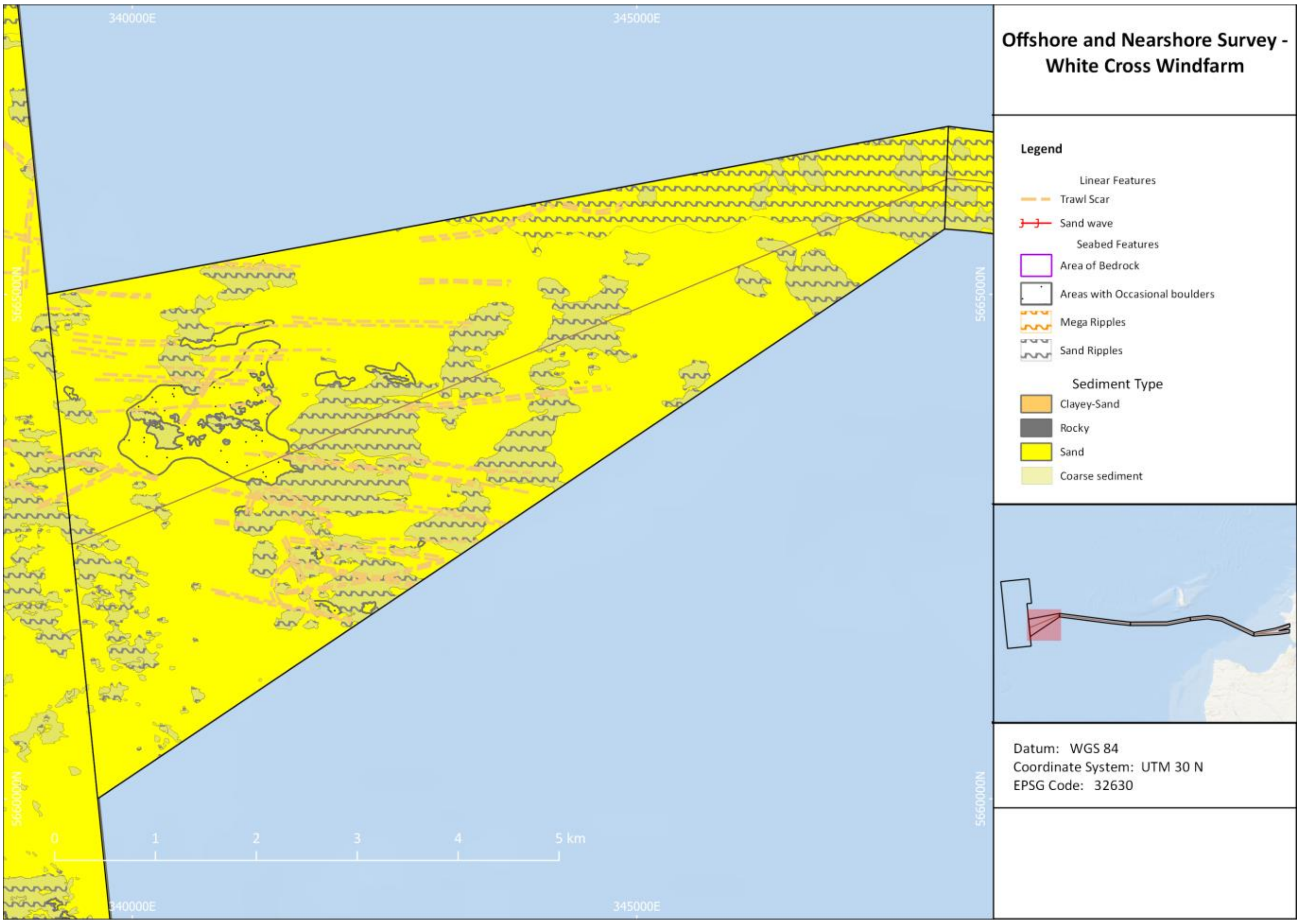

Figure 5-27: Area Fan - seabed interpretation overview

The majority of the area is covered with sand (Figure 5-27), with occasional patches of coarse sediments. The seabed is generally flat and featureless except for the section of ripples that continue from Area 1, at the eastern boundary of this area.

The ripples present at the eastern side start of the area are slightly pronounced, giving quickly way to flat seabed. The wavelengths are generally between 6 and 13 m, with heights varying between 10 and 40 cm and crests running NNW-SSE.

The patches of coarse sediments are similar in appearance to the ones observed in Area 1. They are marked by presence of boulders at the surface, mainly within troughs of faintly pronounced megaripples (Figure 5-28).

Multiple trawl scars were detected across the area, evidence of recent fishing activities in the area.

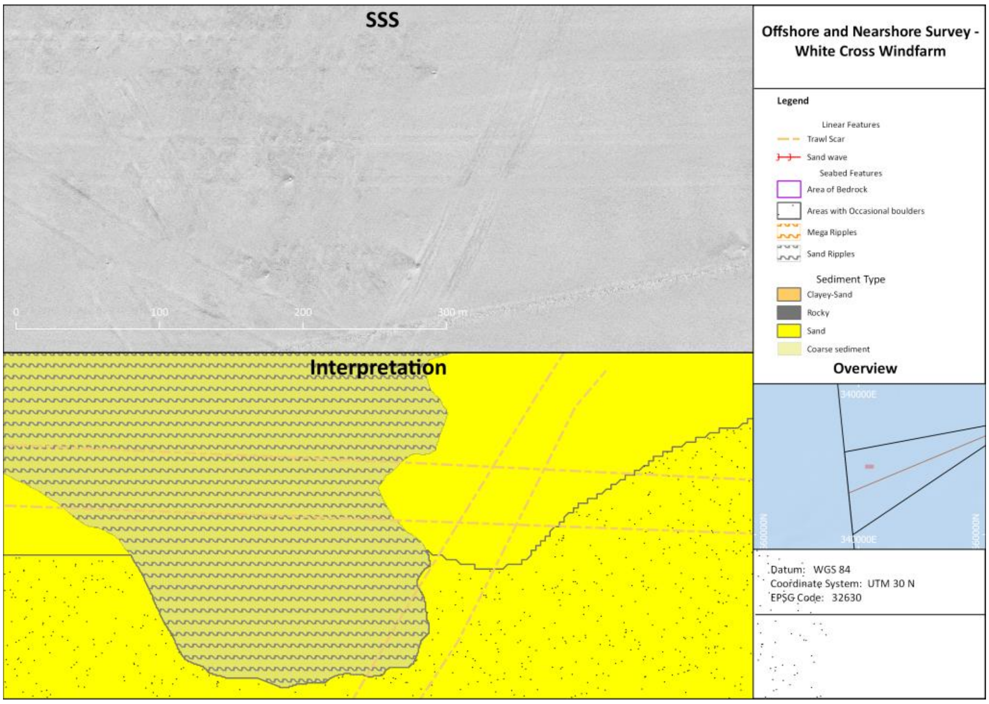

Figure 5-28: Fan area – sand, coarse sediments and boulders

Offshore Wind Farm Area

The Offshore Wind Farm area is located west of area "Fan". Figure 5-29 shows an overview of the interpretation of the seabed in this area.

While the majority of the site is interpreted as covered with sand, there are some local variations. The northern part of the site is mostly covered with sand ripples with wavelength roughly between 15 and 20 m, heights reaching 20 to 40 cm and their crests-oriented N–S, indicative of a dominant current in E-W direction (Figure 5-30). Patches of coarse sediment were regularly reported.

Multiple trawl scars were detected across the eastern section, evidence of recent fishing activities in the area.

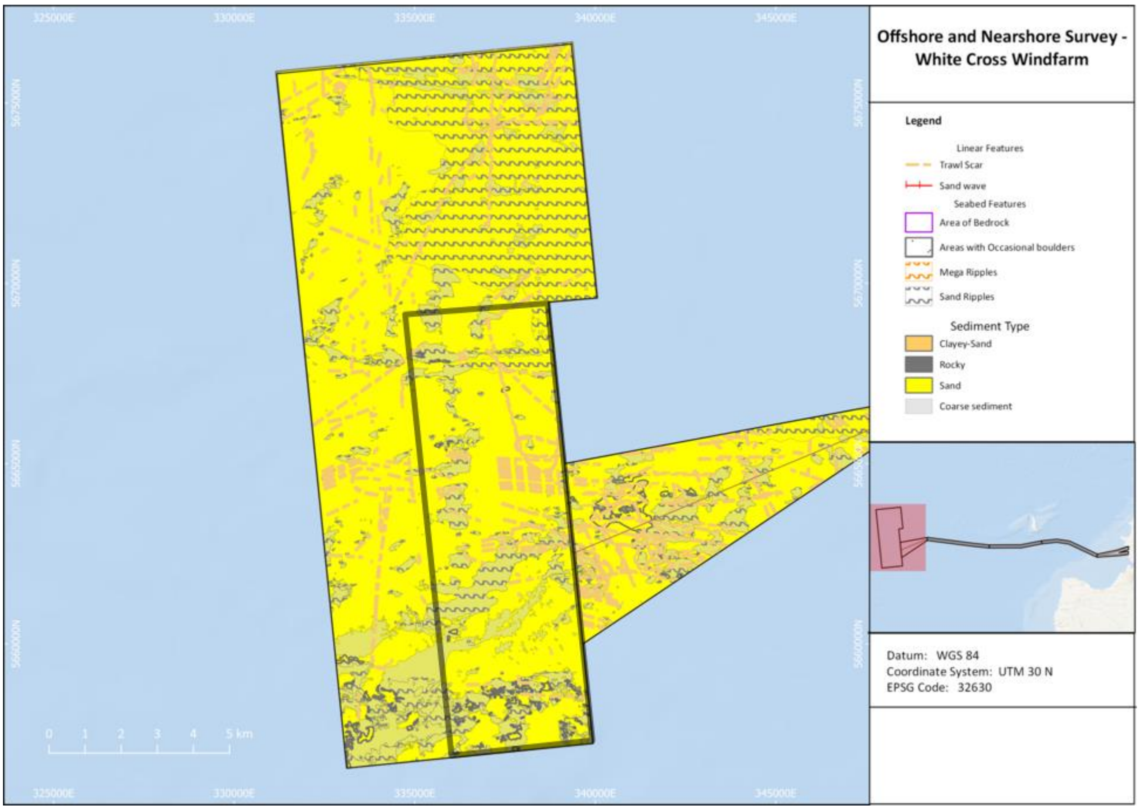

Figure 5-29: Area Offshore Wind Farm - seabed interpretation overview

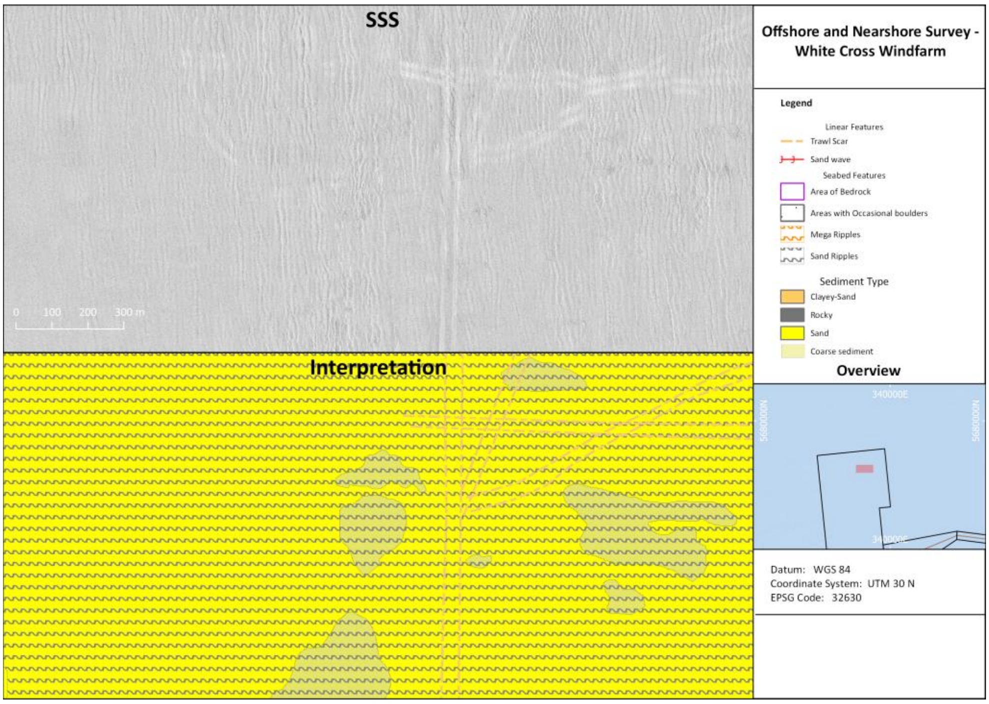

Figure 5-30: Area Offshore Wind Farm – North East Sector

Towards the southern part of the site, the ripples are again regularly visible, but the sediment material within the troughs seems coarser, indicating a thin surficial dynamic layer overlaying a layer of coarser sediment (gravel to boulders) occasionally outcropping. Occasional boulders are also spread over those areas. Occasionally ripples are absent, resulting in patches of poorly sorted silt, sand and coarse sediments / boulder fields (Figure 5-31). The ripple forms here have slightly lower heights, up to 20 cm, wavelengths between 8 and 20 m and crests orientations between N-S to NNW-SSE.

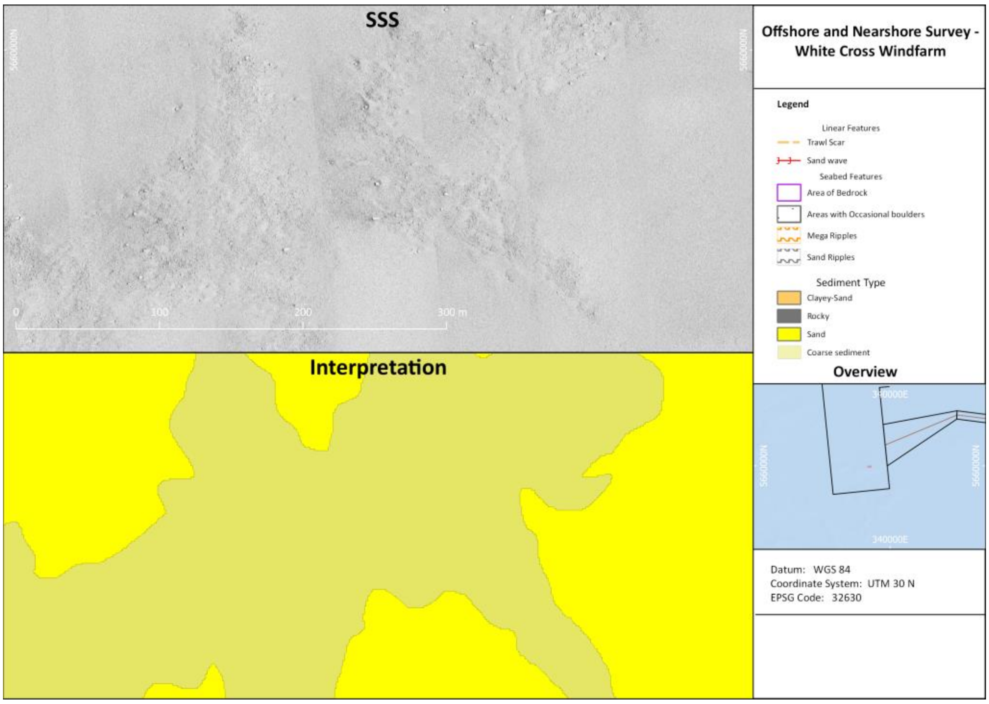

Figure 5-31: Area Offshore Wind Farm – patch of coarser material

Outside those areas, the seabed appears featureless and covered with medium reflectivity material, interpreted as sand (Figure 5-32).

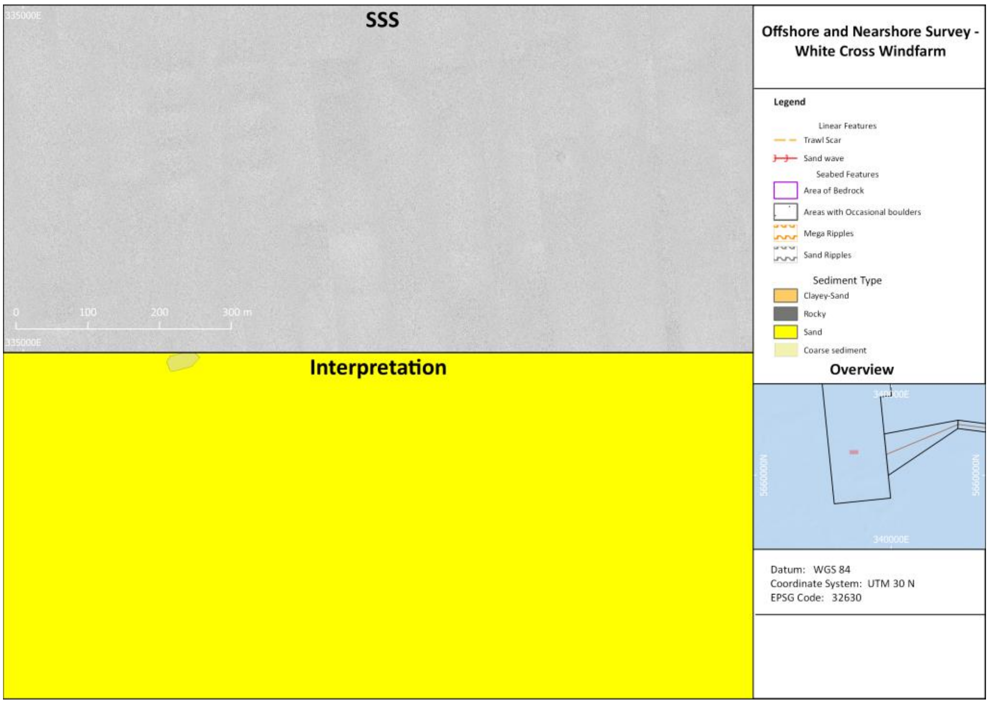

Figure 5-32: Area Offshore Wind Farm – featureless seabed

5.3.2 Side Scan Sonar Contacts

The SSS imagery was interpreted for any seabed surface objects greater than 0.3 m in size. A side scan sonar contact listing was derived from the SSS dataset. All side scan sonar lines were reviewed, and items classified. Table 5-4 summarises the results of the seabed contact picking. In total, 2940 contacts were reported along the survey area. Figure 5-33 to Figure 5-38 give an overview of the targets' distribution per area.

The targets have been subdivided into six categories. It can be observed from Table 5-4 that the large majority consists of boulders (Figure 5-39). The five other classifications are the following:

- "Debris" refers to contacts which appear man made (Figure 5-40),
- "Linear features" are elongated items interpreted as of man-made origin
- "Other" are contacts which appear natural (Figure 5-41),
- "Unknown" are for targets that cannot be identified/categorized with certainty
- The final group are ship "wrecks" (Figure 5-42).

Table 5-4: SSS contacts summary

Contact type	Nearshore	Area 3	Area 2	Area 1	FAN	OWF	Total
Unknown	45	30	6	34	52	124	**291**
Boulder	1	217	145	123	440	1685	**2611**
Other	2	5	6	4	4	4	**25**
Linear Feature	1	2	0	1	2	0	**6**
Wreck	0	2	0	0	0	1	**3**
Debris	0	0	0	0	1	3	**4**
Total	**49**	**256**	**157**	**162**	**499**	**1817**	**2940**

Figure 5-33: SSS contacts in Nearshore area

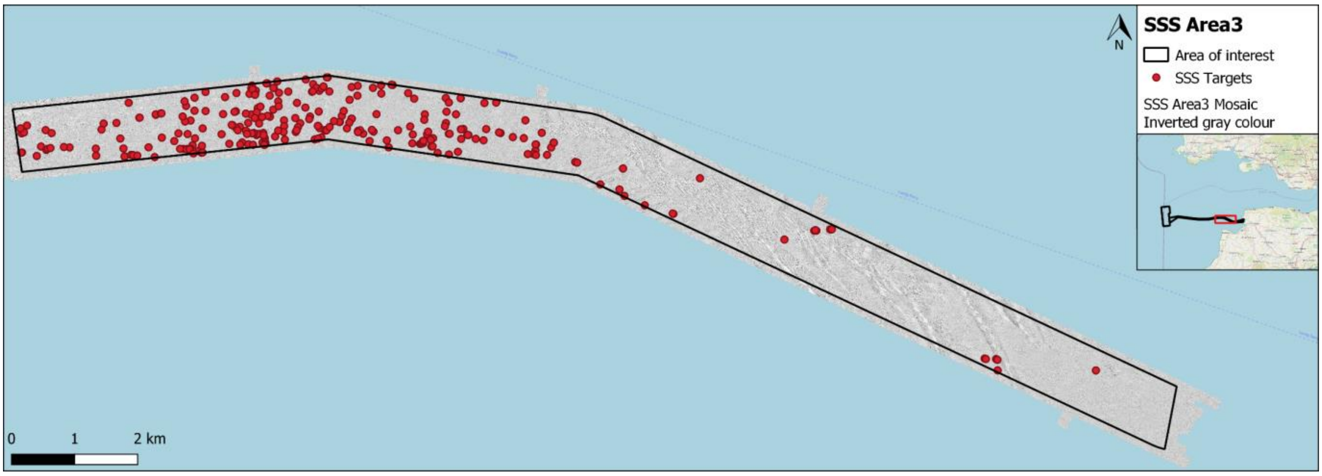

Figure 5-34: SSS contacts in Area 3

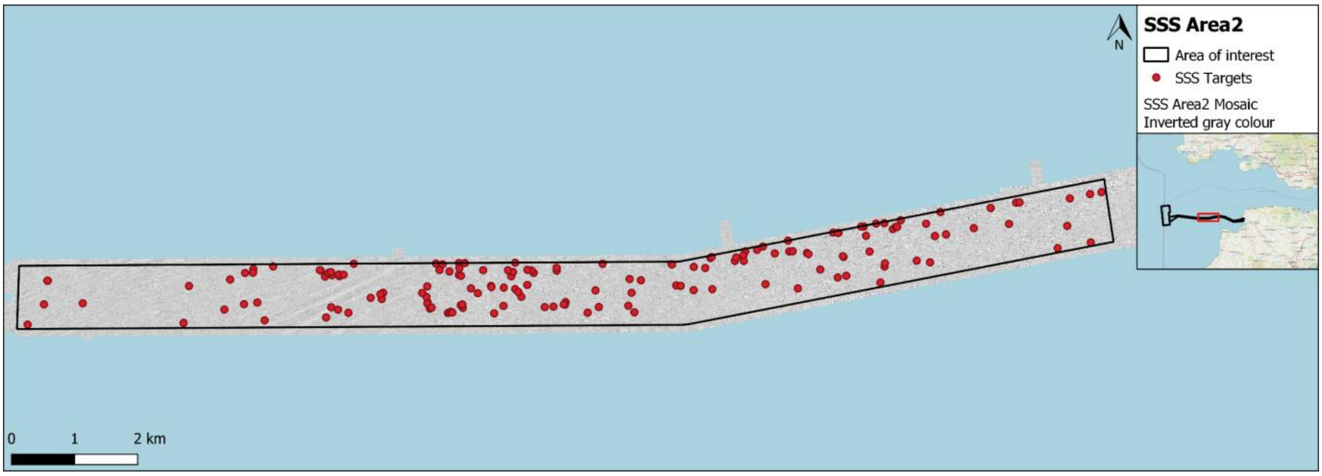

Figure 5-35: SSS contacts in Area 2

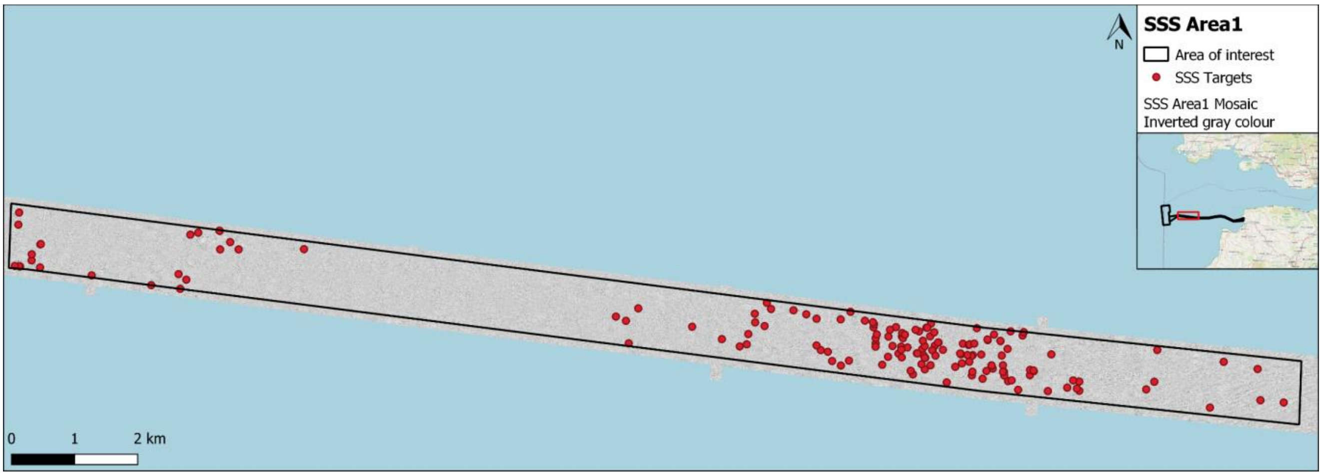

Figure 5-36: SSS contacts in Area 1

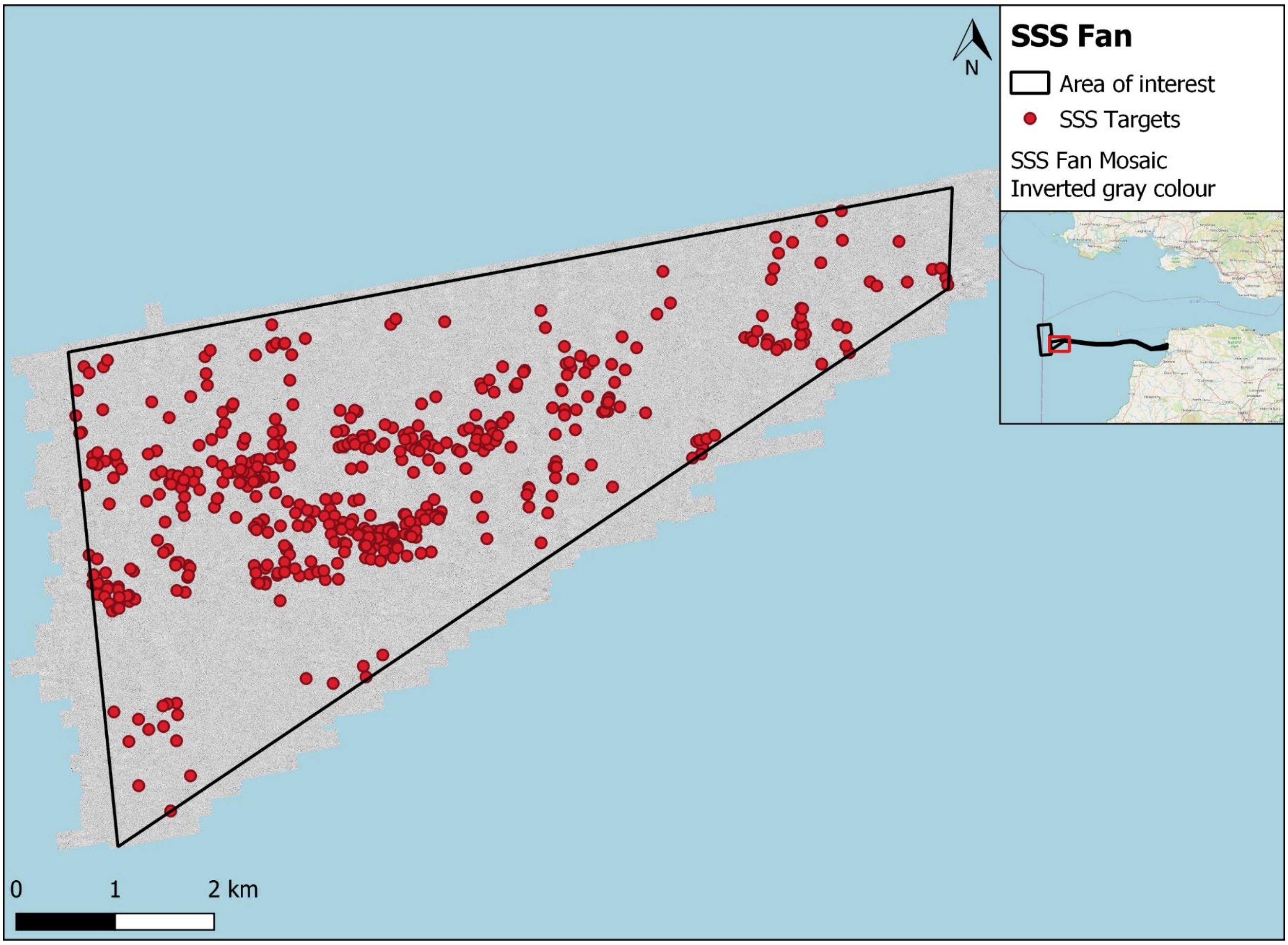

Figure 5-37: SSS contacts in Fan area

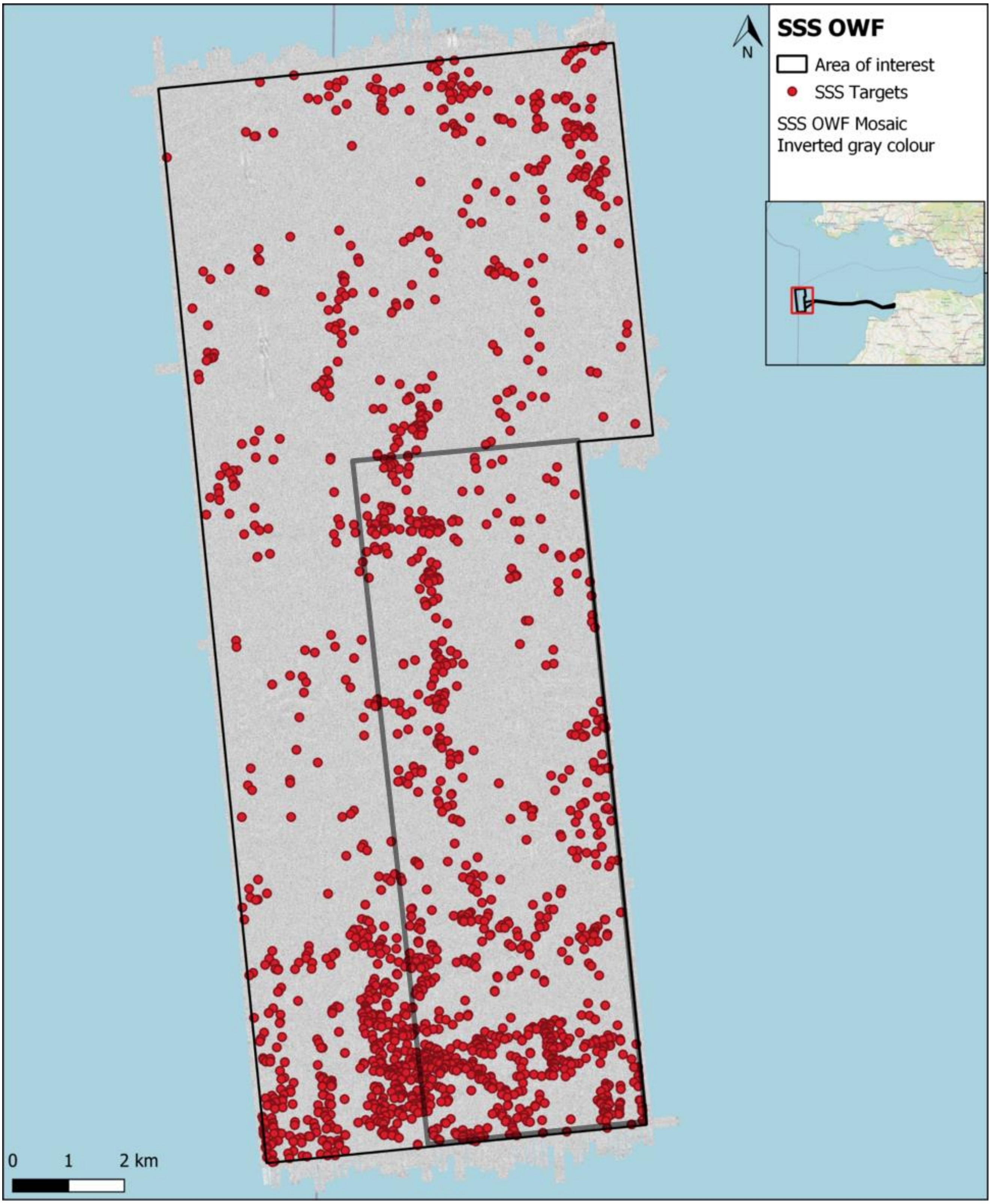

Figure 5-38: SSS contacts in OWF area

Georeferenced Images of all SSS contact were provided as part of the deliverable package. The following figures are showing examples of SSS contacts detected across the survey area.

Boulder

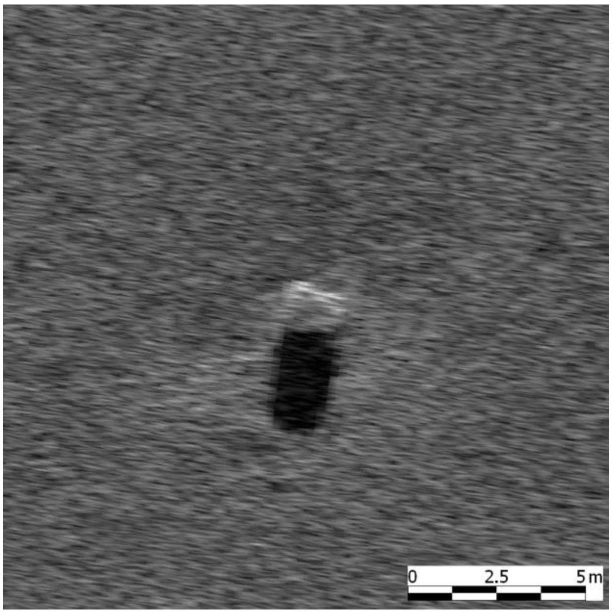

Figure 5-39: Example of SSS contacts, S_WC_3_104 characterised as boulder

Debris / Linear Debris

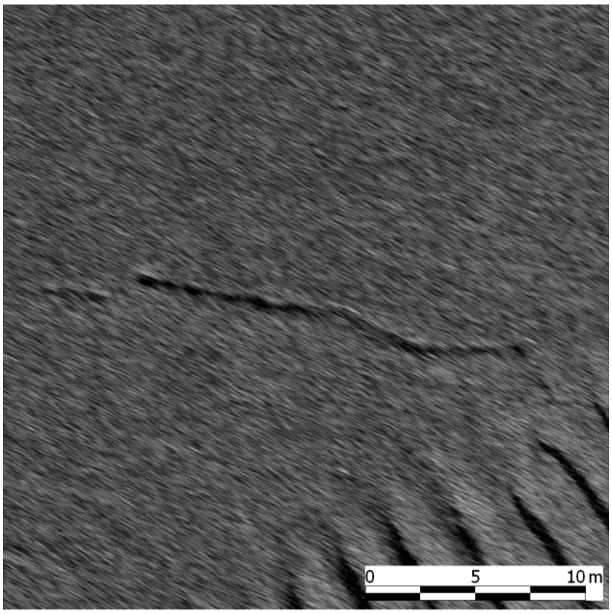

Figure 5-40: Example and S_WC_3_30, characterised as debris and linear debris

Other

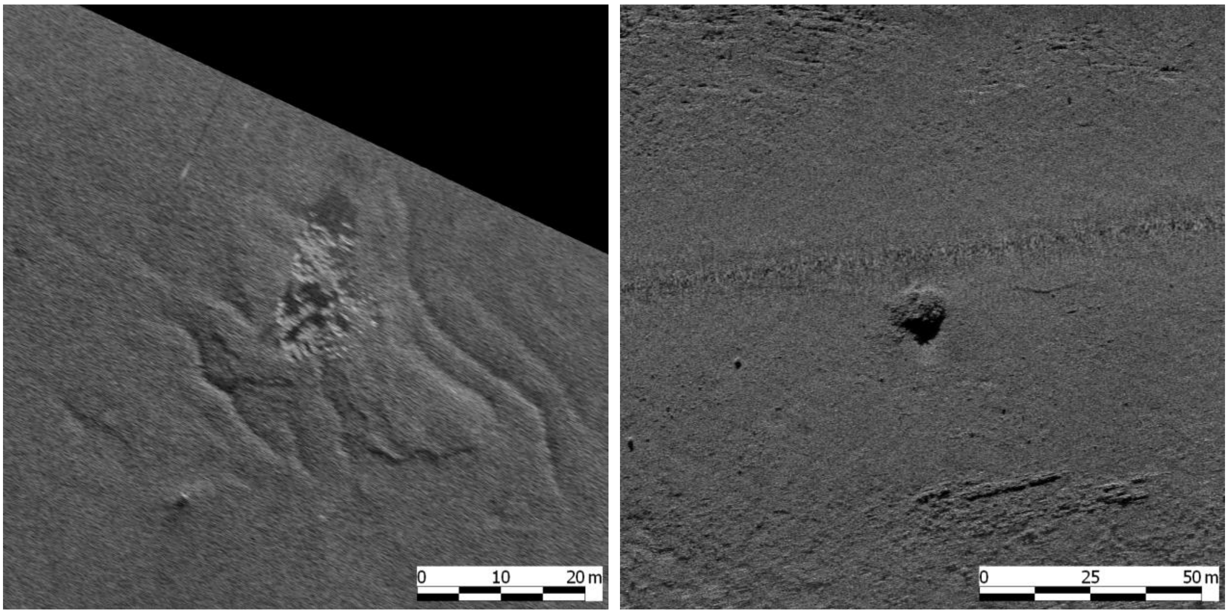

Figure 5-41: Example of SSS contacts, S_WC_3_014 & S_WC3_305, both characterized as other

Wreck

Three wrecks (Figure 5-42) were observed in the survey area. They were detected on SSS data as well as magnetometer and MBES DTM. Details are provided in Table 5-5.

Table 5-5: As found wreck details

SSS target ID	Mag target ID	Easting	Northing	Length	Width	Height	Seen on MBES
S_WC_3_19	M0185	398453.7	5663632.0	11.7	6.3	2.6	Yes
S_WC_3_234	M0711	389369.7	5665020.1	48.5	41.1	3.5	Yes
S_WC_OWF_1384	M0303	332976.7	5672938.9	39.0	11.4	3.2	Yes

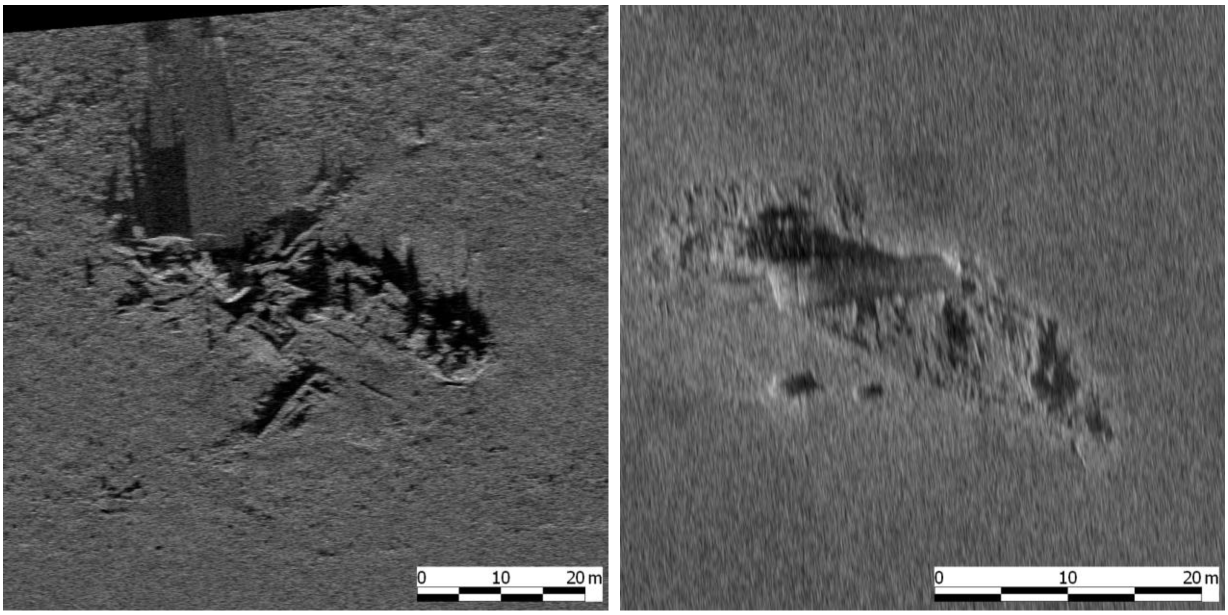

Figure 5-42: SSS contacts S_WC_3_234 and S_WC_OWF_1384 – shipwrecks

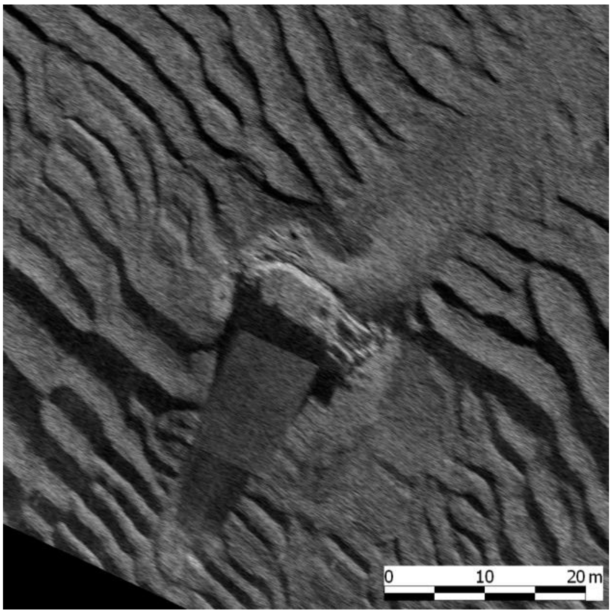

Figure 5-43: S_WC_3_019 – possible shipwreck

5.4 MAGNETOMETER

5.4.1 Magnetic Anomalies

A total of 1161 targets (magnetic anomalies) have been marked, 84 of these have been identified as related to known subsea cables/infrastructure. An example of a target picked as a magnetic anomaly is displayed in Figure 5-44 while as found cable results are detailed in a dedicated section 5.4.2.

There are numerous unidentified targets that are highly likely related to the geology of the survey area. However due to the nature of magnetic survey acquisition requirements (line spacing) and achieved data density, improved object correlation/ interpretation cannot be provided. The three wrecks detected on the SSS records were also detected during the magnetometer survey.

84 magnetic linear anomalies were reported across the site.

A geological background grid has been created of the OWF area with the help of a very long trend filter (800 fiducial non-linear filter) as seen in Figure 5-44. It reveals indications of additional (east west) linear features however these are likely caused by the geology of the area.

Table 5-6: Magnetic contacts summary

Anomaly type	Nearshore	Area 3	Area 2	Area 1	FAN	OWF	Total
Other	364	214	91	29	39	253	990
Linear Feature	0	5	79	0	0	0	84
Wreck	0	2	0	0	0	1	3
Cable	32	32	0	17	0	3	84
Total	396	253	170	46	39	257	1161

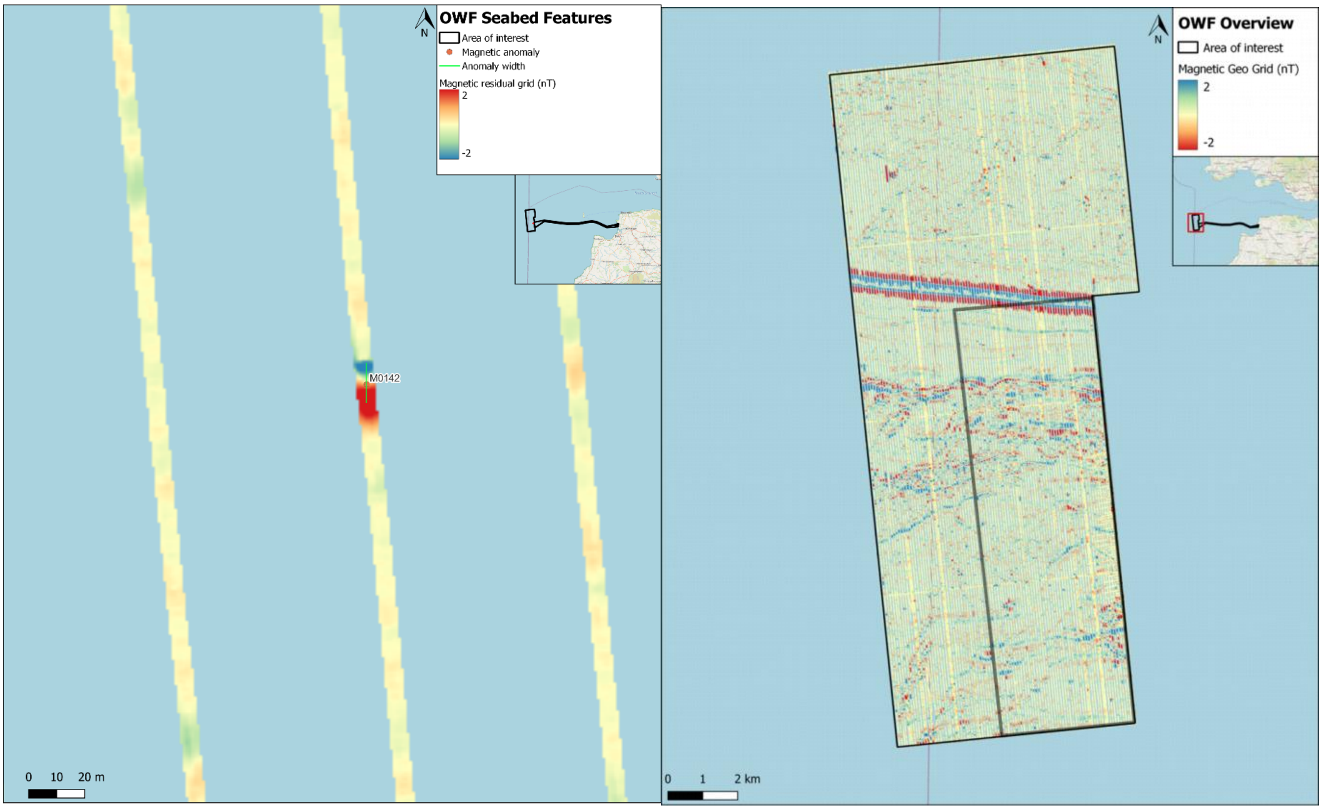

Figure 5-44: Example of MAG contact (left)t and Magnetic OWF Geology grid (right)

5.4.2 Cable Crossings

UK-Ireland 2 Crossing

This cable was faintly detected crossing the export cable corridor. A single clear anomaly was detected on the centre lines. Several possible slight anomalies below target picking threshold were noted on northern survey lines, however, on the southern lines results were not conclusive.

Based on those results, it would cross the route at 348005 E, 5666106 N (Figure 5-45).

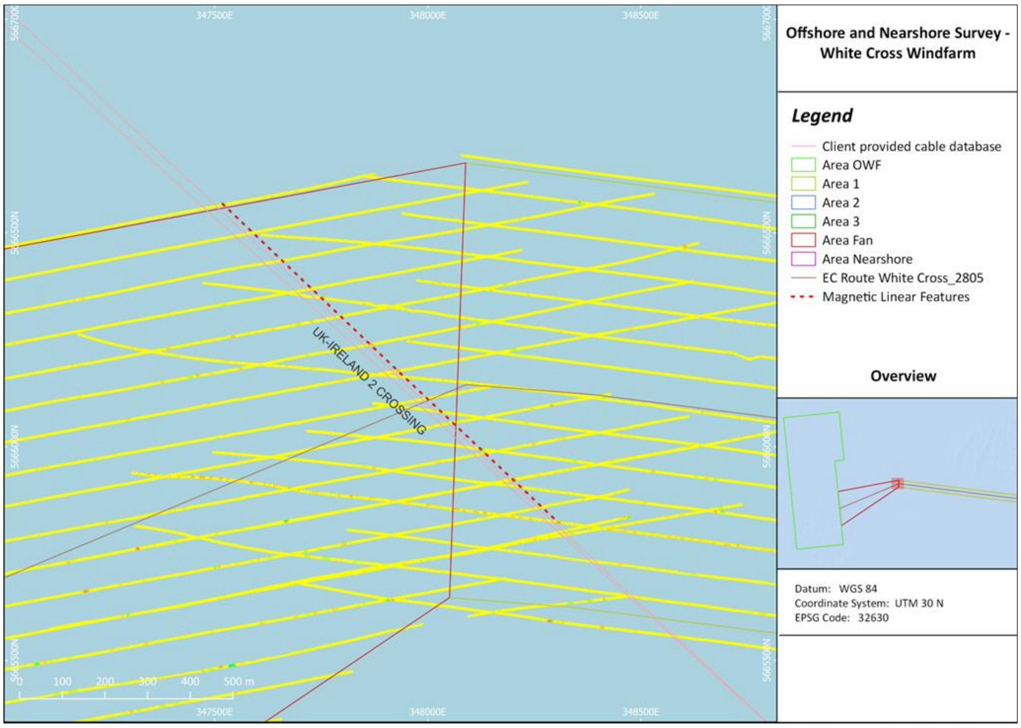

Figure 5-45: UK-IRELAND crossing the Export cable corridor

Further to the North West, the cable was detected across the OWF. Based on the magnetometer, it enters the site at 339647 mE 5673915 mN and exits the OWF area at 337204 E, 5676471 N. Client provided cable database contained two versions of the cable route. The as found results appears to match closely the North-eastern version.

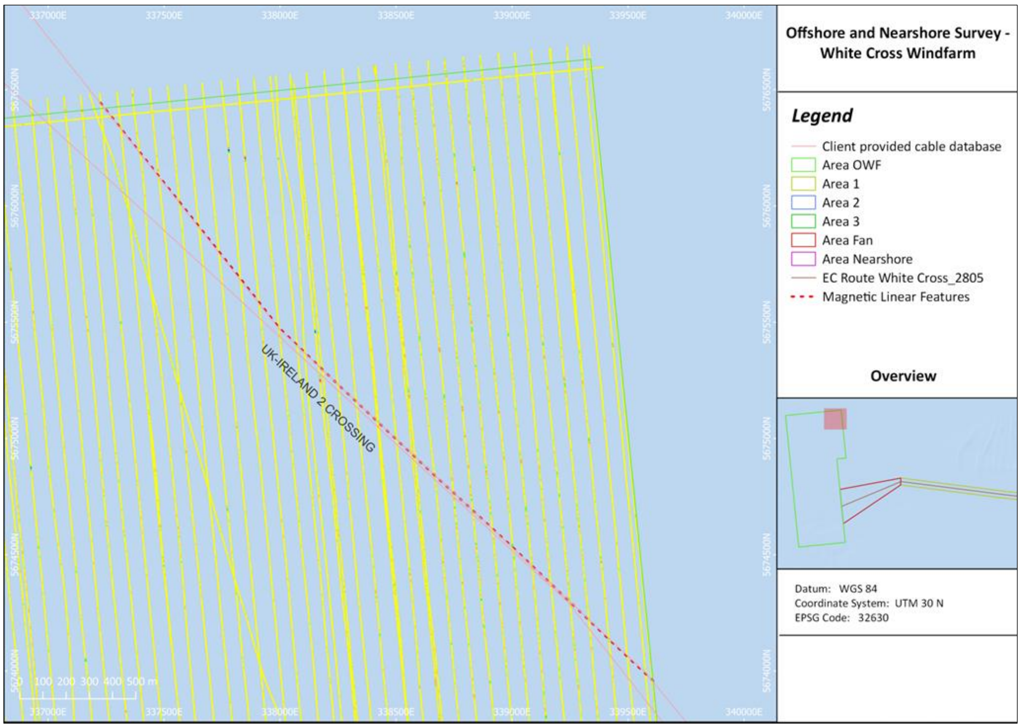

Figure 5-46: UK-IRELAND crossing Offshore Wind Farm

TAT 11

This cable was detected on all the lines. Based on those results, it runs slightly to the North West of Client database positions and crosses the route at 353229 E, 5665506 N (Figure 5-47).

