TotalEnergies E&P North Sea UK Ltd

Culzean Floating Offshore Wind Turbine Pilot Project

Environmental Impact Assessment Report – Chapter 7 – Marine Physical Processes

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XODUS

TotalEnergies

Aberdeen

5th Floor, Capitol Building
429-431 Union Street
AB11 6DA . UK

T +44 1224 219 955
E deborah.morgan@xodusgroup.com
www.xodusgroup.com

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A01	21/02/24	Issued for Use	CM	AC	DM	TEPNSUK
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GLOSSARY

TERMINOLOGY	DESCRIPTION
Culzean Floating Offshore Wind Turbine Pilot Project ("the Project")	The entire Development including all offshore components and all project phases from pre-construction to decommissioning.
Environmental Impact Assessment (EIA)	The procedure to predict, minimise, measure and, if necessary, correct and compensate the impacts produced by any human action.
Export Cable	Cable connecting the Floating Wind Turbine to the Culzean Platform.
Floating Wind Turbine Generator (WTG)	Device that converts the kinetic energy of wind into electrical energy. Can be functionally divided into four parts: wind turbine, tower and transition piece, floating foundation, and mooring system.
Habitats Regulations Assessment (HRA)	Under the Habitats Regulations, all competent authorities must consider whether any plan or project could affect a European site before it can be authorised or carried out. This includes considering whether it will have a 'Likely Significant Effect' (LSE) on a European site, and if so, they must carry out an 'Appropriate Assessment' (AA). This process is known as Habitats Regulations Appraisal (HRA).
Innovation and Targeted Oil and Gas (INTOG)	The Initial Plan Framework Sectoral Marine Plan for Offshore Wind for INTOG encompasses spatial opportunities and a strategic framework for future offshore wind developments within sustainable and suitable locations that will help deliver the wider United Kingdom (UK) and Scottish Government Net Zero targets. The 'IN' component of INTOG consists of small-scale innovative projects of 100 Megawatts (MW) or less. The aim of the 'TOG' component is to supplying renewable electricity directly to oil and gas infrastructure. The Culzean project falls under the TOG component of INTOG.
Marine Licence Application ("the Application")	A Marine Licence is granted under the Marine and Coastal Access Act 2009 for projects between 12-200 Nautical Miles (nm) from shore, or the Marine (Scotland) Act 2010 for projects between Mean High-Water Springs (MHWS) out to 12 nm from shore. The Application includes Habitats Regulations Appraisal (HRA) supporting documentation (where required), an application letter, Marine Licence application form and this Environmental Impact Assessment Report (EIAR).
Net Zero	Refers to a government commitment to ensure the UK reduces its greenhouse gas emissions by 100% from 1990 levels by 2050 and in Scotland, the same target is set for 2045. If met, this would mean the amount of greenhouse gas emissions produced by the UK would be equal to or less than the emissions removed by the UK from the environment.
Project Area	The extent of the immediate area surrounding the floating Wind Turbine Generator (WTG) and cable route as characterised by the extent of the seabed environmental and habitat surveys. Also referred to as the Survey Area where specifically relating to survey activities.
Project Design Envelope	The maximum range of design parameters of all infrastructure assessed as part of the EIA.
Study Area	Receptor specific area used to characterise the baseline.
Survey Area	The area surveyed during site-specific surveys.

ACRONYMS AND ABBREVIATIONS

ACRONYM/ ABBREVIATION	DEFINITION
ATT	Admiralty Total Tide
BGS	British Geological Survey
BODC	British Oceanographic Data Centre
CaP	Cable Plan
CBRA	Cable Burial Risk Assessment
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CEMP	Construction Environmental Management Plan
CMS	Construction Methods Statement
CNS	Central North Sea
CNSE	Central North Sea Electrification
CPF	Central Processing Facilities
CPT	Cone Penetration Tests
CTD	Conductivity, Temperature And Density
d50	Mean Grain Size
DDV	Drop Down Video
DECC	Department of Energy and Climate Change
DLSP	Development Specification and Layout Plan
DTI	Department of Trade and Industry
DTU	Technical University of Denmark
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
EMP	Environmental Management Plan
ETAP	Eastern Trough Area Project
FEED	Front-End Engineering Design
HAT	Highest Astronomical Tide
INNS	Invasive Non-Native Species
INTOG	Innovation and Targeted Oil And Gas
JNCC	Joint Nature Conservation Committee
km	kilometres
LAT	Lowest Astronomical Tide
MASTS	Marine Alliance for Science and Technology for Scotland
MBES	Multibeam Echo Sounder
MD-LOT	Marine Directorate – Licensing Operations Team