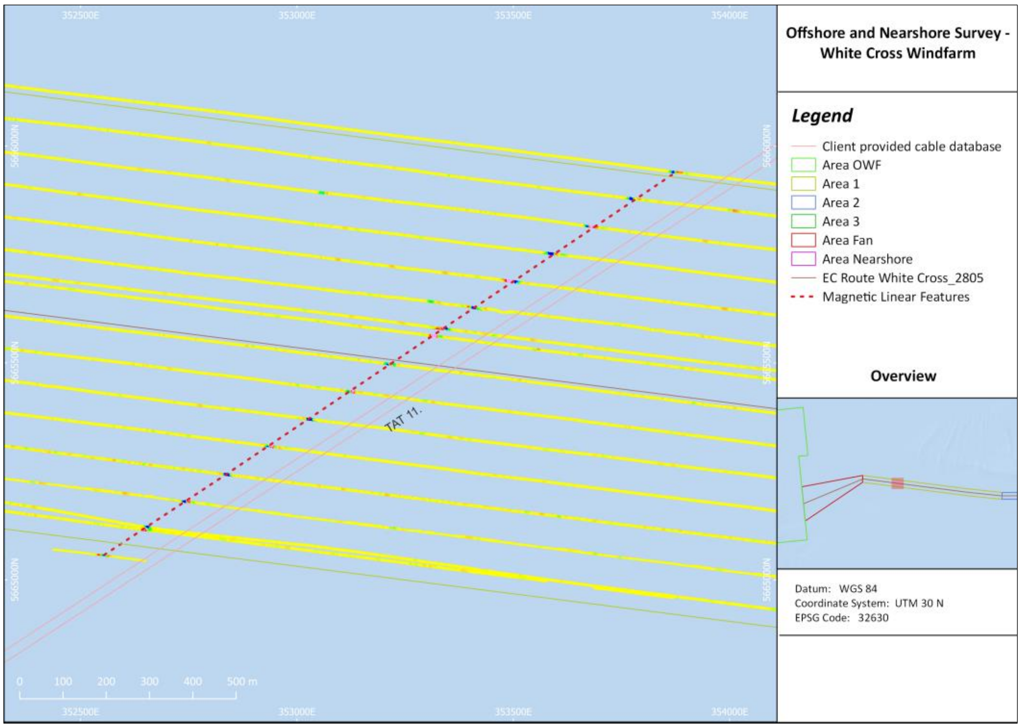

Figure 5-47: TAT 11 crossing

TATA Atlantic South Crossing

This cable was detected on all the lines and the as-found position is in line with Client provided database. Based on those results, it crosses the route at 400251 E, 5662453 N (Figure 5-48). The cable was detected a second time at the Northern extremity of the landfall survey, again in line with client provided database.

Figure 5-48: TATA Atlantic South ECR crossing (left) and landfall approach (right)

TATA Western Europe UK-Spain

This cable was detected on all the lines. Based on those results, it crosses the route at 403273 E, 5661033 N (Figure 5-49). Client provided cable database contained two versions of the cable route. The as found results appears to match closely the Southern version. The cable was detected a second time at the Northern extremity of the landfall survey, again in line with the “southern” version of client provided database.

Figure 5-49: TATA Western Europe UK-Spain ECR crossing (left) and landfall approach (right)

5.5 SHALLOW SEISMIC STRATIGRAPHY

The geological interpretation of the seismic profiles of the Sub-Bottom (SBP) and Single Channel Sparker (SCS) data is based on the Lundy Sheet 51°N-06°W Solid Geology and Seabed Sediments, BGS. Because of the limitations of the penetration of the sub-bottom profiler in the OWF area, only the single channel sparker data has been interpreted in this area. All shallow sediments could be detected in the sparker seismograms, but they have been verified with the SBP data. For the Export Cable Route (ECR) only SBP data has been recorded and interpreted. The SBP data were to some extent sparce and discontinuous, due to the lower energy of the system (when compared to SCS), leading to a limited signal penetration and interpretability (Figure 5-50).

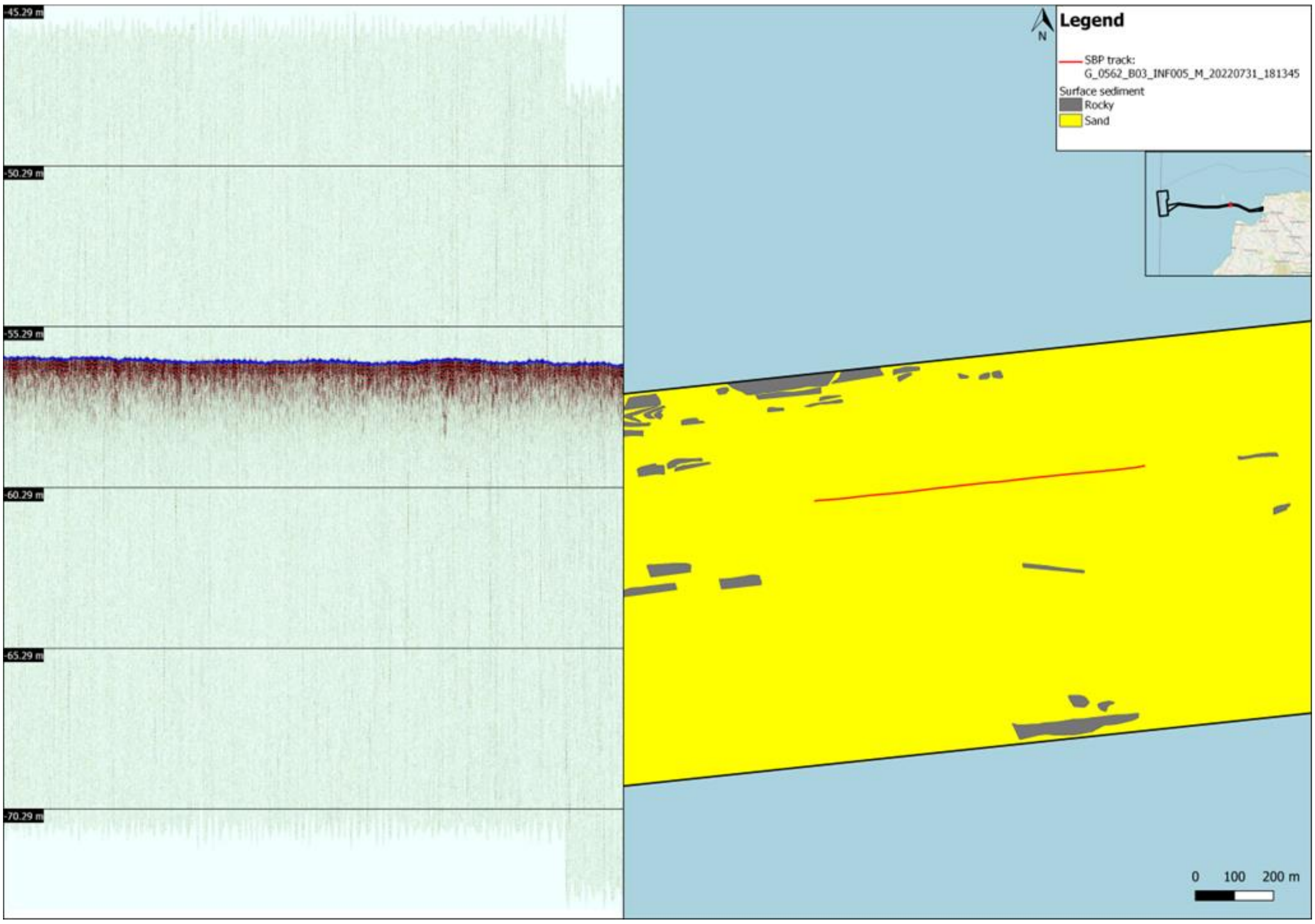

Figure 5-50: Example of limited SBP penetration in ECR

5.5.1 Overview

Unconsolidated Holocene sediments cover the OWF and ECR area completely except for the rock outcrops in Area 2 and Area 3. These sediments were interpreted as Unit E, as presented by an isopach in Figure 5-59 (ECR) and Figure 5-68 (OWF). The ECR only contains information from the SBP system, which had more limited penetration compared to the SCS data. Therefore, the base of Unit E is not always visible.

Consolidated sediments and rocks, older than the Pleistocene Epoch, which are interpreted as bedrock, lie below the Holocene cover (Unit E). Their top is delineated by an erosional plane, which is also the base of Unit E. The SCS data of the OWF shows that the internal structure of these older Units (A, B, C and D) experienced some degree of deformation and are therefore interpreted as bedrock. Different units can be recognized, however only in the OWF where SCS data is available. Please note that the amount of consolidation of these sediments/rocks likely differs between the interpreted

Units, hence the strength of those rocks can differ between the Units. For the ECR, no clear distinction could be made between the Units below the base of the Holocene sediments, because the internal structure of these Units could not be resolved due to limited penetration of the SBP data.

Hence, a different approach was used for interpretation of the ECR sediments. It is assumed that the top of R1, R2 and the rock outcrop in area 2 and 3 mark the same erosional plane on which the Holocene cover lies. However, the dataset is insufficient to clearly state which Units of the bedrock are present below the Holocene sediments and if these have the same characteristics along the whole ECR.

5.5.2 Export Cable Route

Based on the SBP data along the ECR, two distinct reflectors were picked:

- R1 - Top of (assumed) bedrock within shore approaches and nearshore area. Holocene sediments deposited on top. No direct correlation could be made to R2 or tops of other Units.
- R2 - Top of (assumed) bedrock within offshore section, in fan area and close to OWF. Partially correlates with the top of Unit B of the OWF; because of limited penetration it was not possible to get a continuous interpretation of this top along the whole cable route which is the reason it was categorised as a separate reflector.

Unit E (Holocene sediments) is present on the surface of the seabed within entire ECR area. The thickness of Unit E has been presented (Figure 5-59), where the base of Unit E is marked by the reflectors R1 and R2 and tops of Unit A, Unit B and Unit D.

Nearshore

In the nearshore area of the White Cross cable route, one main reflector (R1) was picked (see Figure 5-52). R1 (green) probably marks the top of the Pilton Shales Formation. This formation consists of Devonian and Carboniferous rocks, consisting of mudstone, sandstone and limestone. The only reflector observed below this unit was a localised irregular reflector occasionally observed along the Northern Route landfall lines (Figure 5-51) The absence of further seismic reflectivity in this unit is likely caused by either acoustic blanking or reduced penetration depth due to hard substrate (bedrock).

On top of this horizon, the seismic profile shows continuous parallel layered Holocene sediments (Unit E), mainly composed of fine sand. An internal reflector (purple on Figure 5-51) could be observed on the landfall SBP line.

Unit E has a thickness of around 7m at the landfall approach (Figure 5-59). Then, approximately 1 km away from the shoreline, the Unit thickness decreases rapidly to 2-3 m. From there, the seismic signature gets more erratic and an unconformity with the seabed and underlying R1 is recognizable. During the following four kilometres, the isopach values range from 2 to 5 m, occasionally less, as two small outcrops were detected on the SSS records.

Approximately 5 km away from the shoreline, the Unit’s thickness increases up to 10 m and gradually decreases again to 4 m at the approach to the sand waves zone in area 3.

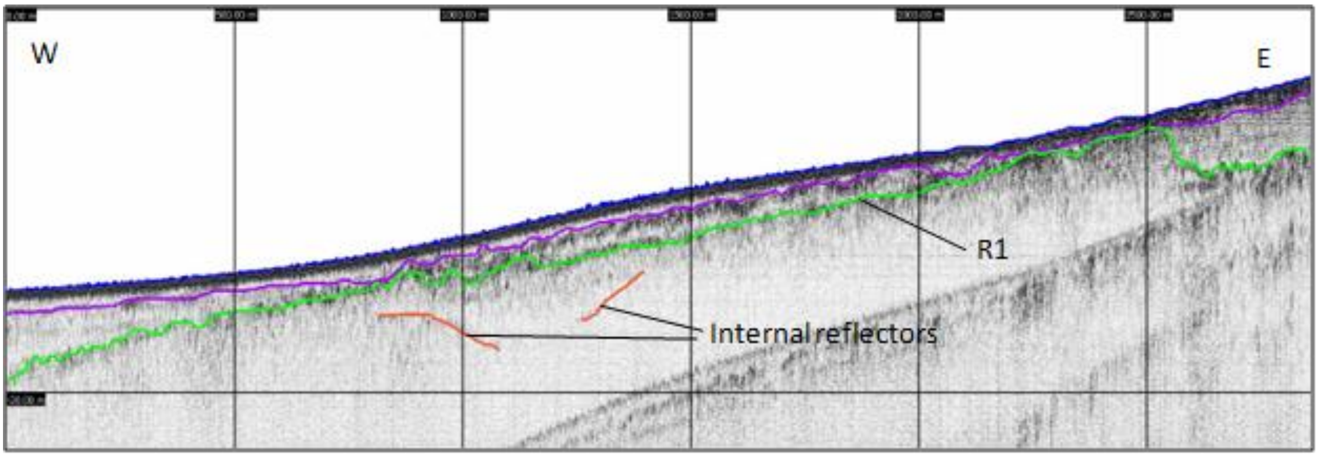

Figure 5-51: Interpreted seismic profile at the landfall approach, Northern route option

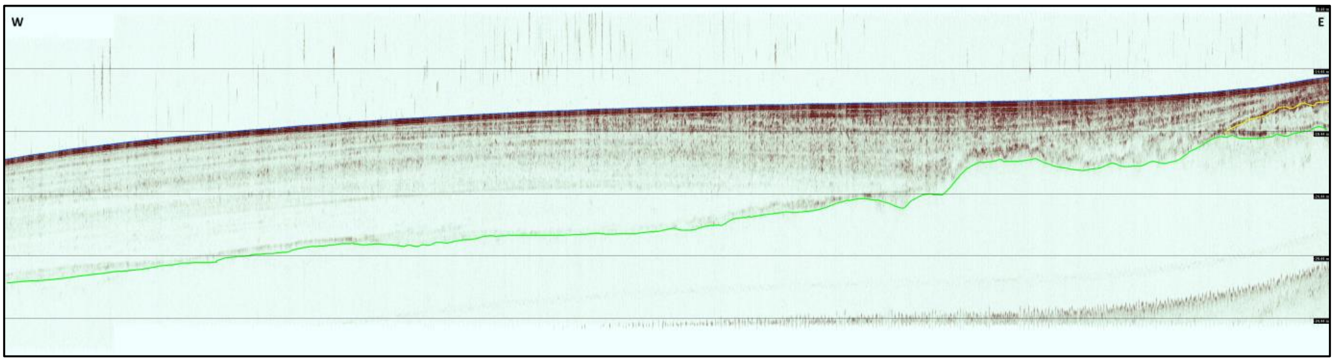

Figure 5-52: Nearshore area of White Cross cable route with R1 (green) (profile length 5 km)

Area 3

The base of Unit E (R1) remains visible in Area 3 but vanishes at the start of the sand waves zone. From there the seismic profile along the remaining of area 3 shows a chaotic pattern of seismic reflections with a low penetration depth of only 2 m. This likely indicates a hard substrate at the seabed. It is interesting to note that the rock outcrops in the area (as marked in the seabed features interpretation) are not distinguishable as such from the other reflectors (i.e., surficial sand base) in the seismic data.

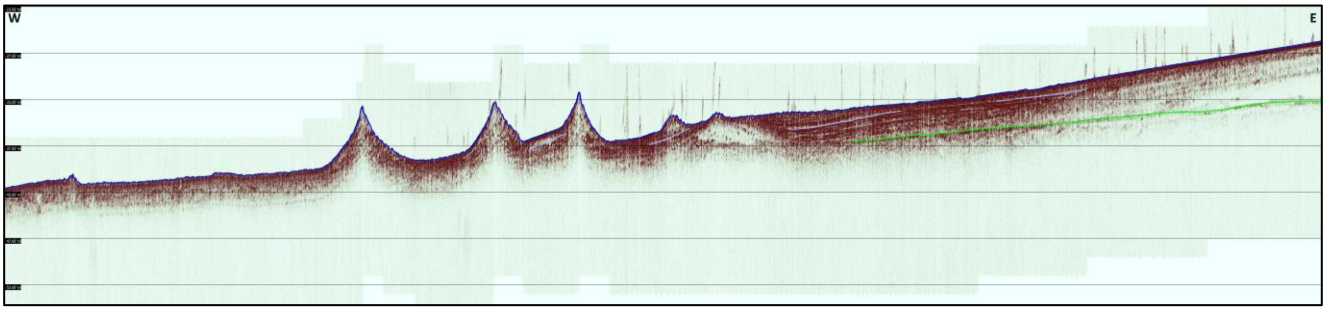

Figure 5-53: Area 3 of White Cross cable route with sand dunes in the east (profile length 6.7 km)

Area 2

In Area 2, the chaotic pattern of seismic reflections continuous and the penetration depth stays low (2 m below seabed); This is again likely caused by a hard substrate at seabed. At the western end of Area 2, where the rock outcrops are no longer detected on the SSS records, an erratic discontinuous reflector (R2) appears approximately 1 m below seabed (Figure 5-54). This reflector can be tracked till the border of Area 1.

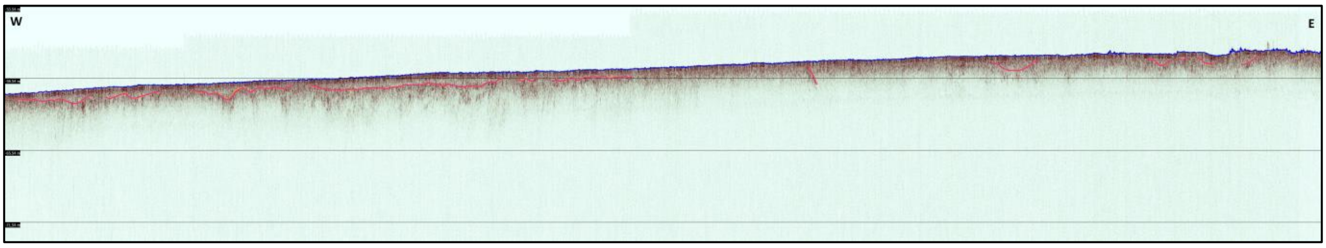

Figure 5-54: Area 2 of White Cross cable route with R2 (pink) (profile length 8 km)

Area 1

The base of Unit E (the first main reflector below the seabed - R2) remains traceable across Area 1, in the eastern part erratic and discontinuous but further to the west the reflector becomes more continuous with a wavey pattern. The base of Unit E (R2) can be tracked till the OWF area. Noteworthy is the increasing penetration depth up to 15 m below seabed in the western part of this area (Figure 5-55). Again, it is unclear which Unit is present below the Holocene sediments of Unit E, therefore this reflector is named R2.

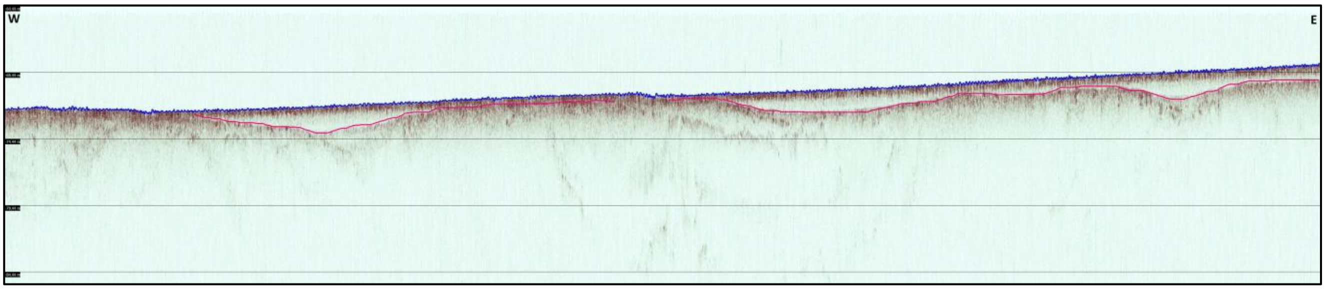

Figure 5-55: Area 1 of White Cross cable route with R2 in the western part (profile length 8 km)

Fan

The base of Unit E (reflector R2) remains visible throughout the Fan area. The penetration depth in the Fan area reaches 15 m below seabed in some parts. The depth of R2 increases from North to South, from 0.5 m to 3 m below seabed. R2 is clearly visible in cross profile T01 (Figure 5-57). Compared with Single Channel Sparker data in the vicinity of this area, R2 is the top of Unit B (see Figure 5-56).

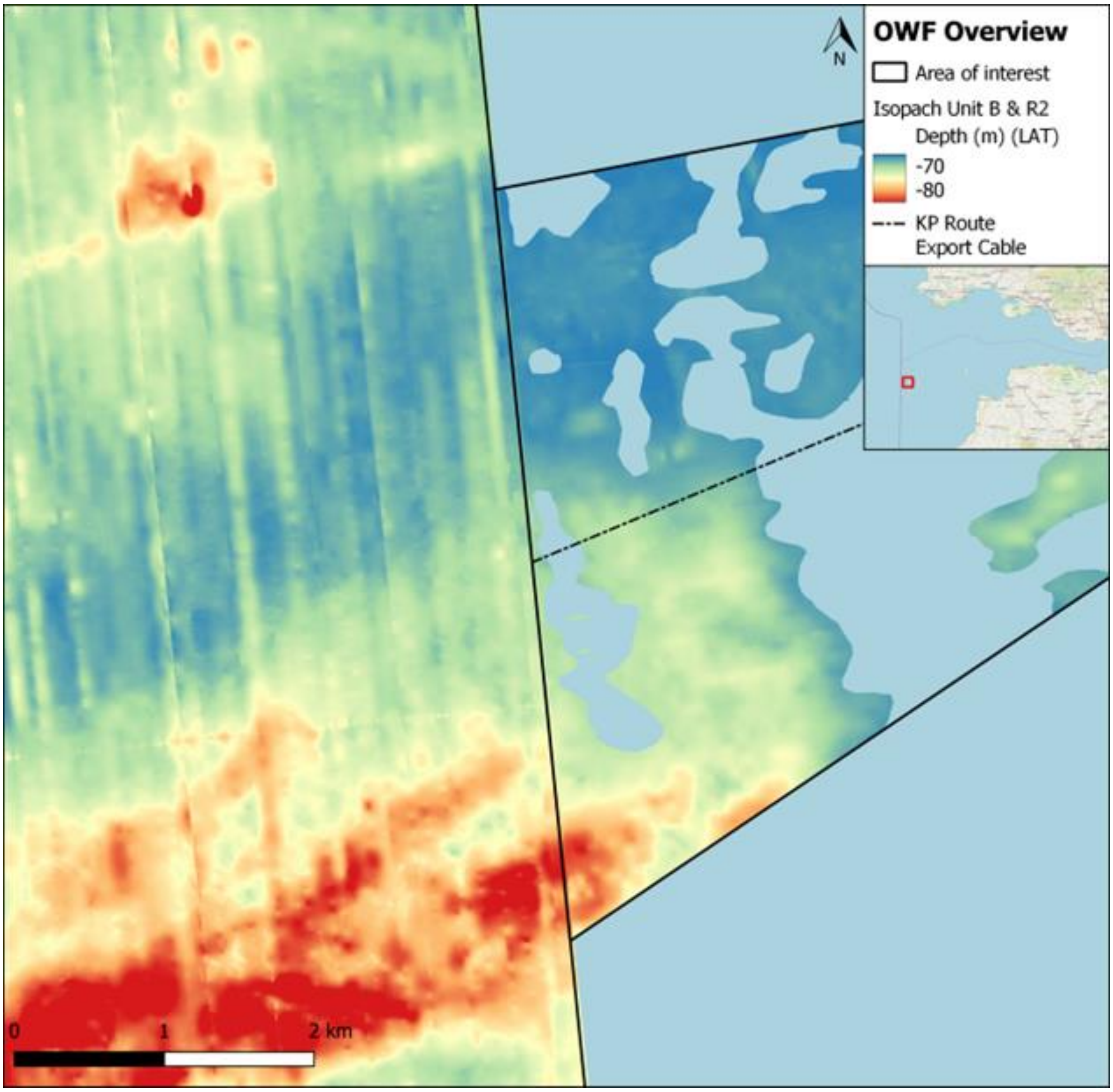

Figure 5-56: The notable visual similarity between SCS Unit B (West) and SBP R2 (East)

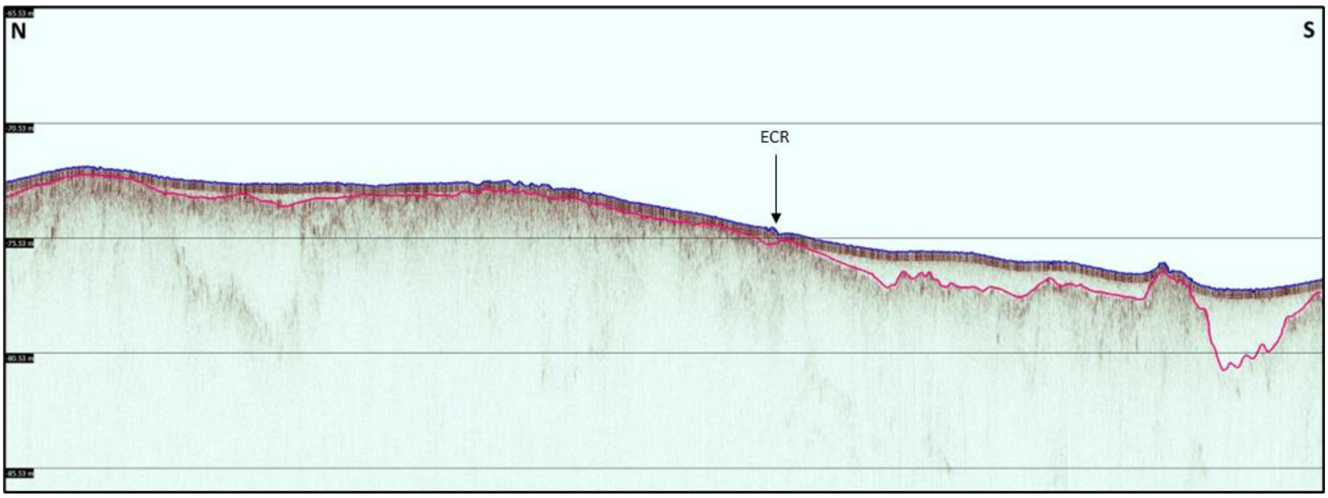

Figure 5-57: Fan area of White Cross cable route cross profile (profile length 5 km)

Isopach ECR

An overview of the base of Unit E (R1 and R2) isopach maps are given in Figure 5-58 and Figure 5-59.

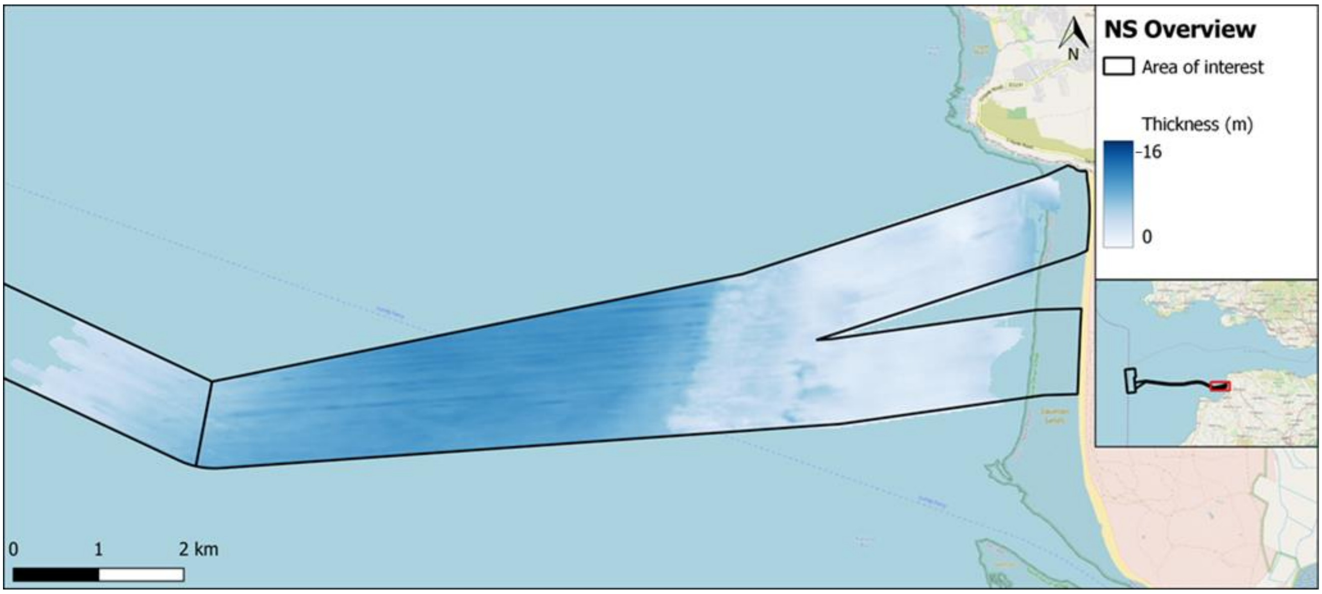

Figure 5-58: Depth below seabed to R1 along ECR (nearshore)

Figure 5-59: Unit E isopach along the ECR (thickness in meters – reflectors R1 and R2 combined)

5.5.3 Offshore Wind Farm

General explanation of geological units

The single channel sparker data of the White Cross OWF shows a consistent pattern from north to south throughout the entire survey area and differs slightly from west to east. For a better visualisation and because lower boundaries of the representable units are not visible in the seismograms, it was chosen to pick the top of the Units as horizons. An overview of the seismic profile with its Units is given in Figure 5-60. All Units are covered with a thin layer of Holocene sediments (Unit E).

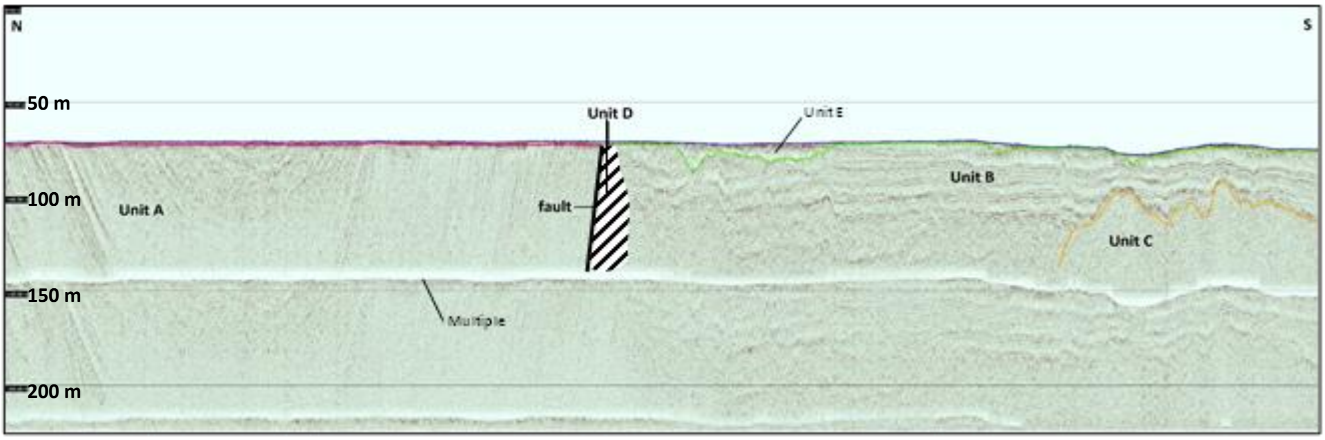

Figure 5-60: Overview of main geological units of White Cross OWF (profile length 20 km)

Based on the SCS data at the OWF, five reflector / Unit can be distinguished, namely:

- Unit A

A major west plunging syncline which makes up the Northern part of the OWF. In depth this syncline is extending beyond the penetration depth of +/- 60m. The top of Unit A is an erosional surface and represents the base of Unit E. Between the top of Unit A and the seabed, Holocene sediments of Unit E are deposited and lie discordant on top of Unit A.

- Unit B

Sub horizontal deposits which increase in thickness towards the west and is bounded by the top of Unit C until it is beyond the penetration depth. The unit experienced some deformation, although not that much compared to Unit A and C. The top of Unit B is an erosional surface and represents the base of Unit E. This unit is covered by Holocene sediments of Unit E.

- Unit C

Could be related to Unit A, however this cannot be seen in the seismic profiles. Parts of layering within this unit can be distinguished although it is not continuous. Because the deformation zone of Unit D is present between Unit A and C, Unit C is seen as a different unit. The top of Unit C is an erosional surface and represents the base of Unit B. Unit C is covered by Unit B.

- Unit D

Unit D represent a high deformation zone probably related to faulting. No clear strata can be defined, and it separates the northern Unit A from the southern Unit B and C. This Unit has been picked to visualise the deformation zone. The top of Unit D is an erosional surface and represents the base of Unit E. Unit D is covered by sediments of Unit E.

- Unit E

Represents the Holocene deposits, which cover the whole of the OWF area.

Unit A (pink on Figure 5-61) displays an internal structure suggesting a major syncline. The Unit covers the whole northern part of the OWF area. It was decided to pick the top of this unit as one seismic horizon, even though it comprises different internal layers, as no further meaningful differentiation could be made. Unit A is also present in the area of shorter survey lines in the northeast part of the OWF (see Figure 5-61), together with a thin cover of Unit E.

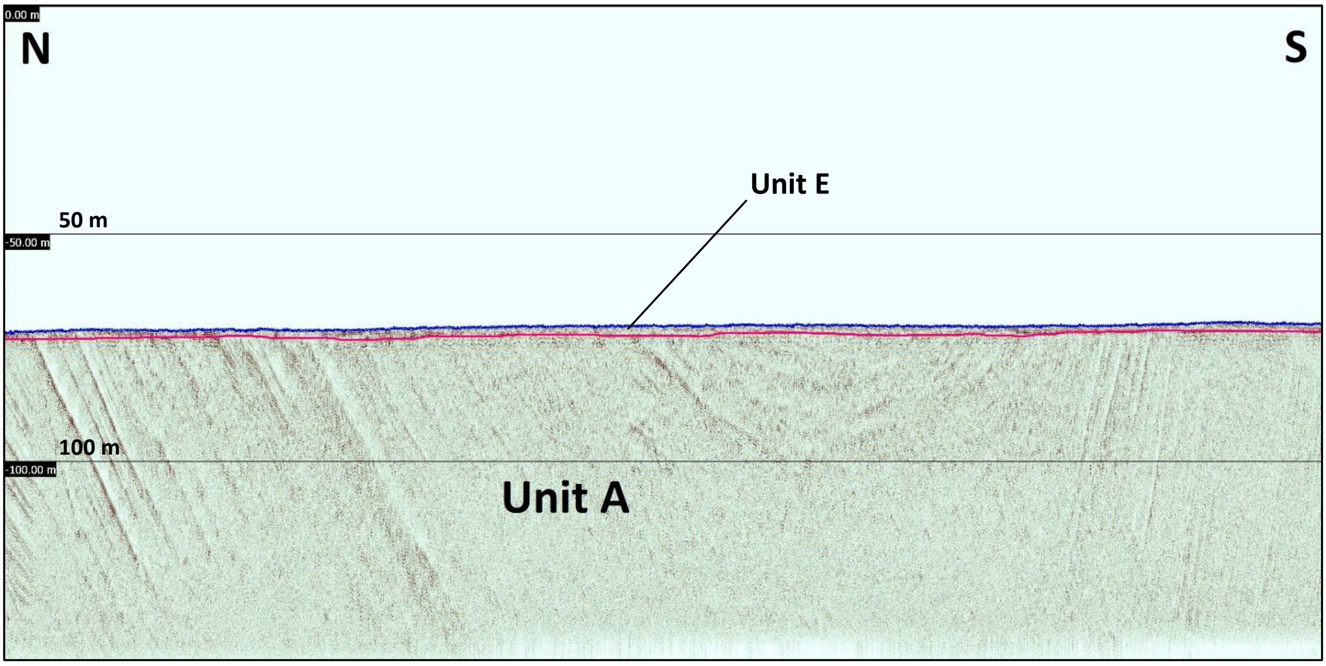

Figure 5-61: Seismic profile of northeast part of OWF area (profile length 8 km)

The syncline is built up by sedimentary rocks of the Cretaceous, Jurassic and Triassic and consist mainly of claystone, sandstone and mudstone.

The cross-profile of the northern part indicates that the axis of the syncline dips towards west with another folding in the western part of the profile, see Figure 5-62. Figure 5-63 shows the top of Unit A depths below seabed in the OWF.

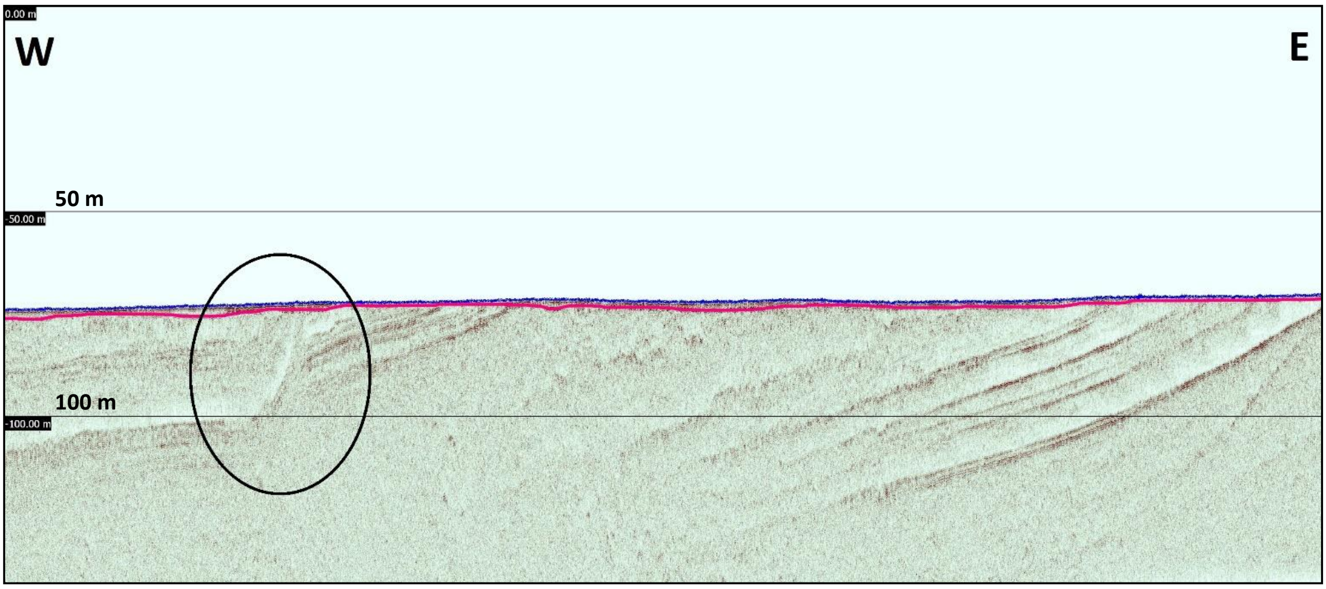

Figure 5-62: Northern cross-profile with west-plunging syncline and folding (black ellipse) (profile length 9 km)

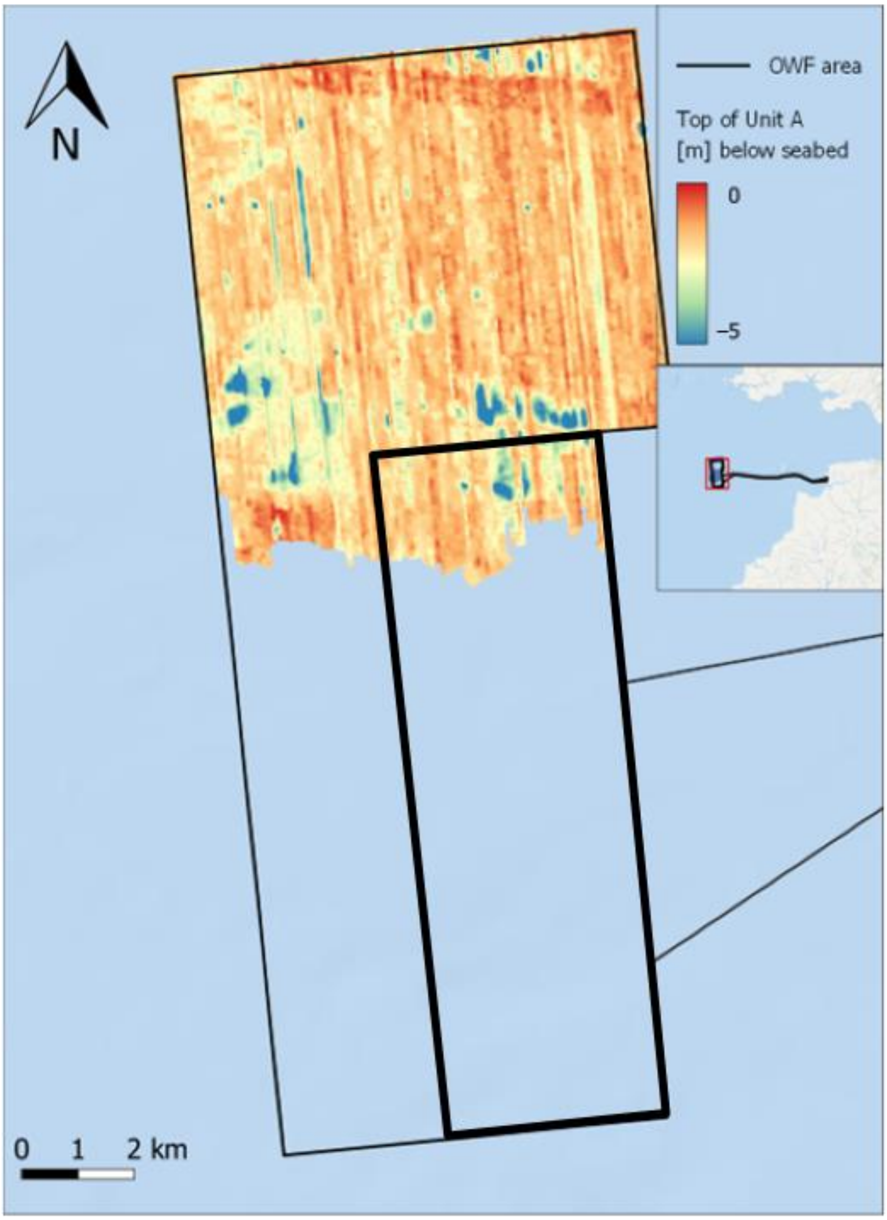

Figure 5-63: Surface showing the top of Unit A

In the middle of the seismic profile a fault (black line on Figure 5-60) defines the border with the southern part of the OWF area.

The southern part is characterized by **Unit B** (green), Figure 5-64 and Figure 5-65, a clay and lignite sequence with continuous parallel seismic reflectors with numerous shallow depressions, which are filled up with more recent horizontal layered sediments. The depressions are not clearly visible in all seismic profiles and therefore vary in depth between adjacent profiles.

Unit B is overlying **Unit C**, a sandstone sequence with discontinuous seismic reflectors. In the western part of the survey area Unit C is not visible, but with the decreasing thickness of Unit B to the east, Unit C becomes more visible, see Figure 5-64 and Figure 5-65.

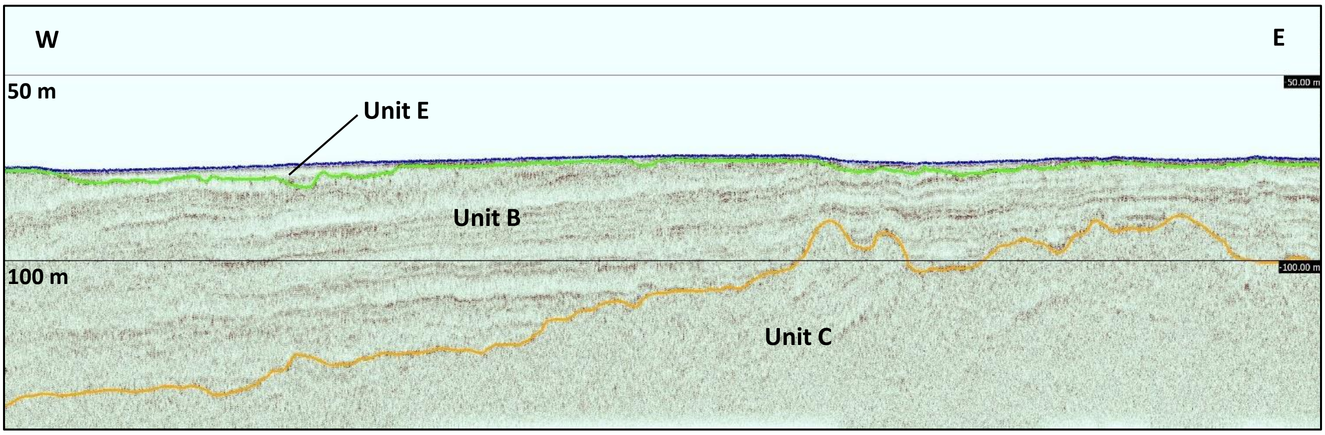

Figure 5-64: Example of a typical W-E cross-section of the southern part of the OWF (profile length 7.5 km)

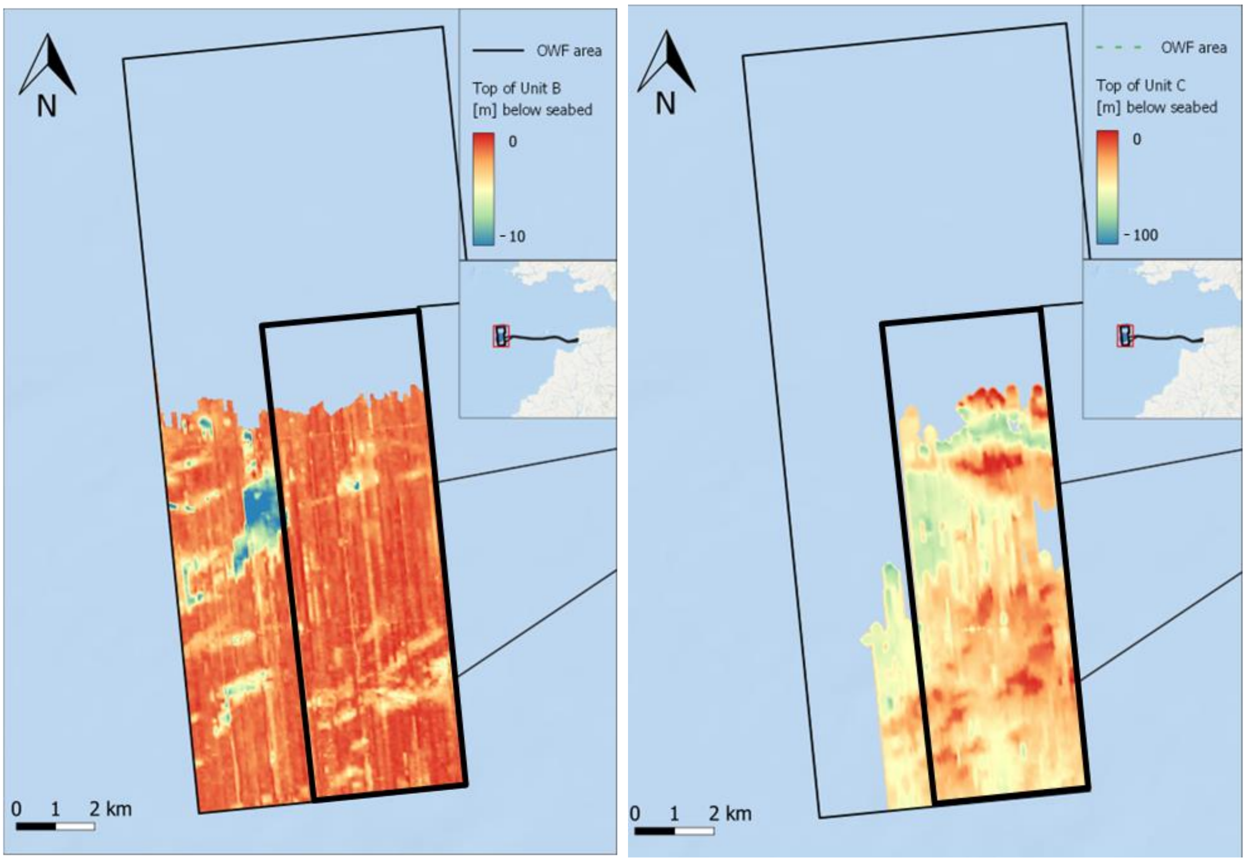

Figure 5-65: Left: Top of Unit B. Right: Top of Unit C

Unit D (Top Unit D = light blue) represent a deformation zone which separates Unit A from Unit B & C. Because of deformation no internal structure can be recognized. Unit D is not visible in all seismic profiles, as shown on Figure 5-67. Unit D is covered by a thin layer of Holocene sediments (Unit E).

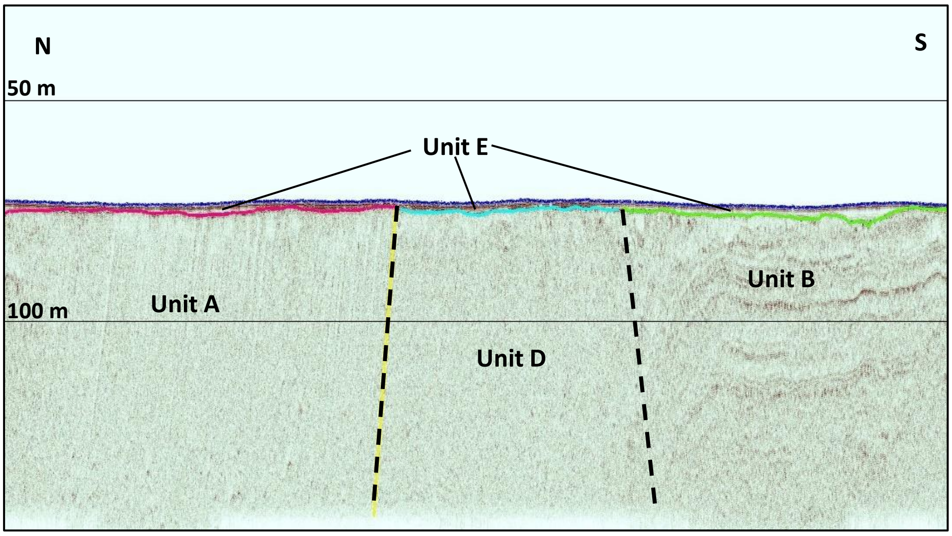

Figure 5-66: Unit D, represents a deformation zone

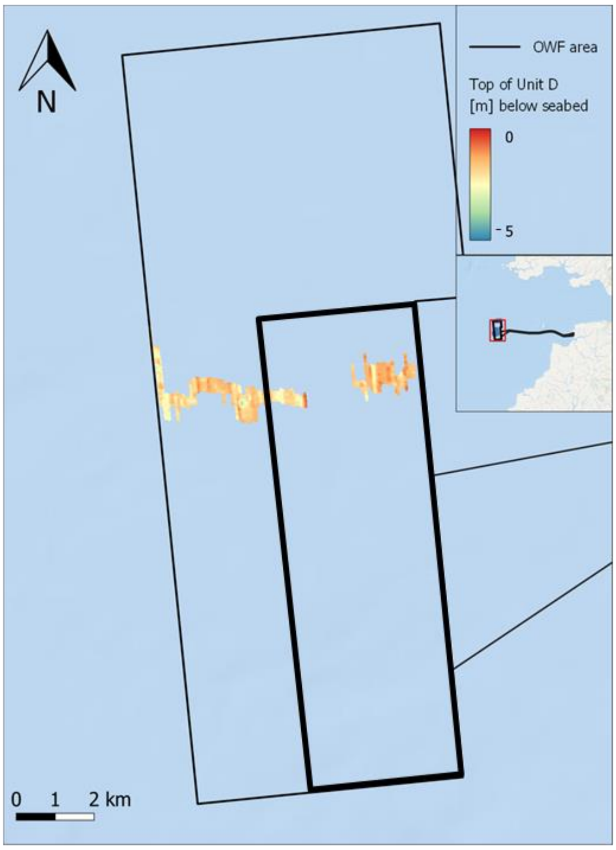

Figure 5-67: Surface showing the top of Unit D

The Holocene sediments of **Unit E** cover the whole Offshore Wind Farm. Its thickness ranges from a few centimetres to almost 16 m, Figure 5-68. Locally some increases in thickness are observed where Unit B presents some erosional depressions.