ACRONYM/ ABBREVIATION	DEFINITION
MDS	Maximum Design Scenario
MHWS	Mean High-Water Springs
MPA	Marine Protected Areas
NID	Nature Inclusive Design
nm	nautical miles
NMPi	National Marine Plan Interactive
NRW	Natural Resource Wales
NTSLF	National Tidal and Sea Level Facility
OEMP	Operational Environmental Management Plan
OESEA3	Offshore Energy Strategic Environmental Assessment 3
PDE	Project Design Envelope
PEMP	Project Environmental Monitoring Programme
PLGR	Pre-Lay Grapnel Run
PSA	Particle Size Analysis
R&D	Research and Development
RCP	Representative Concentration Pathways
SAC	Special Area of Conservation
SBP	Sub-Bottom Profiler
SNCB	Statutory Nature Conservation Bodies
SNH	Scottish Natural Heritage
SPM	Sediment Particulate Matter
SSC	Suspended Sediment Concentrations
SSS	Side Scan Sonar
TEPNSUK	Totalenergies Exploration and Production North Sea United Kingdom
TSS	Total Suspended Solids
UK	United Kingdom
UKCP	United Kingdom Climate Projections
UKCS	United Kingdom Continental Shelf
UKHO	United Kingdom Hydrodynamic Office
VC	Vibrocore
WTG	Wind Turbine Generator
ZoI	Zone of Influence

7 MARINE PHYSICAL PROCESSES

7.1 Introduction

The potential effects of the Culzean Floating Offshore Wind Turbine Pilot Project (the 'Project'), during the construction, operation and maintenance, and decommissioning phases on Marine Physical Processes are assessed in this chapter. Where required, mitigation is proposed, and the residual impacts and their significance are assessed. Potential cumulative impacts have also been considered, while transboundary impacts have been scoped out with the agreement of consultees, as described in Section 7.3.

Xodus Group Limited (Xodus) have drafted and carried out the impact assessment. Further competency details of the Project Team including lead authors for each chapter are provided in Chapter 1: Introduction. Table 7-1 provides a list of all the supporting studies which relate to and have been used to inform this Marine Physical Processes impact assessment.

Table 7-1 Supporting studies

DETAILS OF STUDY	LOCATIONS OF SUPPORTING STUDY
Environmental Baseline Survey Report - Culzean WT Site Survey September 1st, 2023. 104728-TOT-OI-SUR-REP-ENVBASRE	Appendix D: Environmental Baseline Survey Report
Habitat Assessment Report - Culzean WT Site Survey June 2nd, 2023. 104728-TOT-OI-SUR-REP-HABASRE	Appendix C: Habitat Assessment Survey Report
Geophysical Survey Report. TotalEnergies PWT Site Survey. Geophysical, Geotechnical & Environmental Survey. Culzean Field, Central North Sea. 11th August, 2023. 104728-TOT-OI-SUR-REP-SURVEYRE	Appendix J: Geophysical Survey Report

The impact pathways and completed assessment presented herein is used to inform the impact assessments for other topic receptors presented within this Environmental Impact Assessment Report (EIAR), including:

- Chapter 8: Benthic Ecology;
- Chapter 9: Fish and Shellfish Ecology;
- Chapter 12: Commercial Fisheries; and
- Chapter 15: Marine Archaeology.

The impact pathways to the other topic receptors are detailed further in Section 7.12, which considers the inter-related effects between the varying topic receptors addressed within this EIAR.

7.2 Legislation, policy and guidance

The following legislation, policy and guidance are relevant to the assessment of impacts from the Project on Marine Physical Processes:

- Legislation:
  - No specific legislative controls relevant to the scope of the marine physical environment impact assessment.
- Policy:
  - *Scotland's National Marine Plan. General Policy 8. The Scottish Government, 2015; and*
- Guidance:
  - *Offshore Wind Energy in Scottish Waters. Regional Locational Guidance. Marine Scotland. October 2020*
  - Advice to Inform Development of Guidance on Marine, Coastal and Estuarine Physical Processes Numerical Modelling Assessments. Report No 208. (Natural Resources Wales (NRW), 2017);
  - Guidance Note. Marine Physical Processes Guidance to inform Environmental Impact Assessment (EIA). GN041. (NRW, 2020);
  - Guidance on Best Practice for Marine and Coastal Physical Processes Baseline Survey and Monitoring Requirements to Inform EIA of Major Development Projects. Report No 243 (NRW, 2018). Sets out best practice for baseline data needed to inform marine and coastal processes impact assessments and the appropriate acquisition and interpretation of relevant survey data;
  - Coastal Process Modelling for Offshore Wind Farm Environmental Impact Assessment: Best Practice Guidance. (COWRIE, 2009[1]): and
  - Advice on key sensitivities of habitats and Marine Protected Areas in English Waters to offshore wind farm cabling within Proposed Round 4 leasing areas (Natural England and JNCC, 2019). This summarises the Statutory Nature Conservation Bodies (SNCB) advice on habitat sensitivities within Marine Protected Areas (MPAs) particularly relating to cabling activities from Round 4 leasing areas.