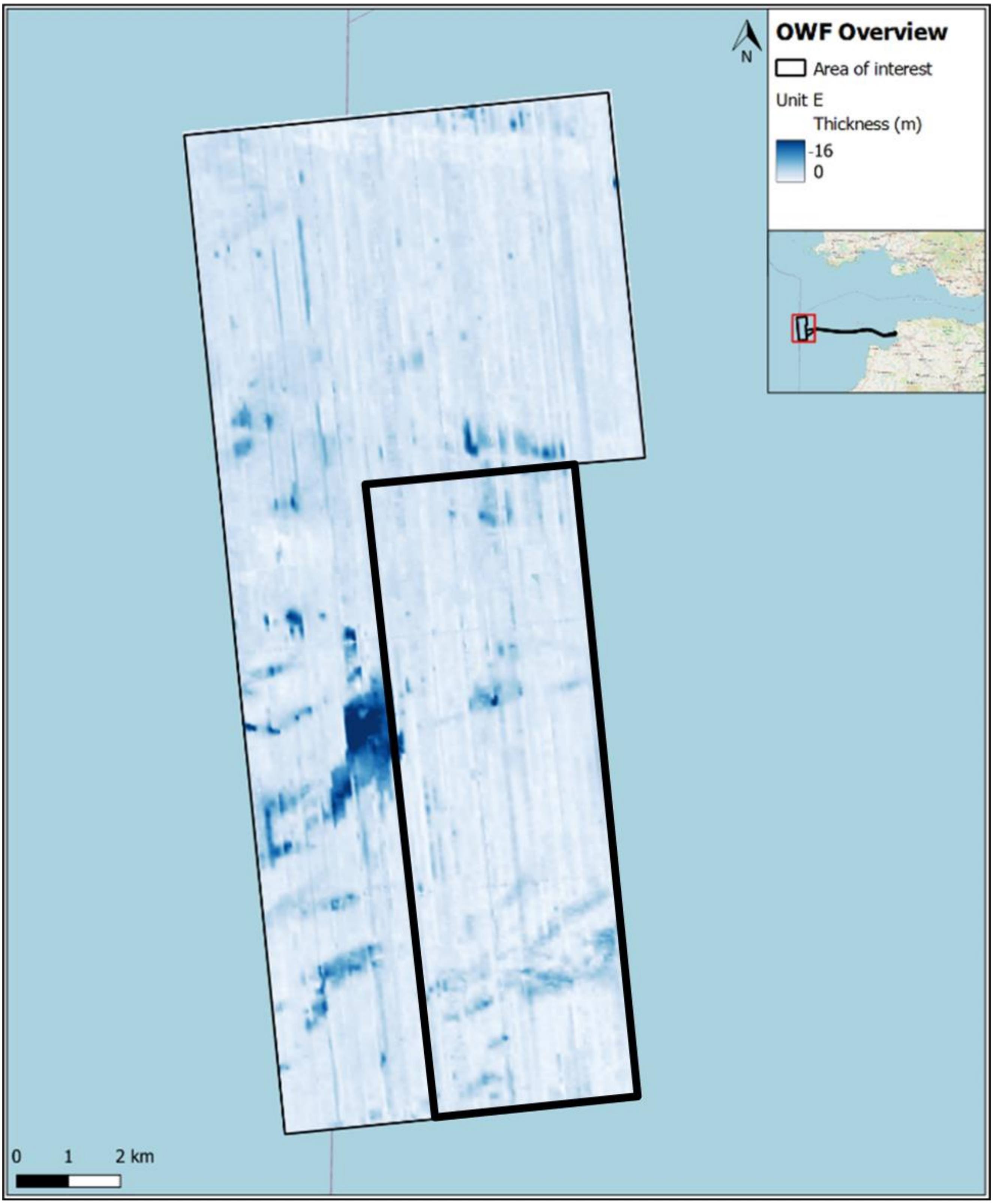

Figure 5-68: Isopach of Unit E (thickness in metres - top of unit A, D and B combined)

APPENDIX A. ENVIRONMENTAL REPORT

APPENDIX B. CHART INDEX

B- 1. MAGNETOMETER CHARTS

Location	Chart ID	Size	Scale
Export Cable	NSW-PJ00285-RS-SC-EXP-001	A1	1:2500
Export Cable	NSW-PJ00285-RS-SC-EXP-002	A1	1:2500
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Export Cable	NSW-PJ00285-RS-SC-EXP-005	A1	1:2500
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Export Cable	NSW-PJ00285-RS-SC-EXP-008	A1	1:2500
Export Cable	NSW-PJ00285-RS-SC-EXP-009	A1	1:2500
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Export Cable	NSW-PJ00285-RS-SC-EXP-012	A1	1:2500
Export Cable – Northern Landfall	NSW-PJ00285-RS-SC-EXP-013	A1	1:2500
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White Cross A	NSW-PJ00285-RS-SC-OWF-002	A1	1:2500
White Cross A	NSW-PJ00285-RS-SC-OWF-003	A1	1:2500
White Cross B	NSW-PJ00285-RS-SC-OWF-004	A1	1:2500
White Cross B	NSW-PJ00285-RS-SC-OWF-005	A1	1:2500
White Cross B	NSW-PJ00285-RS-SC-OWF-006	A1	1:2500
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White Cross J	NSW-PJ00285-RS-SC-OWF-021	A1	1:2500
White Cross J	NSW-PJ00285-RS-SC-OWF-022	A1	1:2500

B- 2. ALIGNMENT CHARTS

11 profiles have been generated, 10 profiles stretching North South in the OWF see Figure 5-69, and 1 profile covering the ECR and ECR North.

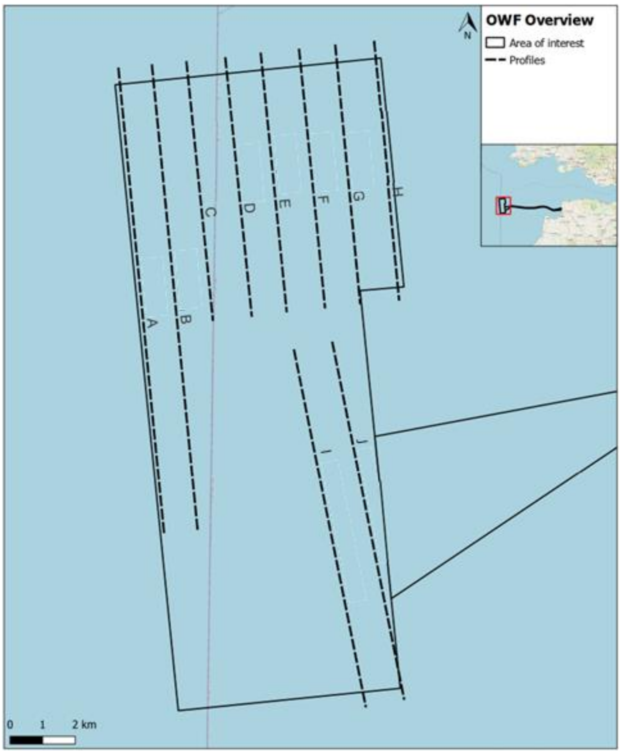

Figure 5-69: Location of the 10 profiles used for the alignment charts across the OWF

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White Cross A	NSW-PJ00285-RS-AC-OWF-004	A1	1:2500
White Cross A	NSW-PJ00285-RS-AC-OWF-005	A1	1:2500
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B- 3. MBES OVERVIEW

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ECR	NSW-PJ00285-NU-MBE-003	A1	1:25000
ECR	NSW-PJ00285-NU-MBE-004	A1	1:25000
ECR	NSW-PJ00285-NU-MBE-005	A1	1:25000
ECR	NSW-PJ00285-NU-MBE-006	A1	1:25000

B- 4. SBP TRACKS

Location	Chart ID	Size	Scale
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OWF / FAN	NSW-PJ00285-NU-SBP-002	A1	1:25000
ECR	NSW-PJ00285-NU-SBP-003	A1	1:25000
ECR	NSW-PJ00285-NU-SBP-004	A1	1:25000

Location	Chart ID	Size	Scale
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ECR	NSW-PJ00285-NU-SBP-006	A1	1:25000

B- 5. SCS TRACKS

Location	Chart ID	Size	Scale
OWF	NSW-PJ00285-NU-SCS-001	A1	1:25000
OWF	NSW-PJ00285-NU-SCS-002	A1	1:25000

White Cross Offshore Windfarm Environmental Statement

Appendix 8.C: Benthic Characterisation Report

Ocean Ecology

Marine Surveys, Analysis & Consultancy

White Cross Offshore Windfarm Benthic Characterisation Survey: Technical Report

REF: OEL_NSEWHI10222_TCR

Details

Version	Date	Description	Author(s)	Reviewed By
V01	04/10/2022	Draft	Clare Hill, Ellie Arthur-Morgan, Samuel Holmes, Elena Cappelli, Emily Sparkes, Lucy Martin	Ross Griffin
V02	06/03/2023	Final	Samuel Holmes	Ross Griffin

Updates

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List of Abbreviations

AIS	Automatic Identification System
AL	Action Level
BAC	Background Assessment Concentration
BSH	Broadscale Habitat
CATAMI	Collaborative and Annotation Tools for Analysis of Marine Imagery
CSQG	Canadian Sediment Quality Guidelines
DDC	Drop Down Camera
EB	Environmental Baseline
EBS	Environmental Baseline Survey
EIA	Environmental Impact Assessment
EMODnet	European Marine Observation and Data Network
EPA	Environmental Protection Agency
ERL	Effects range Low
EUNIS	European Nature Information System
EQS	Environmental Quality Standards
FLOW	Floating Offshore Windfarm
FOCI	Features of Conservation Interest
GPS	Global Positioning System
HA	Habitat Assessment
ISQG	International Sediment Quality Guidelines
IUCN	International Union for Conservation of Nature
JNCC	Joint Nature Conservation Committee
MBES	Multibeam Echosounder
MCZ	Marine Conservation Zone

MHWS	Mean High Water Springs
MLWS	Mean Low Water Springs
MNCR	Marine Nature Conservation Review (Marine Habitat Classification for Britain and Ireland)
NMBAQC	NE Atlantic Marine Biological Quality Control
OEL	Ocean Ecology Limited
OWL	Offshore Windfarm Limited
PAH	Polycyclic Aromatic Hydrocarbon
PEL	Probable Effect Level
PSA	Particle Size Analysis
PSD	Particle Size Distribution
SAC	Special Area of Conservation
SBE	Simply Blue Energy
SPA	Special Protection Area
SSS	Side Scan Sonar
SSSI	Site of Special Scientific Interest
TEL	Threshold Effect Level
THC	Total Hydrocarbons Content
TOC	Total Organic Carbon
TOM	Total Organic Matter
TPH	Total Petroleum Hydrocarbons
WTGs	Wind Turbines Generators

1. Introduction

1.1. Project Overview

White Cross is an approximately 100MW Test and Demonstration floating windfarm located in the Celtic Sea. The project is being developed by Offshore Wind Ltd (OWL). OWL is a joint venture partnership between Cobra Instalaciones y Servicios, S.A. and Floatation Energy plc.

The project array area is located 52.5 km off the Cornish coast in England and covers an area of 142 km^2. The proposed cable landfall will be located at Saunton Sands in Bideford Bay on the North coast of Devon, southwest England. Water depths in the array area range between 65 – 75 m which gradually decrease along the Export Cable Corridor (ECC) to the proposed landfall location (Figure 1). The project has a maximum capacity of 100MW with a baseline layout consisting of 8 x 12MW wind turbines, each mounted on top of a floating foundation with an offshore substation located within the windfarm area.

1.2. Project Background

N-Sea (the lead survey contractor) contracted Ocean Ecology Limited (OEL) to undertake a benthic characterisation survey to provide a description of the biological and physio-chemical nature of the seabed across the project area. The project area is defined as the Windfarm Order Limits including the array, ECC, and landfall areas. This report presents the combined results of the initial preliminary phase of the benthic characterisation survey ('Phase I' herein) and results of the secondary phase (Phase II herein) for a full benthic characterisation of the site.

1.3. Aims and Objectives

Provision of accurate ground truthing for geophysical data collected in June and July 2022 using a combination of Drop-Down Camera (DDC) images and sediment grab sampling was the key focus of the benthic characterisation survey. Information collected will be used to inform the Environmental Impact Assessment (EIA) for the project and will form part of the baseline dataset against which any future changes to the sediment characteristics, macrobenthic communities, and seabed physico-chemical properties will be monitored.

The main aims of the benthic characterisation survey were to:

- Describe benthic communities present within and adjacent to the project area, including biotopes, biodiversity, function, abundance, extent, species richness, representativeness, rarity, and sensitivity. This was to cover the range of water depths across the site and include both infaunal and epifaunal communities.
- Identify and assess the status of species and habitats of conservation importance, including Annex I protected species and habitats (such as *Sabellaria spinulosa* biogenic

reef or stony reef), and Annex V species[1] of the Habitats Regulations, species listed under Schedule 5 of the Wildlife & Countryside Act[2], OSPAR species and habitats[3] and designated features of the MPA network (e.g., SAC and MCZ features); and

- Confirm the presence/absence of any invasive non-native species (INNS), species non-native to UK waters, and species non-native to the local habitat types (e.g., hard-substrate specialists in a wider sedimentary habitat).

[1] https://jncc.gov.uk/our-work/article-17-habitats-directive-report-2019-species/

[2] https://www.legislation.gov.uk/ukpga/1981/69/schedule/5

[3] https://www.ospar.org/work-areas/bdc/species-habitats/list-of-threatened-declining-species-habitats

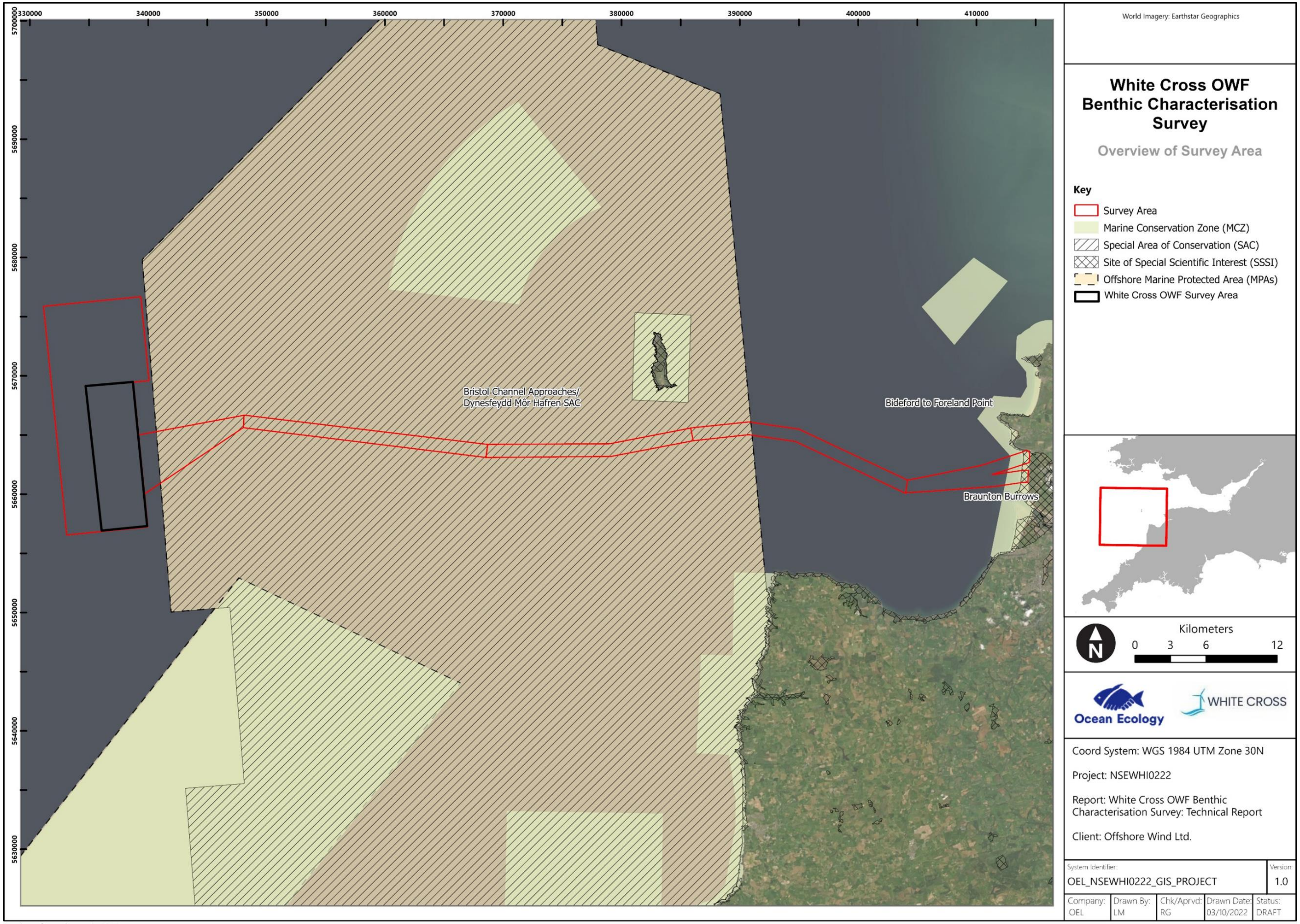

Figure 1 Overview of survey area with sites of conservation interest.

2. Designated Sites

The nearshore extent of the ECC intersects the Bideford to Foreland Point Marine Conservation Zone (MCZ) which extends to the upper shore of Saunton Sands where it overlaps with the onshore Braunton Burrows Special Area of Conservation (SAC) (Figure 1). The offshore extent of the ECC intersects the Bristol Channel Approaches SAC (Figure 1).

2.1. Bideford to Foreland Point Marine Conservation Zone (MCZ)

Bideford to Foreland Point was designated as a MCZ in 2016 to protect a number of key species including pink sea-fan (*Eunicella verrucosa*) and spiny lobster (*Palinurus elephas*) as well as the following habitats:

- Low energy intertidal rock
- Moderate energy intertidal rock
- High energy intertidal rock
- Intertidal coarse sediment
- Intertidal mixed sediment
- Intertidal sand and muddy sand
- Intertidal under boulder communities
- Littoral Chalk communities
- Low energy infralittoral rock
- Moderate energy infralittoral rock
- High energy infralittoral rock
- Moderate energy circalittoral rock
- High energy circalittoral rock
- Subtidal coarse sediment
- Subtidal mixed sediments
- Subtidal sand
- Fragile sponge and anthozoan communities on subtidal rocky habitats
- Honeycomb worm (*Sabellaria alveolata*) reefs,

2.2. Braunton Burrows Special Area of Conservation (SAC) and Site of Special Scientific Interest (SSSI)

Braunton Burrows was designated as a SAC due the following Annex I habitats which are a primary reason for the selection of this site:

- Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes)
- Fixed coastal dunes with herbaceous vegetation (grey dunes)
- Dunes with *Salix repens* ssp. argentea (*Salicion arenariae*)
- Humid dune slacks

As well as due to the presence of Annex I habitat 'mudflats and sandflats not covered by seawater at low tide' which is a qualifying feature of this SAC but not a primary reason for designation.

2.3. Bristol Channel Approaches SAC

The Bristol Channel Approaches SAC spans the Bristol Channel between the northern coast of Cornwall into Carmarthen Bay in Wales. The site has been identified for the protection of harbour porpoise and is within the Celtic and Irish Seas Management Unit.

3. Existing Habitat Mapping

3.1. EMODnet Habitat Mapping

Existing habitat mapping available on the European Marine Observation and Data Network (EMODnet) Seabed Habitats portal[4] indicates that the survey area comprises a number of sediment habitats including European Nature Information System (EUNIS) biotope complexes A5.27 'Deep circalittoral sand', A5.15' 'Deep circalittoral coarse sediment', A5.14 'Circalittoral coarse sediment', A5.25/A5.26 'Circalittoral fine sand or Circalittoral muddy sand', and A5.23/A5.24 'Infralittoral fine sand or infralittoral muddy sand' (Figure 2).

3.2. Geophysical Data

Geophysical data (MBES, SSS and backscatter) was collected throughout the survey area by N-Sea between June and August 2022. The seabed throughout the proposed area was broadly interpreted from the bathymetry as typical shallow ~ 7 – 94 m and gently sloping, gradually deepening from the northeast to the southwest. Nearshore, the seabed was broadly interpreted as a gently sloping (from east to west) homogenous sediment seabed with several long, sinuous sand waves oriented northwest to southeast. Throughout the mid-section of the ECC, harder seabed features indicative of bedrock were evident, extending west *c.*15 km. Offshore, the seabed within the fan and array areas was broadly interpreted as shallow, homogenous rippled seabed shallowing to the northeast and deepening to the southwest.

[4] https://www.emodnet-seabedhabitats.eu/access-data/launch-map-viewer/

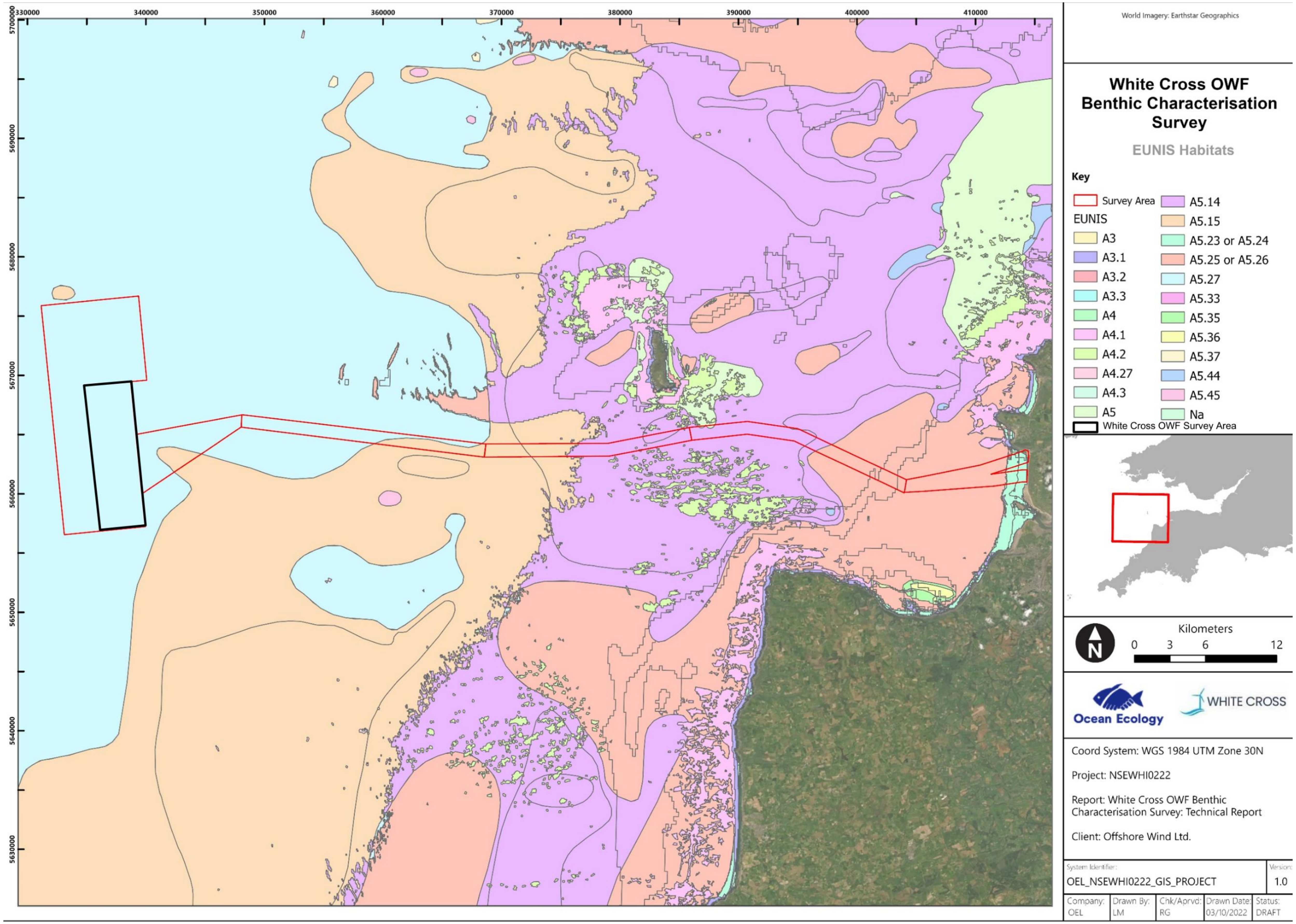

Figure 2 Known EUNIS habitat mapping across the White Cross survey area.

4. Survey Design

4.1. Overview

The benthic sampling plan was developed in line with Phase I of Natural England's "Offshore Wind Marine Environmental Assessments: Best Practice Advice for Evidence and Data Standards" (Natural England 2021) and provides maximum geographic coverage of the survey area, whilst ensuring that all key habitats and communities likely to be encountered across the survey area were adequately targeted. The key principles underpinning the survey design were therefore to ensure:

- Adequate spatial coverage of the array and ECR areas
- Representative sampling of all main sediment types
- Representative examples of all potential features of conservation interest (e.g., Annex I reefs) were adequately ground-truthed.

4.2. Rationale

The sampling plan was produced based on a stratified sampling approach across the project array and ECR areas with micro siting of sampling stations informed by a detailed review and interpretation of the geophysical data collected by N-Sea throughout June to August 2022. Sampling stations were located in consideration of all surface, subsurface and subsea hazards, and their respective exclusion / buffer zones.

The full catalogue of information assessed in the development of the sampling plan included:

- 2022 geophysical campaign processed multibeam echosounder (MBES) bathymetry and side scan sonar (SSS) imagery in mosaiced geotiff format
- 2022 geophysical campaign processed magnetometer and SSS feature analysis to identify potential subsea hazards and Unexploded Ordnance (UXO)
- Interpreted seabed classification from 2022 geophysical campaign
- All available GIS shapefiles and raster in ESRI format including: the array and ECR areas, planned and existing infrastructure including all oil and gas surface and subsurface infrastructure within the project boundary or within close proximity to it; the latest relevant Marine Protected Area (MPA) boundaries, and admiralty charts for the survey area (if available).

4.3. Sampling Design

The sampling plan was developed to ensure sampling was representative of the varying depths and habitats in a stratified design whilst also considering the surface and subsurface infrastructures and hazards and any other notable features identified from the geophysical data review.

The DDC investigation prior to grab sampling was to provide additional information on the sediment / substrate surface and to determine suitability to collect grab samples (i.e., confirm the absence of subsea hazards and protected habitats not identified during the geophysical data review).

MBES and SSS was reviewed simultaneously to micro site samples around a stratified grid which was initially overlain on the project area. SSS and MBES was reviewed manually to identify areas of differing sediment type and seabed elevation. Sediment / substrate type was inferred from SSS based on the reflectivity (coarser sediments providing showing greater reflectivity) and seabed elevation was determined by review of MBES which presents water depth. A representative number of stations was attributed to each of the main Broadscale Habitats (BSH) to ensure coverage of the array area was proportional to the dominant BSH present whilst also considering adequate spatial coverage. Sample locations were further micro sited to consider contaminant sampling which targeted at sampling stations thought to be characterised by fine sediment. The 10 DDC transects were positioned to ground-truth and delineate potential rocky reef features and confirm the presence/absence of key features of conservation interest (e.g. pink sea fan colonies and fragile sponge and anthozoan communities).

The proposed sampling plan is presented visually in Figure 3 and Table 1 and further rationale for each sample location in Appendix I.

Table 1 Numbers of sampling stations per survey block for Phase II sampling. * shallower than 10 m LAT. ** wider corridor at the approach to the array area.

Block	No. of DDC/Grab Stations	No of DDC Transects
Nearshore*	16	-
Area 3	16	3
Area 2	16	7
Area 1	17	-
Fan**	16	-
OWF	34	-
Total	**115**	**10**

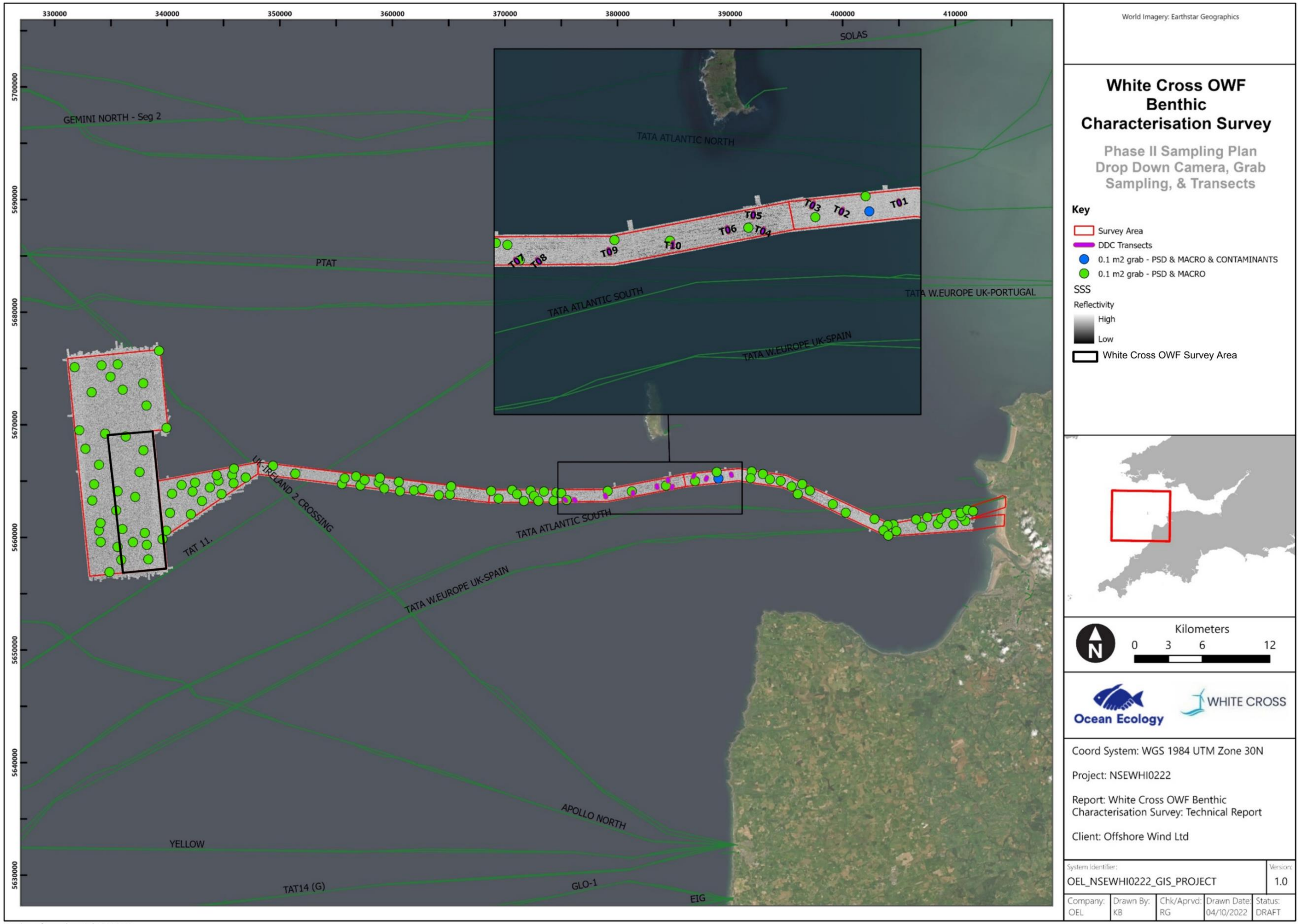

Figure 3 Locations of sampling stations across the White Cross survey area.

5. Field Methods

5.1. Survey Vessels

Phase I was conducted aboard Marine and Coastal Agency (MCA) Category 2, 11.7 m dedicated survey vessel '*Argyll Explorer*' (Plate 1), mobilising out of Padstow and operating from Ilfracombe and Clovelly. The vessel was equipped with a Hemisphere V104s Global Positioning System (GPS) compass system. The Hemisphere V104s's internal GPS receiver automatically searches for and uses a minimum of 4 GPS satellites and manages the navigation information required for position to within 3 m (95% accuracy). Since there is some error in the GPS data calculations, the V104s also automatically tracks a Satellite-Based Augmentation System (SBAS) differential correction to improve its position accuracy to better than 1.0 m 95%. The V104s has an integrated gyro and two tilt sensors to provide an accurate heading for the navigation software.

Phase II was conducted aboard the 34.5m dedicated survey vessel *Geo Focus* (Plate 1). The vessel was equipped with Class 1 Dynamic Positioning (DP). The 40m^2 back deck provided ample space for several items of survey equipment.

Plate 1 Top: Phase I survey vessel, OEL's Argyll Explorer. Bottom: Phase II survey vessel Geo Focus.

5.2. Project Parameters

5.2.1. Horizontal Datum

A summary of geodetic and projection parameters used during the project are provided in Table 2 and Table 3 below.

Table 2 Datum parameters.

Parameter	Details
Name	World Geodetic System 1984 (WGS84)
Ellipsoid	WGS 84
Semi-Major Axis (a)	6378137.000 m
Semi-Minor Axis (b)	6356752.314 m
Inverse Flattening	298.257 223 563
Geodetic parameters EPSG Code	4326

Table 3 Projection parameters.

Projection	Universal Transverse Mercator (UTM)
Zone	30 North
Central Meridian	3° West
Latitude of Origin	0°
False Easting	500 000.00 m
False Northing	0.00 m
Scale Factor at Central Meridian	0.9996
Projected coordinate system EPSG code	32630
Units	metres

5.2.2. Unit Format and Conversions

The following units were used throughout this project and are expressed using the following conventions.

Table 4 Project unit format and convention details.

Unit Formats and Conventions	
Geographical Coordinates	Latitude N DD˚MM.mmmmmm' to 6 decimal places. Longitude E/W DD˚MM.mmmmmm' to 6 decimal places.
Grid Coordinates	Meters in the following format: Easting EEE EEE.eee m to 3 decimal places. Northing NNN NNN.nnn m to 3 decimal places.
Linear distances	Meters to 1 decimal places.
Offset measurement sign conventions	Meters in the following format: 'Y' is positive forward 'X' is positive to starboard 'Z' values are positives upwards from the waterline
Time	Local unless otherwise stated.

5.3. Subsea Positioning

Subsea positioning of the sampling equipment during both phases of the survey was achieved using USBL positioning systems. EIVA NaviPac V4.2 software was employed for all DDC and grab sampling operations to ensure the accurate positioning of the vessel and survey equipment via the USBL system. A navigation screen, displaying EIVA Helmsman Display was provided at the helm position of the vessel for the Officer on Watch as well as for the ecologist/surveyor in the wheelhouse.

5.4. Survey Equipment

5.4.1. Phase I

Sampling equipment utilised during Phase I of the survey is included in Table 5.

Table 5 Equipment utilised onboard the *Argyll Explorer*.

Equipment	Model
Subsea Positioning	Easytrak Nexus 2 Lite Ultra-Short Baseline
Camera System (Primary)	OEL freshwater housing with HD video and high-resolution stills camera (SubC Imaging Rayin BPE)
Camera System (Redundancy)	OEL freshwater housing with HD video and high-resolution stills camera (RovTech Solutions)
Grab Sampler	0.2m^2 Dual Van Veen grab sampler
Equipment Dampener	A-frame fitted equipment dampener system
dGPS	Hemisphere V200s GPS Compass
Gyro Compass	Hemisphere V200s GPS Compass
Navigation Software	EIVA NaviPac V4.5

For Phase I seabed imagery was collected using OEL's freshwater housing camera system to collect high definition (HD) video and high-resolution (up to 24 megapixels (MP)) still images at each targeted station. The camera system consisted of a SubC Rayfin camera, freshwater housing frame, two RovTech LED strip lights with two 5kW green dot lasers (set to 10cm distance for scale), a 300m umbilical and topside computer. The camera was powered with the use of an Uninterruptable Power Supply (UPS) to ensure no damage was caused should the vessel have lost power or caused a power surge. The freshwater housing is height and angle adjustable providing a variety of options for view, lighting, and focal length to maximise data quality with respect to prevailing conditions (e.g., high turbidity). Following a review of seabed imagery during the survey, adjustments to the lighting angle were made to improve illumination within the centre of images.

For Phase I the grab was deployed from the hydraulic A-frame on the aft deck of Argyll Explorer and lowered to the seabed. An 'equipment dampener' mobilised on the A-frame allowed for grab operations to continue in a wider weather window (Plate 2). Sampling was conducted using a 0.2 m^2 Dual Van Veen (DVV) grab (Plate 2).

The DVV is favourable for medium to fine sediments and is ideal for the collection of chemical samples as it enabled to collect samples with undisturbed surface sediments. The DVV was employed for 22 of the 25 stations.

A 0.1m^2 mini-Hamon Grab mobilised as a back-up system was employed for 3 stations due to the presence of medium to coarse sediment.

Plate 2 Left: 0.2 m^2 DVV Grab. Right: Equipment dampener mobilised on A-Frame.

5.4.2. Phase II

Sampling equipment utilised during Phase II of the survey is included in Table 6.

Table 6 Equipment list mobilised onboard the *Geo Focus*.

Equipment	Model
Camera System (Primary)	OEL freshwater housing with High Definition (HD) video and high-resolution stills camera (SubC Rayfin Powerline Ethernet (PLE))
Camera System (Redundancy)	OEL freshwater housing with HD video and high-resolution stills camera (SubC Rayfin PLE)
Grab Sampler	0.1m^2 Day grab sampler
Grab Sampler	0.1m^2 mini-Hamon grab sampler
Survey Software	SubC Rayfin Control
Subsea Positioning	HiPAP Kongsberg transducer

Seabed imagery taken during Phase II was collected using the same frame as that utilised during Phase I as outlined in section 5.2.2, but equipped with a SubC Rayfin Camera system including, LED lamps and swathe lasers (Plate 3). This provided 4K video and high-resolution (up to 21 megapixels (MP)) still images.

Using Phase I as a reference point, sampling was initially conducted using a 0.1m^2 mini-Hamon grab at stations in Area 2. The mini-Hamon grab was used for 58 macrofaunal / PSD stations.

At stations consisting of medium to fine sediment, a 0.1m^2 Day grab was employed, including at the single station where chemical sampling was required. The Day grab was used for 52 macrofaunal / PSD stations and one chemical station.

Plate 3 DDC and Hamon Grab mobilised on aft deck of the '*Geo Focus*'.

5.5. Seabed Imagery Collection

Seabed imagery was collected at DDC stations (co-located with grab sample locations for prior investigation) and along DDC transects in consideration of the Joint Nature Conservation Committee (JNCC) epibiota remote monitoring operational guidelines[5].

[5] Hitchin, R., Turner, & Verling. (2015). *Epibiota Remote Monitoring from Digital Imagery: Operational Guidelines*.

At each DDC station, a minimum of two minutes of video footage and five seabed still images were obtained. The vessel was moved within a 20 m radius of the target location to adequately characterise the target area. Along the transects, a 'bed hoping' approach was employed to ensure representative imagery was collected along the full transects with still images taken every 5-10 m along with continuous video recording. All video footage was reviewed *in situ* by OEL's environmental scientists.

5.6. Grab Sampling

To ensure consistency in sampling, grab samples were screened by the lead marine ecologist and considered unacceptable if:

- The sample was less than 5L. i.e., the sample represented less than half the 10L capacity of the grab used.
- The jaws failed to close completely or were jammed open by an obstruction, allowing fines to pass through (washout or partial washout).
- The sample was taken at an unacceptable distance from the target location (beyond 20 m).

Where a suitable sample could not be collected after three attempts within a 20 m radius of the target location, the sample location was moved by up to 50 m away. Where samples of less than 5L were continually achieved, these samples were assessed on site to establish if the sample volume was acceptable to allow subsequent analysis. No pooling of samples took place. Where a suitable sample was not collected after four attempts, the sample location was abandoned.

5.6.1. Grab Sample Processing (PSD and Macrobenthic Samples)

Initial grab sample processing was undertaken aboard the vessels in line with the following methodology:

- Initial visual assessment of sample size and acceptability made.
- Photograph of the unprocessed sample in sample hopper with station details and scale bar taken.
- Sub-sample removed for PSD analysis and transferred to a labelled tray.
- Remaining sample emptied onto 1.0 mm sieve net laid over 4.0 mm sieve table and washed through using gentle rinsing with seawater hose.
- Photograph of the sieved sample on 1.0 mm sieve net taken.
- Remaining sample for faunal sorting and identification backwashed into a suitable sized sample container and diluted 10 % formalin solution added to fix the sample prior to laboratory analysis.
- Sample containers clearly labelled internally and externally with date, sample ID and project name.

5.6.2. Grab Sample Processing (Chemical Contaminants)

A separate sediment sample was collected for subsequent chemical contaminant analysis at a subset of 15 sampling stations. From each of these samples two subsamples (primary A rep and back up b rep) were retained. Initial sample processing onboard aligned to the following methodology:

- Inspection cover lifted and general assessment of sample size and acceptability made ensuring sediment surface was undisturbed and no obvious sign of contamination. Checks to ensure no grease, oils or lubes entered the sample once the inspection cover was open were also undertaken.
- pH / Redox probe placed into sediment sample and allowed to settle for 2 minutes before taking readings in field logs.
- Sediment samples were sub-sampled and decanted into the recommended sample containers provided by SOCOTEC, the contaminant laboratory specialists, to undertake the MMO suite analysis for disposal at sea along with additional analyses, as summarised below:
- Total Organic Matter by Loss on Ignition (LOI)
- Moisture content
- Total Organic Carbon (TOC)
- Total content and the content of the labile form of heavy metals (Pb, Cu, Zn, Ni, Cd, Cr, As, Hg);
- Organotins (DBT, TBT)
- Polycyclic aromatic hydrocarbons (PAHs) - Acenaphthene, Acenaphthylene, Anthracene, Benzo[a]anthracene, Benzo[a]pyrene, Benzo[b]fluoranthene, Benzo[ghi]perylene, Benzo[e]pyrene, Benzo[k]fluoranthene, Chrysene, Dibenzo[a,h]anthracene, Fluoranthene, Fluorene, Indeno[123,cd]pyrene, Naphthalene, Perylene, Phenanthrene, Pyrene
- Total Hydrocarbon Content (THC);
- Polychlorinated biphenyls (PCBs 25 including the ICES 7)

All samples taken for physico-chemical analysis were stored frozen at -20°C in amber glass containers onboard the vessels. These containers were acid cleaned and solvent-rinsed before use, sealed with a foil liner and tightened appropriately to avoid potential loss of determinands, contamination of samples, or both. A temperature of 25°C was not exceeded at any stage of storage or transportation.

6. Laboratory and Analytical Methods

On arrival to the laboratory, all samples were logged in and entered into the project database created in OEL's web-based data management application ABACUS in line with in-house Standard Operating Procedures (SOPs) and OEL's Quality Management System (QMS).

6.1. Particle Size Distribution (PSD) Analysis

Particle Size Distribution (PSD) analysis of sediment samples was undertaken by in-house laboratory technicians at OEL's NMBAQC (NE Marine Biological Analytical Quality Control Scheme) participating laboratory, in line with NMBAQC best practice guidance (Mason 2016).

6.1.1. Sample Preparation

Frozen sediment samples were first transferred to a drying oven and thawed at 80 °C for at least six hours prior to visual assessment of sediment type. Before any further processing (e.g., sieving, or sub-sample removal), samples were mixed thoroughly with a spatula and all conspicuous fauna (> 1 mm) which appeared to have been alive at the time of sampling removed from the sample. A representative sub-sample of the whole sample was then removed for laser diffraction analysis before the remaining sample screened over a 1mm sieve to sort coarse and fine fractions.

6.1.2. Dry Sieving

The > 1 mm fraction was then returned to a drying oven and dried at 80 °C for at least 24 hours prior to dry sieving. Once dry, the sediment sample was run through a series of Endecott BS 410 test sieves (nested at 0.5 φ intervals) using a Retsch AS200 sieve shaker to fractionate the samples into particle size classes. The dry sieve mesh apertures used are given in Table 7.

Table 7 Sieve series employed for Particle Size Distribution (PSD) analysis by dry sieving (mesh size in mm).

Sieve aperture (mm)												
63	45	32	22.5	16	11.2	8	5.6	4	2.8	2	1.4	1

The sample was then transferred onto the coarsest sieve (63 mm) at the top of the sieve stack and shaken for a standardised period of 20 minutes. The sieve stack was checked to ensure the components of the sample had been fractioned as far down the sieve stack as their diameter would allow. A further 10 minutes of shaking was undertaken if there was evidence that particles had not been properly sorted.

6.1.3. Laser Diffraction

The fine fraction residue (< 1mm sediments) was transferred to a suitable container and allowed to settle for 24 hours before excess water syphoned from above the sediment surface until a paste texture was achieved.

The fine fraction was then analysed by laser diffraction using a Beckman Coulter LS13 320. For silty sediments, ultrasound was used to agitate particles and prevent aggregation of fines.

6.1.4. Data Merging

The dry sieve and laser data were then merged for each sample with the results expressed as a percentage of the whole sample. Once data was merged, PSD statistics and sediment classifications were generated from the percentages of the sediment determined for each sediment fraction using Gradistat v8 software.

Sediment were described by their size class based on the Wentworth classification system (Wentworth 1922) (Table 8). Statistics such as mean and median grain size, sorting coefficient, skewness and bulk sediment classes (percentage silt, sand and gravel) were also derived in accordance with the Folk classification (Folk 1954).

Table 8 Classification used for defining sediment type based on the Wentworth Classification System (Wentworth 1922).

Wentworth Scale	Phi Units (φ)	Sediment Types
>64000 µm	<-6	Cobble and boulders
32000 – 64000 µm	-5 to -6	Pebble
16000 – 32000 µm	-4 to -5	Pebble
8000 – 16000 µm	-3 to -4	Pebble
4000 - 8000 µm	-3 to -2	Pebble
2000 - 4000 µm	-2 to -1	Granule
1000 - 2000 µm	-1 to 0	Very coarse sand
500 - 1000 µm	0 - 1	Coarse sand
250 - 500 µm	1 - 2	Medium sand
125 - 250 µm	2 - 3	Fine sand
63 - 125 µm	3 - 4	Very fine sand
31.25 – 63 µm	4 - 5	Very coarse silt
15.63 – 31.25 µm	5 - 6	Coarse silt
7.813 – 15.63 µm	6 - 7	Medium silt
3.91 – 7.81 µm	7 – 8	Fine silt
1.95 – 3.91 µm	8 - 9	Very fine silt
<1.95 µm	<9	Clay

6.2. Sediment Chemical Analysis

All organic matter, hydrocarbon, metals and organotins analysis was undertaken by SOCOTEC UK Limited. A full description of the methods used to test for each chemical determined and is provided as Appendix XI.

6.2.1. Hydrocarbons

Indices and ratios were calculated to assess source origin of hydrocarbons in the sediment sampled across the survey area (Ines et al. 2013, Aly Salem et al. 2014, Al-hejuje et al. 2015). Generally, there are three sources of hydrocarbons depending on their origin: biogenic, petrogenic and pyrogenic. Hydrocarbons of biogenic origin are the product of biological processes or early diagenesis in marine sediments (e.g., perylene) (Venkatesan 1988, Junttila et al. 2015). Hydrocarbons of petrogenic origin are the compounds present in oil and some oil products following low to moderate temperature diagenesis of organic matter in sediments resulting in fossil fuels. Hydrocarbons of pyrogenic origin are the product of incomplete combustion of organic material (Page et al. 1999, Junttila et al. 2015), such as forest fires and incomplete combustion of fossil fuels.

Based on Polycyclic Aromatic Hydrocarbon (PAH) compounds the following ratios were calculated as follows:

- The ratio between light (LWM) and heavy (HMW) PAHs is typically used as a proxy to determine the origin source of PAH compounds in sediments, ratios above 1 indicate a petrogenic source while ratios below 1 indicate a pyrogenic source. LMW PAHs include compounds with 2-3 rings while HMW PAHs include compounds with more than 4 rings (Edokpayi et al. 2016).
- Phenanthrene / Anthracene ratio: values lower than 10 indicate a pyrogenic source origin for the hydrocarbons; while values higher than ten account for hydrocarbons of petrogenic origin (Kafilzadeh et al. 2011).
- Fluoranthene / Pyrene ratio: for values higher than one, the hydrocarbons are pyrogenic in origin, for values below one, the hydrocarbons are petrogenic in origin (Kafilzadeh et al. 2011).

Based on aliphatic hydrocarbons and n-alkanes, the following index and ratios were calculated:

- Pristane / Phytane ratio: values close to one indicate hydrocarbons of petrogenic origin, values higher than one indicate biogenic origin of alkanes, while ratios below one indicates pyrogenic origin. Pristane is typically found in marine organisms while phytane is a component of oil (Guerra-García et al. 2003) hence the use of this ratio to assess source origin of hydrocarbons

6.2.2. Heavy and Trace Metals

A total of 8 main heavy and trace metals were analysed from sediments taken at each of the 14 stations sampled. These were Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni), and Zinc (Zn).

Where available, mean metal concentrations were compared to the OSPAR Background Assessment Concentration (BAC) (OSPAR et al. 2009), the USA Environmental Protection Agency (EPA) Effect Range Low (ERL) (NJDEP 2009), (DEFRA 2003) Action Level (AL) 1 and AL 2, and the Canadian sediment quality guideline (CSQG) Threshold Effect Level (TEL) and Probable Effect Level (PEL) (CCME 2001). To note that ERL, TEL and PEL are based on field research programmes based on North American data that have demonstrated associations between chemicals and biological effects by establishing cause and effect relationships in particular organisms (CCME 2001). This means they provide a measure of environmental toxicity compared to the other reference levels which instead provide information on the degree of contamination of the sediments. At levels above the TEL, adverse effects may occasionally occur, whilst at levels above the PEL, adverse effects may occur frequently; concentrations below the ERL rarely cause adverse effects in marine organisms. Additionally, the TEL has been adopted as the International Sediment Quality Guideline (ISQG) (CCME 2001), while ERL has been adopted by OSPAR to assess the ecological significance of contaminant concentrations in sediments, where concentrations below the ERL rarely cause adverse effects in marine organisms. For these reasons ERL, TEL and PEL are presented here as reference values despite being based on North American data.

BACs were developed to assess the status of contaminant concentrations in sediment within the OSPAR framework with concentrations significantly below the BAC considered to be near background levels for the North-East Atlantic. Cefas ALs are used as part of a 'weight of evidence' approach to assessing dredged material and its suitability for disposal to sea (DEFRA 2003). Contaminant levels in dredged material which fall below AL1 are of no concern and are unlikely to influence decision-making, while contaminant levels above AL2 are generally considered unsuitable for at-sea disposal.

6.3. Macrobenthic Analysis

All elutriation, extraction, identification, and enumeration of the grab samples was undertaken at OEL's NMBAQC scheme participating laboratory in line with the NMBAQC Processing Requirement Protocol (PRP) (Worsfold & Hall 2010). All processing information and macrobenthic records were recorded using OEL's cloud-based data management application 'ABACUS' that employs MEDIN[6] validated controlled vocabularies ensuring all sample information, nomenclature, qualifiers, and metadata are recorded in line with international data standards.

For each macrobenthic sample, the excess formalin was drained off into a labelled container over a 1 mm mesh sieve in a well-ventilated area. The samples were then re-sieved over a 1 mm mesh sieve to remove all remaining fine sediment and fixative. The low-density fauna was then separated by elutriation with fresh water, poured over a 1 mm mesh sieve, transferred into a Nalgene and preserved in 70 % Industrial Denatured Alcohol (IDA). The remaining sediment from each sample was subsequently separated into 1 mm, 2 mm and 4 mm fractions and sorted under a stereomicroscope to extract any remaining fauna (e.g., high-density bivalves not 'floated' off during elutriation). All macrobenthos present was identified to species level, where possible, and enumerated by trained benthic taxonomists using the most up to date taxonomic literature and checks against existing reference collections. Nomenclature utilised the live link within ABACUS to the WoRMS[7] REST webservice (World Register of Marine Species), to ensure the most up to date taxonomic classifications were recorded. Colonial fauna (e.g., hydroids and bryozoans) were recorded as present (P). For the purposes of subsequent data analysis, taxa recorded as P were given the numerical value of 1.

Following identification, all specimens from each sample were pooled into five major groups (Annelida, Crustacea, Mollusca, Echinodermata, and Miscellaneous taxa) in order to measure blotted wet weight major group biomass to 0.0001 g. As a standard, the conventional conversion factors as defined by (Eleftheriou & Basford 1989) were applied to biomass data to provide equivalent dry weight biomass (Ash Free Dry Weight, AFDW). The conversion factors applied are as follows:

- Annelida = 15.5 %
- Crustacea = 22.5 %
- Mollusca = 8.5 %
- Echinodermata = 8.0 %
- Miscellaneous = 15.5 %

[6] Marine Environmental Data and Information Network
[7] http://www.marinespecies.org

6.4. Macrobenthic Data Analysis

6.4.1. Data Truncation and Standardisation

The macrobenthic species list was checked using the R package '*worms*' (Holstein 2018) to check against WoRMS taxon lists and standardise species nomenclature. Once the species nomenclature was standardised in accordance with WoRMS accepted species names, the species list was examined carefully by a senior taxonomist to truncate the data, combining species records where differences in taxonomic resolution were identified.

6.4.2. Pre-Analysis Data Treatment

All data were collated in excel spreadsheets and made suitable for statistical analysis. All data processing and statistical analysis was undertaken using R v 1.2 1335 (Team & R Core Team 2020) and PRIMER v7 (Clarke & Gorley 2015) software packages. To note that no replicate samples were available for macrobenthic analysis thus no mean values could be calculated per sampling station.

In accordance with the OSPAR Commission guidelines (OSPAR 2004) records of colonial, meiofaunal, parasitic, egg and pelagic taxa (e.g. epitokes and larvae) were recorded, but were excluded when calculating diversity indices and conducting multivariate analysis of community structure. Newly settled juveniles of macrobenthic species may at times dominate the macrobenthos, however the OSPAR (2004) guidelines suggest they should be considered an ephemeral component due to heavy post-settlement mortality and not therefore representative of prevailing bottom conditions (OSPAR 2004). OSPAR (2004) further states that "Should juveniles appear among the ten most dominant organisms in the data set, then statistical analyses should be conducted both with and without these in order to evaluate their importance". As juveniles of Amphiuridae and Spatangoida appeared in the top ten most dominant taxa across White Cross, a 2STAGE analysis was conducted to compare the two data sets (with and without juveniles) which revealed a 92 % of similarity between the two and therefore juveniles were retained in the dataset for all further analyses and discussion.

In accordance with NMBAQC PRP (Worsfold & Hall 2010), Nematoda were recorded during the macrobenthic analysis and included in all datasets for all further analyses and discussion.

6.4.3. Multivariate Statistics

Prior to multivariate analyses, data were displayed as a shade plot with linear grey-scale intensity proportional to macrobenthic abundance (Clarke et al. 2014) to determine the most efficient pre-treatment (transformation) method. Macrobenthic abundance data from grab samples was square root transformed to prevent taxa with intermediate abundances from being discounted from the analysis, whilst allowing the underlying community structure to be assessed.

The PRIMER v7 software package (Clarke & Gorley 2015) was utilised to undertake the multivariate statistical analysis on the biotic macrobenthic dataset.

To fully investigate the multivariate patterns in the biotic data, macrobenthic assemblages were characterised based on their community composition, with hierarchical clustering and non-metric multidimensional scaling (nMDS) used to identify groupings of sampling stations that could be grouped together as a habitat type or community. SIMPER (similarities-percentage) analysis was then applied to identify which taxa contributed most to the similarity within that habitat type or community. A detailed description of analytical routines is provided in Appendix VII.

6.4.4. Determining EUNIS Classifications

Macrobenthic assemblages were characterised based on their community composition, with hierarchical clustering used to identify groupings of sampling stations that could be grouped together as a habitat type or community. Setting these groupings as factors within PRIMER, SIMPER analysis was then applied to identify which taxa contributed the most to the similarity within that community. EUNIS classifications were then assigned based on the latest JNCC guidance (Parry 2019).

6.5. Seabed Imagery Analysis

All seabed imagery analysis was undertaken using the Bio-Image Indexing and Graphical Labelling Environment (BIIGLE) annotation platform (Langenkämper et al. 2017) and in line with JNCC epibiota remote monitoring interpretation guidelines (Turner et al. 2016) with consideration of the latest NMBAQC/JNCC Epibiota Quality Assurance Framework (QAF) guidance and identification protocols.

A full reef habitat assessment was conducted on all images to determine whether habitats met the definitions of Annex I reef habitats as detailed in Table 9 and Table 10. The annotation label tree, provided as Appendix VIII, used during analysis had major headings for each of reef type. Under each reef type labels were assigned for each of the categories required to determine whether reef habitat was present. Any images that were designated as a low resemblance stony reef were further assessed in line with (Golding et al. 2020).

Table 9 Characteristics of stony reef (Irving 2009).

Characteristic	'Reefiness'			
	Not a Reef	Low	Medium	High
Composition (proportion of boulders/cobbles (>64 mm))	< 10 %	10 - 40 % matrix supported	40 - 95 %	> 95 % clast-supported
Elevation	Flat seabed	< 64 mm	64 mm - 5 m	> 5 m
Extent	< 25 m^2	>25 m^2		
Biota	Dominated by infaunal species	> 80 % of species present composed of epibiotal species		

Table 10 Characteristics of *Sabellaria spinulosa* reef (Gubbay 2007).

Characteristic	'Reefiness'			
	Not a Reef	Low	Medium	High
Elevation (cm)	< 2	2 - 5	5 – 10	> 10
Extent (m^2)	< 25	25 – 10,000	10,000 – 1,000,000	> 1,000,000
Patchiness (% Cover)	< 10	10 - 20	20 – 30	> 30

6.5.1. Tier 1 Analysis

The first stage, "Tier 1", consisted of assigning labels that referred to the whole image, providing appropriate metadata for the image. Metadata "Image Labels" included:

- Broadscale Habitat (BSH) type.
- EUNIS habitat classification.
- Substrate type (and percentage cover in 10% intervals).
- The presence of any Annex I habitats, Features of Conservation Importance (FOCI) or Habitats of Conservation Importance (HOCI).
- The presence of any visible impacts or other modifiers (such as discarded fishing gear or marine litter (as per the Marine Strategy Framework Directive (MSFD) categories), visible physical damage to the seabed, evidence of strong currents, non-native species, etc.).
- Image quality categories (including "Not Analysable" category).

Depending on the presence of reef, this also included:

- Extent: As it is not possible to fully determine the extent of reef habitats from a single image alone this label was used to identify areas that are highly unlikely to constitute reef habitats. An example is an image that shows a large boulder being preceded and succeeded by images of unconsolidated sandy sediments.
- Biota: Labels assigned to determine whether epifauna dominate the biological community observed.
- Elevation: Labels assigned depending on reef type. Laser points will be used to assist in the assignment of categories.

The substratum observed in each still image was recorded as a percentage cover substratum type where possible (based on substrate types from NMBAQC/JNCC Quality Assurance Framework). Determination of sediment type (such as coarse, mixed, sand etc.) was facilitated using the adapted Folk sediment trigon (Long 2006) incorporated into a sediment category correlation table. Percentage cover of the different substrate types was used to determine and assign EUNIS codes and BSH.

6.5.2. Tier 2 Analysis

The second stage, "Tier 2", consisted of annotating biota within an image on a presence/absence basis using point annotations. This was achieved by using a customised OEL label tree (based on the Collaborative and Annotation Tools for Analysis of Marine Imagery (CATAMI)) (Althaus et al. 2015)).

6.6. Habitat/Biotope Assignment

All grab samples for which PSD and macrobenthic data were available were assigned a EUNIS habitat and/or biotope based on the latest JNCC guidance (Parry 2019). These were utilised alongside the imagery analysis to assess the various habitats and biotopes encountered across the survey area.

6.7. Habitat / Biotope Mapping

All mapping processes were conducted in ESRI ArcPro Version 3.0.0. All seabed imagery assigned a EUNIS habitat in BIIGLE was utilised alongside the acoustic information and ground-truthed data from the grab samples to manually delineate the boundaries (polygons) of the various habitats encountered across the survey area. Confidence scores were assigned to each polygon to give an indication of their accuracy. A value of 1 (low confidence) or 2 (high confidence) was assigned depending on the following:

- Whether ground-truth data was available within the polygon
- Whether multiple data sources confirmed/suggested the presence of the same habitat/biotope within a polygon
- Whether the boundaries of the habitat/biotope were clearly defined either by seabed imagery, ground-truth or acoustic data

Highest scores were given to polygons where all data sources identified the same habitat/biotope, with distinct boundaries. Lower scores were assigned to polygons where ground-truth data is limited, and boundaries not obvious. In these cases, polygons were drawn based upon expert judgement, given the information available.

7. Results

7.1. Particle Size Distribution Data

The composition of sediment data at each grab sampling stations throughout the survey area are mapped in Figure 5. Grab sampling logs and sample photos for 134 stations are provided in Appendices II and III respectively and full PSD data has been provided in Appendices IX and X.

7.1.1. Sediment Type

Sediment types at each grab sampling station as classified by the (Folk 1954) classification are summarised in Appendix X and illustrated in Figure 4. Despite some variation in sediment types between stations, the majority of stations were dominated by sand. Mud content was highest close to land at ST01 and also high at ST38. Gravel content was low overall but variable along the ECR with a few stations along the route found to contain > 50 % gravel composition (ST03, ST07, ST09, ST10, ST102, ST118, and ST123). The majority of samples were comprised of sand representing EUNIS BSH A5.2 (Sand and Muddy Sand). Some stations were classified as Sandy Gravel (sG) or Gravelly Sand (gS) representing EUNIS BSH A5.1 (Coarse Sediment); 7 stations were classified as Muddy Sandy Gravel (msG) and 4 stations as Gravelly Muddy Sand (gmS) representing EUNIS BSH A5.4 (Mixed Sediment) (Figure 5).

Most of the sediments recorded were classified as moderately sorted (40 %) and comprised almost entirely of sand. Remaining stations classified as moderately well sorted (11 %), poorly (30 %) to very poorly sorted (19 % of stations). This variation results from a mixed composition of different size fractions of all three principal sediment types (gravel, sand, and mud).

7.1.2. Sediment Composition

The percentage contribution of gravels (> 2 mm), sands (0.63 mm to 2 mm), and fines (< 63 µm) at each station are presented in Figure 6. Sand was the main sediment fraction present at most stations, comprising the largest percentage contribution across the survey area. The mean proportion (± Standard Error, SE) of sands across all stations was 85 % (± 1.5), the mean (±SE) mud, and gravel content across the survey area was 6 % (± 0.7) and 9 % (± 1.4) respectively. Sand content was greatest at station ST078 and lowest at ST09. The mean grain size at sampling stations ranged from 34.83 µm at station ST01 to 5,559 µm at station ST123 (Figure 7).

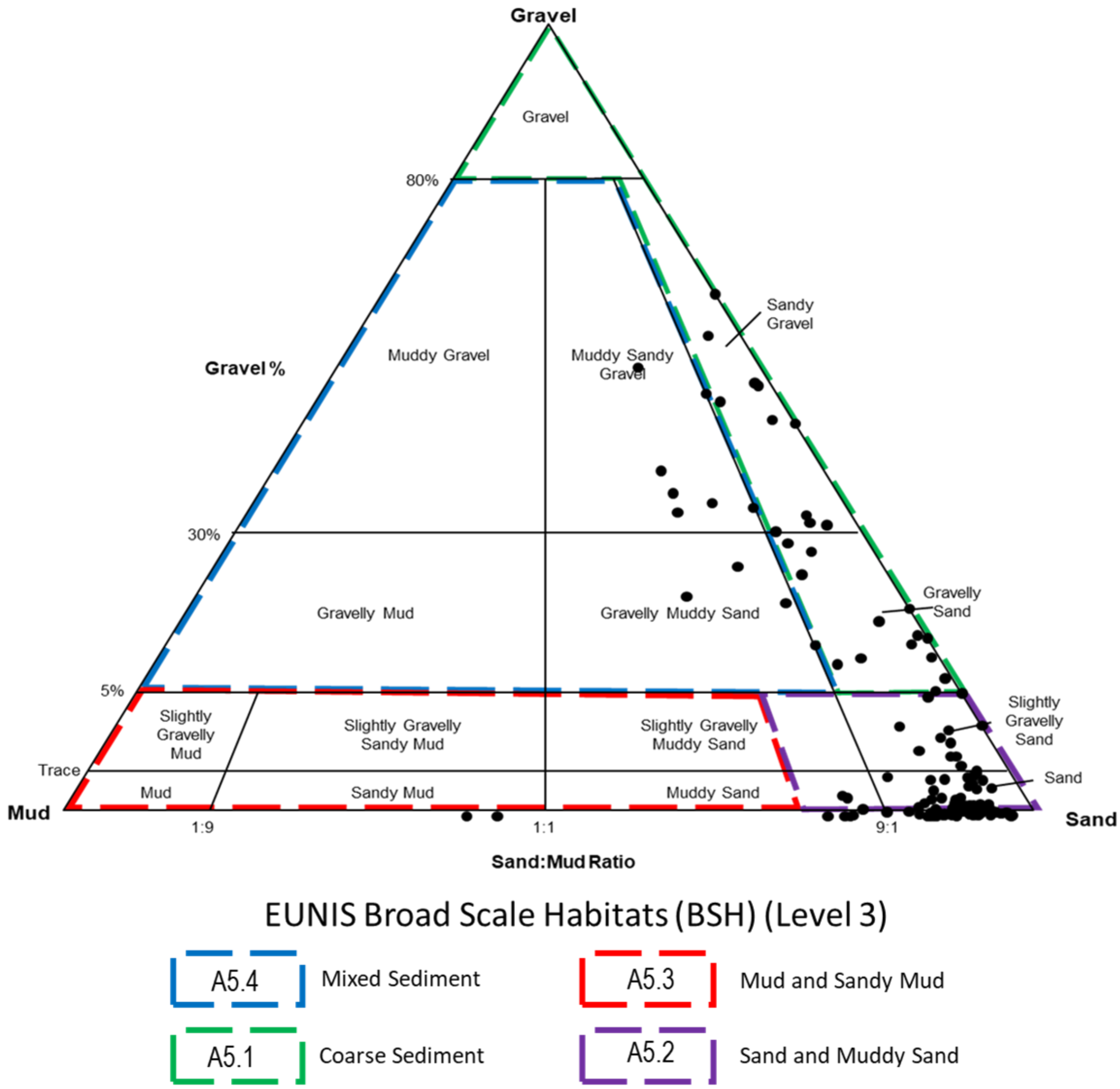

Figure 4 Folk (Folk 1954) triangle classifications of sediment gravel percentage and sand to mud ratio of samples collected across the survey area, overlain by the modified Folk triangle for determination of mobile sediment BSHs under the EUNIS habitat classification system (adapted from (Long 2006)).

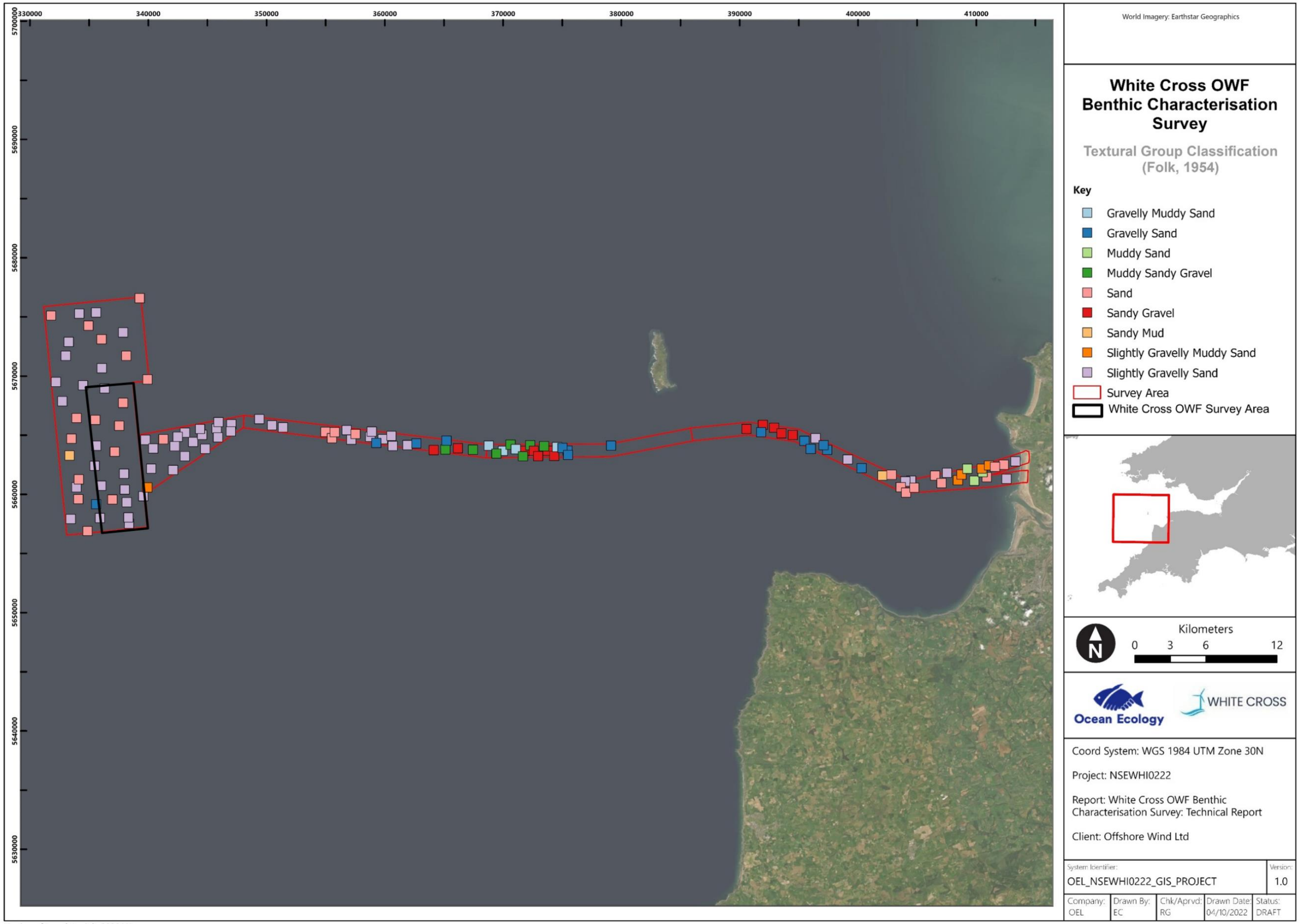

Figure 5 Textural group classification at each sampling station across the survey area.

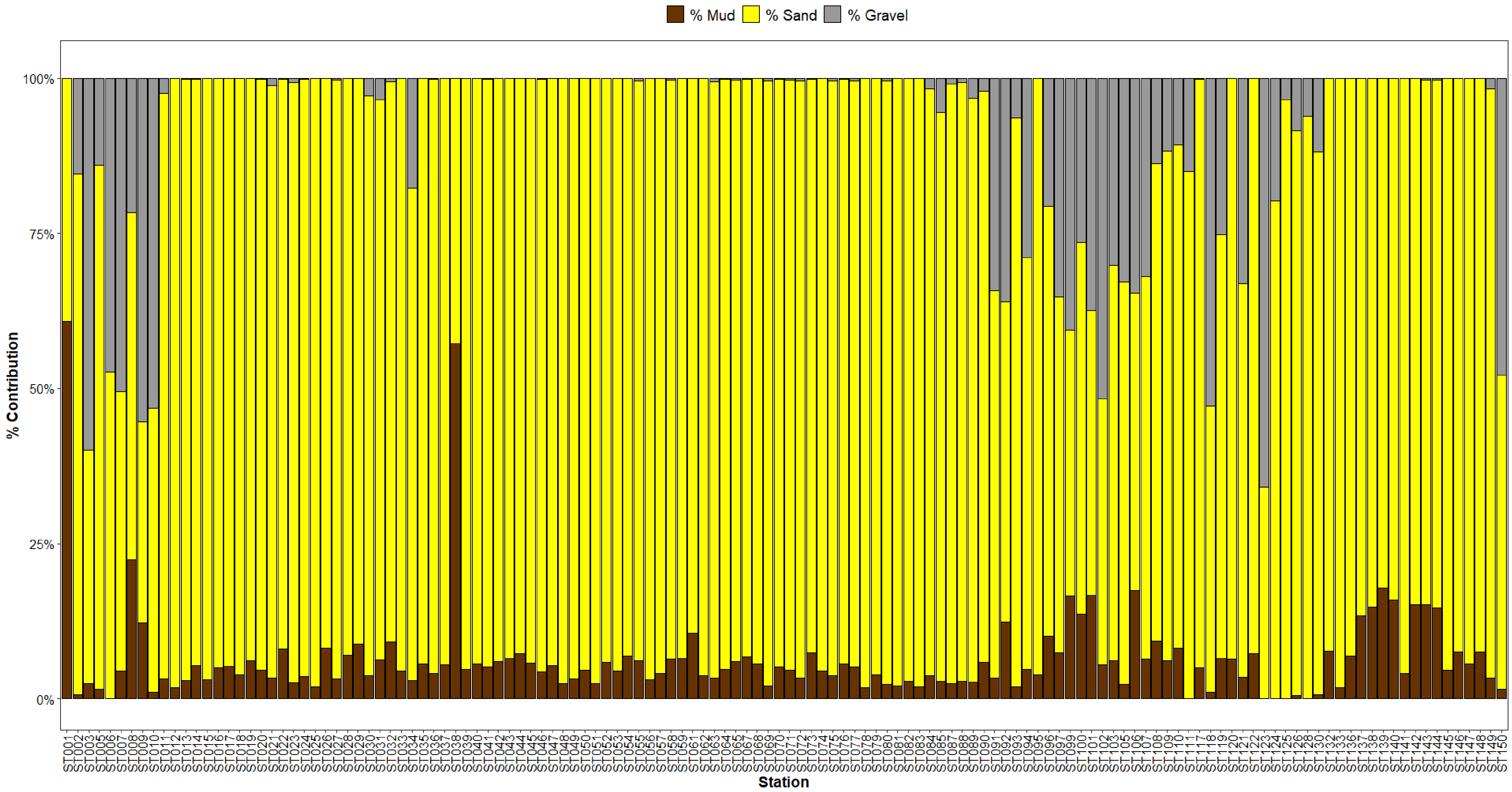

Figure 6 Percentage volume of gravel (G), sand (S), and mud (M) at each sampling station across the survey area.

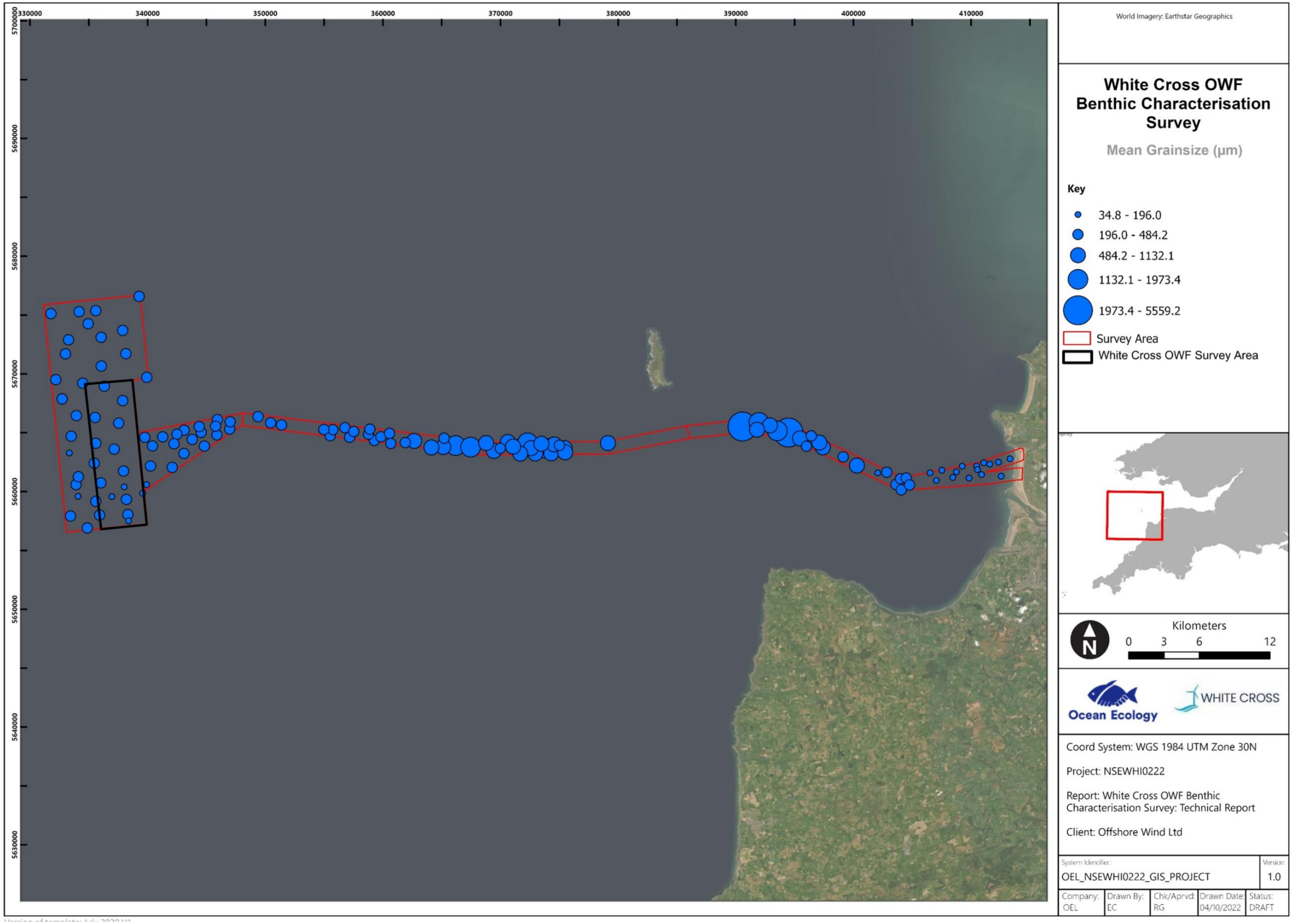

Figure 7 Mean grain size (µm) at each sampling station across the survey area.

7.2. Sediment Chemistry

Sediment samples for chemical contaminant analysis were collected from 15 stations sampled across the survey area. Grab samples taken for chemical analyses were analysed for Total Organic Carbon (TOC) and Total Organic Matter (TOM) (Section 7.2.1), heavy and trace metals (Section 7.2.2), Polycyclic Aromatic Hydrocarbon (PAH) and Total Hydrocarbon Content (THC) (Section 7.2.3), Organotins (Section 7.2.4), and Polychlorinated Biphenyls (PCBs) (Section 7.2.5). Raw sediment chemistry data are provided in Appendix XI (provided separately).

7.2.1. Total Organic Carbon (TOC) and Total Organic Matter (TOM)

TOC concentrations ranged from < 0.02 % at ST01 to 1.16 % at ST09 with an average value (± SE) of 0.30 ± 0.07 % across the survey area (Figure 8). In general, relatively higher TOC values were recorded at stations located in the middle reaches of the survey area, compared to the stations located to the east and more offshore. No clear trend was observed between mud content in the sediment and percentage contribution of TOC.

TOM concentrations ranged from 1.2 % at stations ST013, ST018 and ST019 to 4.9 % at ST009 with an average value (± SE) of 1.912 ± 0.32 % across the survey area (Figure 9).In general, relatively lower TOM values were recorded at stations located to the east and more offshore compared to stations located in the middle reaches and towards the shore of the survey area. No clear trend was observed between mud content in the sediment and percentage contribution of TOM.

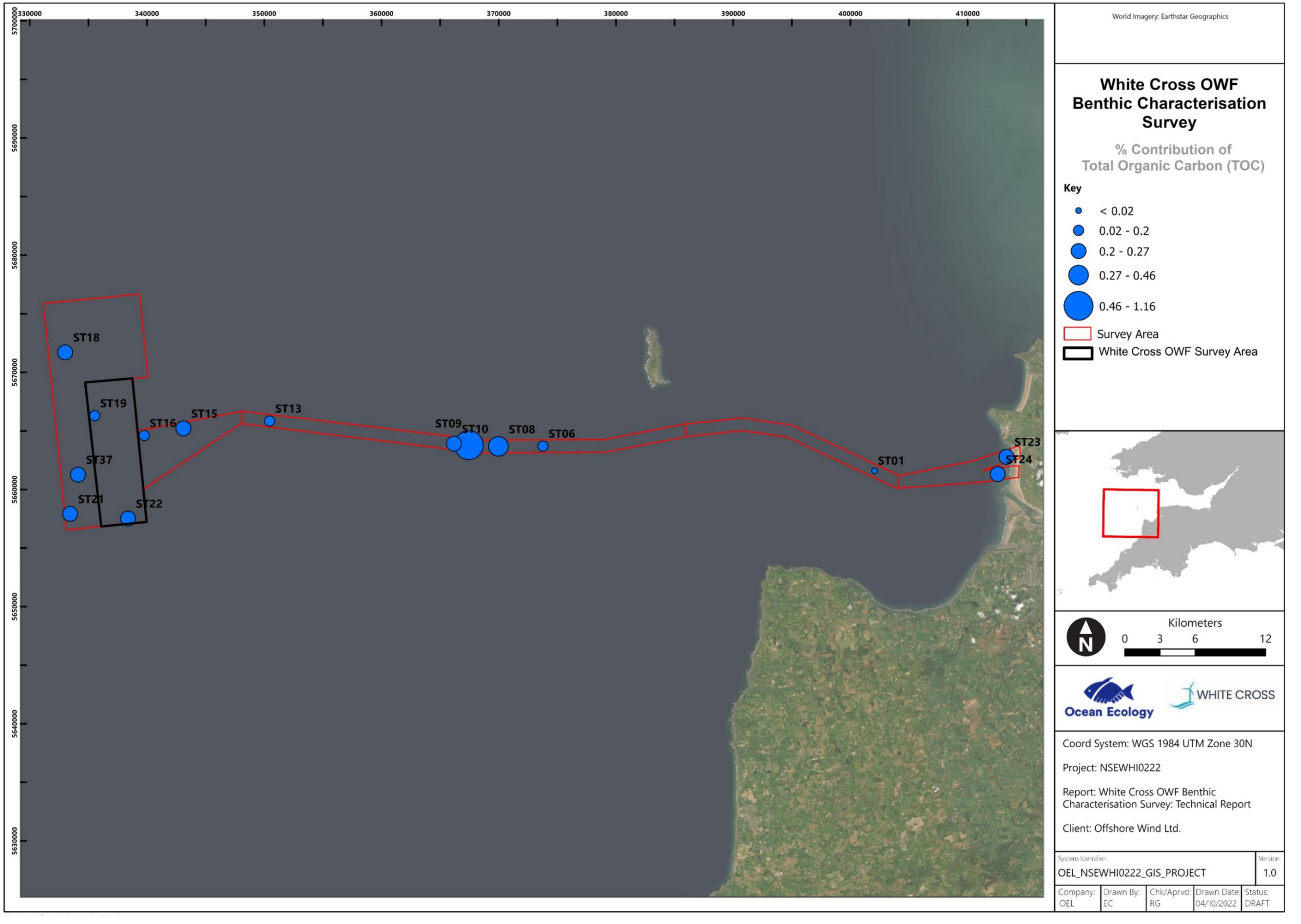

Figure 8 Percentage contribution of TOC across the survey area.

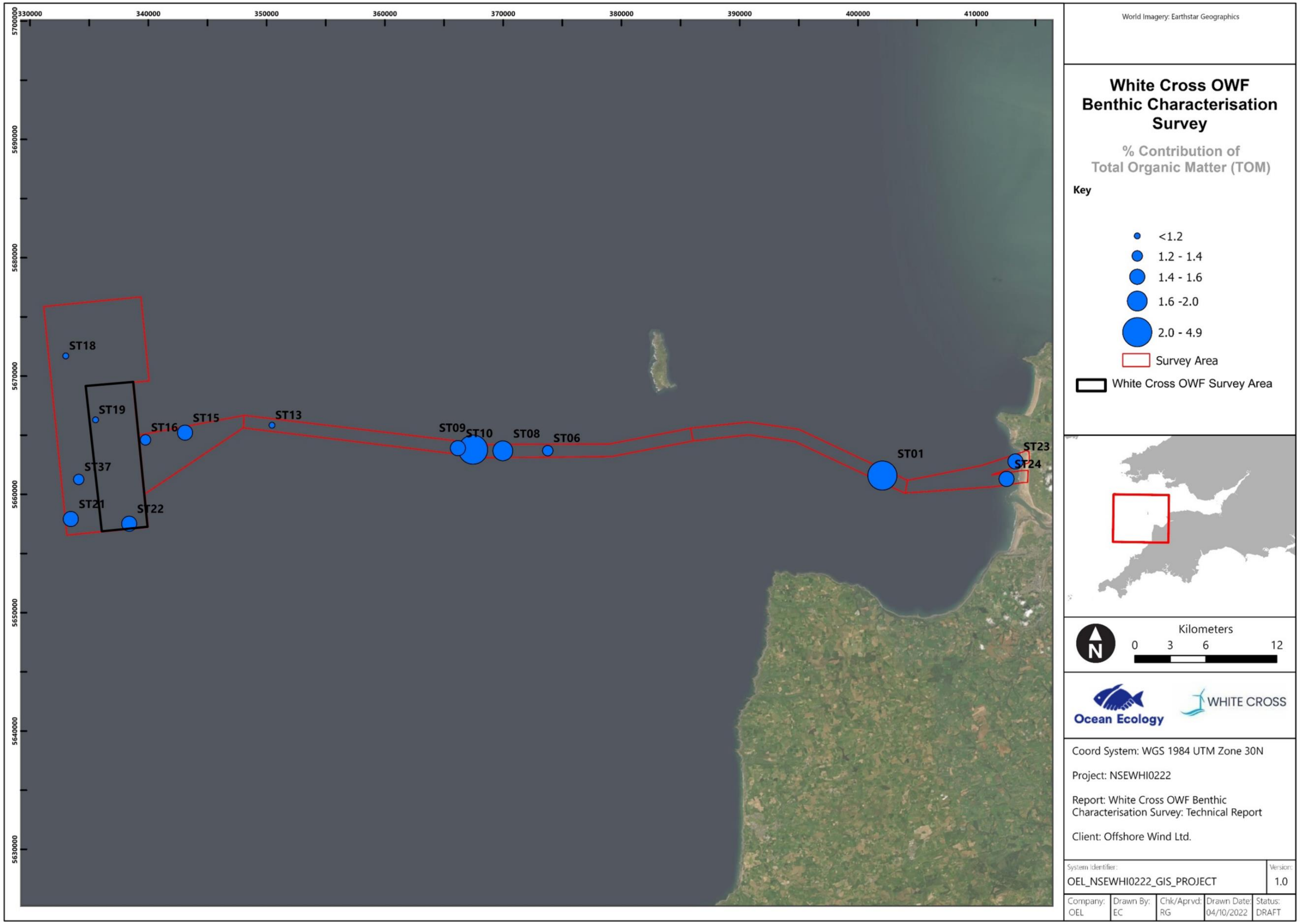

Figure 9 Percentage contribution of TOM across the survey area.

7.2.2. Heavy and Trace Metals

A total of eight main heavy and trace metals were analysed from sediments taken at each of the 15 sampling stations. These were: Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni), and Zinc (Zn).

Raw data for the eight main heavy and trace metals (dry-weight concentration, mg kg^{-1}) are shown in Table 11 together with available reference levels (see Section 6.2.2 for details on national and international reference levels). Two of the main heavy and trace metals exceeded Cefas AL 1, these were As (mean value ± SE across survey area of 21.4 ± 3.88 mg kg^{-1}) at four stations: ST06, ST08, ST09 and ST10 and Ni (mean value ± SE across survey area of 10.9 ± 1.24 mg kg^{-1}) at ST01. The mean value for As across the survey site was calculated to be above the Cefas AL 1 refence level. Levels of As also exceeded the PEL reference level at two survey stations. However, As and Ni concentrations were well below the Cefas AL 2 threshold level. Of notice, Cd was below detection limit (0.04 mg kg^{-1}) at seven of the 15 stations sampled.

The most abundant metal was Zn which ranged from 27.9 mg kg^{-1} at ST37 to 108 mg kg^{-1} at ST01, however, it was always recorded below any of the reference levels (Table 11). Also recorded in relatively high concentrations was As, ranging between 11.0 mg kg^{-1} at ST22 and 54.2 mg kg^{-1} at ST06. The third most abundant metal was Pb which varied from 9.20 mg kg^{-1} at ST19 and ST21 and 36.0 mg kg^{-1} at ST01, these Pb levels did not exceed reference levels. Similarly, Cr was detected at higher concentrations (mean value across survey area of 12.7 mg kg^{-1} ±1.25 mg kg^{-1}) but also did not exceed reference levels.

Figure 10 illustrates the spatial distribution of these four metals across the survey area. Typically, Zn, Pb, Cr, and As had lower concentrations at stations located more offshore with no obvious east-west concentration gradient.

No clear trend was observed between the concentration of heavy and trace metals and the amount of mud in the sediments.

Table 11 Main heavy and trace metals (mg kg^{-1}) in sediments. Shading indicates values above AL1.

Analyte	Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Mercury (Hg)	Nickel (Ni)	Lead (Pb)	Zinc (Zn)
ST01	16.20	0.07	24.70	16.40	0.14	21.60	36.00	108.00
ST06	54.20	< 0.04	12.80	7.10	0.03	12.30	17.00	38.30
ST08	40.70	0.06	12.60	8.30	0.05	11.60	17.60	50.80
ST09	22.70	0.06	22.80	13.40	0.09	18.90	29.30	89.30
ST10	49.80	< 0.04	10.10	7.50	0.03	13.60	13.60	37.40
ST13	13.60	< 0.04	9.40	4.50	0.03	6.80	10.70	33.40
ST15	13.60	< 0.04	10.40	4.90	0.02	7.10	10.00	41.60
ST16	12.10	0.05	10.40	4.30	0.02	6.90	9.30	32.30
ST18	13.10	< 0.04	10.80	5.20	0.02	7.10	10.40	35.80
ST19	12.10	< 0.04	10.30	4.70	0.02	6.70	9.20	34.80
ST21	12.00	0.06	10.00	4.90	0.02	6.30	9.20	28.60
ST22	11.00	0.06	10.20	4.90	0.02	7.10	9.60	33.50
ST23	18.60	0.05	11.10	6.80	0.02	13.70	16.00	69.00
ST24	19.30	0.04	11.00	6.20	0.02	13.70	15.90	65.40
ST37	11.40	< 0.04	14.00	4.20	0.02	9.30	9.70	27.90
Min	11.00	0.04	9.40	4.20	0.02	6.30	9.20	27.90
Max	54.20	0.07	24.70	16.40	0.14	21.60	36.00	108.00
Mean	**21.36**	**0.06**	**12.71**	**6.89**	**0.04**	**10.85**	**14.90**	**48.41**
Standard Error	3.75	0.00	1.20	0.91	0.01	1.24	2.05	6.20
CEFAS AL1	20	0.4	40	40	0.3	20	50	130
CEFAS AL2	100	5	400	400	3	200	500	800
OSPAR BAC	25	0.31	81	27	0.07	36	38	122
ERL	8.2*	1.2	81	34	0.15	21*	47	150
TEL	7.24	0.7	52.3	18.7	0.1	-	30.2	124
PEL	41.6	4.2	160	108	0.7	-	112	271

*The ERLs for As and Ni are below the BACs therefore As and Ni concentrations are usually assessed only against the BAC.

Table 12 Number of stations across the White Cross survey area exhibiting elevated heavy and trace metals levels in comparison with OSPAR, CEFAS and Canadian/International Sediment Quality Guidelines.

Metal	OSPAR		CEFAS		Canadian SQG	
	BAC	ERL	AL1	AL2	TEL	PEL
As	3	15*	4	0	15	2
Cd	0	0	0	0	0	0
Cr	0	0	0	0	0	0
Cu	0	0	0	0	0	0
Pb	0	0	0	0	1	0
Hg	2	0	0	0	1	0
Ni	0	1*	1	0	-	-
Zn	0	0	0	0	0	0

*The ERLs for As and Ni are below the BACs therefore As and Ni concentrations are usually assessed only against the BAC.

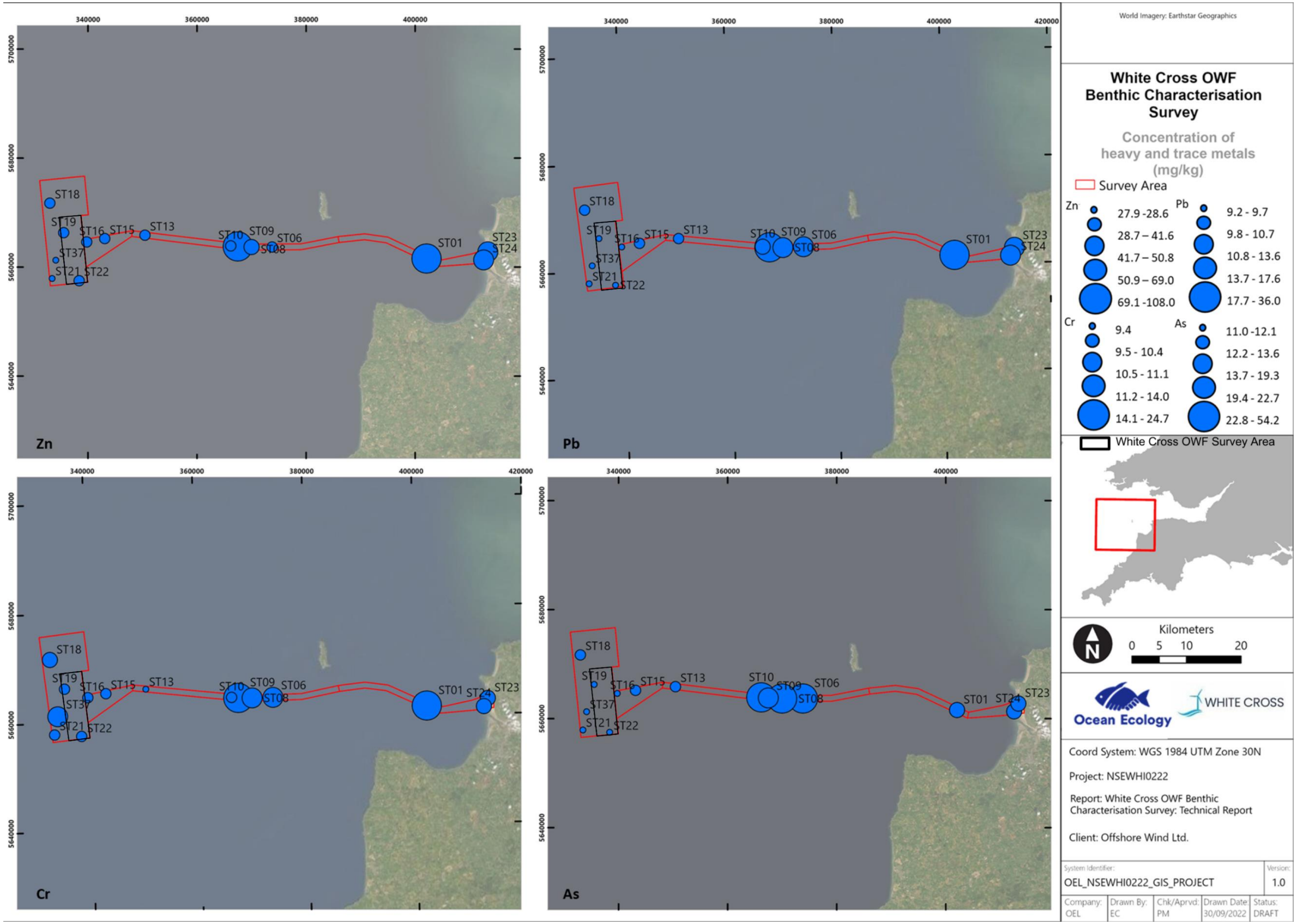

Figure 10 Concentration of the key heavy and trace metals sampled across the survey area. Note different scales for each chemical.

7.2.3. Polycyclic Aromatic Hydrocarbons (PAHs) and Total Hydrocarbons (THC)

The full range of PAHs as specified in the Department of Trade and Industry (DTI) regulations (DTI 1993) as well as by the EPA was tested for all 15 contaminant sub-samples collected.

The results of the PAHs analysis undertaken are reported in Appendix XI. PAH concentrations were compared to Cefas AL1 (no Cefas AL2 available for PAHs), OSPAR BAC levels and ERLs, and TEL and PEL where possible (Table 13). The Cefas AL1 reference level was exceeded at ST09 for Fluoranthene. Both the BAC and TEL reference levels were exceeded at ST08 and ST09 for multiple PAHs including Naphthalene, Phenanthrene, Pyrene, Acenaphthene, Acenaphthylene, Anthracene, Benzo[a]anthracene, Benzo[a]pyrene, Dibenzo[ah]anthracene, Fluoranthene, and Fluorene (Table 13 and Table 14). However, when averaged across the survey area, only Naphthalene concentrations (mean value across survey area of 8.19 $\mu g\ kg^{-1} \pm 4.03\ \mu g\ kg^{-1}$) exceeded the BAC reference level.

The most abundant PAHs were: Fluoranthene with a mean concentration across the survey area of 16.61 $\mu g\ kg^{-1} \pm 8.01\ \mu g\ kg^{-1}$ and a maximum concentration of 122.00 $\mu g\ kg^{-1}$ at ST09, Phenanthrene with a mean concentration across the survey area of 13.25 $\mu g\ kg^{-1} \pm 6.25\ \mu g\ kg^{-1}$ and a maximum concentration of 98.00 $\mu g\ kg^{-1}$ at ST09 and Pyrene with a mean concentration across the survey area of 13.07 $\mu g\ kg^{-1} \pm 6.23\ \mu g\ kg^{-1}$ and a maximum concentration of 95.00 $\mu g\ kg^{-1}$ at ST09.

PAHs with an elevated concentration above refence levels were only found at ST09 and ST08. All other stations saw PAHs with levels below all reference levels (Table 13 and Table 14). In general PAHs showed no obvious trend and no clear east-west gradient was observed. Higher concentrations of PAHs were observed as ST09 and ST08 which are located in the middle of the survey area cable route.

To determine the origin source of PAH compounds in sediments, the ratio between LMW and HMW PAHs was calculated. Based on this ratio all stations were characterised by PAHs of pyrogenic origin (LMW/HMW < 1). Similarly, the ratios of Phenanthrene / Anthracene (Ph/Ant) indicated a pyrogenic origin of PAHs as this ratio was below 10 at all stations. However, it should be noted that Anthracene concentrations were below detection limit at 6 of the 15 stations and therefore it was not possible to calculate Ph/Ant at these locations. Therefore, the Fluoranthene / Pyrene ratio (Fl/Py) was calculated to determine the origin of PAHs. At all stations the Fl/Py ratio was higher than one at all stations indicating a pyrogenic origin source of PAHs across the survey area (Figure 11).

Table 13 Summary of PAH concentrations (µg kg^{-1}) in sediments. Shading indicates values above reference levels.

Analyte	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene
Min	< 1	< 1	< 1	< 1	< 1	< 1
Max	***60***	***7.44***	***13.00***	***25.60***	***98.00***	***18.3***
Station of Max	ST09	ST09	ST09	ST09	ST09	ST09
Cefas AL1	**100**	**100**	**100**	**100**	**100**	**100**
Cefas AL2	-	-	-	-	-	-
BAC	**8**	-	-	-	**32**	**5**
ERL	**160**	-	-	-	**240**	**85**
TEL	**34.6**	**5.87**	**46.9**	**21.2**	**86.7**	**46.9**
PEL	**391**	**128**	**245**	**144**	**544**	**245**

Analyte	Fluoranthene	Pyrene	Benzo[a]anthracene	Chrysene (inc. Triphenylene)	Benzo[b]fluoranthene	Benzo[k]fluoranthene
Min	2.09	< 1	< 1	1.30	1.67	< 1
Max	***122.0***	***95.0***	***60.90***	***95.0***	***102.0***	***40.8***
Station of Max	ST09	ST09	ST09	ST09	ST09	ST09
Cefas AL1	**100**	**100**	**100**	**100**	-	-
Cefas AL2	-	-	-	-	-	-
BAC	**39**	**24**	**16**	**20**	-	-
ERL	**600**	**665**	**261**	**384**	-	-
TEL	**113**	**153**	**74.8**	**108**	-	-
PEL	**1494**	**1398**	**693**	**846**	-	-

Analyte	Benzo[e]pyrene	Benzo[a]pyrene	Perylene	Ideno[123,cd]pyrene	Dibenzo[a,h]anthracene	Benzo[ghi]perylene
Min	1.23	< 1	< 1	1.05	< 1	1.12
Max	***74***	***79.30***	***21.8***	***79.7***	***17.3***	***77.4***
Station of Max	ST09	ST09	ST09	ST09	ST09	ST09
Cefas AL1	-	**100**	-	**100**	**100**	**100**
Cefas AL2	-	-	-	-	-	-
BAC	-	**30**	-	**103**	-	**80**
ERL	-	**430**	-	-	-	-
TEL	-	**88.8**	-	-	**6.22**	-
PEL	-	**763**	-	-	**135**	-

Table 14 Number of stations across the survey area exhibiting elevated PAHs levels in comparison with OSPAR and Canadian Sediment Quality Guidelines (CSQG). Fluoranthene exceeded Cefas AL1.