7.3 Scoping and consultation

Stakeholder consultation has been ongoing throughout the EIA process and has played an important part in ensuring the scope of the baseline characterisation and impact assessment are appropriate with respect to the Project and the requirements of the regulators and their advisors.

The Scoping Report was submitted to Scottish Ministers (Via Marine Directorate – Licensing Operations Team (MD-LOT)), on 14th April 2023, who then circulated the report to relevant consultees. The Scoping Opinion was received on 20th July 2023. Relevant comments from the Scoping Opinion and other consultation specific to Marine Physical Processes are provided in Table 7-2 below. In addition, Table 7-2 provides a summary of how these comments have been addressed within the EIAR.

[1] *Despite the age of this guidance, it is continually applied in the impact assessment for a range of OWF developments across the UK and is a recognised industry best practice.*

Table 7-2 Summary of consultation responses specific to Marine Physical Processes

CONSULTEE	COMMENT	RESPONSE
Scoping Opinion		
Scottish Ministers (via MD-LOT)	This Scottish Ministers are content with the study area as defined in section 6.1.3 of the Scoping Report, which comprised the project area and a buffer of 5km.	The Project Study Area agreed by MD-LOT is applied in the impact assessment completed for the Marine Physical Processes topic.
	In Table 6-3 of the Scoping Report, the Developer proposed to scope out potential scour. The reasoning for this is unclear, especially as the embedded mitigation proposed in Table 6-2 of the Scoping Report refers to minimising cable protection, suggesting a level of protection may be required. As such, the Scottish Ministers advise that the potential introduction of scour is scoped in. The Developer should also consider secondary scour around any installed scour protection within the EIA Report. This is supported by the NatureScot representation.	The potential introduction of scour or edge scour has been included within the EIA and the potential for scour occurring is assessed in Section 7.9.2.1.
	The Scottish Ministers welcome the Developers embedded mitigation measures as proposed in Table 6-2 of the Scoping Report.	The Project embedded mitigation measures are included in Section 7.8.
	Regarding cumulative impacts on Marine Physical Processes, the Scottish Ministers agree with the proposed approach considered by the Scoping Report. The Scottish Ministers agree with the Developer that transboundary impacts can be scoped out from further consideration in the EIAR. This is supported by the NatureScot representation	Noted. No further response required.
NatureScot	We are content with the study area as defined in section 6.1.3, which comprises the project area and a buffer of 5 km, based on the extent of tidal ellipses in the vicinity.	Noted. The agreed Project Study Area is applied in the impact assessment presented within this chapter.

CONSULTEE	COMMENT	RESPONSE
	We are content with the key data sources as listed in section 6.1.4.	Noted. The agreed data sources have been applied within the impact assessment presented within this chapter.
	NatureScot are content with the potential impacts scoped in as per Table 6-3 of the Scoping Report.	The scoped in impacts are assessed in Section 7.9 of this EIAR.
	Key impact pathways to consider We are broadly content with the potential impacts scoped in as per Table 6-3 of the Scoping Report. However, we advise there are elements that require further consideration as outlined below. Introduction of scour The reasoning for scoping out potential scour is unclear, especially as the embedded mitigation merely refers to minimising cable protection, and thus a level of protection may still be required. We recommend that the potential introduction of scour is scoped in and should also take into account secondary scour around any installed scour protection.	The potential introduction of scour or edge scour has been included within this chapter and the extent of the potential for scour occurring is assessed in Section 7.9.2.1.
	Cumulative impacts We are content with the approach to the cumulative impact approach, as outlined in section 5.4 and 6.1.8.	The potential for cumulative impacts associated with nearby projects are considered for new projects in Section 7.11.
	Mitigation and monitoring We welcome the embedded mitigation measures as proposed in Table 6-2.	Noted. The embedded mitigations are applied within this chapter as shown in Section 7.8.
	Transboundary impacts We agree that transboundary impacts are scoped out from further consideration in the EIAR.	Noted, transboundary impacts have been scoped out of this chapter.