Analyte	Cefas	OSPAR		CSQG	
	AL1	BAC	ERL	TEL	PEL
Acenaphthene	0	-	-	1	0
Acenaphthylene	0	-	-	1	0
Anthracene	0	2	0	0	0
Benzo[a]anthracene	0	2	0	0	0
Benzo[a]pyrene	0	1	0	0	0
Benzo[b]fluoranthene	-	-	-	-	-
Benzo[ghi]perylene	0	0	0	-	-
Benzo[e]pyrene	-	-	-	-	-
Benzo[k]fluoranthene	-	-	-	-	-
Chrysene	0	0	0	0	0
Dibenzo[ah]anthracene	0	-	-	1	0
Fluoranthene	1	2	0	1	0
Fluorene	0	-	-	1	0
Indeno[1,2,3-cd]pyrene	0	0	0	-	-
Naphthalene	0	2	0	1	0
Perylene	0	-	-	-	-
Phenanthrene	0	2	0	1	0
Pyrene	0	2	0	0	0

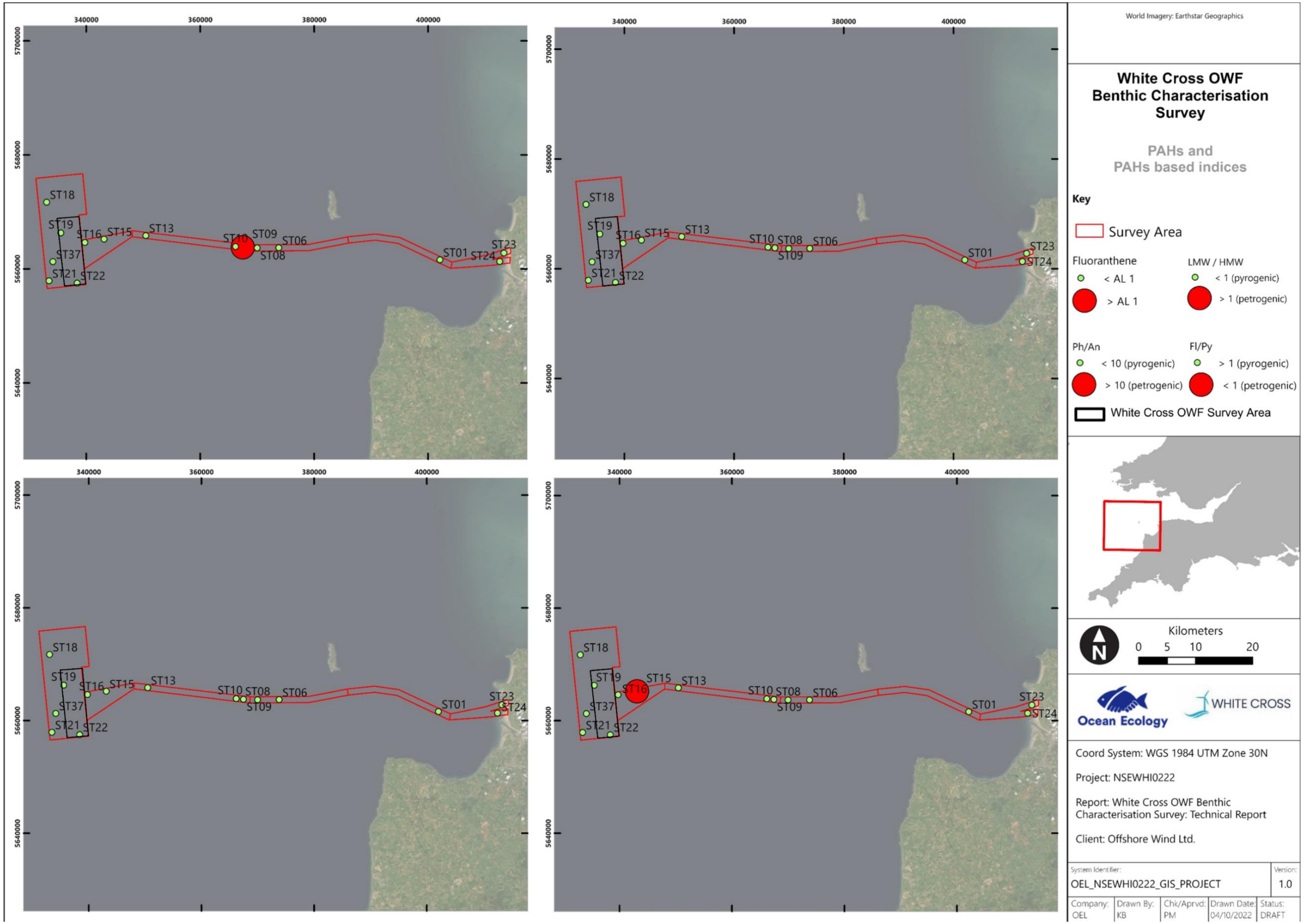

Figure 11 Concentration (µg kg^{-1}) of Fluoranthene against Cefas AL1 and PAHs based indices across the survey area. Note different scales for each chemical.

7.2.4. Organotins

The concentrations of two organotins (Dibutyltin (DBT) and Tributyltin (TBT)) were analysed from the sediment taken at each of the 15 station and reported in Appendix XI.

All stations had organotin concentrations below the detection limit of 0.001 mg kg^{-1}. To provide context, Cefas AL1 for organotins is 0.1 mg kg^{-1} and AL2 is 1 mg kg^{-1}.

7.2.5. Polychlorinated Biphenyls (PCBs)

All 25 PCBs congeners were analysed from the sediments taken at each of the 15 stations and reported in Appendix XI.

No Cefas Action Levels exist for each individual PCBs, however most PCBs had concentrations below the detection limit of 0.00008 mg kg^{-1} across the survey area. Cefas Action Levels do exist for the sum of all 25 PCBs congeners (Σ25PCBs) and for the sum of the 7 ICES PCBs (ΣICES7) as reported in Table 15. The 7 ICES PCBs have been selected to cover the range of toxicological properties of the group. Both Σ25PCBs and ΣICES7 were above Cefas AL1 at station ST01, while only Σ25PCBs was above Cefas AL1 at ST10. At all stations both Σ25PCBs and ΣICES7 were below Cefas AL 2.

Table 15 PCBs (mg kg^{-1}) against Cefas AL1 and AL2. Shading indicates concentrations above AL1.

Station	Σ25PCBs	ΣICES7
ST01	0.039	0.014
ST06	0.000	0.000
ST08	0.004	0.002
ST09	0.012	0.004
ST10	0.023	0.008
ST13	0.010	0.003
ST15	0.000	0.000
ST16	0.000	0.000
ST18	0.000	0.000
ST19	0.000	0.000
ST21	0.000	0.000
ST22	0.000	0.000
ST23	0.000	0.000
ST24	0.015	0.004
ST37	0.002	0.001
CEFAS AL1	0.02	0.01
CEFAS AL2	0.2	-

7.3. Macrobenthos

7.3.1. Macrobenthic composition

A diverse macrobenthic assemblage was identified across the survey area from the 134 macrobenthic samples collected, with a total of 12,651 individuals and 487 taxa recorded. The mean (± SE) number of taxa per station was 27 ± 2, mean (± SE) abundance per station was 94 ± 11 and mean (± SE) biomass per station was 0.3945 ± 0.1205 gAFDW.

The full abundance matrix is provided in Appendix XII. The biomass (gAFDW) of each major taxonomic group (Annelida, Crustacea, Mollusca, Echinodermata, and Miscellaneous) in each sample collected is presented in Appendix XIII.

As shown in Figure 12, juvenile specimens of the brittle star family Amphiuridae were the most abundant taxon sampled accounting for 11.4 % of all individuals recorded. They were also the most frequently occurring taxon recorded in 72.4 % of samples and accounted for the greatest average density per sample. Other key taxa were the Ross worm *S. spinulosa*, which accounted for the maximum abundance per sample (Figure 12c), and the two-toothed Montagu shell *Kurtiella bidentata* which was second to the juveniles of Amphiuridae in contribution to abundance and average density per sample.

Figure 13 illustrates the relative contributions to total abundance, diversity, and biomass of the major taxonomic groups in the macrobenthic community sampled across the survey area. Annelida taxa contributed most to abundance as they accounted for approximately 37 % of all individuals recorded, followed by Echinodermata taxa accounting for the 25 %. Annelida taxa contributed the most to the overall diversity of the macrobenthic assemblages at 44 %, while Echinodermata taxa dominated the biomass and accounted for the 52% of the total biomass (Figure 13).

The sampling stations with the highest abundance were stations ST118, ST009 and ST006 all of which dominated by Annelida taxa (Figure 14). Sampling stations with the highest richness (number of taxa) were stations ST118, ST003 and ST106 with specimens belonging to 152, 105 and 104 different taxa, respectively (Figure 14). Biomass ranged between 0.0021 and 15.2515 gAFDW per sample, with the highest value found at station ST118 due to high Echinodermata biomass (Figure 14).

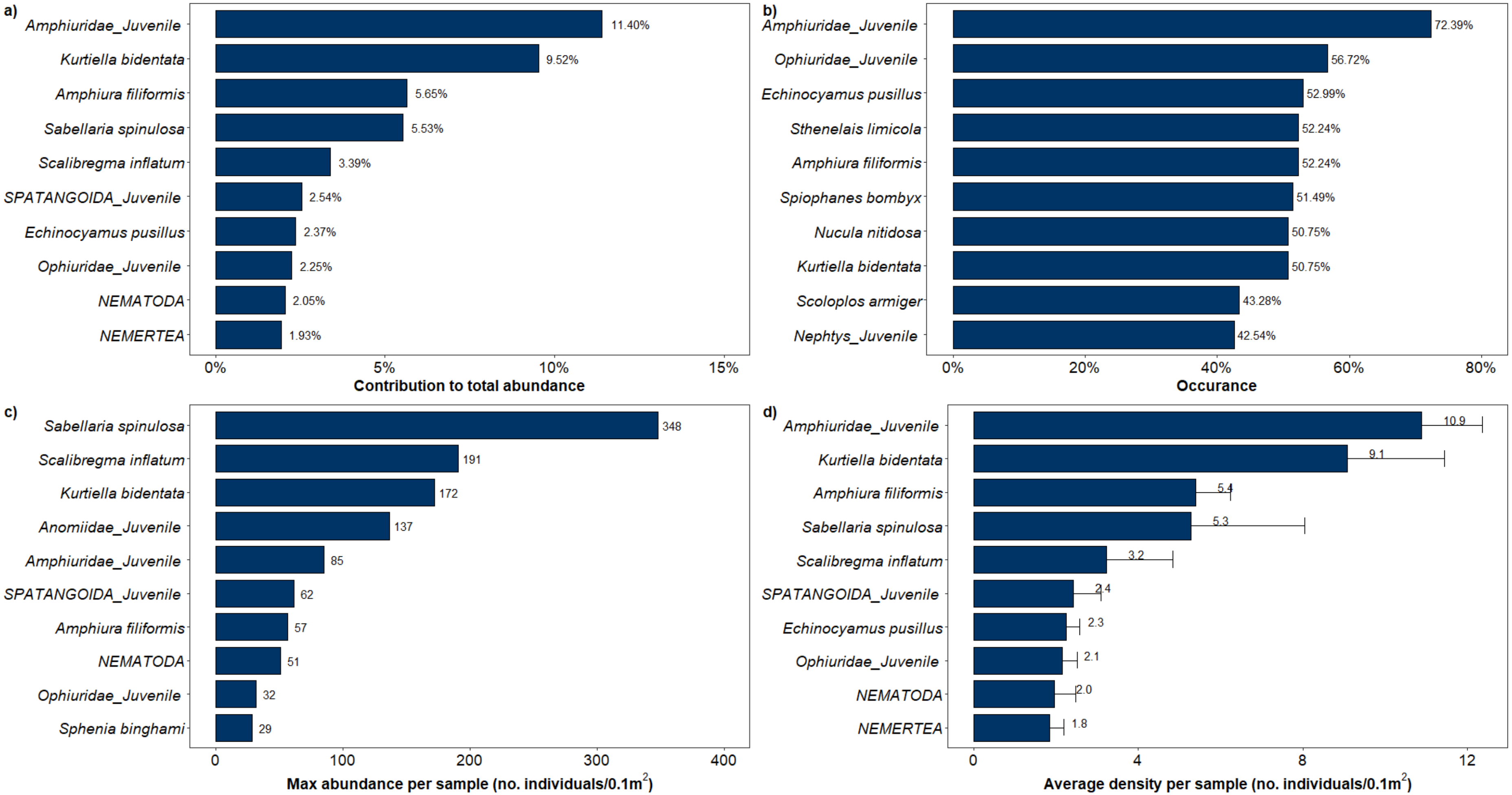

Figure 12 Percentage contributions of the top 10 macrobenthic taxa to total abundance (a) and occurrence (b) from samples collected across the survey area. Also shown are the maximum densities of the top 10 taxa per sample (c) and average densities of the top 10 taxa per sample (d).

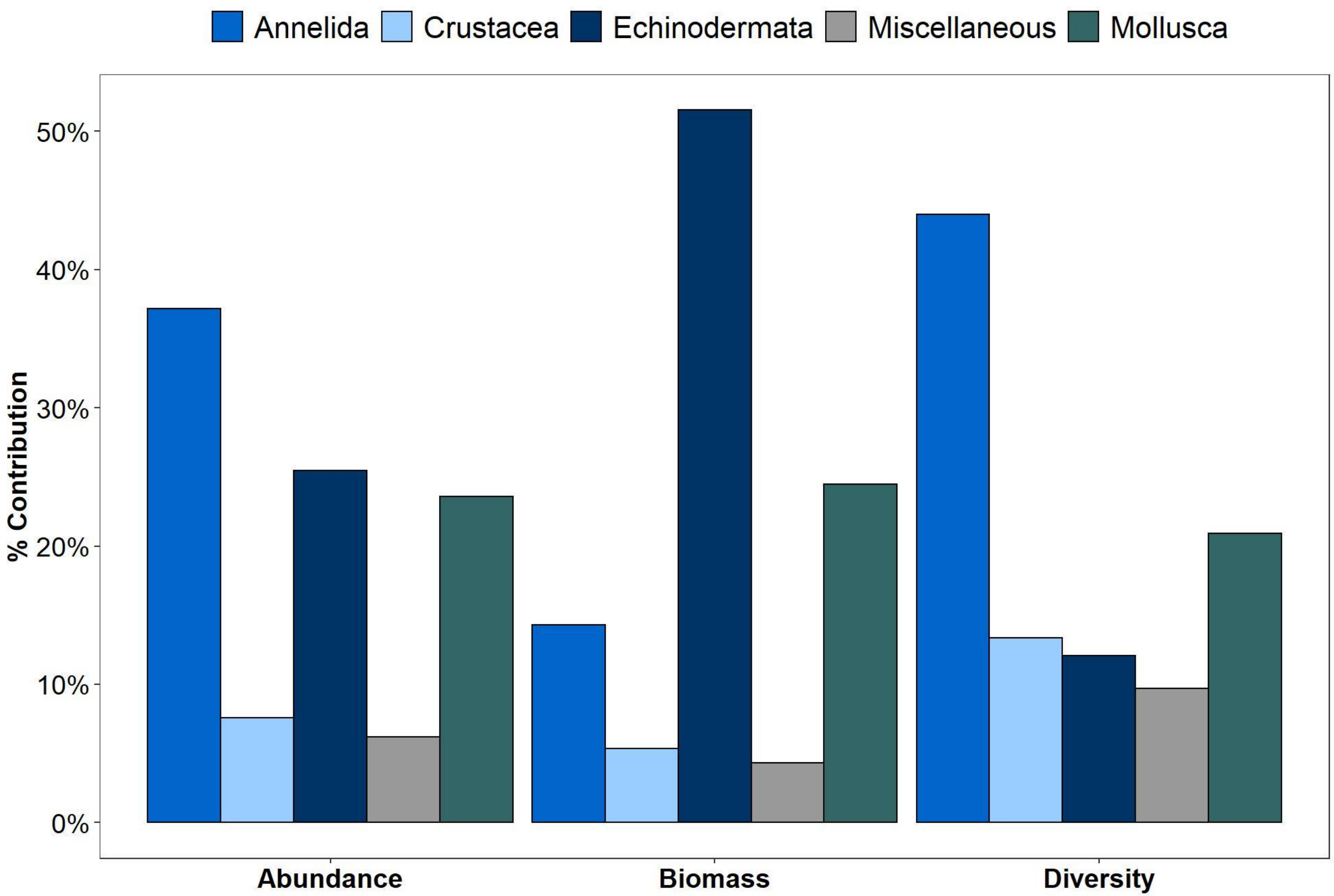

Figure 13 Relative contribution of the major taxonomic groups to the total abundance, diversity and biomass of the macrobenthos sampled across the survey area. Abundance counts exclude colonial taxa.

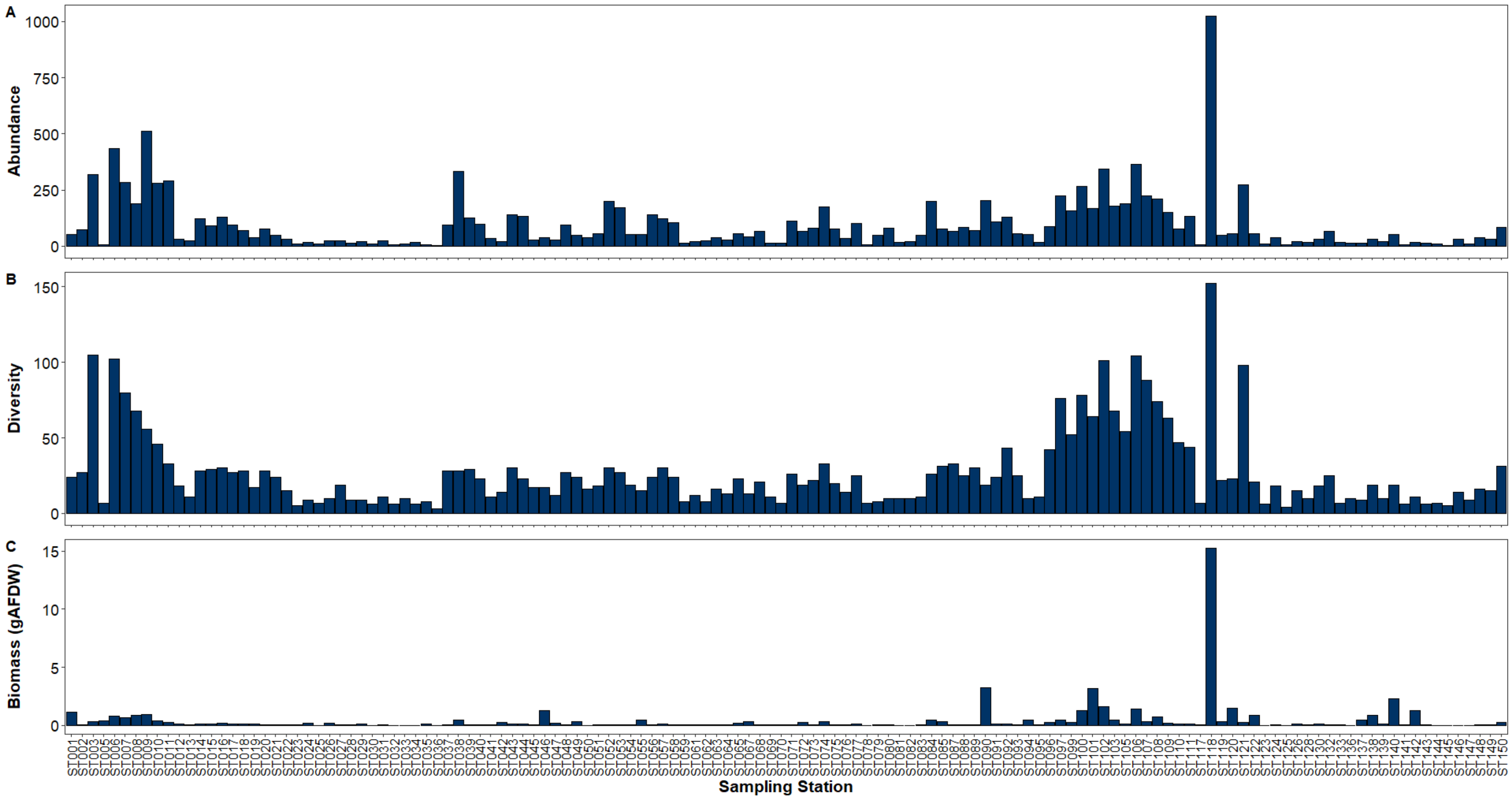

Figure 14 Abundance, diversity and biomass (gAFDW) per station across the White Cross survey area.

7.4. Macrobenthic Groupings

Multivariate analysis was undertaken on the square-root transformed macrobenthic grab abundance data, to identify spatial distribution patterns in the macrobenthic assemblages across the survey area and identify characterising taxa present.

Cluster analysis of the macrobenthic data was performed on a Bray-Curtis similarity matrix to analyse the spatial similarities in macrobenthic communities recorded across all sampled stations. The dendrogram resulting from the cluster analysis and associated Type 1 SIMPROF (similarity profile routine) permutation test of all nodes within the dendrogram, identified 22 statistically significantly similar groups ($p > 0.05$) and 6 outlier stations that did not belong to any group. A dendrogram resulting from the cluster analysis and associated Type 1 SIMPROF permutation test are provided in Appendix XIV. To enable a broad interpretation of the community present across the survey area, a similarity slice at 31 % was used to amalgamate the 28 SIMPROF groups which yielded to 15 broader macrobenthic groups and 14 outlier stations remaining on their own; 7 of the 15 macrobenthic groups were made of only two or three stations each.

To visualise the relationships between the sampled macrobenthic assemblages, a non-metric multi-dimensional scaling (nMDS) plot was generated on the community abundance data (Figure 15). The nMDS represents the relationships between the communities sampled, based on the distance between sample (station) points. The stress value of the nMDS ordination plot (0.22) indicates that the two-dimensional plot provides a reasonable representation of the similarity between stations, however caution needs to be used when interpreting patterns between and within groups. This relatively high stress value is most likely due to the presence of several groups (clusters) made only of a few stations owning the high diversity in the macrobenthic community observed across the survey area. In general, the degree of clustering of intra-group sample points demonstrates the level of within group similarity (e.g., points within Macrobenthic Group H shows distinct clustering), whilst the degree of overlap of inter-group sample points is indicative of the level of similarity between different Macrobenthic Groups (e.g., Macrobenthic Groups L and K).

SIMPER (similarity percentage analysis) was used to identify the key taxa contributing to the within group similarity of each of the 15 macrobenthic groups; the full SIMPER results are provided in Appendix XV.

Macrobenthic Group A (2 stations) - Characterising taxa present at the two stations (ST024 and ST025) belonging to this group were the hermit crab *Diogenes pugilator* and the amphipod *Bathyporeia elegans.* Average similarity of this group was 35.13 %.

Macrobenthic Group B (2 stations) - The taxa contributing most to similarities between the two sampling stations (ST130 and ST150) within this group (average similarity: 34.57%) were Nemertea, the polychaete *Spiophanes bombyx*, the pea urchin *E. pusillus* and the bivalve *Goodallia triangularis*.

Macrobenthic Group C (2 stations) – Dominant taxa contributing within this group were the tellin *Asbjornsenia pygmaea*, the cumacean *Bodotria scorpioides*, the pea urchin *E. pusillus* and the bivalve *G. triangularis* all together contributing to over 55% of t the within group average similarity of 42.09%.

Macrobenthic Group D (2 stations) – Characterising taxa present at the two stations (ST002 and ST111) belonging to this group (average similarity 40.86 %) were the bivalves *A. pygmea* and *Spisula elliptica*, the pea urchin *E. pusillus* and the polychaete *Glycera lapidum*.

Macrobenthic Group E (3 stations) – Key taxa contributing to the within group average similarity of 39.79 % were the Ross worm *S. spinulosa*, the pea urchin *E. pusillus*, the polychaete *Lumbrineris cingulata* and the brittle star *Amphipholis squamata*. Stations ST003, ST118 ST121 belonged to this group.

Macrobenthic Group F (15 stations) – Characterising taxa present at the stations belonging to this group were the polychaetes *Mediomastus fragilis*, *G. lapidum*, *Syllis garciai* and *Lumbrineris*, venerid bivalves such as *Spisula* sp. and *Diplodonta rotundata*, the pea urchin *Echinocyamus pusillus* along with amphipods such as *Ampelisca spinipes*. Average similarity of this group was 40.11 %.

Macrobenthic Group G (4 stations) – The taxa contributing most to similarities between the four sampling stations within this group (average similarity: 38.15%) were juvenile specimens of Ophiuridae, the bivalve *Nucula nitidosa* and the pea urchin *E. pusillus*.

Macrobenthic Group H (13 stations) – Key taxa contributing to the within group average similarity of 36.22% were the bean-like tellin *Fabulina fabula*, the polychaete *Magelona johnstoni* and juveniles of the venerid bivalve *Spisula*.

Macrobenthic Group I (2 stations) – Only two stations (ST012 and ST128) belonged to this group with the pea urchin *E. pusillus* and juveniles of the heart urchin Spatangoida and of the polychaete *Nephtys* contributing to over 80 % of the within group average similarity of 35.42 %

Macrobenthic Group J (4 stations) –The key taxa contributing to the average similarity of 45.44% were the amphipod *Bathyporeia elegans* and juveniles of the polychaete *Nephtys*.

Macrobenthic Group K (7 stations) – Key taxa characterising this group were the bivalves *Kurtiella bidentata* and *N. nitidosa*, and echinoderms such as juveniles of Amphiuridae and Ophiuridae. Average similarity of this group was 41.79 %.

Macrobenthic Group L (6 stations) – Key taxa contributing to the within group average similarity of 36.22% were the brittle star *Amphiura filiformis* and the polychaetes *Lumbrineris cingulata* and *Scoloplos armiger*.

Macrobenthic Group M (56 stations) – This was the largest of the macrobenthic groups and was characterised by the following key taxa contributing to the within group average similarity of 39.91%: the brittle star *A. filiformis*, the bivalves *K. bidentata, N. nitidosa* and *Abra prismatica*, the polychaetes *Spiophanes bombyx* and *S. armiger* and the pea urchin *E. pusillus*.

Macrobenthic Group N (2 stations) – Only two stations (ST141 and ST144) belonged to this group with the transparent razor shell *Phaxas pellucidus* and the basket shell *Varicorbula gibba* contributing to the within group average similarity of 32.94 %

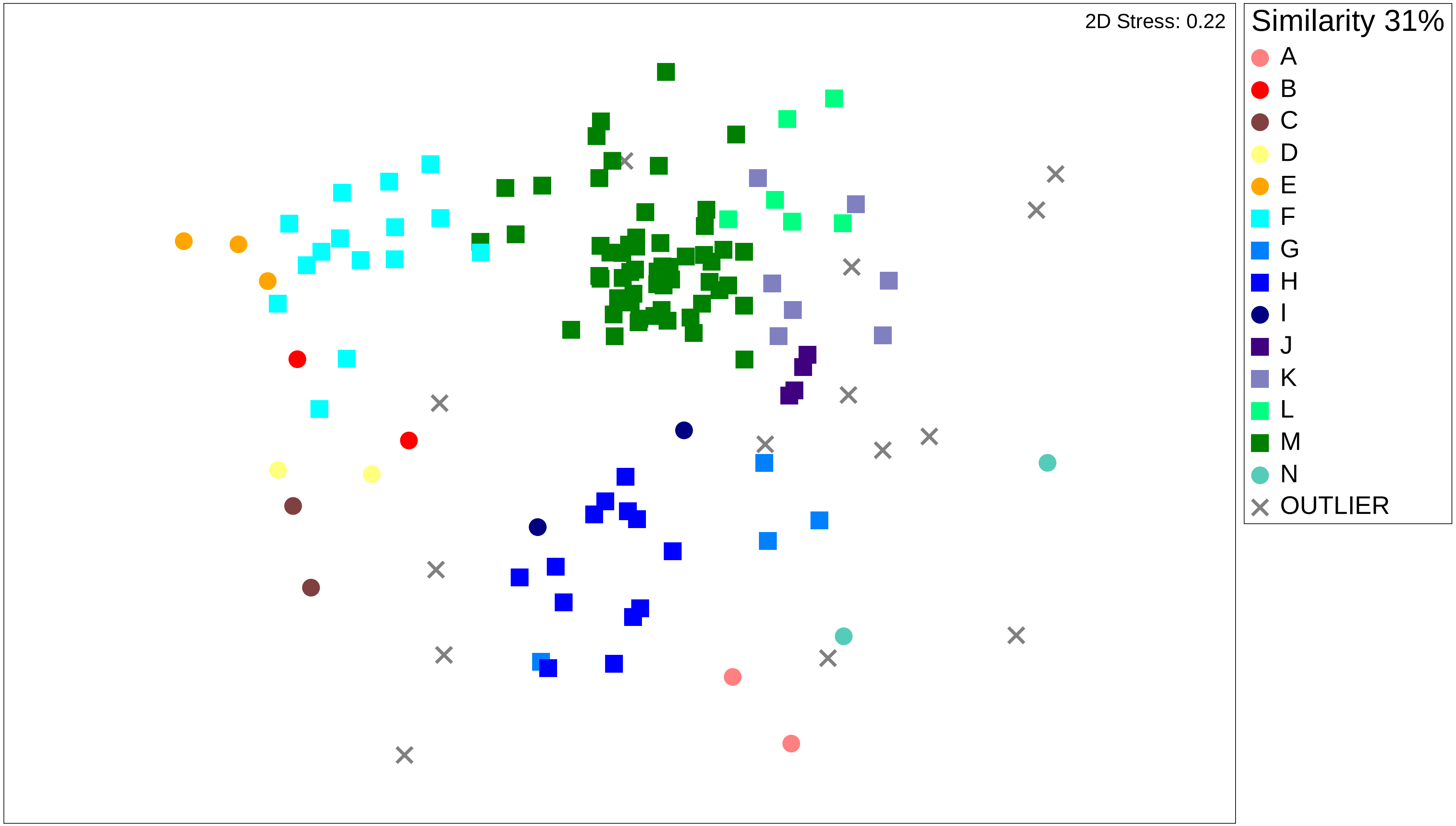

Figure 15 Two-dimensional nMDS ordination of macrobenthic communities sampled across the survey area, based on square root transformed and Bray-Curtis similarity abundance data. Samples symbolised based on similarity slice at 31 %. Circles indicate groups made up of three or less stations, squares indicate groups made up of more than three stations; crosses indicate outliers.

7.4.1. Biotope Assignment

For each of the Macrobenthic Groups determined using cluster analysis and a 31 % similarity slice, biotopes and habitats were assigned in line with JNCC guidance based upon their faunal and physical characteristics (Parry 2019). The spatial distribution of the habitat and biotopes encountered across the survey area is mapped in Figure 16.

All outlier stations were assigned to their corresponding BSH based on sediment analysis as the macrobenthic multivariate analysis did not show any pattern in the community composition that could be used to assign a biotope.

Similarly, most of the macrobenthic groups which were made up of only a handful of stations were assigned to level 4 EUNIS classifications as their macrobenthic assemblages were not dominated by any key taxa typically associated to a biotope. Therefore, macrobenthic groups B, C and D most closely aligned with EUNIS level 4 habitat "A5.14 Circalittoral coarse sediment", macrobenthic group A was classified as EUNIS "A5.25 Circalittoral fine sand", while macrobenthic groups G, K and L best aligned with EUNIS level 4 habitat "A5.26 Circalittoral muddy sand".

Despite only comprising three stations, the community observed in Macrobenthic Group E was very distinctive and most closely aligned with the biotope "A5.142 *Mediomastus fragilis, Lumbrineris spp.* and venerid bivalves in circalittoral coarse sand or gravel". This biotope is described as typical of circalittoral gravels and/or coarse to medium sands which is consistent with the sediment found at the stations falling into this group. Additionally key characterising taxa of A5.142 such as *M. fragilis, L. cingulata, G. lapidum, E. pusillus,* Nemertea*, S. bombyx, A. squamata, Timoclea ovata* and *Hydroides norvegicus* were all driving community average similarity within macrobenthic group E.

Two biotopes aligned with the community observed within Macrobenthic Group F: "A5.142 *Mediomastus fragilis, Lumbrineris spp.* and venerid bivalves in circalittoral coarse sand or gravel" and "A5.451 Polychaete-rich deep *Venus* community in offshore mixed sediments". As Macrobenthic Group F was made up of a mixture of stations classified as either "A5.1 coarse sediment" or "A5.4 Mixed sediment" based on PSA data alone, it is not surprising that a mosaic biotope was identified at these locations which reflects local heterogeneities in the seabed. Characterising taxa of this mosaic biotope included *M. fragilis, G. lapidum, E. pusillus,* Nemertea, *Ampelisca spinipes, L. cingulata,* syllid species and venerid bivalves such as *Spisula* and *Diplodonta*.

The biotope that most closely aligned with the community observed in Macrobenthic Group H was "A5.242 *Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand". This biotope is typical of infralittoral stable fine sands and slightly muddy sands which is consistent with the PSA results however stations belonging to this group were mostly located in the main array not in the infralittoral zone (Figure 16). Characterising taxa of this biotope include *F. fabula, Magelona* spp. as well as *S. bombyx* and *Spisula* sp. all of which drove community average similarity within macrobenthic group H.

The biotope that most closely aligned with the community observed in Macrobenthic Group J was "A5.233 - *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand". This is consistent with the PSA results which classified the stations falling into this group as sand and muddy sand. This biotope occurs in sediment subject to physical disturbance as the result of wave action in shallow waters (< 30 m). Once again, stations belonging to this group were not located in the infralittoral zone but more offshore in the "fan" section of the survey area and main array (Figure 16).

Two biotopes aligned with the community observed in Macrobenthic Group M: "A5.252 -*Abra prismatica*, *Bathyporeia elegans* and polychaetes in circalittoral fine sand" and "A5.351 - *Amphiura filiformis*, *Mysella bidentata* and *Abra nitida* in circalittoral sandy mud". Macrobenthic Group M included 56 of the 134 stations analysed of which 47 were classified as BSH A5.2 while the remaining were a mix of BSHs A5.1, A5.3 and A5.4. Considering that this group covered a large portion of the survey area with slight variations in sediment type and composition, it is not surprising that a mosaic biotope was identified at these locations. Characterising taxa of this mosaic biotope included *A. filiformis, K. bidentata, N. nitidosa, E. pusillus, A. prismatica* and *S. bombyx*.

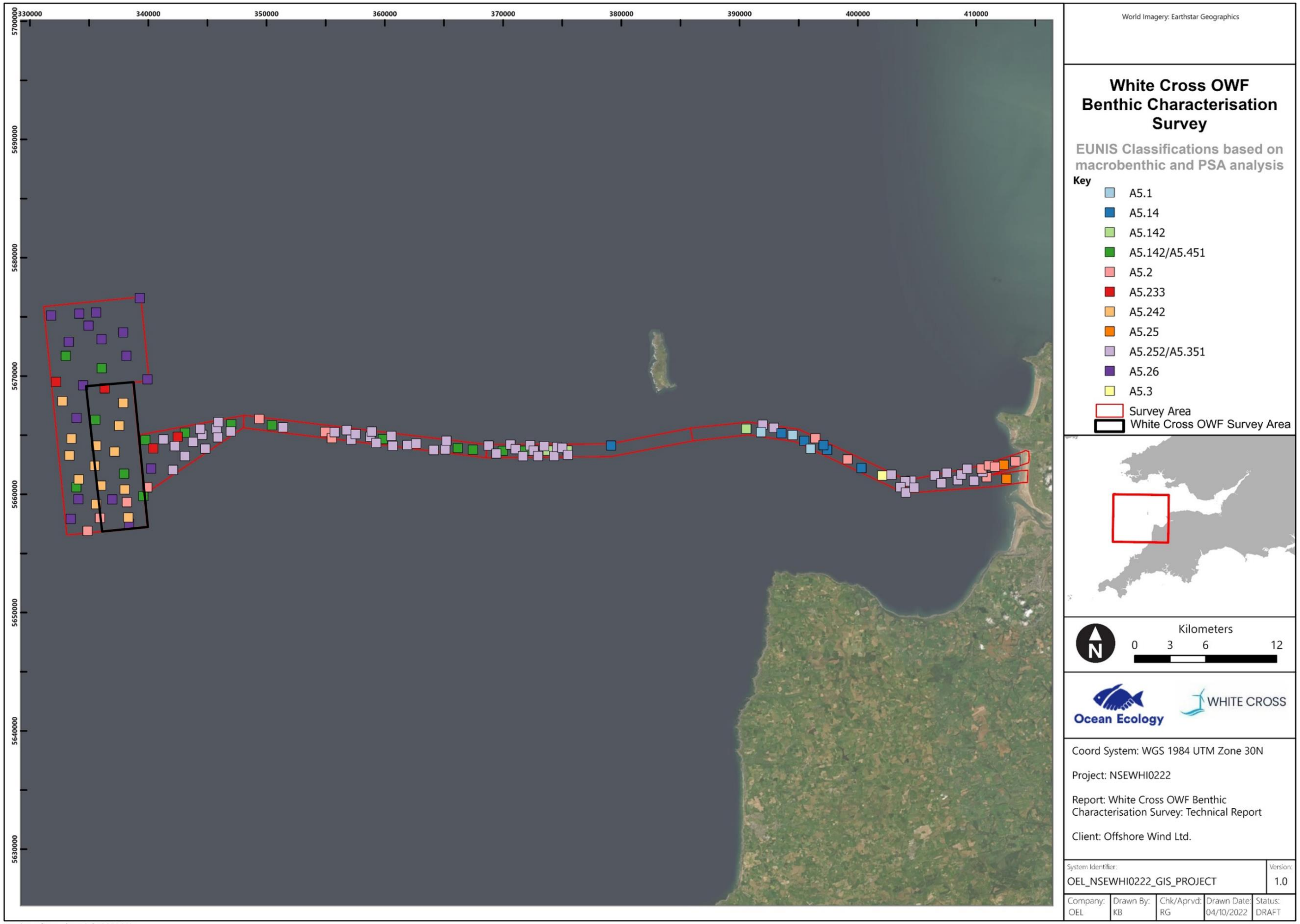

Figure 16 Spatial distribution of habitat and biotopes identified across the survey area based on macrobenthic and sediment analysis.

7.5. Notable Taxa

Five taxa of interest were identified from the 134 grab samples collected across the survey area (Table 16).

The polychaete *Goniadella gracilis* is an invasive non-native species (INNS) and occurred only at 9 stations where a total of 34 individuals were identified. This species is native of Southern Africa and North-eastern USA with the first record in UK water dating back to 1970 in Liverpool Bay[8].

Another INNS observed across the survey area was the Slipper limpet *Crepidula fornicata* which only occurred at station ST121 where one individual was identified. This species is native of the Atlantic coast of the USA and was imported to England in the late 1800s together with American oysters.

The Ross worm *S. spinulosa* is a protected species when occurring in reef form under the OSPAR list of threatened and/or declining species and habitats (2008) and as an Annex I species under the EU Habitat Directive. The latter directive has been transposed into UK law under the Conservation of Offshore Marine Habitats and Species Regulations 2017 (as amended)[9]. A total of 708 specimens of *S. spinulosa* were identified across the survey area based on grab samples with 348 individuals counted at station ST118 and the reminder occurring between 17 other stations. Nevertheless, the seabed imagery analysis showed no sign of reef forming structures at these locations (Section 7.6.1).

Two Mollusca taxa identified across the survey area are designated as economically important species, these were the queen scallop *Aequipecten opercularis* and clams of the family Veneridae. A total of 6 queen scallop specimens were counted across three stations while 11 Veneridae clams were found across 6 stations.

Table 16 Notable taxa found across the White Cross survey area.

Taxon	Major Group	Designation	N of individuals
Aequipecten opercularis	Mollusca	Economically Important Species	6
Crepidula fornicata		Invasive & Non-Native	1
Goniadella gracilis	Annelida	Invasive & Non-Native	34
Sabellaria spinulosa	Annelida	OSPAR threatened and/or declining species	708
Veneridae	Mollusca	Economically Important Species	11

[8] GB non-native species secretariat
[9] The Conservation of Offshore Marine Habitats and Species Regulations 2017 have been amended by The Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019 to implement the necessary changes following the UK leaving the EU.

7.6. Seabed Imagery

A total of 140 DDC stations and 10 transects were sampled resulting in the collection of 1,031 high-resolution still images. Full image analysis proforma are presented in Appendices XVIII and XIX.

A total of 10 EUNIS classifications were encountered across the survey area (Table 17, Figure 17). A5.26 was the most frequently encountered classification, assigned to 479 out of 1,031 of the analysed images (46.5 % of analysed images). This was followed by 196 images assigned to A4.13 (19.0 % of analysed images) and 192 images assigned to A5.44 (18.6 % of analysed images). Example images of the key EUNIS classifications are included in Plate 4.

Table 17 EUNIS classifications (both 2012 and 2022 codes) identified across the survey area.

EUNIS BSH (2012)	EUNIS Level 4 (2012)	EUNIS Description	EUNIS Code (2022)
A4.1- High Energy Circalittoral Rock	A4.1	Atlantic and Mediterranean high energy circalittoral rock.	MC12
	A4.13	Mixed faunal turf communities on circalittoral rock.	MC121
	A4.131	Bryozoan turf and erect sponges on tide-swept circalittoral rock.	MC1213
A5.1 - Subtidal Coarse Sediment	A5.14	Circalittoral coarse sediment	MC32
	A5.141	*Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles	MC3211
A5.2 - Subtidal Sand	A5.23	Infralittoral fine sand	MB52
	A5.25	Circalittoral fine sand	MC52
	A5.26	Circalittoral muddy sand	MC52
A5.3 - Subtidal Mud	A5.35	Circalittoral sandy mud	MC62
A5.4 - Subtidal Mixed Sediment	A5.44	Circalittoral mixed sediments	MC42

Plate 4 Example imagery collected across the survey area, including EUNIS habitat classification, station number, and image log number.

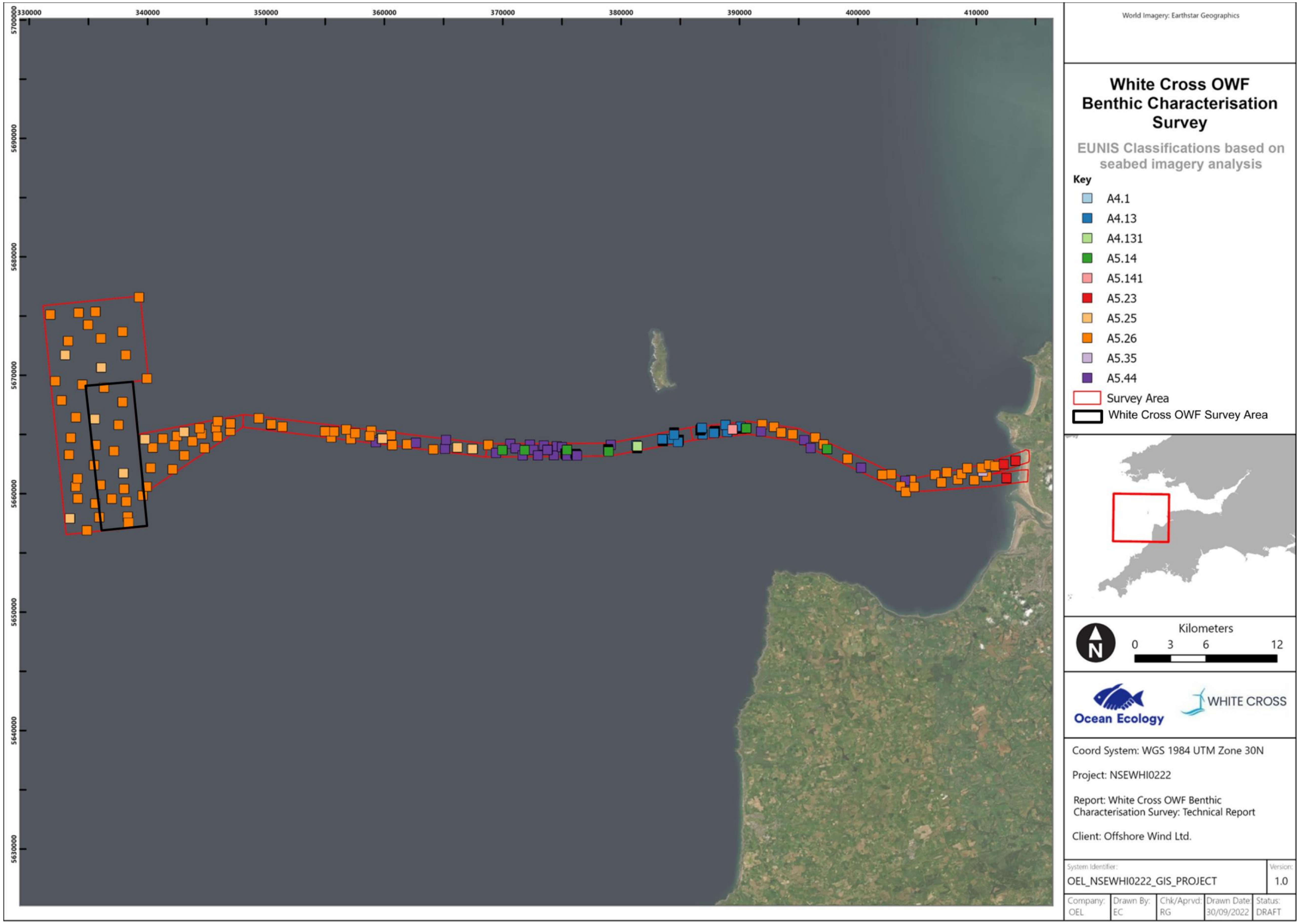

Figure 17 EUNIS classifications identified across the survey area based on seabed imagery.

7.6.1. Annex I Reefs

A full reef habitat assessment was conducted on all images to determine whether habitats met the definitions of Annex I reef habitats as detailed in Table 9 and Table 10. The full Annex I reef assessment for each image is presented in Appendix XVI and XVII. A summary of this Annex I reef assessment is presented in Table 18. Of the areas meeting the criteria of Annex I reef, 50 % consisted of Bedrock, 35 % of Low Stony, 10 % of Bedrock & Low Stony, 4 % of Low Stony and Bedrock and 1 % of Medium Stony (Figure 18). In the instances where bedrock and stony reefs co-occurred, video transects were further analysed to assess whether the two features could be identified. Based on the assessment of both video footage and the still images, the overall biological community observed and the fact that cobbles were visible in a large number of images where bedrock was recorded, it is highly likely that there was continuous bedrock present under the stony reef veneer, but the height of stony cover was such that it was not possible to observe the bedrock underneath.

No biogenic reef habitat was observed across the survey area despite individuals of *S. spinulosa* being found in the grab samples. The tube aggregations observed at these stations were not deemed to meet the reef qualifying criteria set out in Table 10 (See sections 6.5 and 7.5).

Table 18 Summary of Annex I reef assessment for each station/transect at which potential reef was observed (number of pictures per station/transect).

Station/Transect	Annex I Reef Assessment					
	Not a Reef	Low	Medium	Bedrock	Bedrock & Low Stony	Low Stony & Bedrock
ST112	0	2	0	3	1	0
ST113	0	2	0	0	3	0
ST114	0	5	0	0	0	0
ST115	0	3	0	0	0	3
ST116	0	4	0	0	0	1
T01	6	8	0	10	0	0
T02	0	9	1	8	3	1
T03	1	14	1	9	1	1
T04	0	6	0	12	2	1
T05	0	7	0	13	4	0
T06	0	6	0	16	1	0
T07	19	1	0	6	0	0
T08	16	0	0	13	1	0
T09	20	4	0	4	0	0
T10	2	3	0	10	5	1

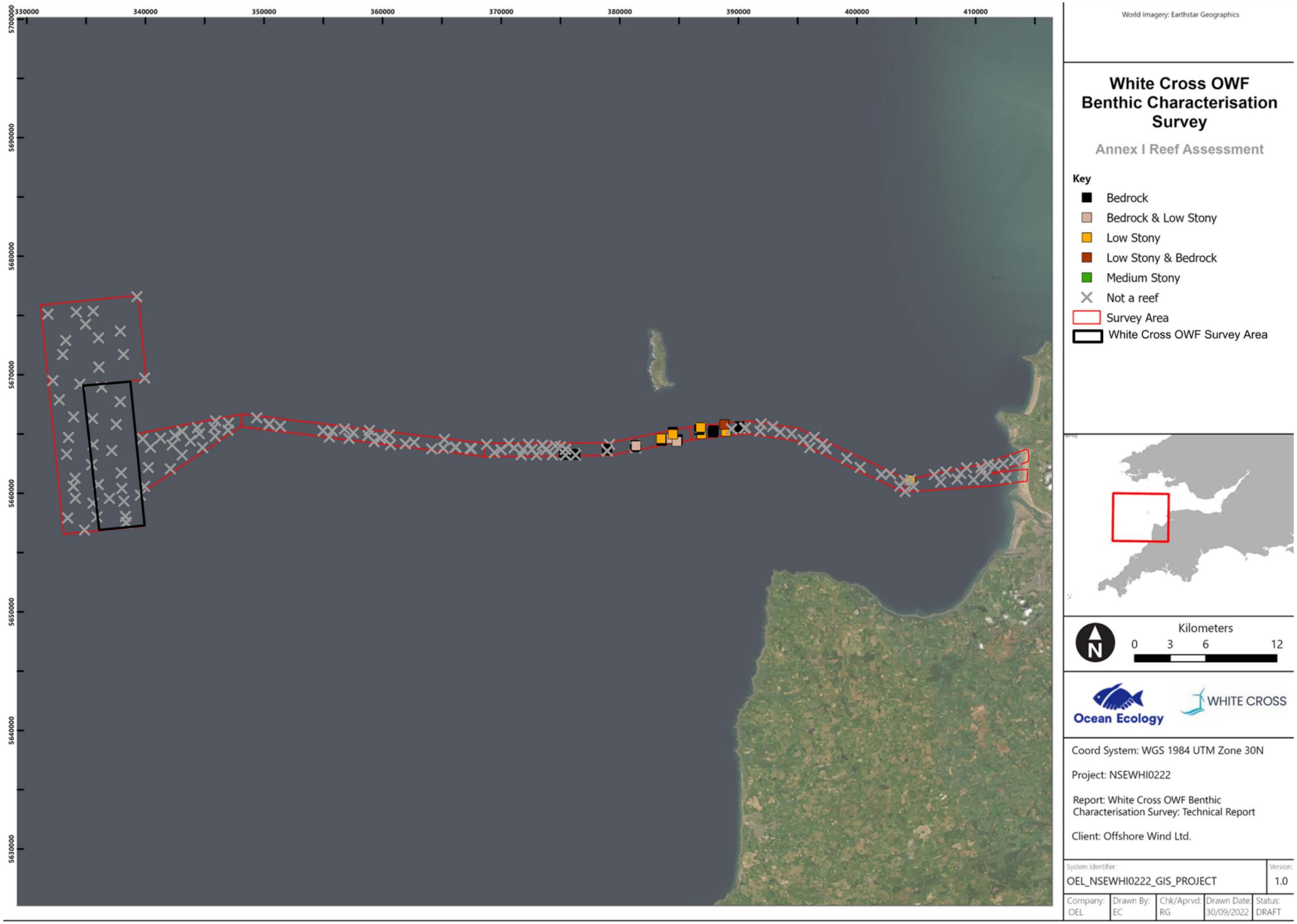

Figure 18 Annex I reef habitats identified across the survey area based on imagery analysis.

7.7. Habitat/Biotope Mapping

Seabed imagery and site characterisation sampling were undertaken to identify the principal habitats that occurred across the survey area. Acoustic data was additionally interrogated to identify the boundaries of the biotopes and habitats inferred from seabed imagery and grab samples analyses as mapped by station/transect in Figure 19 and listed in Table 19.

The main complexes identified across the survey area were the mosaic habitat made up of EUNIS level 5 habitat "A5.252 *Abra prismatica, Bathyporeia elegans* and polychaetes in circalittoral fine sand" and "A5.351 *Amphiura filiformis, Mysella bidentata* and *Abra nitida* in circalittoral sandy mud" observed at 56 of the 134 grab sampling stations and EUNIS level 4 habitat "A5.26 circalittoral muddy sand" which was assigned to 479 out of 1,031 seabed images analysed.

In general, habitat dominated by sand characterised the more offshore part of the survey area, as well as the portion of the survey area closer to land; conversely habitat dominated by mixed and coarse sediments were more common in the central part of the ECR, where Annex I reef habitats were also observed based on the imagery analysis (Figure 19). Of the sand dominated habitats, the most offshore supported macrobenthos such as *F. fabula, Magelona johnstoni, A. filiformis, A. alba, N. nitidosa* and venerid bivalves, while the more inshore were characterised by *E. pusillus* and various polychaetes. Coarse and mixed sediment habitats supported a rich community dominated by polychaetes such as *M. fragilis* and *Lumbrineris* spp. as well as venerid bivalves like *T. ovata* and *Spisula* spp..

Table 19 EUNIS classifications identified within the survey area.

EUNIS BSH (2012)	Method	EUNIS Level 4 (2012)	EUNIS Description	EUNIS Code (2022)
A4.1- High Energy Circalittoral Rock	Seabed imagery	A4.1	Atlantic and Mediterranean high energy circalittoral rock.	MC12
		A4.13	Mixed faunal turf communities on circalittoral rock.	MC121
		A4.131	Bryozoan turf and erect sponges on tide-swept circalittoral rock.	MC1213
A5.1 - Subtidal Coarse Sediment	Imagery & Grab	A5.14	Circalittoral coarse sediment	MC32
	Seabed imagery	A5.141	*Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles	MC3211
	Grab	A5.142	*Mediomastus fragilis, Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel	MC3212
A5.2 - Subtidal Sand	Seabed imagery	A5.23	Infralittoral fine sand	MB52
	Grab	A5.233	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	MB5233
	Grab	A5.242	*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand	MB5236
	Imagery & Grab	A5.25	Circalittoral fine sand	MC52
	Grab	A5.252	*Abra prismatica, Bathyporeia elegans* and polychaetes in circalittoral fine sand	MC5212
	Imagery & Grab	A5.26	Circalittoral muddy sand	MC52
A5.3 - Subtidal Mud	Seabed imagery	A5.35	Circalittoral sandy mud	MC62
	Grab	A5.351	*Amphiura filiformis, Mysella bidentata* and *Abra nitida* in circalittoral sandy mud	MC6211
A5.4 - Subtidal Mixed Sediment	Seabed imagery	A5.44	Circalittoral mixed sediments	MC42
	Grab	A5.451	Polychaete-rich deep Venus community in offshore mixed sediments	MD4211

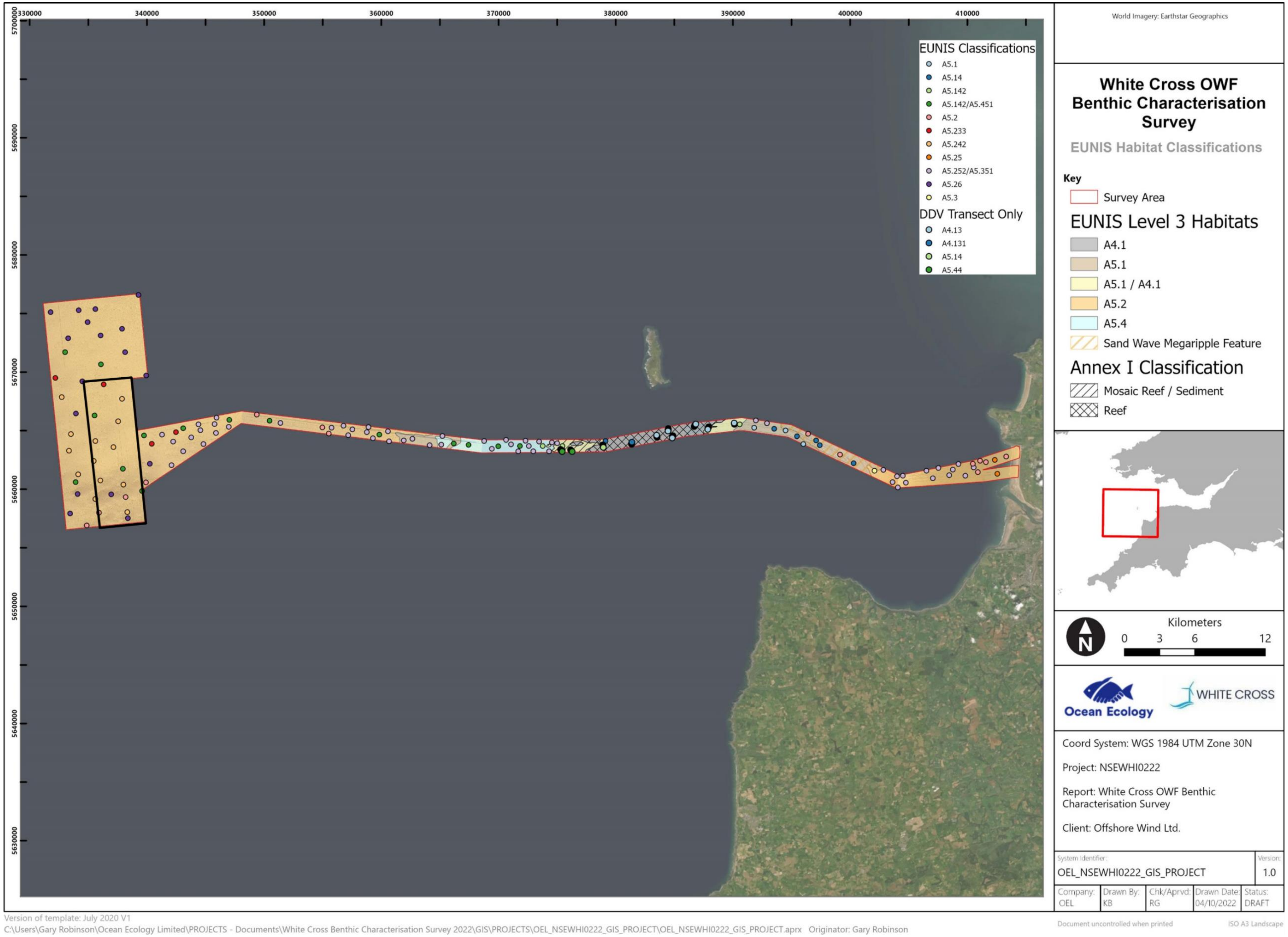

Figure 19 EUNIS classifications assigned across the survey area overlain on MBES data.

8. Discussion

This report presents the results and interpretation of the seabed imagery, macrobenthic and sediment analysis with the aim to set out the environmental baseline conditions across the proposed White Cross OWF. The findings will be used to inform final engineering design and the installation process of the proposed windfarm as well as providing a robust dataset for future comparison if required.

8.1. Sediments

Despite some variation in sediment types between stations, the majority of stations were dominated by sand. Mud content was highest close to land at ST01, mud content was also high at ST38. Gravel content was overall low but variable along the cable route with a few stations along the route found to contain > 50 % gravel composition. The majority of samples were comprised of sand representing EUNIS BSH A5.2 (Sand and Muddy Sand). Some stations were classified as Sandy Gravel (sG) or Gravelly Sand (gS) representing EUNIS BSH A5.1 (coarse sediment); seven station were classified as Muddy Sandy Gravel (msG) and four stations as Gravelly Muddy Sand (gmS) representing EUNIS BSH A5.4 (Mixed Sediment).

These sublittoral sediment types could represent ‘subtidal sands and gravels’ and ‘subtidal mixed muddy sediments’ listed as habitats of principal importance under Section 41 of the Natural Environment and Rural Communities Act 2006. To note that these habitats are among the most common habitats found below the mean low water springs (MLWS) around the coast of the UK.

Most of the sediments recorded were classified as moderately sorted and comprised almost entirely of sand. Remaining stations classified as moderately well sorted, poorly to very poorly sorted. This variation results from a mixed composition of different size fractions of all three principal sediment types (gravel, sand, and mud).

Sand was the main sediment fraction present at most stations, comprising the largest percentage contribution across the survey area. Sand content was greatest at station ST078 and lowest at ST09. The mean grain size at sampling stations ranged from 34.83 µm at station ST01 to 5,559 µm at station ST123.

No pattern was observed between stations with relatively high mud (> 5 %) and TOC content despite many studies based on the coastal ocean and marine environment having found a positive relationship between organic carbon content and proportions of finer sediment grain size (Winterwerp & van Kesteren 2004, McBreen et al. 2008, Hunt et al. 2020). Average TOC compares well with global sediment average TOC content for the deep ocean (0.5 %) (Seiter et al. 2004).

8.2. Sediment Chemistry

Several guidelines exist to assess the degree of contamination and likely ecological impacts of contaminants in marine sediments. These regulations defined the levels below which effects are of no concern and/or rarely occur (AL1, BAC, TEL) and the levels above which adverse biological effects are considerable and/or occur frequently (AL2, ERL, PEL). *Ad hoc* decisions need to be made when contaminant concentrations fall between these levels. To note that Cefas ALs1 are typically the most conservative measures to assess sediment contamination and often result in "false positives" meaning that non-toxic sediment samples fail to pass this screening test. Conversely, ALs2 tend to be rather permissive allowing samples with relatively high contaminant concentrations to fall between AL1 and AL2 and thus requiring expert judgment to further assess their potential toxicity (MMO 2015, Mason et al. 2020). Recent studies have been revising these ALs with the goal of reducing the range of concentrations falling between AL1 and AL2 and minimise the number of samples requiring an *ad hoc* treatment; however, no policy has been made yet based on these recommendations and suggestions (MMO 2015, Mason et al. 2020).

Among all metals measured during the survey, As, Hg, Pb and Ni were the only metals with concentrations above reference levels at one or more stations. Specifically, As was above Cefas AL1 at 4 stations, while Ni was higher than AL1 at one station. Hg and Pb both occurred in concentrations above the TEL at stations ST01. Hg and Pb concentrations exceeding the TEL has possibly to do with the TEL being based on North American data and as such it may not be representative of UK conditions (Section 6.2.2) (MMO 2015, Mason et al. 2020). In comparison OSPAR BAC and Cefas ALs are based on UK data and therefore are more suitable for the current assessment. No obvious pattern emerged when comparing stations with elevated As and Ni concentrations with mud content, however elevated TOC and metals concentrations were observed in the middle section of the ECC which could be related to transportation and deposition across the survey area. Elevated metal sediment concentrations do not necessarily imply toxicity to benthic communities (Rees et al. 2007) as the bioavailability of these metals is more important than simply concentration levels. Despite the elevated As levels at four stations, no macrobenthic anomalies were identified at these locations to suggest any adverse effects were present. No stations had metals concentrations above AL2, overall meaning that adverse biological effects were rare. However, TEL and ERL values have been used for reference where possible throughout this assessment as these are the only guideline values that provide a measure of environmental toxicity compared to OSPAR BAC and Cefas ALs that instead provide information on the degree of contamination in the sediments. Most of the measured PAHs exceeded the BAC at stations ST08 and ST09. Additionally, Fluoranthene was above Cefas AL1 at station ST09. Stations with elevated PAHs concentrations also had relatively high TOC, and metals concentrations which could be related to transportation and deposition across the survey area; however, no macrobenthic anomalies were identified at these locations to suggest any adverse effects were present.

When assessing the origin source of PAH compounds in sediments, the ratio between LMW and HMW PAHs was found to be lower than 1 at all stations indicating a pyrogenic origin, similarly the Fl/Py ratio was higher than 1 at all stations also indicating a pyrogenic source of PAHs). PAHs of pyrogenic origin can derive from various activities which ultimately involve the combustion of organic substances at high temperatures under low oxygen conditions. These may include incomplete combustion of motor fuels, or products derived from the foundry and steel industries. All organotins measured were below the detection limit of 0.001 mg kg^{-1}.

8.3. Macrobenthos

A diverse macrobenthic assemblage was identified across the survey area from 134 macrobenthic samples collected, with a total of 12,651 individuals and 487 taxa recorded. The most abundant and frequent taxon sampled with the greatest average density per sample was juveniles of the brittle star *Amphiuridae*. Other key taxa included the Ross worm *S. spinulosa* which accounted for the maximum abundance per sample and the two-toothed Montagu shell *K. bidentata* which was second to juveniles of *Amphiuridae* for abundance and density per sample. Annelida taxa contributed the most to abundance and overall diversity of the macrobenthic assemblages, whilst Echinodermata taxa dominated by biomass, accounting for over 50 % of the total biomass.

Macrobenthic communities can be highly heterogenous as they are heavily influenced by ambient environmental conditions such as sediment composition (Cooper et al. 2011), hydrodynamic forces and physical disturbance (Hall 1994), depth (Ellingsen 2002), and salinity (Thorson 1966). Multivariate analysis on macrobenthic data identified 15 macrobenthic groups (31 % similarity slice) and 14 outlier stations across the White Cross survey area owing the high diversity in the macrobenthic community and the associated difficulties in determining a few key dominant species within each group. Nevertheless, a clear distinction was observed between stations located in the middle of the ECR and all other stations. Sediment composition was a key factor in determining the macrobenthic community structure at these locations (Hall 1994, Cooper et al. 2011) and was clearly reflected in Macrobenthic Groups B, C, D and E indicating an affinity for coarser substrates compared to the other macrobenthic groups typical of sandy substrates with variable mud content. Coarser sediment supported a community characterised by *M. fragilis* and *Lumbrineris* and venerid bivalves, while finer sediments were characterised by high abundances of *E. pusillus*, *A. filiformis, K. bidentata* and *N. nitidosa*.

Five notable taxa were identified across the survey area. These included OSPAR threatened and/or declining species Ross worm (*S. spinulosa*) (however there were no sign of reef forming structures observed), INNS polychaete *Goniadella gracilis* and INNS slipper limpet *C. fornicata*, and two Economically Important Species: the queen scallop *A. opercularis* and clams of Veneridae family.

8.4. Seabed Imagery

A total of 10 EUNIS habitat types were encountered across the survey area. A5.26 (Circalittoral muddy sand) was the most frequently encountered EUNIS habitat, assigned to 479 out of 1,031 of the analysed images (46.5 % of analysed images). This was followed by 196 images assigned to A4.13 (Mixed faunal turf communities on circalittoral rock) (19.0 % of analysed images) and 192 images assigned to A5.44 (Circalittoral mixed sediments) (18.6 % of analysed images). (Example habitat images included in Plate 3).

8.4.1. Annex I Reefs

The White Cross survey area consisted almost entirely of muddy sand and mixed sediments, however areas of Annex I reef were identified in the middle section of the survey area along the ECR. These corresponded to seabed imagery that we assigned to the EUNIS classifications A4.1, A4.13 and A4.131. Annex I reefs identified consisted of Bedrock (50 %), Low Stony (35 %), Bedrock & Low Stony (10 %), Low Stony and Bedrock (4 %), and Medium Stony (1 %). Along most transects where reef was identified stony and bedrock reef co-occurred. Based on assessment of video footage, the overall biological community present within the images and the fact that cobbles were visible in a large number of images where bedrock was recorded, it is highly likely that there was continuous bedrock present under the stony reef, but the height of stony cover was such that it was not possible to see the bedrock underneath. Where bedrock and stony reef were observed to co-occur within the same images, the labels 'Bedrock & Low Stony' and 'Low Stony and Bedrock' were used depending on which type of reef was predominant. Additionally, large parts of these reef areas were interspersed with mixed and coarse sediments further pointing to the presence of mosaic habitats across the middle section of the ECR where most likely areas of bedrock were covered by stony reefs and/or a veneer of coarse and mixed sediments while in places bottom currents and sediment dynamics exposed the bedrock reef.

8.5. EUNIS Habitats/Biotopes

PSD data clearly indicated the dominance of sandy sediments across White Cross with areas of coarse (A5.1) and mixed (A5.4) sediments in the middle section of the ECR. This was corroborated by the imagery analysis which showed the dominance of EUNIS habitat "A5.26 Circalittoral muddy sand" across most of the survey area while the middle part of the ECR was characterised by Annex I reef habitats as well as coarse and mixed sediments. On the other hand, the macrobenthic data showed more complexity compared to sediment and seabed imagery as the macrobenthic community was extremely diverse with no obviously key species dominating the assemblage. This resulted in a high number of statistically significant groups based on multivariate analyses performed on macrobenthic abundance data and a relatively low confidence in the biotopes and habitat complexes identified based on this data as it was difficult to delineate clear boundaries between groups/habitats/biotopes.

This was further demonstrated by the presence of mosaic habitats across large portion of the survey area where sandy and muddy biotopes coexisted (A5.252/A5.351) as well as coarse and mixed sediment habitats (A5.142/A5.451). Acoustic data was then interrogated to aid in the definition of boundaries between the habitats and biotopes identified based on PSA, imagery and macrobenthic analysis. As most of the survey area was dominated by sands, the acoustic data did not show any anomalies that could be used to draw boundaries that would reflect the EUNIS complexes identified based on the macrobenthic analysis; conversely hard substrates such as Annex I reefs and coarse sediments were well represented in the acoustic data. For these reasons the habitat mapping in Figure 19 shows EUNIS level 3 classifications as polygons for which a combination of acoustic data, seabed imagery and PSD data was used to delineate their boundaries, while the higher-level classifications based on macrobenthic data were superimposed at station level to reflect the high diversity of the community observed across White Cross.

The main complexes identified across the survey area were the mosaic habitat made up of EUNIS level 5 habitat "A5.252 *Abra prismatica, Bathyporeia elegans* and polychaetes in circalittoral fine sand" and "A5.351 *Amphiura filiformis, Mysella bidentata* and *Abra nitida* in circalittoral sandy mud" observed at 56 of the 134 grab sampling stations. Annex I reef habitats were identified based on the imagery analysis at stations located south of Lundy along the cable route.

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White Cross Offshore Windfarm

Appendix 8.D: Ocean Cable Risk Burial Assessment Study

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1.0 Introduction

1.1 Purpose of Document

The purpose of this document is to present the findings of the burial assessment study carried out for the White Cross offshore windfarm project.

The document provides a description of the inputs used, methodology applied, results of the study, and the conclusions and recommendations arising from the study.

1.2 Abbreviations

Acronym / Term	Definition
AC	Alternating Current
AIS	Automatic Identification System
AONB	Area of Outstanding Natural Beauty
BAS	Burial Assessment Study
BOD	Basis of Design
CBRA	Cable Burial Risk Assessment
DOL	Depth of Lowering
DWT	Dead Weight Tonnage
FOS	Factor of Safety
LAT	Lowest Astronomical Tide
MHW	Mean High Water
MHWS	Mean High Water Springs
OECC	Offshore Export Cable Corridor
OSP	Offshore Substation Platform
OWF	Offshore Wind Farm
OWL	Offshore Wind Ltd
pUXO	Potential Unexploded Ordnance
SI	Standard International
UTM	Universal Transverse Mercator
UXO	Unexploded Ordnance

1.3 Definitions

Acronym / Term	Definition
development area	The area comprising the onshore development area and the offshore development area
export cable corridor	The area in which the export cables will be laid, from the offshore substation platform to the onshore substation comprising both the offshore export cable corridor and onshore export cable corridor
inter-array cables	Cables which link the wind turbines to each other and the offshore substation platform
landfall	Where the offshore export cables come ashore
offshore development area	The windfarm site and offshore export cable corridor to landfall
offshore export cables	The cables which would bring electricity from the offshore substation platform to the landfall
offshore export cable corridor	The proposed offshore area in the which the export cables will be laid, from the perimeter of the windfarm site to landfall
offshore substation platform	A fixed or floating structure located within the windfarm site, containing electrical equipment to aggregate the power from the wind turbines and convert it into a more suitable form for export to shore
onshore development area	The onshore area above MHWS including the underground onshore export cables connecting to the onshore Project substation
onshore export cables	The cables which bring electricity from the landfall to the onshore substation
onshore export cable corridor	The proposed onshore area in which the export cables will be laid, from landfall to the onshore substation
onshore substation	Part of an electrical transmission and distribution system. Substations transform voltage from high to low, or the reverse by means of the electrical transformers.
transition bay	Underground structures at the landfall that house the joints between the offshore export cables and the onshore export cables
windfarm site	The area within which the wind turbines, offshore substation platform and inter-array cables will be present
White Cross offshore windfarm (the Project)	100MW capacity offshore windfarm including associated onshore and offshore infrastructure

2.0 Units, Datums and Coordinates

2.1 Datum and Coordinate System

All data recorded, presented or communicated shall clearly state units, origin, datum or convention as required. A Project specification will be prepared detailing data deliverable requirements. This includes requirements for spatial data, survey data and drawings.

Onshore shall be defined as positions landward of Mean High Water (MHW).

Offshore shall be defined as positions seaward of MHW.

2.1.1 Vertical Datum

Vertical elevations offshore shall be referenced to Lowest Astronomical Tide (LAT).

2.1.2 Horizontal Datum

Offshore locations shall be referenced to and recorded in WGS84 UTM Zone 30N.

Orientations shall be to grid north; WGS84 grid for offshore.

2.2 Units

All units of measurement used in this document relate to Standard International (SI), unless otherwise stated.

3.0 Description of Offshore Development

3.1 Introduction and Project Description

This section provides an overview of the Project. It details the main components of the windfarm site and associated offshore substation platform and energy transmission infrastructure.

3.2 Development Overview

The White Cross Floating Offshore Windfarm (the Project) is a proposed 100MW test and demonstration floating windfarm located in the Celtic Sea. The Project is being developed by Offshore Wind Ltd (OWL), a joint venture partnership between Cobra Instalaciones Servicios, S.A. and Flotation Energy Ltd. The windfarm site boundary is shown below in **Figure 3-2** and **Figure 3-3**.

In summary, the development comprises the following:

- An offshore wind farm of maximum capacity 100MW.
- 5-8 floating wind turbines, complete with moorings and inter-array cables.
- A potential offshore substation platform (OSP), including the required metering and voltage conversion transformers to the offshore export cable back to shore at an expected 132kV.
- Offshore export cables connecting the OSP to a transition bay located at the landfall.
- Onshore export cables connecting the Project onshore substation to the transition bay. The grid connection will be at an existing substation at East Yelland in Devon.

There are several options for the onshore export cable corridor with a shortlist of sites for the landfall and associated transition bay locations.

All cabling will be Alternating Current (AC). This applies to the inter-array cables, offshore export cables and onshore export cables.

The project scope overview is shown in **Figure 3-1**.

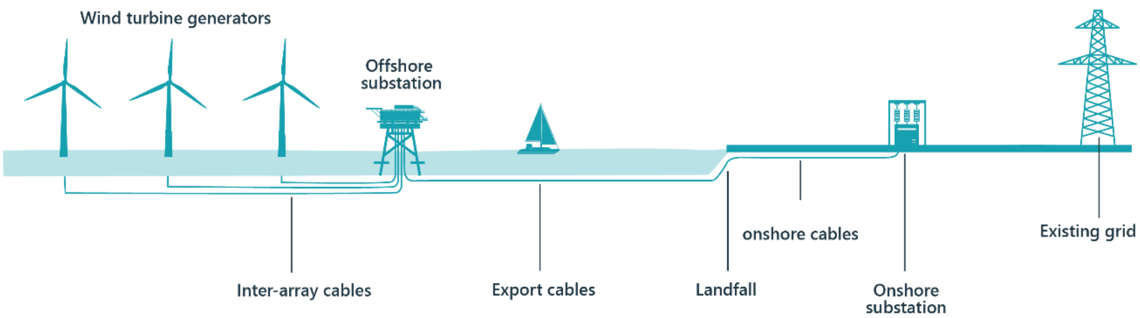


Figure 3-1: Project Concept Overview

A designated port or harbour has yet to be determined for the construction phase and as an Operations and Maintenance (O&M) base. At present the assumptions of locations in the Celtic Sea area should be considered for both construction and O&M ports.

3.3 Project Location

The windfarm site is located in the Celtic Sea and is located 52.5km off the Cornish Coast as shown in **Figure 3-2** and **Figure 3-3**. The 50km^2 site was accepted by the Crown Estate on the 12th July 2022. Water depths in the windfarm site are approximately 69m LAT to 78m LAT as confirmed during Phase 1 ground investigation geophysical surveys performed in 2022.

In the vicinity of the windfarm site, there also exist numerous planned windfarms and associated cables, marine aggregate areas, offshore wave site and numerous international telecommunication cables. See **Figure 3-4** and **Section 4.3.7**.

The windfarm site lies outside of protected areas, but the offshore export corridor will traverse environmental designated areas heading to the landfall as detailed in **Section 4.3.7**.

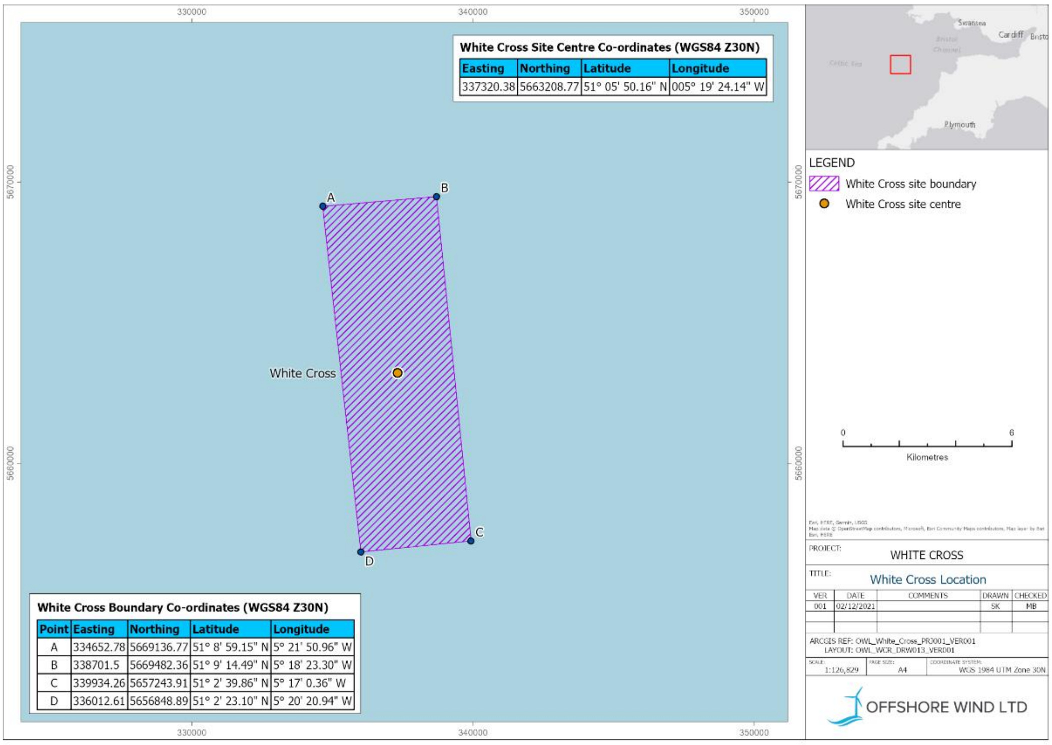
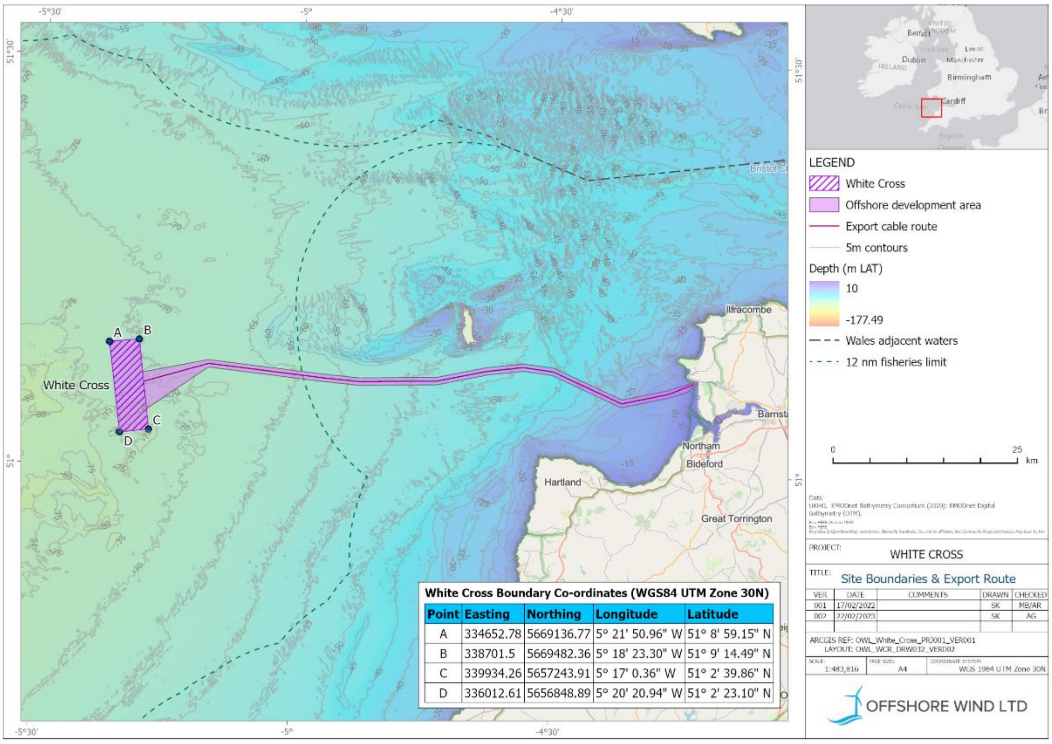
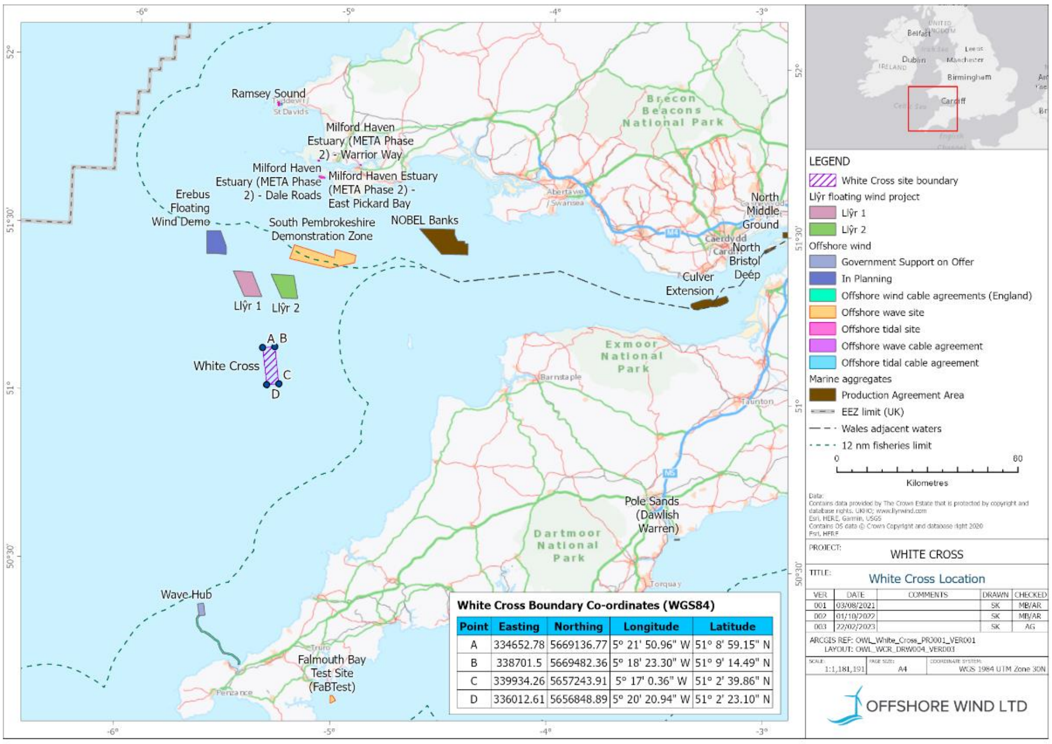


Figure 3-2 White Cross Offshore Windfarm Site Location



Point	Easting	Northing	Longitude	Latitude
A	334652.78	5669136.77	5° 21' 50.96" W	51° 8' 59.15" N
B	338701.5	5669482.36	5° 18' 23.30" W	51° 9' 14.49" N
C	339934.26	5657243.91	5° 17' 0.36" W	51° 2' 39.86" N
D	336012.61	5656848.89	5° 20' 20.94" W	51° 2' 23.10" N

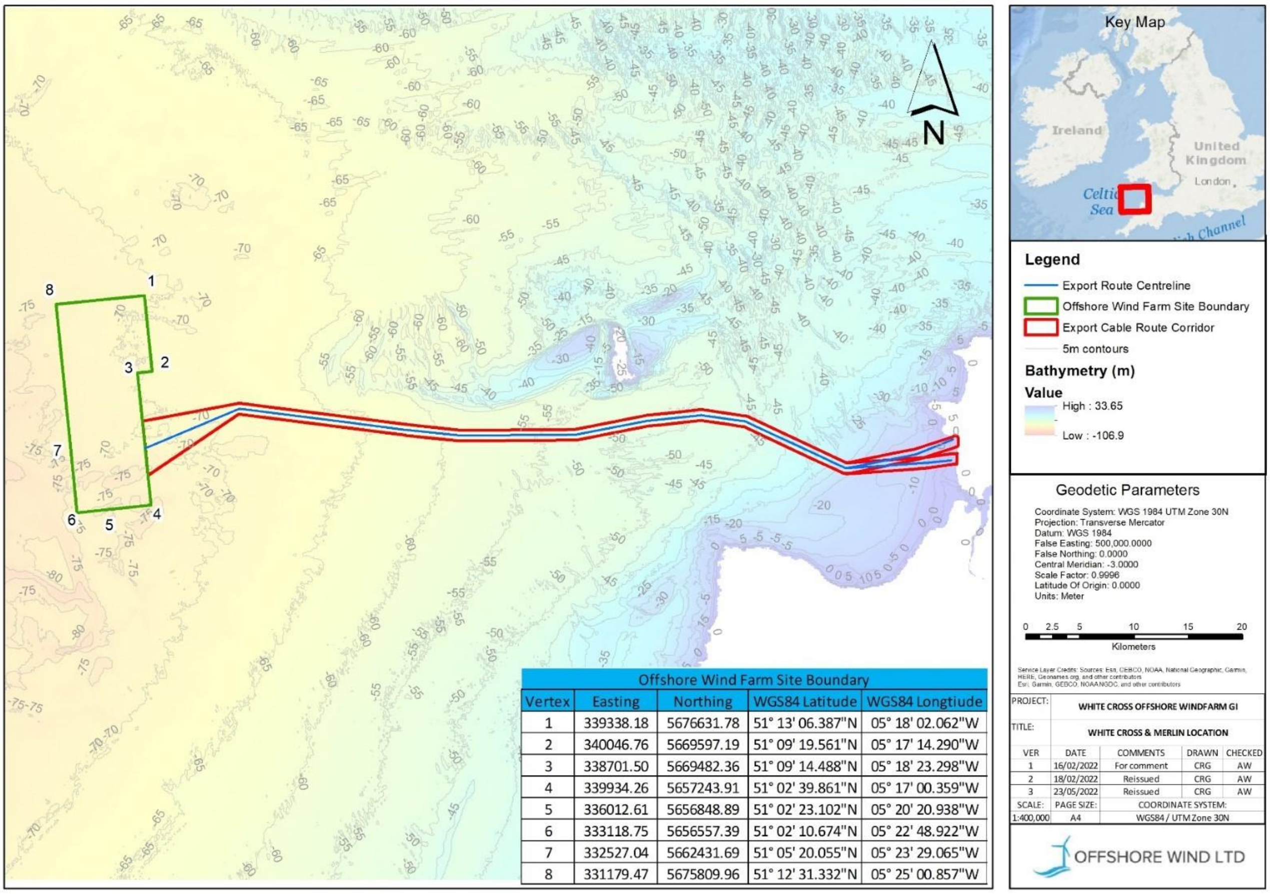
Figure 3-3 White Cross Offshore Windfarm Site Location



Point	Easting	Northing	Longitude	Latitude
A	334652.78	5669136.77	5° 21' 50.96" W	51° 8' 59.15" N
B	338701.5	5669482.36	5° 18' 23.30" W	51° 9' 14.49" N
C	339934.26	5657243.91	5° 17' 0.36" W	51° 2' 39.86" N
D	336012.61	5656848.89	5° 20' 20.94" W	51° 2' 23.10" N

Figure 3-4 Offshore Projects in Operation and Development in the Celtic Sea

The location of the offshore windfarm site, offshore cable corridor and landfall locations are shown in **Figure 3-5** below.



Offshore Wind Farm Site Boundary				
Vertex	Easting	Northing	WGS84 Latitude	WGS84 Longtiude
1	339338.18	5676631.78	51° 13' 06.387"N	05° 18' 02.062"W
2	340046.76	5669597.19	51° 09' 19.561"N	05° 17' 14.290"W
3	338701.50	5669482.36	51° 09' 14.488"N	05° 18' 23.298"W
4	339934.26	5657243.91	51° 02' 39.861"N	05° 17' 00.359"W
5	336012.61	5656848.89	51° 02' 23.102"N	05° 20' 20.938"W
6	333118.75	5656557.39	51° 02' 10.674"N	05° 22' 48.922"W
7	332527.04	5662431.69	51° 05' 20.055"N	05° 23' 29.065"W
8	331179.47	5675809.96	51° 12' 31.332"N	05° 25' 00.857"W

VER	DATE	COMMENTS	DRAWN	CHECKED
1	16/02/2022	For comment	CRG	AW
2	18/02/2022	Reissued	CRG	AW
3	23/05/2022	Reissued	CRG	AW

Figure 3-5: Windfarm Site, Offshore Export Cable Corridor and Landfall

4.0 Burial Assessment Inputs

4.1 General

This section includes a summary of the input data used in the Burial Assessment Study.

4.2 Site Layout

The White Cross Offshore Windfarm site considered in this Burial Assessment Study consists of the Windfarm Site and the Offshore Export Cable Corridor, as shown in **Figure 4-1**. Two landfall options are provided for the Offshore export Cable Corridor, a more northerly route, and a southerly route, both to Saunton Sands Beach; for the purpose of this study, the route is considered as a single route until the point where these diverge approx. 10km from landfall, then both landfall route options are assessed.

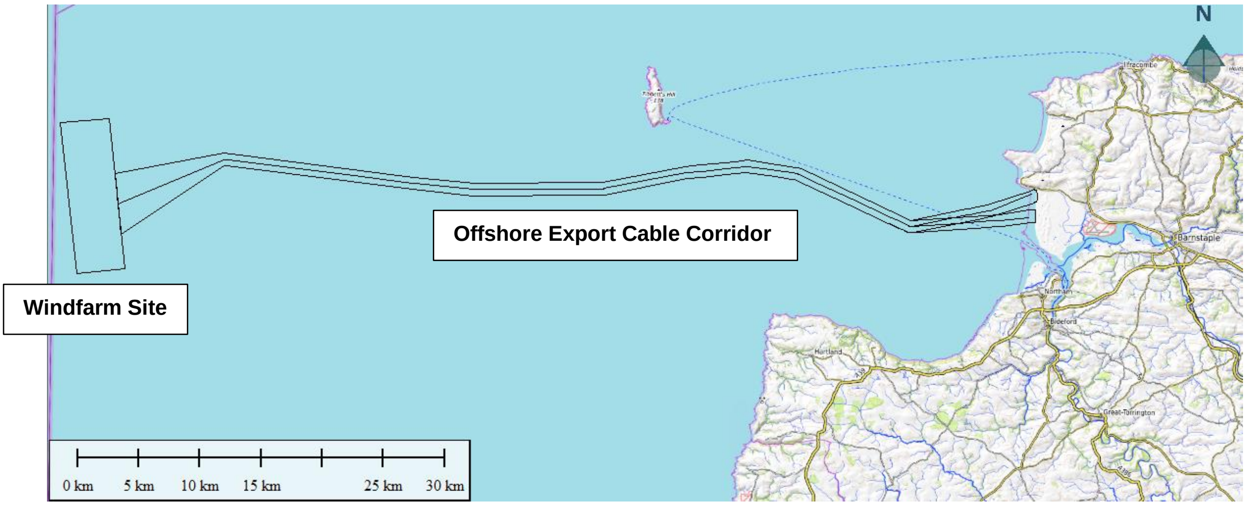


Figure 4-1: White Cross Offshore Windfarm Site Overview

4.3 Site Data: Windfarm Site

4.3.1 Bathymetry

The water depths at the windfarm site range from approximately 69m to 79m. The bathymetry data used in the study is shown in **Figure 4-2**. Slopes at the site are gentle, as shown in **Figure 4-3**; the slope at the site does not exceed 1°. This slope will not pose a challenge for cable burial using standard trenching equipment. Bathymetry data is consistent with the results of the Phase 1 ground investigation geophysical surveys [Ref. 7].

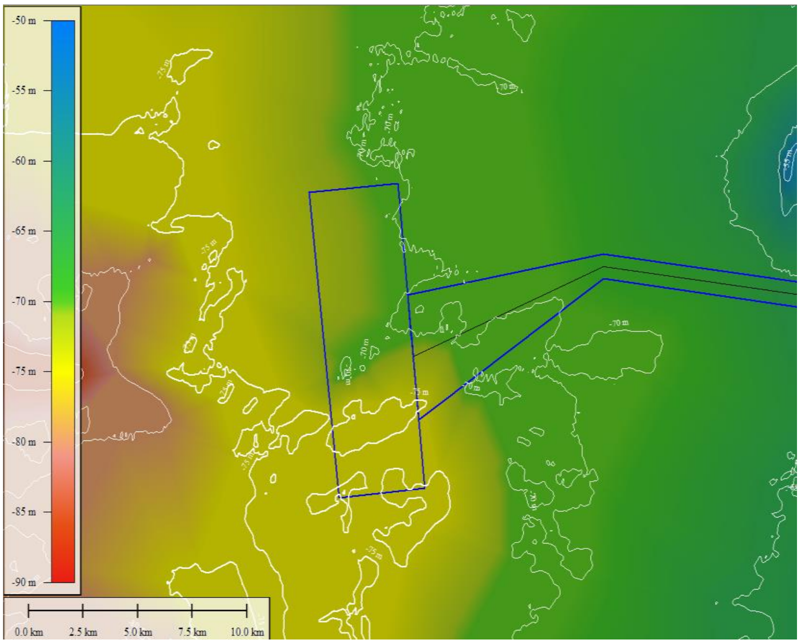


Figure 4-2: Windfarm Site Bathymetry [Ref. 5]

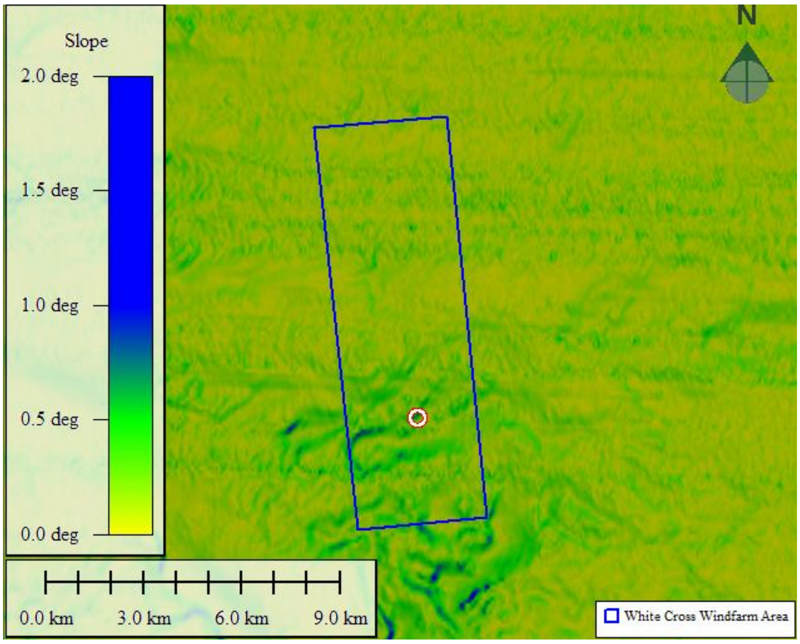


Figure 4-3: Windfarm Site Slope [Derived from Ref. 5]

4.3.2 Soil Types

Primary and secondary sediment classification for the Windfarm Area is shown in **Figure 4-4**. The site is classified as Sand (Primary), with areas of Coarse sediment (Secondary) throughout.

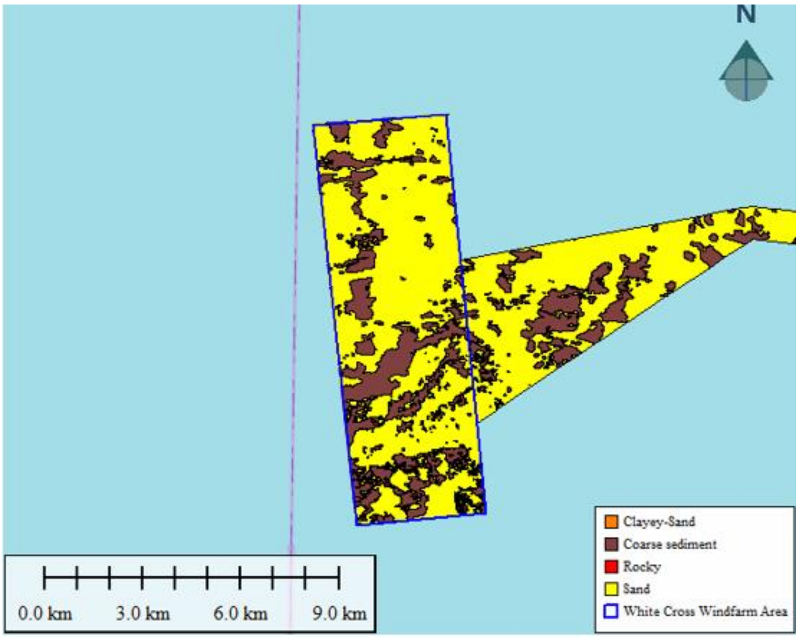


Figure 4-4: White Cross Windfarm Site Seabed Sediment [Ref. 7]

4.3.3 Seabed Mobility

Detailed assessments of both general sandwave mobility in the offshore development area and global seabed mobility relating to foundations in the windfarm site have yet to be performed; however, areas of sand ripples have been identified in the Windfarm Site, as shown in **Figure 4-5**. These formations can be indicative of sediment mobility.

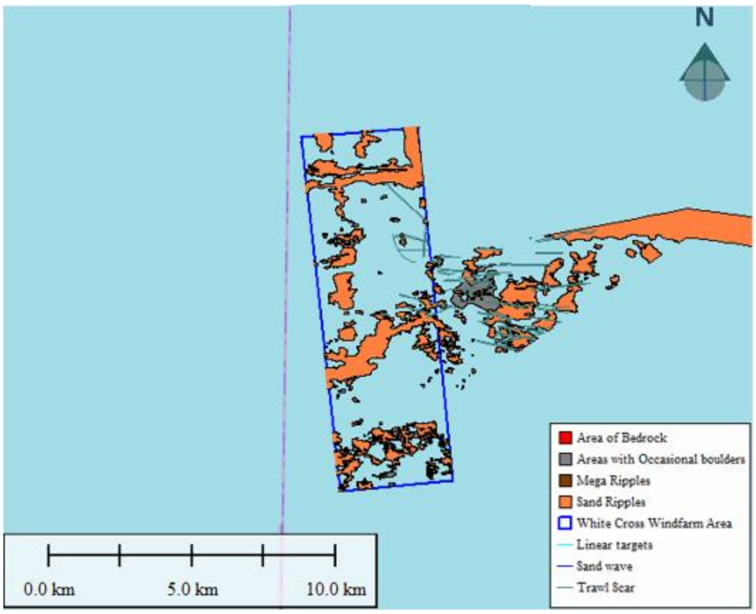


Figure 4-5: White Cross Windfarm Site Seabed Features including Mobile Sediments [Ref. 7]

wood.

4.3.4 Third Party Infrastructure

There are no existing cables or pipelines reported within the Windfarm Area. There is a future X-Links 2 power cable that may traverse the White Cross Windfarm Area, although this has not been considered in this Burial Assessment Study at this time.

4.3.5 UXO

The findings of the magnetometer survey indicate a large number of magnetic contacts within the Windfarm Area; these are shown in **Figure 4-6**. There is a possibility that some of these magnetometer contacts may indicate the presence of Unexploded Ordnances (UXOs); a Medium UXO Risk has been identified for Cable Pre-Lay activities and Cable Installation and Burial in areas with water depths greater than 60 m in the Unexploded Ordnance Threat and Risk Assessment [Ref. **3**]. A number of magnetic contacts in the North-East corner of the Windfarm area indicate that they are part of a linear feature, which may suggest that they could potentially be discarded fishing gear or disused cables. No shipwrecks have been identified within the Windfarm Area.

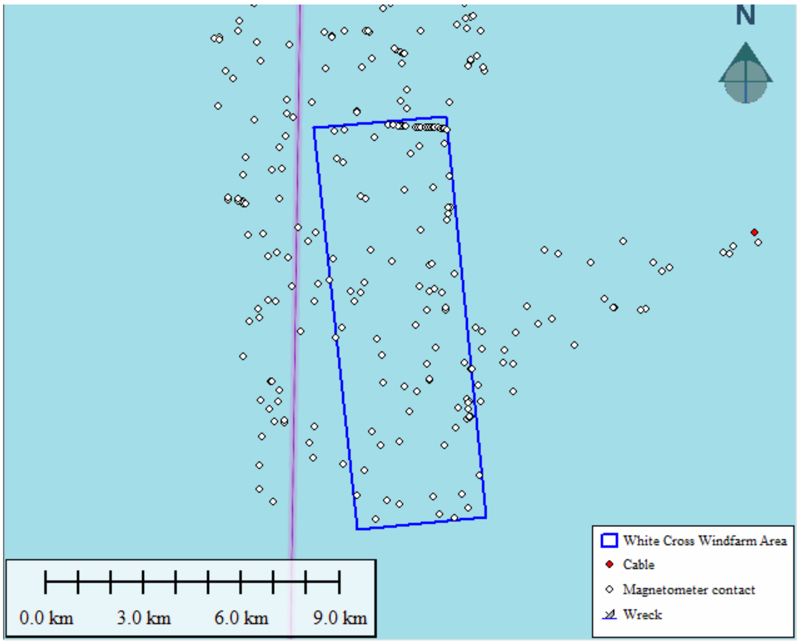


Figure 4-6: White Cross Windfarm Site Magnetic Survey Reports [Ref. 7]

4.3.6 Fishing and Shipping

Vessel route density data for the Windfarm Area is publicly available via the EMODnet Human Factors project [Ref. **4**].

Data for 2021 has been used in this study and the resolution of the data is 1km^2. Route Density for all vessel types is presented in **Figure 4-7**.

Route Density for Fishing vessels is presented in **Figure 4-8**. This indicates that some level of fishing activity takes place across the entire Windfarm Area.