In line with the Scoping Opinion, aspects relevant to Marine Physical Processes but scoped out of further assessment in this EIAR include:

- Impacts on designated features within designated sites (all Project phases);
- Changes to tide and wave regime during operation and maintenance;
- Impacts on local sediment transport regime and seabed morphology during operation and maintenance; and
- Impacts of stratification during operation and maintenance.

7.4 Study Area

The Project is located in the United Kingdom Continental Shelf (UKCS) Block 22/25a in a mature area of the Central North Sea (CNS). The Project is owned and operated by TotalEnergies Exploration and Production North Sea UK (TEPNSUK) and lies approximately 222 kilometres (km) from the east coast of Scotland, in a water depth of approximately 87 m – 91 m below lowest astronomical tide (LAT).

The Marine Physical Processes Study Area ('the Study Area') applied to inform this topic is defined as the Project Area plus a 5 km buffer around the Project boundary (Figure 7-1), as agreed during consultation (Table 7-2). The applied buffer is based on the extent of the mean spring tidal excursion in the vicinity of the Project and has been rounded up to 5 km to account for any potential extreme events.

Consideration has also been given to:

- The distance which suspended sediment plumes may be advected (and interact with any potentially sensitive receptors); and
- The distance from the Project that tide and wave blockage impacts may potentially be detected, informed by expert judgement and consideration of prevailing directions across the Study Area.

For this report, only the potential impacts of the Project on Marine Physical Processes within the Project and Study Areas are discussed. However, a wider context has been provided where appropriate, especially in characterisation of the regional environmental conditions that ultimately drive the Marine Physical Processes within the Project Area.

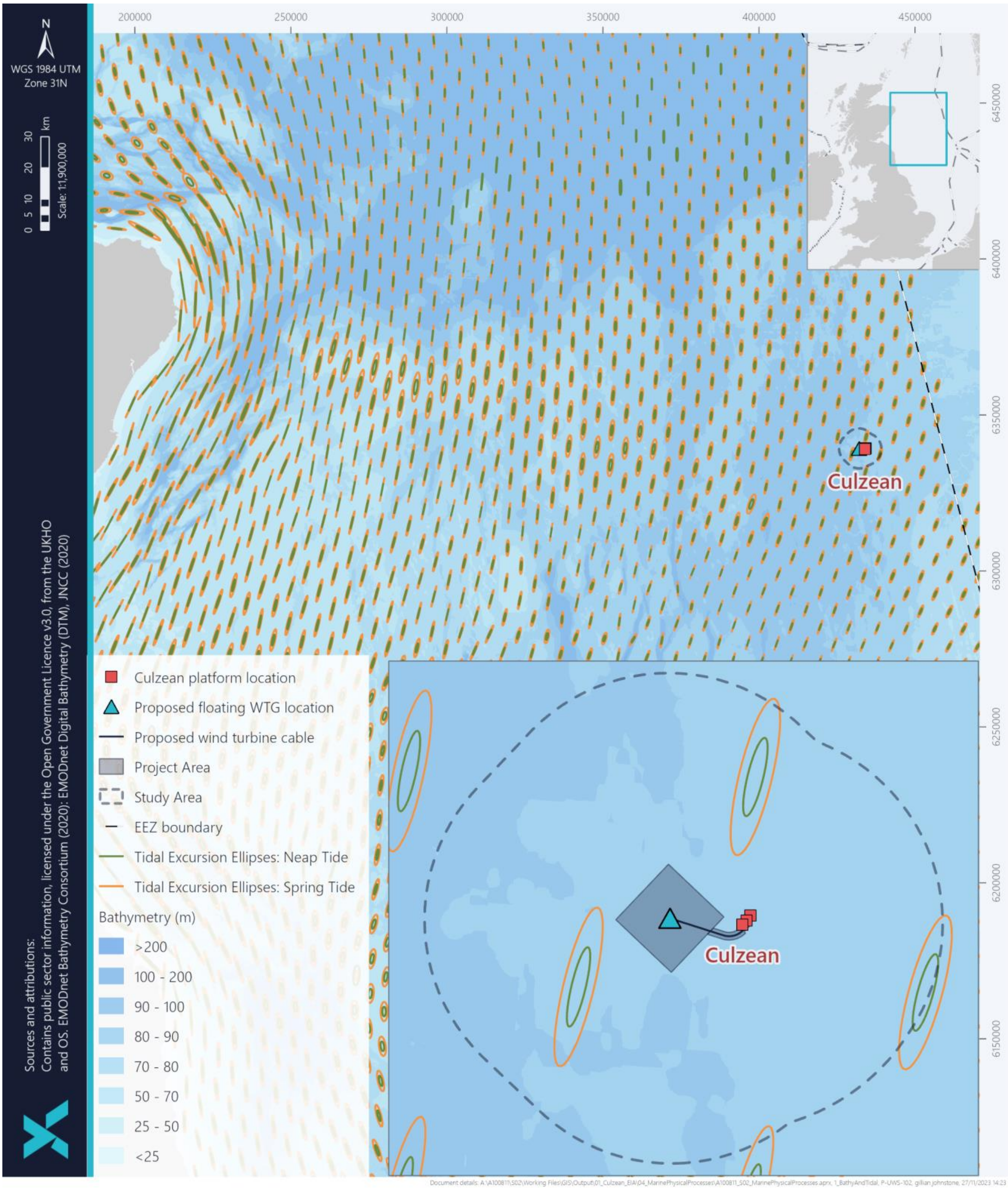

Figure 7-1 Study Area for Marine Physical Processes

7.5 Baseline Environment

This section outlines the current baseline for Marine Physical Processes within the defined Study Area.

The baseline characterisation provides a description of physical features in the marine environment which could be influenced by Project activities. These features include the geology, seabed, metocean characteristics (including water levels, currents and waves) and water column properties (in particular; suspended sediment concentration (or turbidity), temperature, salinity and stratification). This baseline description helps to establish the reference condition against which the potential physical effects of the Project are assessed. In addition, the baseline represents the marine physical process conditions that are expected to prevail without any development occurring over an equivalent duration as the seabed lease. Given the Project timescales span several years (e.g. one month for construction and up to 10 years for operation) then baseline variability over this period is also a consideration, including the likely effects of climate change.

The main offshore Marine Physical Processes considered in the baseline characterisation include:

- Geology;
- Bathymetry and morphology;
- Seabed sediment and sediment transport regime;
- Hydrodynamic regime;
- Wave regime;
- Wind regime;
- Fronts and stratification; and
- Designated sites.

Due to the entirely offshore location of the Project, being 222 km from the coast, there is not considered to be any pathway for interaction with coastal morphology, so this chapter does not consider the coast as a potential physical receptor.

7.5.1 Data sources

The baseline environment for this EIAR has been established based on site-specific geophysical and environmental surveys completed for the Project, as described further in Section 7.5.2, in addition with a desk-based review of the data and information sources from secondary sources, as listed in Table 7-3.

Table 7-3 Summary of key datasets and reports

TITLE	SOURCE	YEAR	AUTHOR
Bathymetry, Geology and Seabed Sediment			
British Geological Survey (BGS) Offshore GeoIndex Map	http://mapapps2.bgs.ac.uk/geoindex_offshore/home.html	2023	BGS
Strategic Environmental Assessment Data Portal	https://webapps.bgs.ac.uk/data/sea/app/search	2021	BGS
Marine Scotland Data Portal	https://marine.gov.scot/data/marine-scotland-data-portal	2023	Marine Scotland
EMODnet Bathymetry	https://www.emodnet-bathymetry.eu/	2023	EMODnet
Gardline Environmental Baseline Survey	159388 (MOUK) GS5987A (MOG) - Amendment 3	2013	Gardline
Metocean Regime (Water Levels, Currents, Waves)			
National Tidal and Sea Level Facility(NTSLF)- Observational Water Level Records	https://www.ntslf.org/	2020	NTSLF
UK Offshore Energy Strategic Environmental Assessment 3 (OESEA3). Appendix 1D - Water Environment (Regional Sea 6 &7)	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/504541/OESEA3_A1d_Water_environment.pdf	2016	Department of Energy and Climate Change (DECC)
Admiralty Total Tide (ATT) tidal prediction software	UK Hydrodynamic Office (UKHO) Admiralty Maritime Data Solutions	2023	UKHO
Atlas of UK Marine Renewable Energy, Interactive Map	https://www.renewables-atlas.info/explore-the-atlas/	2008	ABPmer
SEASTATES Metocean Data and Statistics Interactive Map	https://www.seastates.net/explore-data/	2018	ABPmer
Centre for Environment, Fisheries and Aquaculture Science (Cefas) WaveNet	https://wavenet.cefas.co.uk/map	2023	Cefas
British Oceanographic Data Centre (BODC) data Centre	https://www.bodc.ac.uk/data/	2022	BODC
United Kingdom Climate Projections (UKCP) 18	https://www.metoffice.gov.uk/research/approach/collaboration/ukcp	2018	Met Office
National Marine Plan interactive (NMPi)	https://marinescotland.atkinsgeospatial.com/nmpi/	2023	NMPi