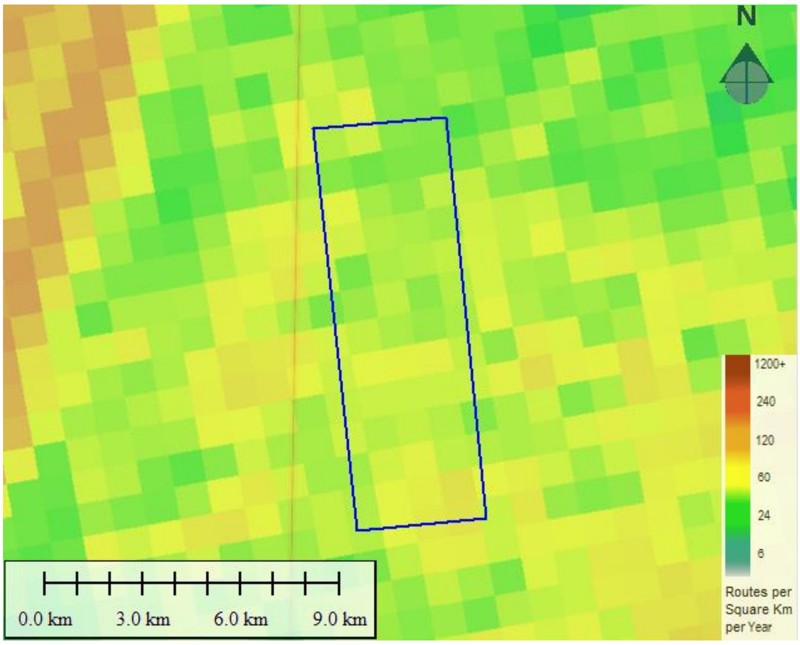


Figure 4-7: White Cross Windfarm Site Vessel Route Density for 2021 – All Vessel Types

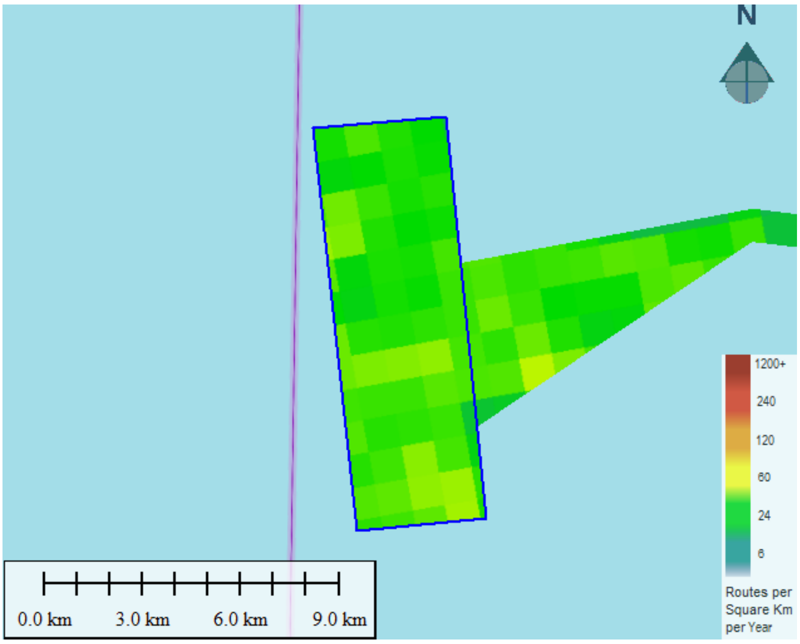


Figure 4-8: White Cross Windfarm Site Vessel Route Density for 2021 – Fishing Vessels

4.3.7 Environmentally Protected Areas

The Windfarm Site is not located in any environmentally protected areas.

4.4 Site Data: Offshore Export Cable Corridor

4.4.1 Bathymetry

The water depths along the offshore export cable corridor range from approximately 75m at the offshore end to the MHWS. The bathymetry data used in the study is shown in **Figure 4-9**. Slopes at the site are gentle in general across the majority of the corridor (< 1°); there are some steeper areas corresponding with an area of apparent sandwaves where slopes increase to approx. 3°, as shown in **Figure 4-10**. These slopes should not pose a challenge for cable burial using standard trenching equipment.

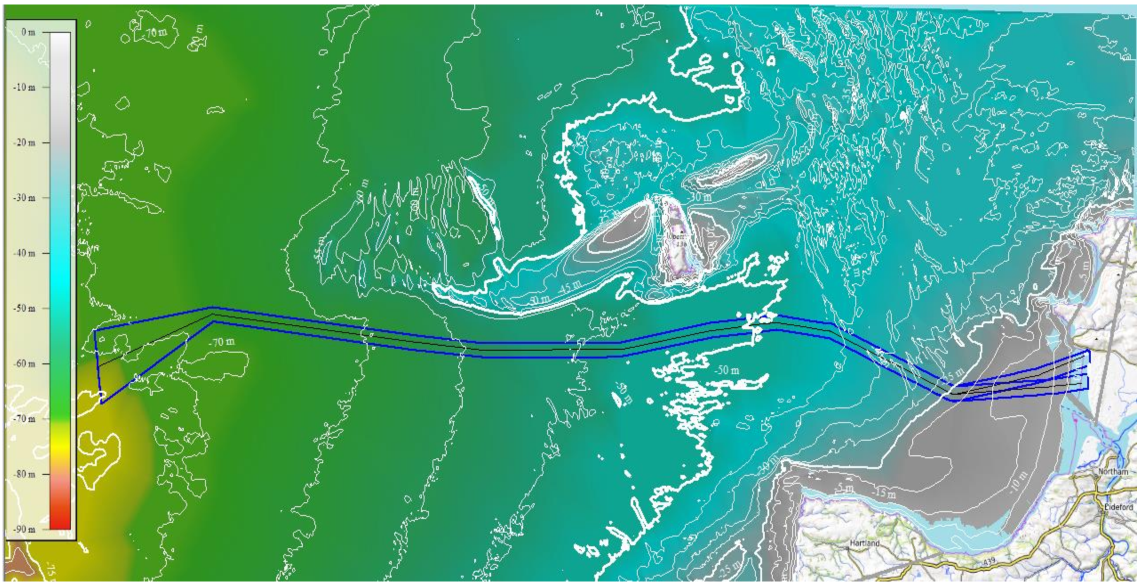


Figure 4-9: Offshore Export Cable Corridor Bathymetry [Ref. 5]

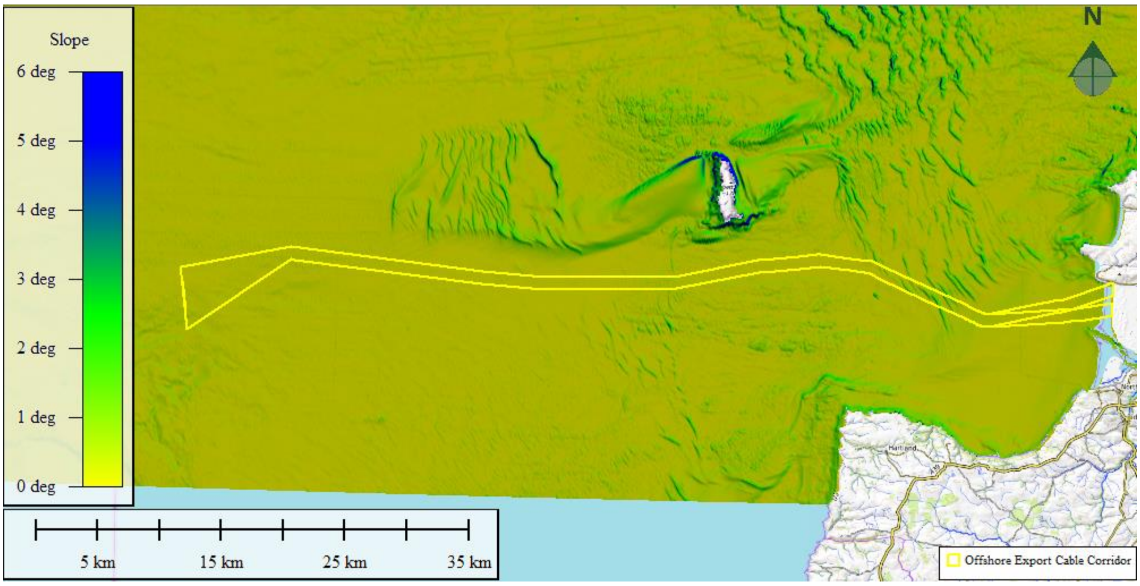


Figure 4-10: Offshore Export Cable Corridor Slope [Derived from Ref. 5]

4.4.2 Soil Types

Primary and secondary sediment classification for the Offshore Export Cable Corridor is shown in **Figure 4-11**. The majority of the corridor is classified as Sand, with some areas of Rocky seabed or Clayey-Sand (Primary); there are areas of Coarse sediment (Secondary) towards the offshore end of the corridor. The rocky area is exposed bedrock, as confirmed in the Phase 1 geophysical survey report [Ref. 7], which may pose a challenge for cable burial depending on the strength of the rock.

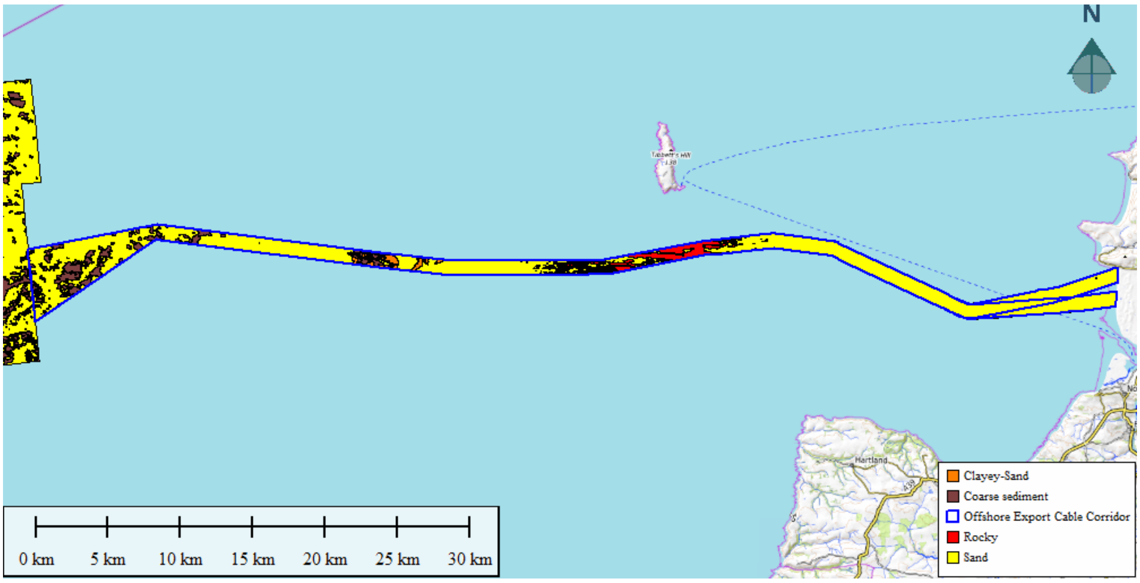


Figure 4-11: Offshore Export Cable Corridor Seabed Sediment [7]

4.4.3 Seabed Mobility

Detailed assessments of both general sandwave mobility in the offshore development area has yet to be performed; however, areas of sand ripples, mega ripples and sand waves have been identified in the Offshore Export Cable Corridor, as shown in **Figure 4-12**. These formations can be indicative of sediment mobility.

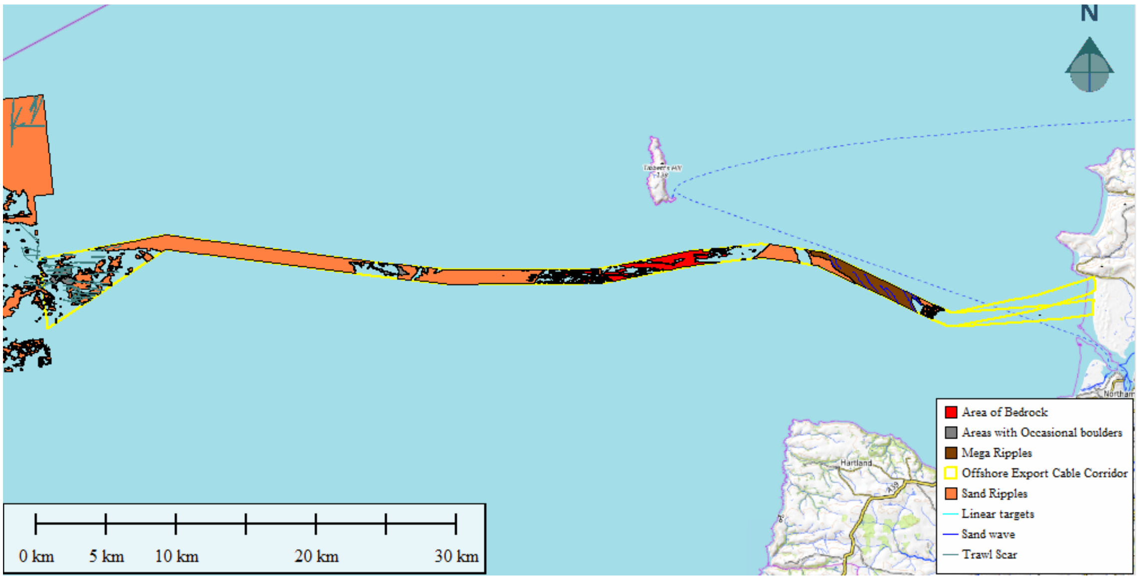


Figure 4-12: Offshore Export Cable Corridor Seabed Features including Mobile Sediments [Ref. 7]

4.4.4 Third Party Infrastructure

There are four existing third-party cables on the seabed between the windfarm site and the landfall, comprising three in-service and one out-of-service telecommunication cables as shown in **Figure 4-13** and detailed in **Table 4-1**. These existing cables will have to be crossed by the White Cross offshore export cables. Crossing agreements will be entered into by the Company and the existing cable owners or operators.

Table 4-1: Details of Existing Cables

Cable	Status	Owner / Operator	Ready for Service / Operation	Expected / Actual End of Service	Landfall Locations
TATA Western Europe	In-service	TATA Communications	2002	2027	Saunton (UK) and Bilbao (Spain)
TATA Atlantic South	In-service	TATA Communications	2001	2026	Saunton (UK) and New Jersey (USA)
TAT 11	Out-of-service	Vodafone	1993	2003	Oxwich Bay, Swansea (UK), Saint-Hilaire-de-Riez, (France) and New Jersey (USA)

Cable	Status	Owner / Operator	Ready for Service / Operation	Expected / Actual End of Service	Landfall Locations
UK-Ireland Crossing 2 (aka Pan-European Crossing)	In-service	Lumen Technologies (previously Century Link)	2000	2025	Bude, UK and Ballinesker, Ireland

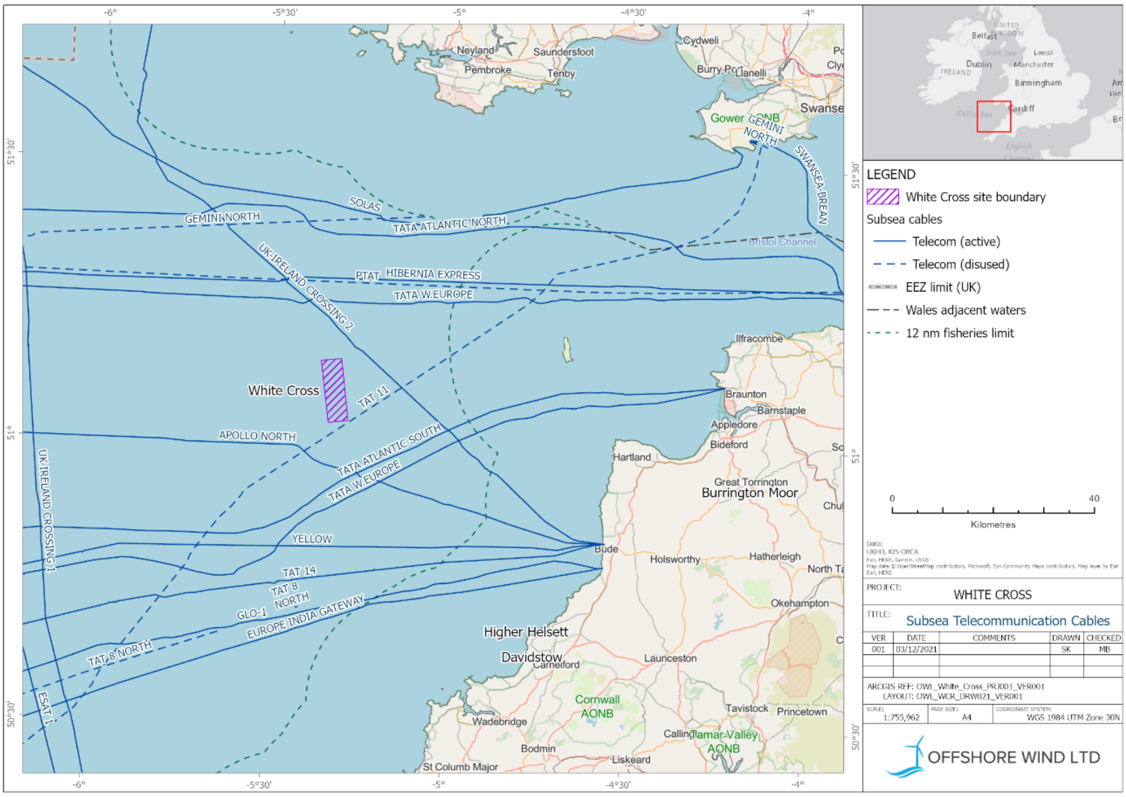


Figure 4-13: Existing Subsea Telecommunications Cables in the Celtic Sea

The three cables listed in **Table 4-2** will be installed prior to the construction of the White Cross project. All three cables are expected to make landfall at Bude, to the south the White Cross project, and therefore it is anticipated that there will be no interaction and no requirement for proximity or crossing agreements.

Table 4-2: Details of Future Cables

Cable	Status	Owner / Operator	Ready for Service / Operation	Expected / End of Service	Landfall Locations
Grace Hopper	Future	Google	2022	2047	Bude (UK) and Bilbao (Spain)

Cable	Status	Owner / Operator	Ready for Service / Operation	Expected / End of Service	Landfall Locations
2Africa	Future	Consortium of Facebook, Vodafone, and others	2023	2048	Bude (UK) and Carcavelos, Lisbon (Portugal)
Amitie	Future	Consortium of Facebook, Vodafone, Microsoft, and others	2022	2047	Bude (UK), Le Porge (France) and Lynn (USA)

4.4.5 UXO

The findings of the magnetometer survey [Ref. 7] indicate a large number of magnetic contacts within the Offshore Export Cable Corridor, in particular to the South of Lundy Island (coinciding with a WWI German Minefield [Ref. 3]); these are shown in **Figure 4-14**. There is a strong possibility that some of these magnetometer contacts may indicate the presence of Unexploded Ordnances (UXOs); a High UXO Risk has been identified for Cable Pre-Lay activities and Cable Installation and Burial in the offshore and nearshore areas in the Unexploded Ordnance Threat and Risk Assessment [Ref. **3**]. A single shipwreck has been identified within the Offshore Export Cable Corridor, which may be a munitions related wreck.

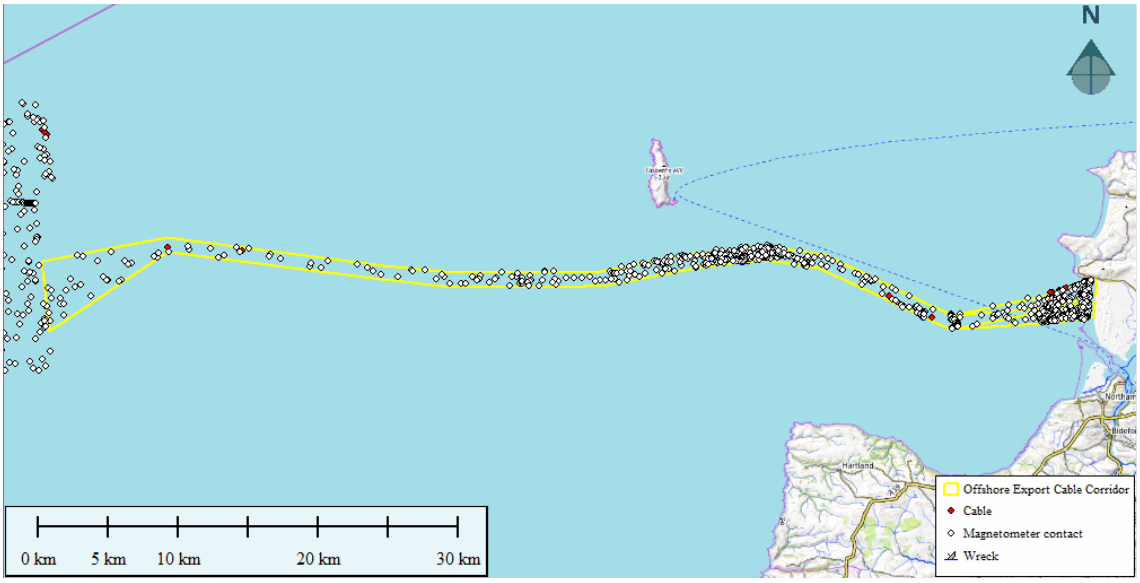


Figure 4-14: Offshore Export Cable Corridor Magnetic Survey Reports

4.4.6 Fishing and Shipping

Vessel route density data for the Windfarm Area is publicly available via the EMODnet Human Factors project [Ref. **4**].

Data for 2021 has been used in this study and the resolution of the data is 1km^2. Route Density for all vessel types is presented in **Figure 4-15**.

Route Density for Fishing vessels is presented in **Figure 4-16**. This indicates that some level of fishing activity takes place across the Offshore Export Cable Corridor.

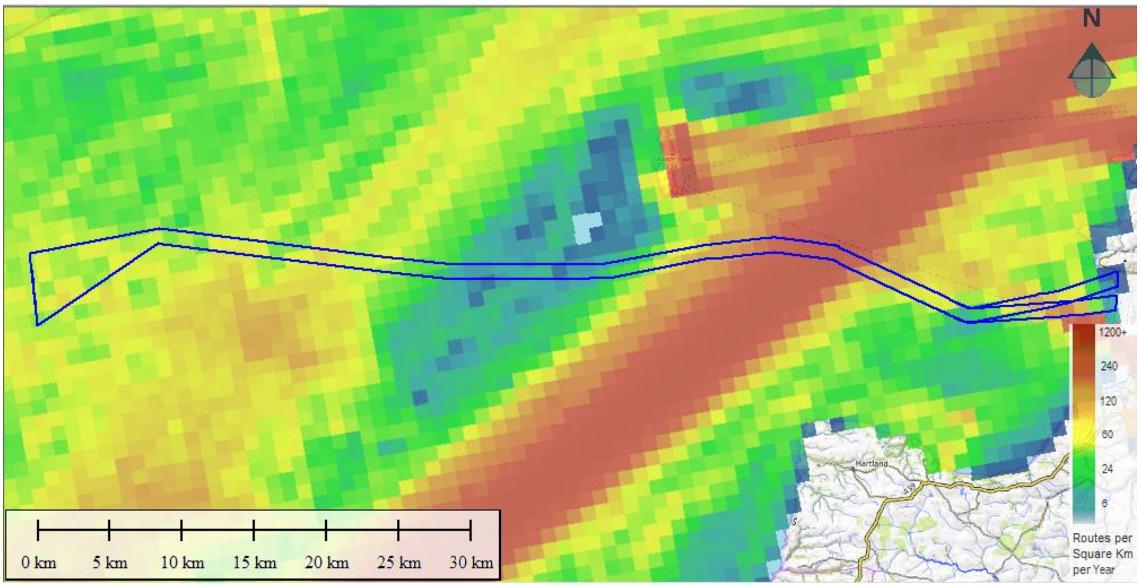


Figure 4-15: Offshore Export Cable Corridor Vessel Route Density for 2021 – All Vessel Types

Figure 4-16: Offshore Export Cable Corridor Vessel Route Density for 2021 – Fishing Vessels

4.4.7 Environmentally Protected Areas

The Offshore Export Cable Corridor traverses the Bristol Channel Approaches Area of Outstanding Natural Beauty (AONB) as shown in **Figure 4-17**.

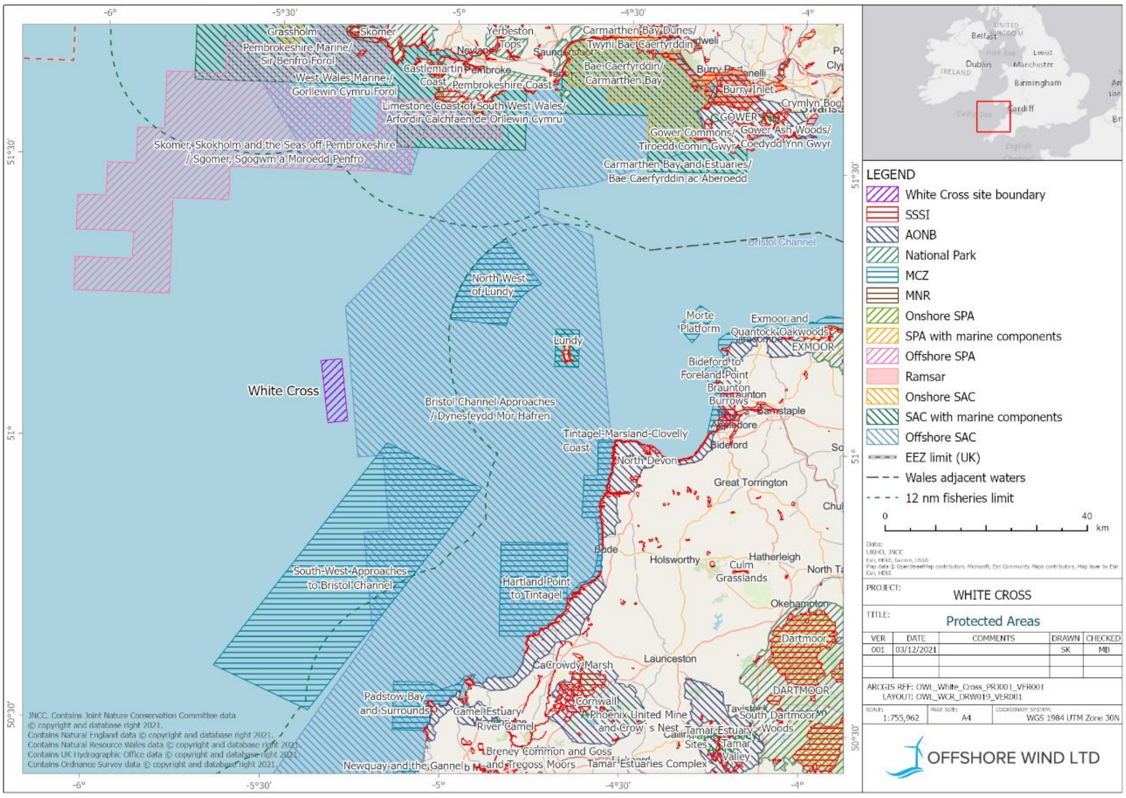


Figure 4-17: White Cross Offshore Protected Areas

4.5 Power Cables

The key cable parameters for the inter-array and export cables for this study are presented in **Table 4-3**.

Table 4-3: Key Cable Properties [Ref. 6]

Parameter	Unit	Inter Array Cable	Export Cable
Nominal Voltage	kV	66	132
Cable outer diameter	mm	220	300
Nominal burial depth*	m	1.5	1.5
Quantity	-	TBC	TBC – expect 2

*It is assumed that this is trench depth, DOL to top of cable is equivalent to Nominal Burial Depth minus Cable Outer Diameter.

4.6 CBRA Parameters

The inputs relating to the CBRA method are described in this section.

4.6.1 Vessel Data

The shipping data available from EMODnet is high-level, with a resolution of 1km × 1 km.

Vessel route density data is available for the following vessel types:

- Cargo
- Tanker
- Passenger
- Fishing
- Other

This assessment considers the total vessel route density to be assigned to the largest vessel type present in each segment of the cable route. The assumed DWT for each vessel type used in this assessment is presented in **Table 4-4**. Based on the assumed DWT, anchor sizes are extracted from **Figure 4-18** and in turn the seabed penetration depth can be obtained using the factors in **Figure 4-19**.

Table 4-4: Explanation of Specified Vessel DWT

Vessel Type	Approx. Vessel Type DWT	Explanation / Source
Cargo	75,000	Based on largest Cargo vessel present in Bristol Channel on Marine Traffic on 23/11/22. (Vessel Name: Saga Fortune)
Tanker	50,000	Based on largest Tanker present in Bristol Channel on Marine Traffic on 23/11/22. (Vessel Name: UOG Phoenix)
Passenger	2,000	Based on Passenger vessel on route Bideford – Lundy Island (Vessel Name: MS Oldenburg)
Fishing	2,000	Based on largest Fishing vessel present in Bristol Channel on Marine Traffic on 23/11/22. (Vessel Name: F/V Corail)
Other	20,000	Mid. range value selected to avoid over-conservatism.

DWT Class (tons)			ANCHOR WEIGHT (kg)	FLUKE LENGTH (m)
min	max	DWT (tons)		
0	1000	0-1,000	718	0.92
1000	1500	1,000-1,500	846	0.96
1500	2000	1,500-2,000	973	1.00
2000	5000	2,000-5,000	1695	1.20
5000	10000	5,000-10,000	2771	1.46
10000	15000	10,000-15,000	4100	1.74
15000	20000	15,000-20,000	5216	1.93
20000	40000	20,000-40,000	7862	2.27
40000	50000	40,000-50,000	9042	2.37
50000	75000	50,000-75,000	11615	2.52
75000	100000	75,000-100,000	13702	2.60
100000	150000	100,000-150,000	16697	2.69
150000	200000	150,000-200,000	18582	2.76
200000	250000	200,000-250,000	19912	2.83
250000	300000	250,000-300,000	21242	2.92
300000	350000	300,000-350,000	23230	3.10
350000	400000	350,000-400,000	26250	3.60
-	-	Unspecified	-	-

Figure 4-18 Anchor Sizing by Vessel DWT

Soil Type	Seabed Penetration Depth (× fluke length)
Rock > 1MPa	0.25
Grainy soils and riprap	0.5
Stiff clays > 150kPa	0.5
Sandy soils	1
Soft to firm clays from 40 to 150kPa	1.5
Very soft clays < 40kPa	4

Figure 4-19 Seabed Penetration by Soil Type

The distance travelled by a dragged anchor (D_{ship}) is assumed to be the distance relating to the segment (1,000 m) for all vessel routes traversing that segment, i.e., the route density × 1,000m.

The velocity of the vessel on deployment of an anchor (V_{ship}) is assumed to be 4 knots, as per recommended value in CBRA documentation when no suitable data is available [Ref. **1**].

4.6.2 Nominal Seabed

The nominal seabed or mean seabed level, relative to which burial depths are provided, is assumed at this time to be represented by the seabed. This assumption may need to be adjusted if sediments in the area are found to be significantly mobile.

4.6.3 Water Depth Classification

The sample water depth classification table provided in the CBRA guidance documents has been applied in this study for the determination of P_{WD} and is reproduced in **Figure 4-20**.

No anchorages have been identified within or very close to the project area.

The project area is considered to be open sea, i.e., not within a geographically constrained shipping channel.

Table 5 Example of Probability Modifiers for Water Depth

Vessel deadweight, DWT (t)	2,000	5,000	20,000
Vessel draft	4.0	6.0	10.0
Water Depth/Profile	Probability Modifier		
Water Depth Greater than e.g. 50m	0	0	0.1
Water Depth between e.g. 30m and 50m	0.0	0.1	0.3
Water Depth between e.g. 10m and 30m	0.3	0.5	0.9
Wide Shipping Channel with shallow water at margins	0.2	0.5	0.6
Narrow Shipping Channel with shallow water at margins	0.3	0.7	0.9
Proximity of a designated anchorage	0.9	0.9	0.9

Figure 4-20 Water Depth Classification Guidance for P_{WD} [Ref. 2]

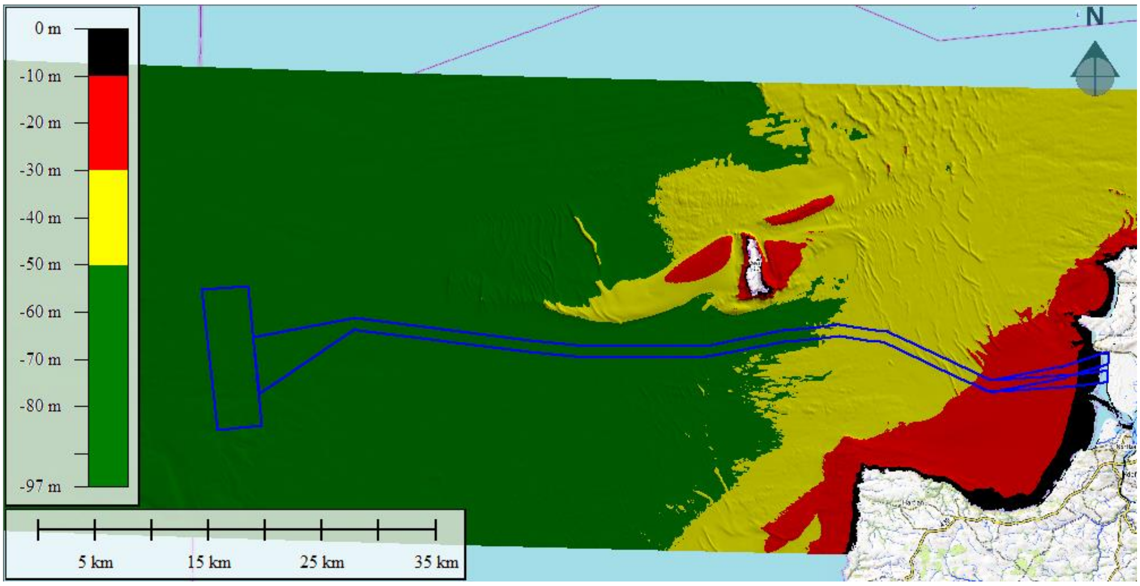


Figure 4-21 White Cross Site Water Depths by CBRA Classification

4.6.4 $P_{incident}$

There are a number of published failure rates included in the CBRA methodology, among them a “Probability of loss of control on board a ship when on collision course per pass” of 2.0 × 10^{-4}, as published in DNV-RP-F107. This value is used as the probability of an incident occurring requiring deployment of an anchor ($P_{incident}$) in the present study. It is noted that the selection of $P_{incident}$ has a significant influence on the results of the anchor strike probability calculation.

Table 7 Example of Failure rates and return periods from the literature

Reference	Probability per vessel per year	Return period (years)
DNV-RP-F107: Probability of loss of control onboard when on collision course per pass (main reasons no crew on bridge, negligent/tired/drunk crew, accident or radar failure/poor visibility)	$2x10^{-4}$	5000
DNV-RP-F107: Machinery breakdown for single engine tankers in the north sea	$1.75x10^{-1}$	5.7
Kristoffersen & Monnier (1997) (SAFECO)	2.5x10-4	4000
DNV for Marine Coastguard Agency Probability of engine failure	$1.5x10^{-4}$	6667
Southampton Solent University, 15 years of Shipping Accidents: A review for WWF Average vessel loss rate per year (1997 to 2011)	$1.43x10^{-3}$	700
IMO, International Shipping Facts and Figures Average vessel loss rate per year (2006 to 2010)	$1.44x10^{-3}$	694
OGP Total loss per ship per year	$3x10^{-3}$	333

Figure 4-22: $P_{incident}$ Values Published in CBRA Methodology [Ref. 2]

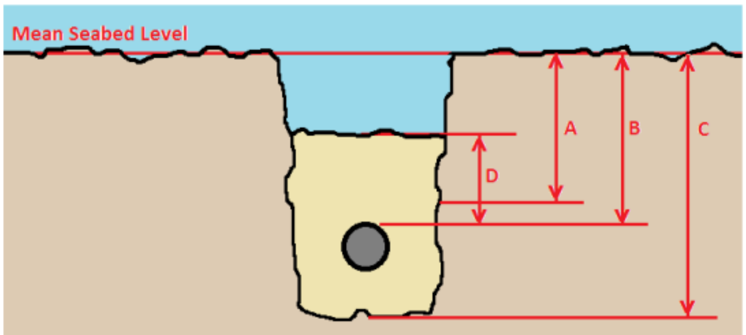
4.6.5 $P_{traffic}$

A value of 1 for $P_{traffic}$ has been applied and represents a desire to protect from all vessels. The CBRA methodology allows for a lower value to be applied, if a project decision was made to protect from a lower percentile of vessels, e.g., 0.9 for 90th percentile.

4.6.6 Limits on Depth of Lowering

The project nominal burial depth is 1.5 m. It is assumed that this refers to trench depth. Depth of lowering (DOL) to top of cable can be calculated by subtracting the cable diameter from the trench depth, as illustrated in **Figure 4-23**.

The maximum single pass trench depth is assumed to be 1.5 m, based on capabilities of standard trenching tools.



A Recommended Minimum Depth of Lowering
B Target Depth of Lowering
C Target Trench Depth
D Depth of Cover

Figure 4-23 Definition of CBRA Burial Terminology [Ref. 1]

5.0 Methodology

This section describes the methodology applied in the Burial Assessment Study to evaluate the required depth of lowering (DOL) for the White Cross offshore windfarm offshore cables.

The Carbon Trust Cable Burial Risk Assessment (CBRA) methodology [Ref. **1**] is employed for this burial assessment study. This methodology was originally developed for offshore wind and is considered the current "State-of-the-Art" for subsea cabling.

CBRA considers natural and anthropogenic threats to subsea cables in determining the minimum required Depth of Lowering (DOL). It allows for a degree of risk to be assumed by a project (e.g., project may decide to protect from 90th percentile vessel, if the risk of anchor strike from largest vessels is deemed acceptable). As this study is being undertaken at a relatively early stage of the White Cross project, using high level data for certain key inputs, an acceptable risk level for the project has not been applied and risk is presented for information based on the data available.

Determining the appropriate depth of lowering for the cable is an iterative process. The inputs are assessed, and a depth of lowering is proposed; if this depth of lowering results in an acceptable level of residual risk, this is the "Proposed DOL". However, if the residual risk is deemed to be too high for the project, iterations can be made; for example, refinement of the shipping data used, or alteration of the route to avoid particular hazards, such as steep slopes, pUXOs, submarine slides, etc. This process is summarised in **Figure 5-1**.

CBRA does not provide guidance on local burial depth requirements due to licensing etc., however, as CBRA is an accepted industry standard practice, it may be a useful tool in demonstrating justification for appropriate optimisations.

Following the CBRA, if there are any areas where burial is not expected to be a practical solution, a proposal will be presented on alternative external protection methods including the use of rock armour.

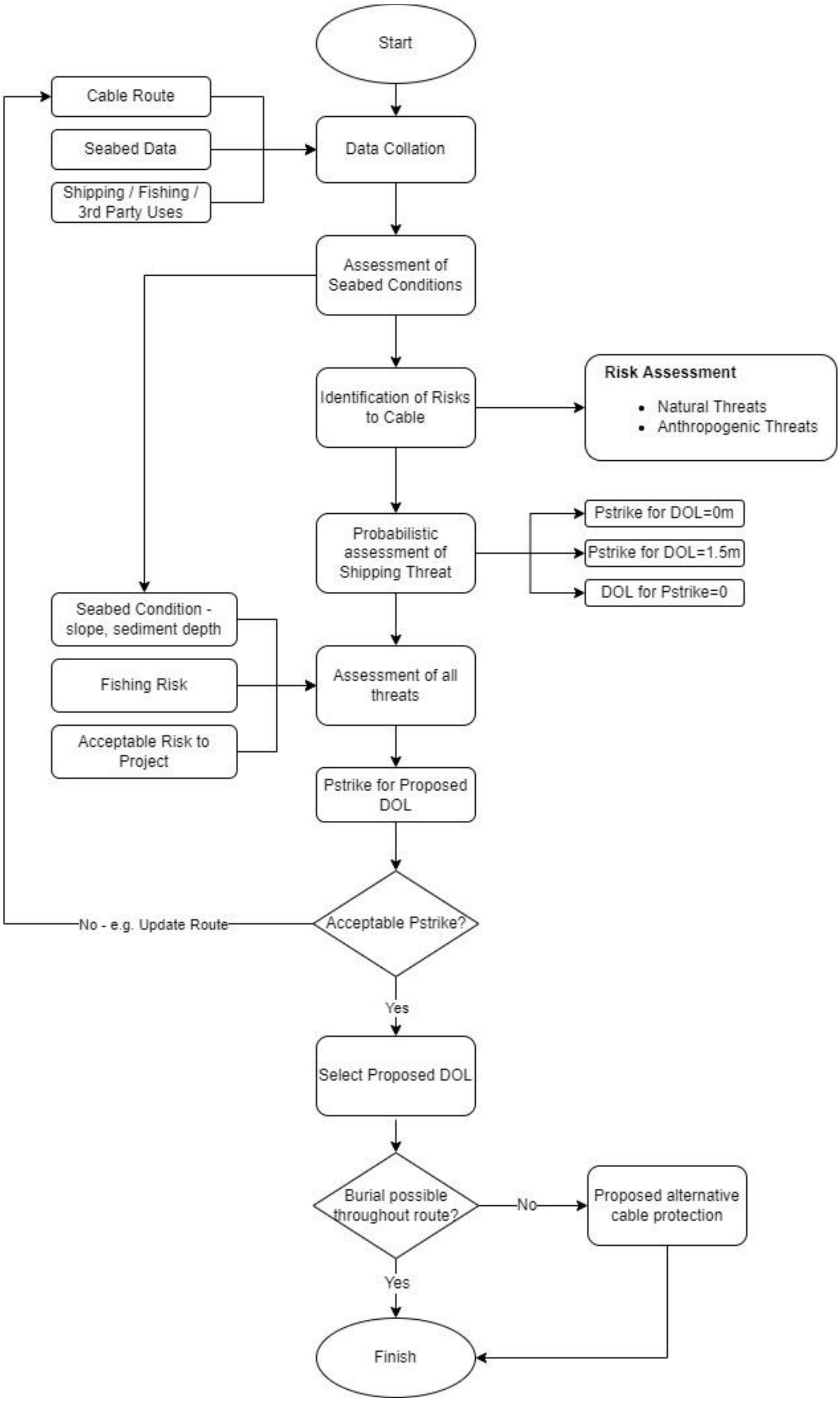


Figure 5-1: Assessment Methodology

6.0 Results

6.1 General

The results of the Burial Assessment Study are presented in the sub-sections that follow.

6.2 Hazard Identification

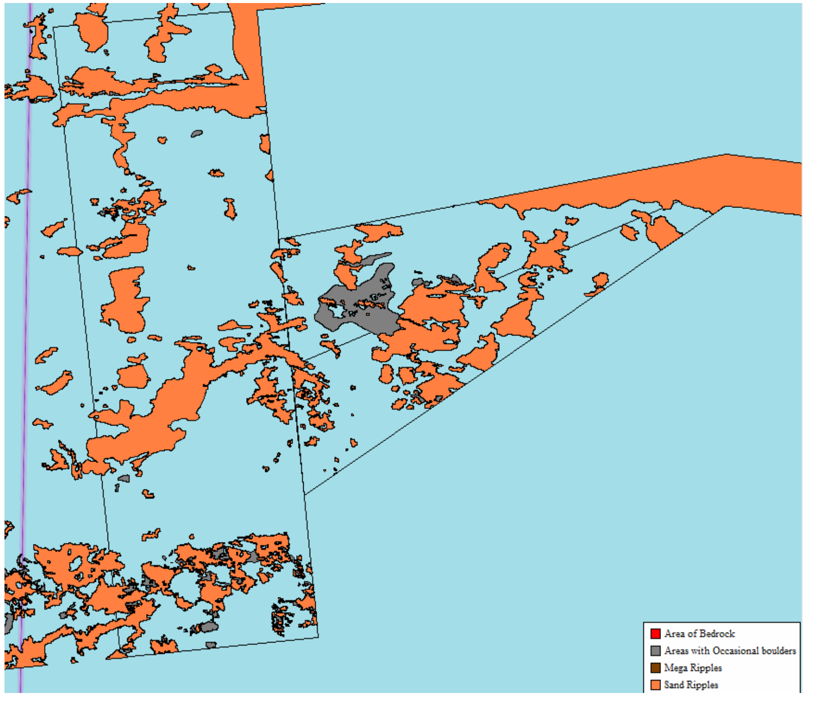
A hazard identification exercise has been performed, considering natural and anthropogenic (man-made) risks to the cable along the proposed Offshore Export Cable Corridor and within the Windfarm Site.

6.2.1 General Discussion of Risks as Handled By CBRA

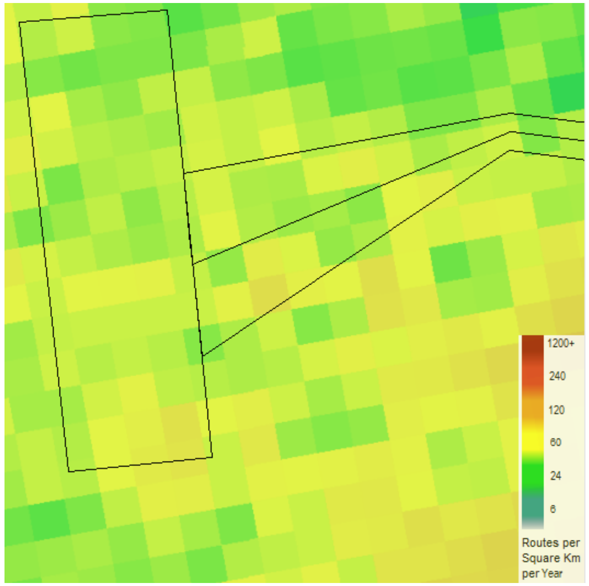
The key risks to cables as considered by the CBRA methodology are described in this sub-section, along with guidance on how each risk is handled with regard to burial. The applicability of these risks to the Windfarm Site and Offshore Export Cable Corridor is presented in **Sections 6.2.2** and **6.2.3**, respectively.

- **Sediment Mobility**
  It is recommended to bury below mobile sediment. This may require additional depth of lowering, or pre-sweeping, in areas where mobile sediment is identified.
- **Seismic Activity**
  Burial is not recommended as protection from seismic activity.
- **Submarine Landslide**
  Protection by burial is only recommended if the cable can be buried below the base level of any known landslide areas. Primary action should be to re-route cable to avoid such hazards.
- **Dredging / Aggregate Extraction / Subsea Mining**
  Burial is not recommended as protection from these risks. It is recommended to avoid areas where these activities are carried out. Where these areas cannot be avoided, the cable must be buried beneath the maximum dredging/excavation level.
- **UXOs**
  Protection from UXOs is not covered by the CBRA methodology. It is assumed that any UXOs confirmed along the final route will be removed or avoided by rerouting of the cable.
- **3rd Party Infrastructure**
  Burial may not be possible in the vicinity of 3rd Party Infrastructure such as existing cables or pipelines; therefore, crossings over the existing infrastructure may be required. Typically, disused cables can be cut and retrieved with permission of the owner. It is also recommended to allow for extra depth of lowering if any future cables or pipelines are planned in the area, to allow for sufficient DOL of the future infrastructure above the current cable.
- **Fishing**
  Based on research carried out and presented in the Carbon Trust CBRA methodology documentation, the maximum penetration depth for typical fishing equipment is 0.3m, even in very soft sediments. If a typical factor of safety of 2 is applied, a minimum DOL of 0.6m is required in areas where bottom trawling occurs.
- **Vessel Anchoring**
  CBRA includes a probabilistic methodology for quantifying the risk to a cable from anchor strike. This methodology is presented in detail in **Section 6.3.1**.

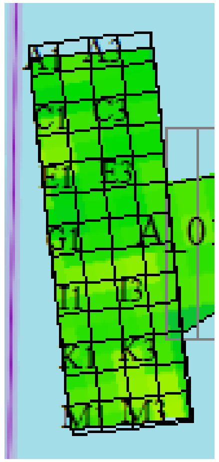
6.2.2 Hazards: Windfarm Site

Threat Type	Threat Description	General notes on treatment in CBRA	Hazard identification - Windfarm Site
Natural	Sediment Mobility	CBRA recommends burial beneath non-mobile sediment. Pre-sweeping or increased DOL typically required.	Areas of sand ripples are noted throughout the Windfarm Site. This typically indicates the potential for sediment mobility. 

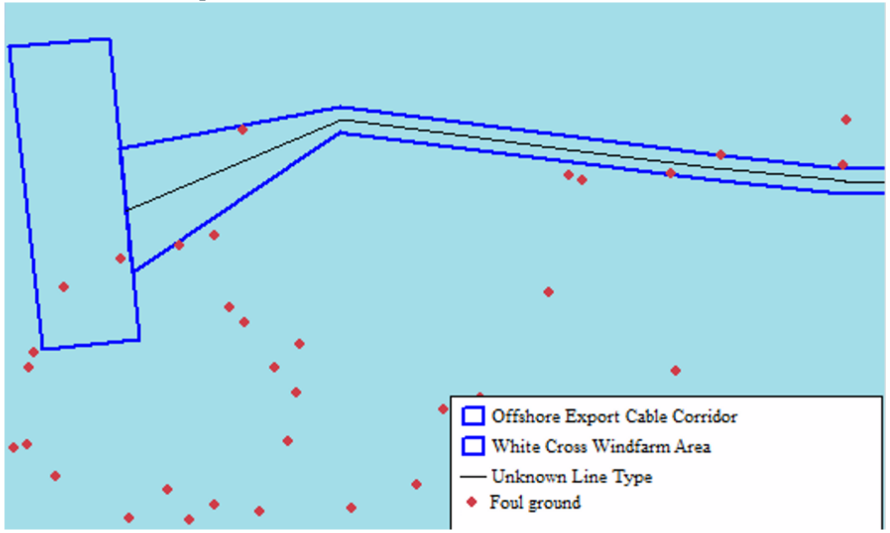
Threat Type	Threat Description	General notes on treatment in CBRA	Hazard identification - Windfarm Site
Natural	Seismic Activity	CBRA does not recommend burial as a means of protection from seismic activity, therefore cable routing should take this into consideration.	There is no indication of seismic activity in the area.
Natural	Submarine Landslides	CBRA does not recommend burial as a means of protection from submarine landslide, therefore cable routing should take this into consideration.	There is no indication of submarine landslide activity in the area.

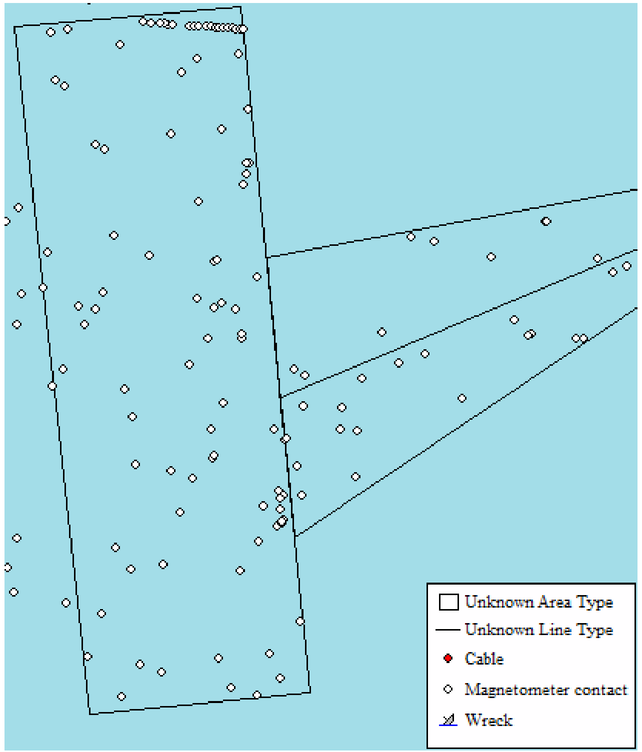
Threat Type	Threat Description	General notes on treatment in CBRA	Hazard identification - Windfarm Site
Anthropogenic	Shipping	Probabilistic assessment methodology recommended by CBRA.	Shipping traffic density at the Windfarm Site is moderate to low and largely comprised largely of fishing vessels, but with some traffic from Cargo vessels and Tankers also. These larger vessels carry large anchors which pose a risk of anchor strike to a reasonably deep depth, although the moderate to low density of traffic decreases the risk of an anchor strike occurring. 

wood.

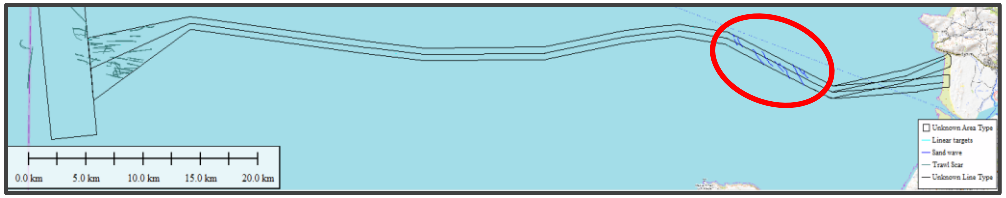
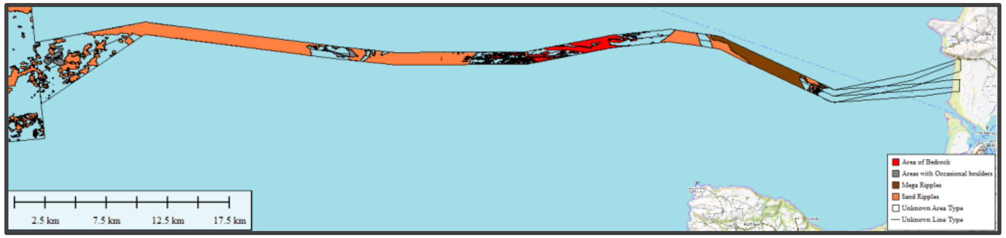
Threat Type	Threat Description	General notes on treatment in CBRA	Hazard identification - Windfarm Site
Anthropogenic	Fishing	Typical DOL for protection from fishing equipment is 0.6 m (0.3 m x FOS 2).	Fishing is prevalent throughout the Windfarm Site, as shown by the fishing vessel density map. Fishing equipment poses a risk of snagging or entanglement to an unburied cable. 
Anthropogenic	Mining	CBRA does not recommend burial as a means of protection from mining activities, therefore cable routing should take this into consideration and avoid these areas.	There is no evidence of mining activity in the area.

Threat Type	Threat Description	General notes on treatment in CBRA	Hazard identification - Windfarm Site
Anthropogenic	Dredging	In areas where dredging is practiced, CBRA recommends burial below the maximum dredged level. Pre-dredging or increased DOL typically required.	There is no evidence of dredging activity in the area.
Anthropogenic	Aggregate Extraction	CBRA does not recommend burial as a means of protection from aggregate extraction activities, therefore cable routing should take this into consideration and avoid these areas.	There is no evidence of aggregate extraction activity in the area.

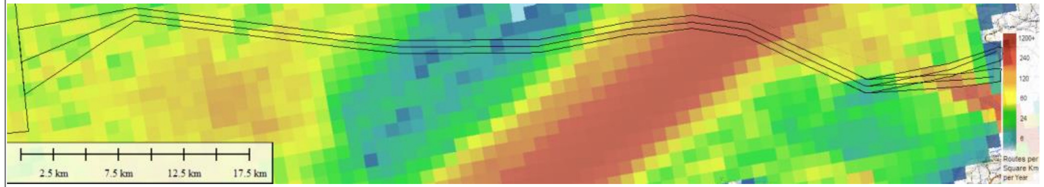
Threat Type	Threat Description	General notes on treatment in CBRA	Hazard identification - Windfarm Site
Anthropogenic	Dumping		Two areas of foul ground are identified in the Windfarm Site. 
Anthropogenic	3rd Party Infrastructure (Cables, Pipelines, Other)		No cables have been identified in the Windfarm Site at present.
Anthropogenic	3rd Party Infrastructure (Aquaculture)		There is no evidence of aquaculture activity in the area.

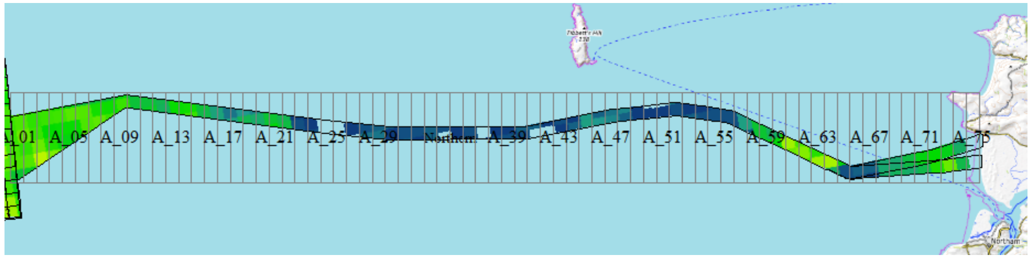
Threat Type	Threat Description	General notes on treatment in CBRA	Hazard identification - Windfarm Site
Anthropogenic	UXOs	CBRA does not recommend burial as a means of protection from UXOs. Cable route should either divert around confirmed UXOs, or they should be removed.	There are 97 magnetic targets within the Windfarm Site. The nature of these magnetic contacts is unknown at present, but there is potential for some of these to be pUXOs. 

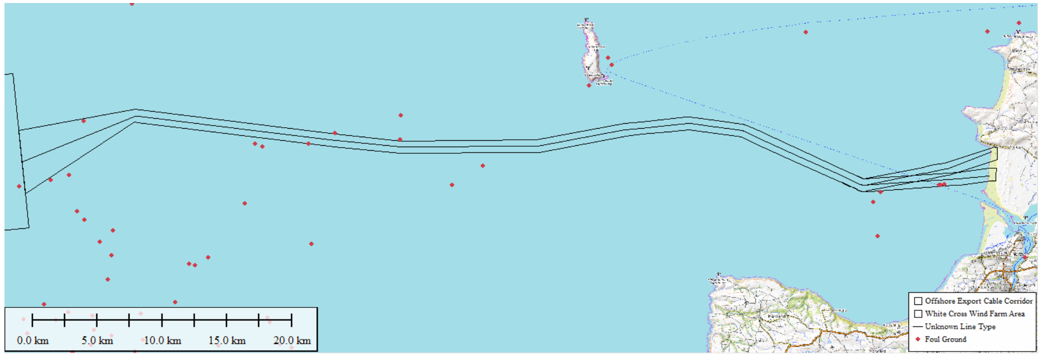
6.2.3 Hazards: Offshore Export Cable Corridor

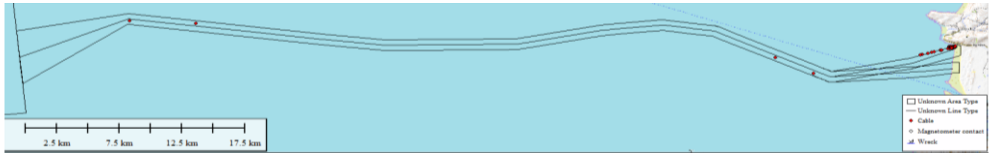
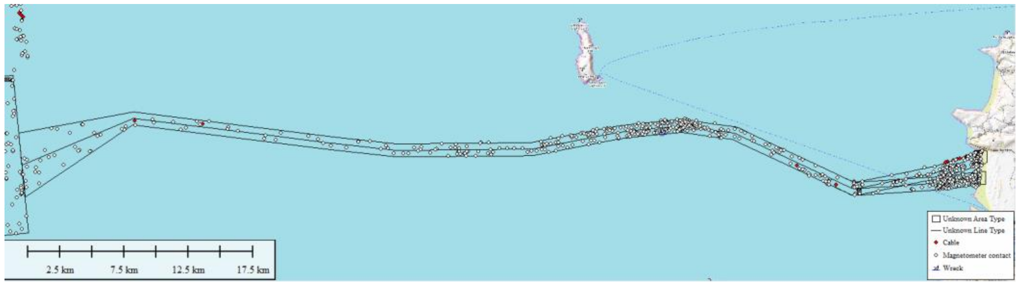
Threat Type	Threat Description	General notes on treatment in CBRA	Hazard identification - OECC Route
Natural	Sediment Mobility	CBRA recommends burial beneath non-mobile sediment. Pre-sweeping or increased DOL typically required.	Areas of sand ripples and mega ripples are noted throughout the OECC Route. In addition, there is an area of sand waves noted. These formations typically indicate the potential for sediment mobility.  
Natural	Seismic Activity	CBRA does not recommend burial as a means of protection from seismic activity, therefore cable routing should take this into consideration.	There is no indication of seismic activity in the area.

wood.

Threat Type	Threat Description	General notes on treatment in CBRA	Hazard identification - OECC Route
Natural	Submarine Landslides	CBRA does not recommend burial as a means of protection from submarine landslide, therefore cable routing should take this into consideration.	There is no indication of submarine landslide activity in the area.
Anthropogenic	Shipping	Probabilistic assessment methodology recommended by CBRA.	An area of high-density shipping activity crosses the OECC route (indicated by the red colouring below). This shipping activity is made up largely of Cargo vessels with some Tanker traffic. These large vessels carry large anchors which pose a risk of anchor strike to a reasonably deep depth and the high density of shipping traffic increases the risk of an anchor strike occurring. 

Threat Type	Threat Description	General notes on treatment in CBRA	Hazard identification - OECC Route
Anthropogenic	Fishing	Typical DOL for protection from fishing equipment is 0.6 m (0.3 m x FOS 2).	Fishing activity is prevalent to varying degrees over the majority of the OECC route, as shown by the fishing vessel density map. Fishing equipment poses a risk of snagging or entanglement to an unburied cable. 
Anthropogenic	Mining	CBRA does not recommend burial as a means of protection from mining activities, therefore cable routing should take this into consideration and avoid these areas.	There is no evidence of mining activity in the area.
Anthropogenic	Dredging	In areas where dredging is practiced, CBRA recommends burial below the maximum dredged level. Pre-dredging or increased DOL typically required.	There is no evidence of dredging activity in the area.

Threat Type	Threat Description	General notes on treatment in CBRA	Hazard identification - OECC Route
Anthropogenic	Aggregate Extraction	CBRA does not recommend burial as a means of protection from aggregate extraction activities, therefore cable routing should take this into consideration and avoid these areas.	There is no evidence of aggregate extraction activity in the area.
Anthropogenic	Dumping		Some areas of foul ground are identified on the OECC Route. These areas do not coincide with the presently assumed route (centreline of Export Cable corridor) and should be avoided in any re-routing. 

Threat Type	Threat Description	General notes on treatment in CBRA	Hazard identification - OECC Route
Anthropogenic	3rd Party Infrastructure (Cables, Pipelines, Other)		Four telecoms cables are known to cross the proposed OECC Route. These include three in-service cables (UK-Ireland Crossing 2, TATA Atlantic South and TATA W Europe) and the disused TAT 11 cable. A number of magnetic targets have been identified as "cable". Crossings of the in-service cables will be required, while the disused cable can likely be cut and secured; all crossing activities will require a crossing agreement with the existing cable owner. 
Anthropogenic	3rd Party Infrastructure (Aquaculture)		There is no evidence of aquaculture activity in the area.
Anthropogenic	UXOs	CBRA does not recommend burial as a means of protection from UXOs. Cable route should either divert around confirmed UXOs, or they should be removed.	There are 740 magnetic contacts within the Export Cable Route. The nature of these magnetic contacts is unknown at present, but there is potential for some of these to be pUXOs. There is also one shipwreck on the OECC route (SE of Lundy Island); details of the wreck are unavailable at present; however, shipwrecks can pose a UXO threat to nearby cables. 

6.3 Protection from Anchor Strike

The methodology for quantifying the risk to cable of anchor strike is described in this section, along with results of the probabilistic assessment for risk of damage to the cable due to shipping which has been carried out on both the offshore export cable corridor and the windfarm site.

6.3.1 Probabilistic Methodology

The risk to the cable due to shipping can be quantified using the following probabilistic formula.

The offshore export cable corridor is discretised into 1000m segments for the purpose of this assessment (65 segments common to the Northerly and Southerly routes, plus 10 additional segments on each of the Northerly and Southerly routes towards landfall, i.e., 85 segments in total), while the windfarm area is divided into segments of approximately 1km^2 (52 segments in total), allowing for the fact that the inter-array cable routing has not yet been finalised and the inter-array cables could be situated anywhere within the Windfarm Site. The segmentation is shown in **Figure 6-1** and **Figure 6-2** for the Windfarm Site and Offshore Export Cable Corridor, respectively. The risk of anchor strike in each segment is assessed.

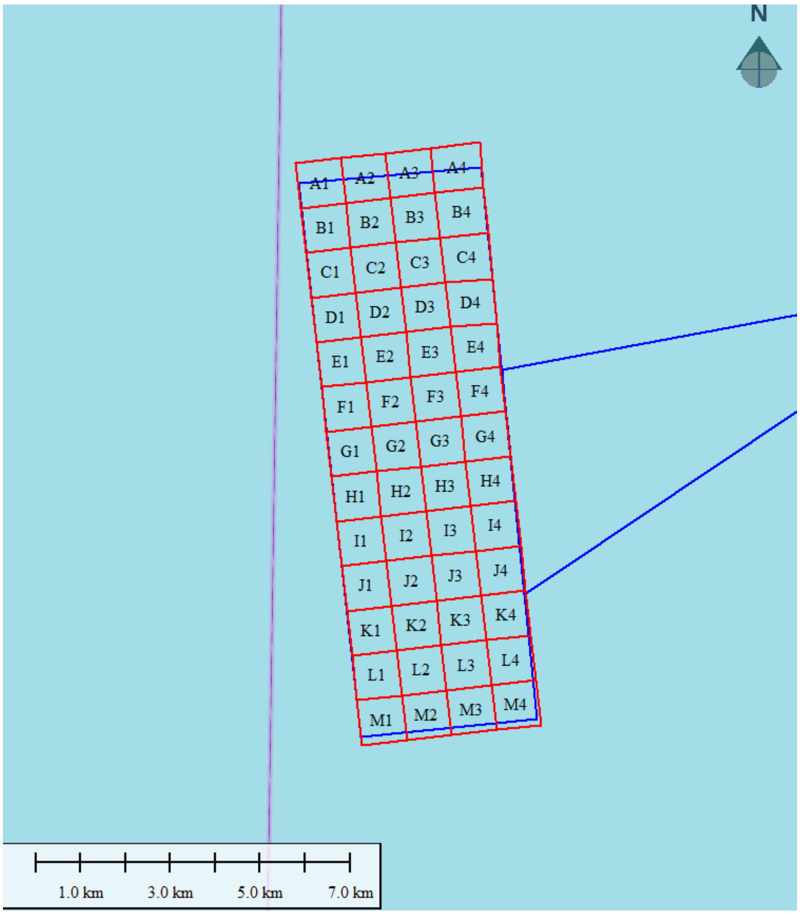


Figure 6-1: Windfarm Site Segmentation

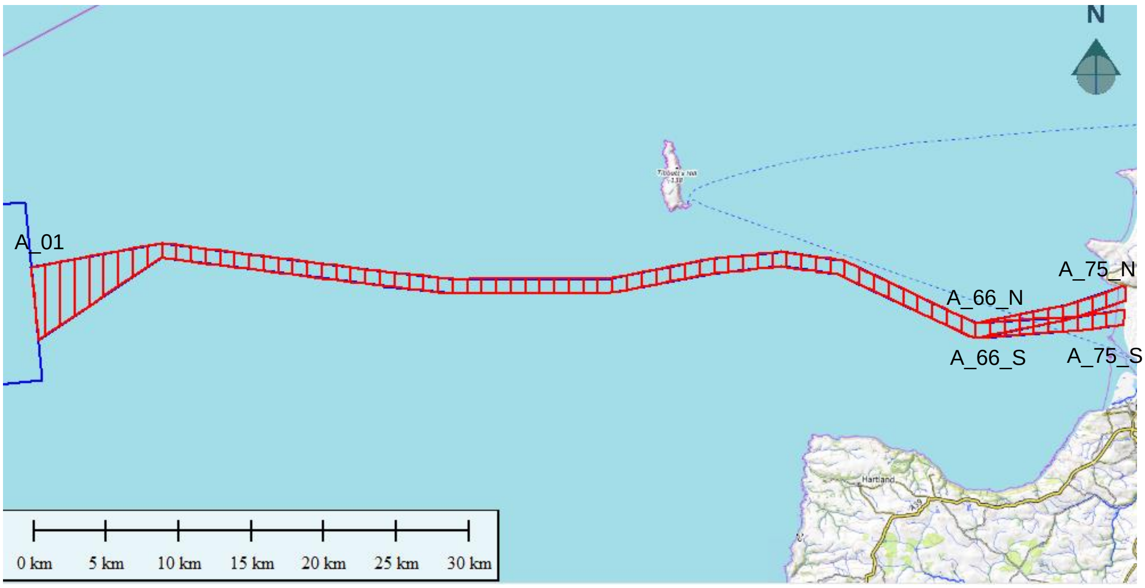


Figure 6-2: Offshore Export Cable Corridor Segmentation

The equation in **Figure 6-3** is proposed by the Carbon Trust CBRA methodology as a method to quantify the probability of anchor strike (P_{strike}) for each segment of the cable.

$$P_{Strike} = P_{Traffic\ Risk} \sum_{1}^{Number\ of\ vessels\ in\ the\ section} \left(\frac{D_{Ship\ Drag}}{V_{Ship} * 8760\ hrs\ per\ year} * P_{Incident} * P_{WD} \right)$$

$P_{Traffic\ Risk}$	probability modifier based on the tolerable level of risk
P_{WD}	probability modifier for nature and depth of seabed
V_{Ship} [metre/hr]	ship speed when the anchor is deployed
$D_{Ship\ Drag}$ [metres]	distance travelled by the anchor in order to be a threat to the cable
$P_{Incident}$	probability of incident requiring the deployment of an anchor for that vessel size and type
8760 hrs	factor to annualise the results

Figure 6-3: Probabilistic Formula to Assess the Risk from Anchoring, CBRA [Ref. 2]

The following are the key inputs to this formula:

- Water depth
- Segment classification (shipping channel, anchorage, open sea)
- The number of vessel tracks crossing or close to the cable
- Vessel size (DWT)
- Soil type

A navigational risk assessment has been prepared for the Project, however Route Density data from EMODnet Human Factors is used in this calculation. The maximum route density reported within the project area in a segment is considered to be applicable to the entire segment. This is considered to be a reasonable assumption as the segments are to the order of 1km^2, and the data is presented at a resolution of 1km^2.

The anchor penetration depth for a segment is based on the largest vessel type present in the segment and is based on the soil type and typical fluke length corresponding to the assumed vessel DWT (see **Table 6-1** for factors based on soil type).

Table 6-1: Anchor Penetration Depth Factors Based on Soil Type

Soil Type	Factor Applied to Typical Fluke Length for Anchor Penetration Depth (Penetration Depth = Fluke Length × Factor)
Rock > 1MPa	0.25
Grainy soils and riprap	0.5
Stiff clays > 150kPa	0.5
Sandy soils	1
Soft to firm clays (40 to 150kPa)	1.5
Very soft clays < 40kPa	4

6.3.2 Windfarm Site

The probability of anchor strike (Pstrike) per segment within the Windfarm Site if the cable is left unburied (DOL=0m) is assessed using the probabilistic methodology above. The results of this assessment are presented in **Figure 6-4**.

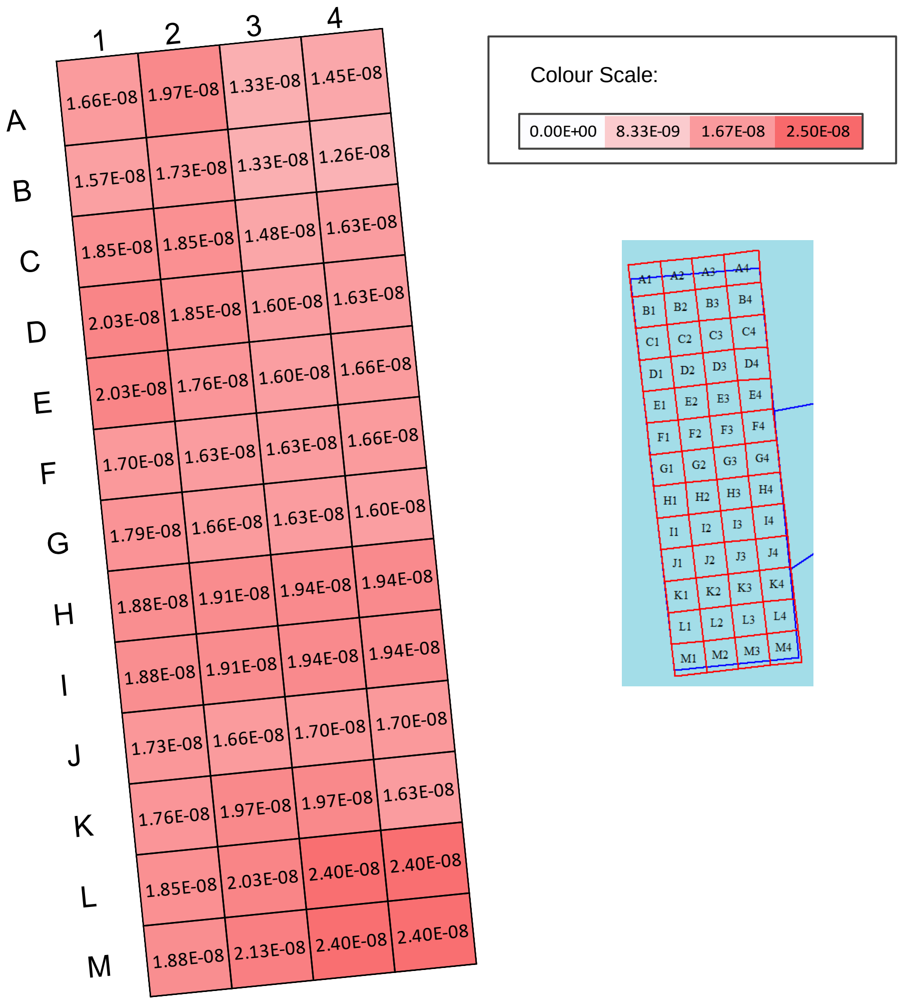


Figure 6-4: Windfarm Site Pstrike for DOL=0m or DOL=1.5m

The risk of anchor strike for the inter-array cables in the Windfarm Site is very low based on the data available; this is due to low vessel traffic density and the relatively deep water classification of these segments. The maximum risk of anchor strike (2.4E-08 incidents per year per sq. km) occurs in the South-East corner of the Site, where the vessel density is slightly higher. The total risk of anchor strike in the Windfarm Site is 9.36E-07 incidents per year.

Note that while a burial depth of 0 m (unburied cable) yields a low Pstrike risk, an unburied cable is exposed to the elements and likely to suffer from other cable failure mechanisms such as fatigue and potential instability, in addition to the risk being assessed here, which is specifically associated with an anchor drag event. Cable on-bottom stability does not form part of the present study and a separate on-bottom stability study should be undertaken to assess this risk once an inter-array cable design has been selected.

The maximum anchor penetration depth across the Windfarm Site is presented in **Figure 6-5**. This represents the depth of lowering that would be required to achieve Pstrike = 0, i.e., the depth the cable must be buried to so that there is no risk of anchor strike. As this exceeds the nominal project burial depth of 1.5m throughout, the risk profile for burial to 1.5m is equivalent to that shown in **Figure 6-4**, noting that the risk of an anchor strike remains unless the burial depth exceeds the anchor penetration depth.

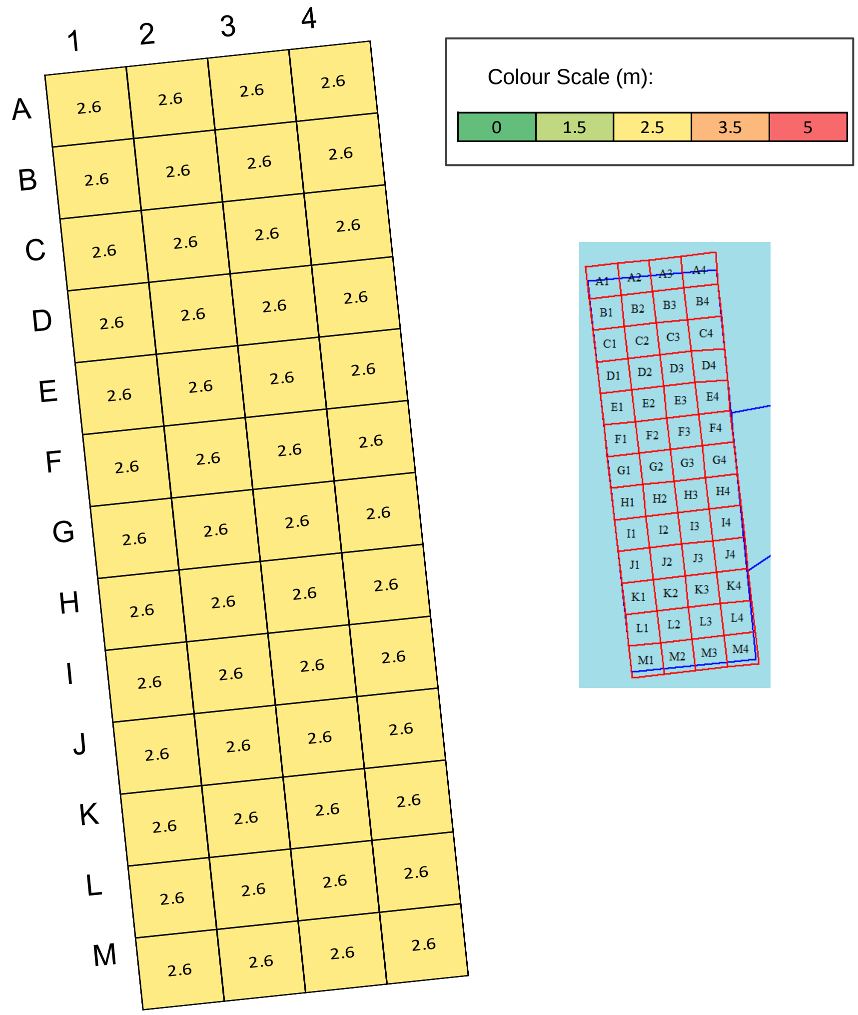


Figure 6-5: Windfarm Site Anchor Penetration Depth

The anchor penetration depths calculated are impacted by the vessel size assumed and the soil type (sandy throughout); the largest vessel present in the Windfarm Site in the publicly available data is a cargo vessel. Refinement of the data set through the procurement of a shipping study using AIS data will allow for a more accurate anchor penetration depth to be calculated.

6.3.3 Offshore Export Cable Corridor

The probability of anchor strike (Pstrike) per segment within the Offshore Export Cable Corridor if the cable is left unburied (DOL=0m) is assessed using the probabilistic methodology above. The results of this assessment are presented in **Figure 6-6**. Note that the yellow shaded segments represent the Northerly landfall approach, while the purple shaded segments represent the Southerly landfall approach.

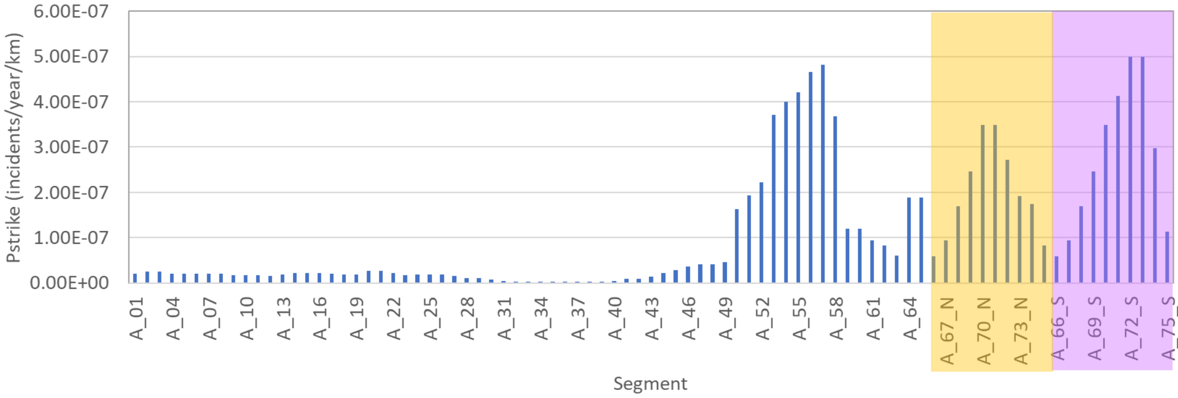


Figure 6-6: Offshore Export Cable Corridor Pstrike for DOL=0m

The risk of anchor strike for the export cables is very low at the offshore end of the Offshore Export Cable Corridor, based on the data available, and increases toward landfall. The risk of anchor strike on the Southerly landfall approach is slightly higher than on the Northerly landfall approach, due to higher vessel density in this area.

The maximum risk of anchor strike (5.0E-07 incidents per year per km) occurs towards the Southerly landfall, with another slightly lower peak (reaching a maximum of 4.8E-07 incidents per year per km) occurs where the main shipping lane to the Bristol Channel crosses the Export Cable route. The total risk of anchor strike on the Windfarm Site is 9.53E-06 incidents per year, which is approximately equivalent to a return period of 1 incident in 100,000 years on the export cable route.

As per the inter-array cables, note that while a burial depth of 0m (unburied cable) yields a low Pstrike risk, an unburied cable is exposed to the elements and likely to suffer from other cable failure mechanisms such as fatigue and potential instability, in addition to the risk being assessed here, which is specifically associated with an anchor drag event. Cable on-bottom stability does not form part of the present study and a separate on-bottom stability study should be undertaken to assess this risk once an export cable design has been selected.

The maximum anchor penetration depth along the Offshore Export Cable Corridor is presented in **Figure 6-7**. This represents the depth of lowering that would be required to achieve Pstrike = 0, i.e., the depth the cable must be buried to so that there is no risk of anchor strike. This depth is largely driven by the soil type and vessel type, which are annotated on the plot. Refinement of the assumptions relating to vessel size through the procurement of a shipping study using AIS data will allow for a more accurate anchor penetration depth to be calculated.

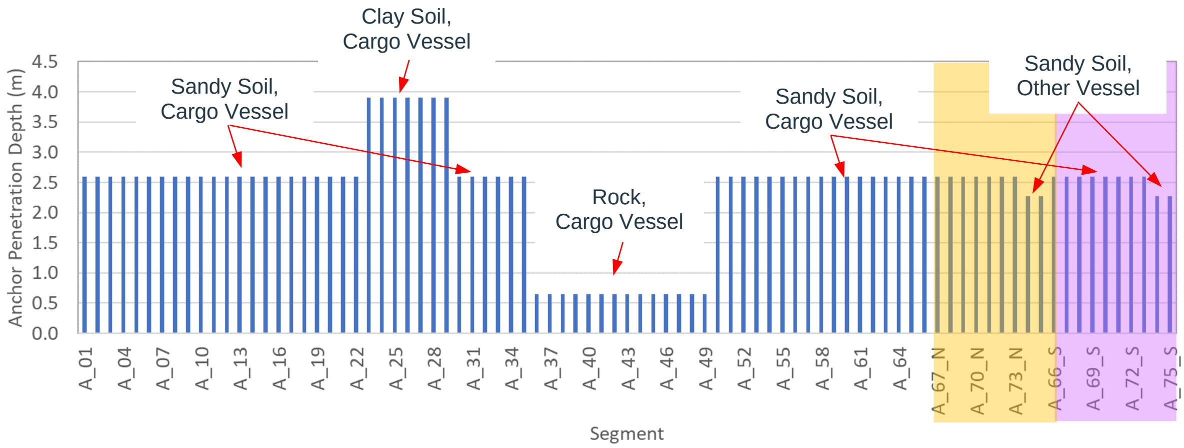


Figure 6-7: Offshore Export Cable Corridor Anchor Penetration Depth

The second pass of the Anchor Strike Probability calculation considers burial to 1.5m throughout the export cable route and the resulting Pstrike along the Offshore Export Cable Corridor is shown in **Figure 6-8**. Burial to a depth of 1.5m in segments A-36 to A-49 would reduce the Pstrike in these segments to 0, yielding a total Pstrike of 9.26E-06 incidents per year per km. However, it is noted that these segments correspond with the area of exposed bedrock; therefore, burial to 1.5m is highly unlikely to be achievable.

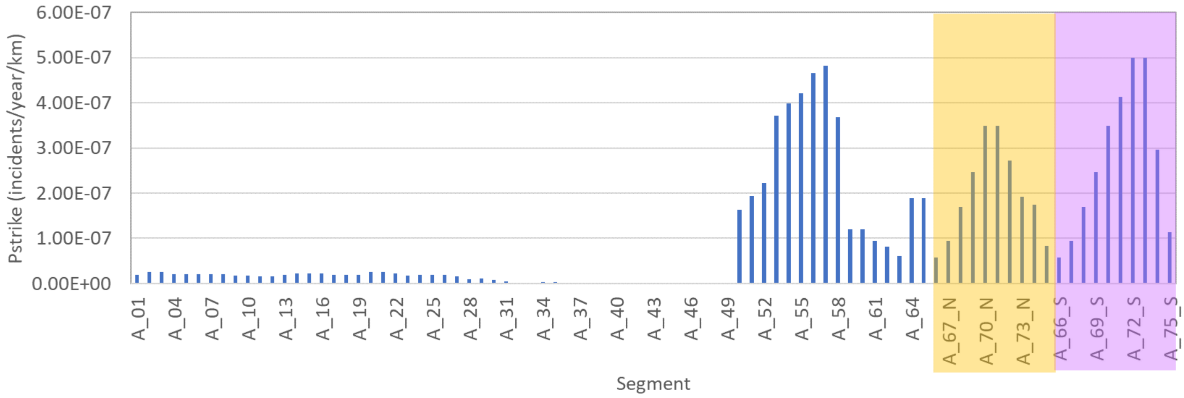


Figure 6-8: Offshore Export Cable Corridor Pstrike for DOL=1.5m

6.4 Cable Burial Assessment

6.4.1 General

A full CBRA assessment has been carried out for the cable, considering the risks described in **Section 6.2**. The results of this assessment include a proposed depth of lowering for the cable and the associated residual risk.

A CBRA assessment spreadsheet has been populated with the best available data for each segment of the cable, including shipping considerations, presence of fishing activity, known crossings, sediment thickness and areas of exposed bedrock. This data, combined with the constraints of maximum achievable trench depth for a single pass, and the project nominal burial depth, are used to calculate a proposed depth of lowering for the cable, considering the segments set out in **Figure 6-1** and **Figure 6-2**. Residual risk to the cable is calculated for this proposed DOL. Note that the CBRA calculation of Pstrike conservatively does not take damping of the soil into consideration when the cable is buried.

6.4.2 Windfarm Site

The windfarm site is uniformly considered to be comprised of sandy soils, and it is assumed that there is sufficient sediment depth to achieve a trench depth of 1.5m (project nominal burial depth and max. achievable trench depth for a single pass of a trencher). Given that the risk profile is unchanged for DOL = 0m and DOL = 1.5 m, it is proposed to bury the cable to a depth that would protect from interaction with fishing equipment, i.e., DOL=0.6m. This proposed DOL is considered for the entire Windfarm Site and is summarised in **Table 6-2**. The residual Pstrike for DOL=0.6m is presented in **Figure 6-9**. The total residual Pstrike for the Windfarm Site is 9.36E-07 incidents per year.

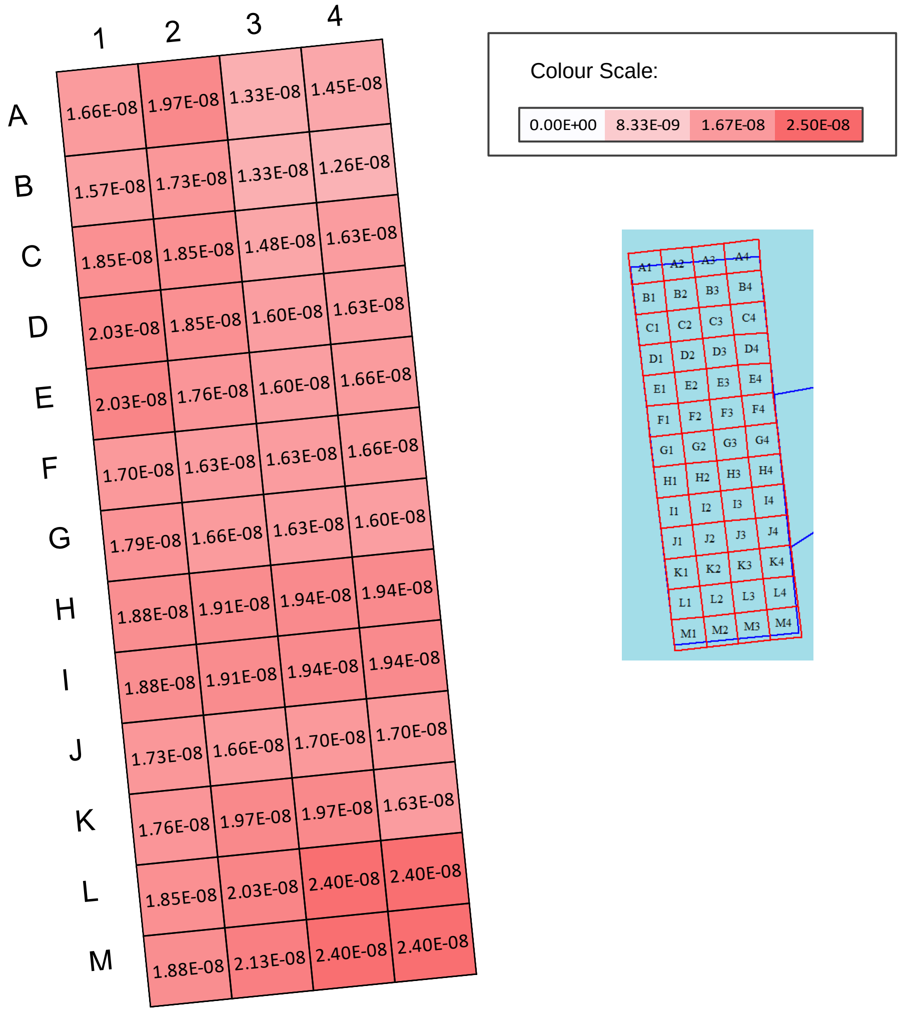


Figure 6-9: Windfarm Site Pstrike for Proposed DOL=0.6m

Table 6-2: Windfarm Site Proposed DOL

Segment	Proposed DOL
A1	0.6
A2	0.6
A3	0.6
A4	0.6
B1	0.6
B2	0.6
B3	0.6
B4	0.6
C1	0.6
C2	0.6
C3	0.6
C4	0.6
D1	0.6
D2	0.6
D3	0.6
D4	0.6
E1	0.6
E2	0.6
E3	0.6
E4	0.6
F1	0.6
F2	0.6
F3	0.6
F4	0.6
G1	0.6
G2	0.6
G3	0.6
G4	0.6
H1	0.6
H2	0.6
H3	0.6
H4	0.6
I1	0.6
I2	0.6

Segment	Proposed DOL
I3	0.6
I4	0.6
J1	0.6
J2	0.6
J3	0.6
J4	0.6
K1	0.6
K2	0.6
K3	0.6
K4	0.6
L1	0.6
L2	0.6
L3	0.6
L4	0.6
M1	0.6
M2	0.6
M3	0.6
M4	0.6

Assuming sufficient sediment thickness, burial to 0.6m is achievable in a single pass of standard trenching equipment, is below the nominal burial depth for the project, would provide adequate protection to the cable from interaction with fishing equipment and results in a low residual Pstrike (i.e., provides reasonable protection from anchor strike). A reduction in the DOL below 0.6m is not recommended.

As there are no existing cables, pipelines or other seabed infrastructure within the Windfarm Site, no crossings are considered. No rock armour is considered to be required for protection of the inter-array cable; however, this study does not consider rock armour that may be required for stabilisation of inter-array cables on approach to WTGs.

Sand ripples are identified across significant parts of the Windfarm Site, although no sand waves are identified. Following completion of a seabed morphology study, it may be found necessary to perform some pre-lay excavation works on areas of mobile sediment through with the eventual inter-array cable routes pass. This excavation work has not been considered in the present study, but an estimated sand excavation volume of 29,760m^3 could be considered, based on 5% coverage of a total inter-array cable length of 30km (considered to be the upper bound, based on a requirement for 8 WTGs at White Cross and additional cabling to facilitate a loop topology.

6.4.3 Offshore Export Cable Corridor

An assessment of the sediment depths along the Offshore Export Cable Corridor, based on the Shallow Intermediate Geology isopach contour data results in the sediment depths outlined in **Figure 6-10**.

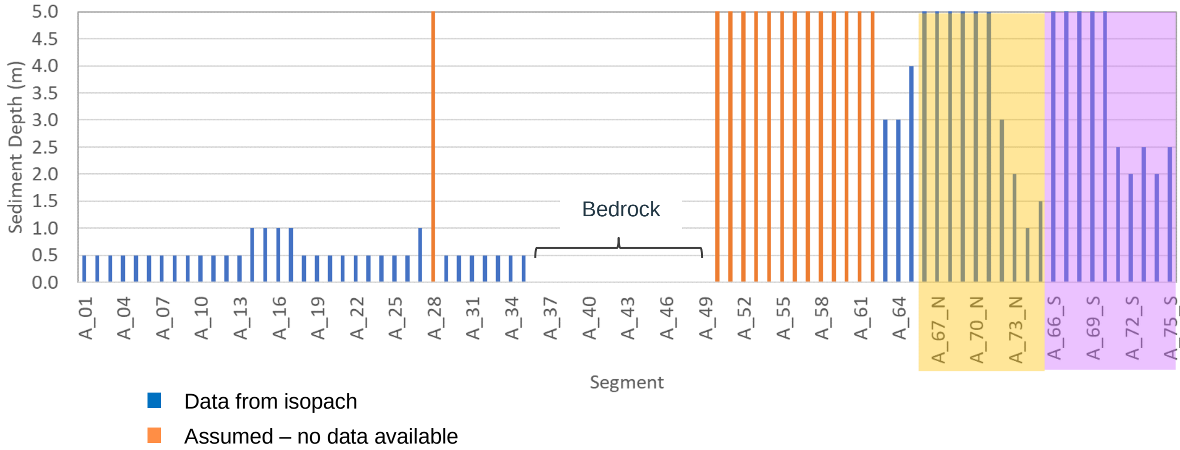


Figure 6-10: Offshore Export Cable Corridor Sediment Depth

The proposed DOL, therefore, considers the maximum achievable burial depth, up to a trench depth of 1.5m (the project nominal burial depth and max. achievable by a single trencher pass), noting that 1.5m trench depth equates to a DOL of 1.2m for the assumed 300mm export cable. The proposed DOL is presented in **Figure 6-11** and summarised in **Table 6-3**.

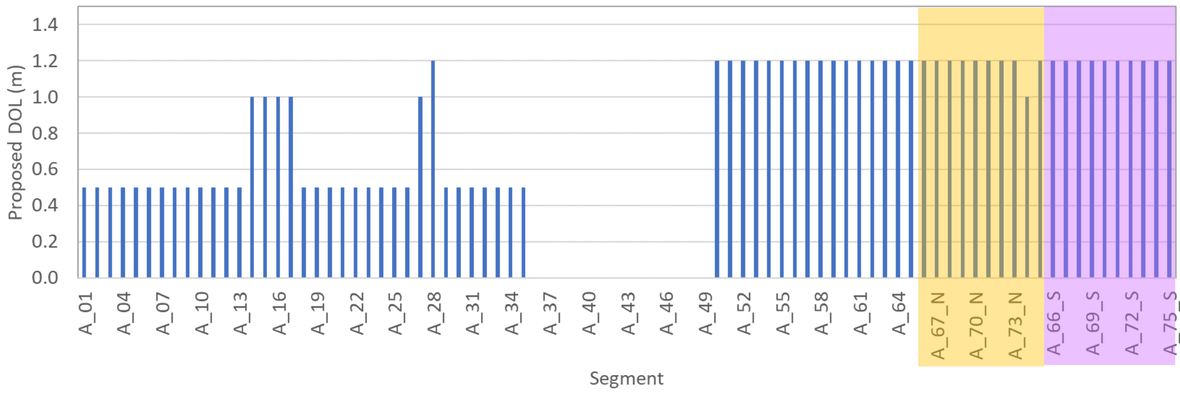


Figure 6-11: Offshore Export Cable Corridor Proposed DOL

Table 6-3: Offshore Export Cable Corridor Proposed DOL

Segment	Proposed DOL
A_01	0.5
A_02	0.5
A_03	0.5
A_04	0.5
A_05	0.5
A_06	0.5
A_07	0.5
A_08	0.5
A_09	0.5
A_10	0.5
A_11	0.5
A_12	0.5
A_13	0.5
A_14	1
A_15	1
A_16	1
A_17	1
A_18	0.5
A_19	0.5
A_20	0.5
A_21	0.5
A_22	0.5
A_23	0.5
A_24	0.5
A_25	0.5
A_26	0.5
A_27	1
A_28	1.2
A_29	0.5
A_30	0.5
A_31	0.5
A_32	0.5
A_33	0.5
A_34	0.5

Segment	Proposed DOL
A_35	0.5
A_36	0
A_37	0
A_38	0
A_39	0
A_40	0
A_41	0
A_42	0
A_43	0
A_44	0
A_45	0
A_46	0
A_47	0
A_48	0
A_49	0
A_50	1.2
A_51	1.2
A_52	1.2
A_53	1.2
A_54	1.2
A_55	1.2
A_56	1.2
A_57	1.2
A_58	1.2
A_59	1.2
A_60	1.2
A_61	1.2
A_62	1.2
A_63	1.2
A_64	1.2
A_65	1.2
A_66_N	1.2
A_67_N	1.2
A_68_N	1.2
A_69_N	1.2
A_70_N	1.2

Segment	Proposed DOL
A_71_N	1.2
A_72_N	1.2
A_73_N	1.2
A_74_N	1
A_75_N	1.2
A_66_S	1.2
A_67_S	1.2
A_68_S	1.2
A_69_S	1.2
A_70_S	1.2
A_71_S	1.2
A_72_S	1.2
A_73_S	1.2
A_74_S	1.2
A_75_S	1.2

The residual Pstrike for this proposed DOL is presented in **Figure 6-12**.The maximum Pstrike for a segment of 5E-07 incidents per year per km occurs on the Southerly landfall approach, while the total residual Pstrike along the Offshore Export Cable Corridor is 9.53E-06 incidents per year, approximately equivalent to 1 anchor strike incident in 100,000 years.

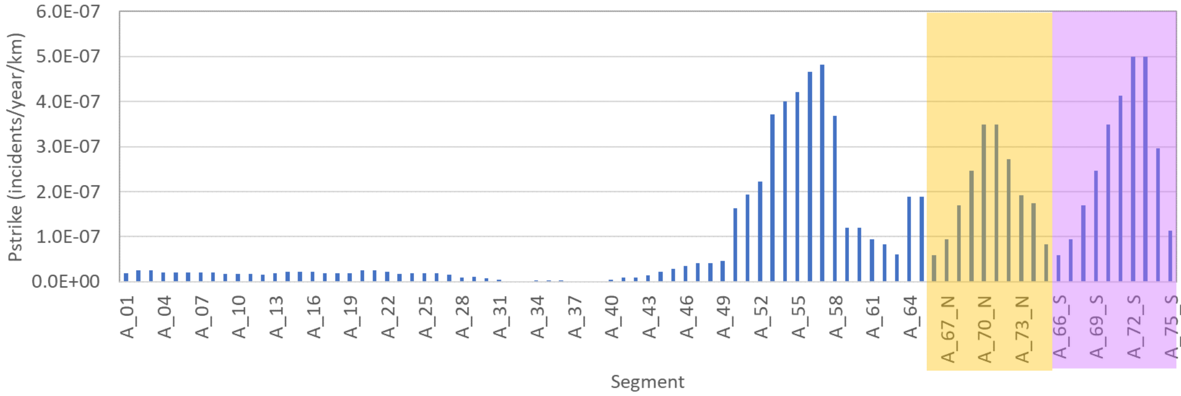


Figure 6-12: Offshore Export Cable Corridor Pstrike for Proposed DOL

Assuming sufficient sediment thickness, burial to the proposed DOL is achievable in a single pass of standard trenching equipment and is below the nominal burial depth for the project. The proposed DOL is 0.5m at certain parts of the route, based on the sediment thickness; given that this data has not yet been finalised, this is considered reasonably likely to provide adequate protection to the cable from interaction with fishing equipment at this stage of the project, however it would be preferable to bury to a minimum of 0.6m if sediment depth allows.

The resulting Pstrike for the overall export cable indicates reasonable protection from anchor strike would be provided by the proposed DOL.

There is an area of exposed bedrock, however, from segment A-36 to A-49, in which trenching will not be possible. While rock cutting may be an option, further assessment of the strength of the bedrock is recommended. If rock cutting were found to be possible, the depth of rock cutting required would be just in excess of the cable outer diameter (i.e., 300mm) such that the cable would sit below the shoulders of the trench, protecting the cable from any anchors drag incidents.

In the case of rock cutting not being feasible, or perhaps being deemed too costly, an alternative method of protecting the cable is through the use of rock armour. The linear quantity of bedrock amounts to approximately 14km, per export cable. Based on the assumed two export cables required, this amounts to approx. 28km of unburied cable. A typical rock berm has a height of approx. 1m and a crest width of 1m; allowing for a slope of 1 in 3 on the sides of such a rock berm, the required volume of rock for protection of the export cables at this location is 112,000m^3, assuming two export cables laid at a distance from each other. Naturally, if a single export cable is required, this volume of rock can be halved.

Three existing in-service telecommunications cables have been identified as crossing the Offshore Export Cable Corridor. Crossing of these cables will be required. A rock berm as described above can be used for protection of the cable at crossings also. The typical length of a rock berm for a cable crossing is 250m, while the height of such a rock berm may extend to 1.8m if the existing cable is unburied on the seabed. The total volume of rock required for three such crossings is 5,400m^3 per export cable (total 10,800m^3 for two export cables laid at a distance from each other).

Sand ripples and mega ripples have been identified across almost the entire Offshore Export Cable Corridor, with an area of sand waves noted between segments A_59 to A_63, a distance of 5km per cable. As a minimum, it is expected that sandwave preclearance works will be required for this area of sandwaves; this will require excavation of approximately 750,000m^3 of sand, based on two export cables laid at a distance from each other, with 50% sandwave coverage over the area and clearance of a 50m wide channel per cable. Additional areas may be identified through the seabed morphology study where sandwave preclearance is required.

7.0 Conclusions & Recommendations

7.1 Conclusions

The conclusions of this Burial Assessment Study are as follows:

- A depth of lowering (DOL) of 0.6m to top of cable is proposed for the Windfarm Site. This would result in a residual risk of anchor strike of 9.36E-07 incidents per year.
- The proposed DOL on the Offshore Export Cable Corridor ranges from 0.6m to 1.2m, with the exception of the section of exposed bedrock, and three locations where existing in-service telecommunications cables need to be crossed. This would result in a residual risk of anchor strike of 9.53E-06 incidents per year.
- The section of exposed bedrock extends for approx. 14km; rock berms totalling approx. 112,000m^3 volume of rock will be required for protection and stabilisation of two export cables in this area.
- 10,800m^3 of rock is estimated to be required to facilitate crossing of the three in-service cables (6 crossings in total).
- Sandwaves have been indicated along 5km of the Offshore Export Cable Corridor; these will require excavation prior to export cable lay. Up to an estimated 750,000m^3 of sand will need to be excavated.
- Additional areas of sandwaves or other mobile sediment formations may be identified through a seabed morphology study of the area.
- The study is based on high-level shipping data sourced from the EMODnet Human Factors project. While this data is valuable in performing a high-level CBRA such as this, the data and assumptions made could be refined by obtaining a shipping study based on AIS data.

7.2 Recommendations

The recommendations arising from the Burial Assessment Study are as follows:

- A shipping study should be performed using AIS data to gain a greater understanding of the frequency and nature of the vessel traffic on the Offshore Export Cable Corridor and within the Windfarm Site.
- A seabed morphology study (or similar) should be performed to assess the mobility of the sediment within the project area and in the surrounding vicinity.
- An assessment of the strength of the exposed bedrock on the Offshore Export Cable Corridor is recommended to establish the feasibility of rock cutting in this area.
- A refinement of the CBRA should be performed once this data is available.

8.0 References

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2. Application Guide for the Specification of the Depth of Lowering Using the CBRA Methodology, CTC857
3. 6 Alpha Associates, Unexploded Ordnance Threat and Risk Assessment, reference 9475_UXOTATA_White Cross OWF_OWL_V1.0, version 1.0, dated 14th February 2022
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