TITLE	SOURCE	YEAR	AUTHOR
Water Column Properties			
Cefas Suspended Sediment Climatologies around the UK (Monthly average non-algal Suspended Particulate Matter concentrations on the UK shelf waters)	CEFAS_2016_Suspended_Sediment_Climatologies_around_the_UK.pdf (publishing.service.gov.uk) http://data.cefas.co.uk/#/View/18133	2016	Cefas
Climatology of Surface and Near-bed Temperature and Salinity on the North-West European Continental Shelf for 1971–2000 (2009).	https://data.marine.gov.scot/sites/default/files//berx-hughes_2009.pdf	2009	Berx, B., Hughes
BODC Observational Conductivity Temperature Depth (CTD) Records	https://www.bodc.ac.uk/	2019	BODC
General Information			
Sectoral Marine Plan: Regional Local Guidance	https://www.gov.scot/publications/sectoral-marine-plan-regional-locational-guidance/documents/	2020	Scottish Government
Coastal Cells in Scotland: Cell2 – Fife Ness to Cairnbulg Point	https://www.dynamiccoast.com/files/Ramsay_Brampton_Cell_02.pdf	2000	Ramsay & Brampton
European Union's Earth Observation Programme	https://www.copernicus.eu/en	2023	Capernicus

7.5.2 Project site-specific surveys

Several site-specific surveys have been completed across the Project. These include geophysical, geotechnical and environmental surveys which have been described further in following sections. Outputs of the Project site-specific surveys are summarised in an Environmental Baseline Report (Appendix D), Environmental Habitat Assessment Report (Appendix C) and Geophysical Survey Report (Appendix J) used to directly inform the baseline characterisation and impact assessment presented within this EIAR.

7.5.2.1 Geophysical

The geophysical survey scope included the acquisition of multibeam echo sounder (MBES), side scan sonar (SSS), magnetometer, sub-bottom profiler (SBP) and Sparker data. The MBES, SSS and magnetometer data were acquired across the full extent of the Project, with the SBP and Sparker acquired as transects across the Project extent. The combination of the MBES and SSS, were used to capture the bathymetry, identify seabed features and variations in seabed sediment type. The SBP was used to map variations in the top 3 to 5 m of seabed sediment and shallow geology, while the lower frequency Sparker system was used for detailed geological mapping of the uppermost 50 m of the geological units. The results of the geophysical survey are summarised in Appendix J.

7.5.2.2 Geotechnical

The shallow geotechnical survey included vibrocore (VC) and cone penetration tests (CPT) investigations at the three planned mooring locations and at 500 m intervals along the proposed cable route to the Culzean Central Processing Facilities (CPF) platform. The information was used to provide an understanding of deeper geological units within the Project, with results summarised in Appendix J.

7.5.2.3 Environmental Baseline Survey

An environmental baseline survey (Appendix D) and habitat assessment (Appendix C) were completed for the Project, which comprised benthic, sediment and water sampling. The environmental sampling occurred at eight locations across the Project Area, with seven across the turbine site Survey Area and one within the cable corridor, as illustrated in Figure 7-2. The benthic and sediment sampling included faunal grab and sediment sampling (primarily using 0.1 m^2 dual van Veen grabs and 0.1 m^2 Hamon grabs in areas of coarse sediment) and Drop-Down Video (DDV). Four grab samples were acquired per sample site, including three for benthic faunal analyses and one for Particle Size Analysis (PSA) and contaminant analysis. The water sampling for Total Suspended Solids (TSS) (as a representation of the water column Suspended Sediment Concentration (SSC)) was completed using five litre Niskin bottles attached to a rosette sampler with an external Conductivity, Temperature and Density (CTD) sensor. Water samples were acquired at two water depths (i.e. surface and at the bottom), with the CTD acquiring measurements throughout the water column as the sampler was lowered through the water column and retrieved.

The geophysical data acquired across the Project Area (Section 7.5.2.1) was applied with the analysed grab samples to determine and confirm the seabed sediments (Appendix D) and the development of the EUNIS habitat classifications (Appendix C).

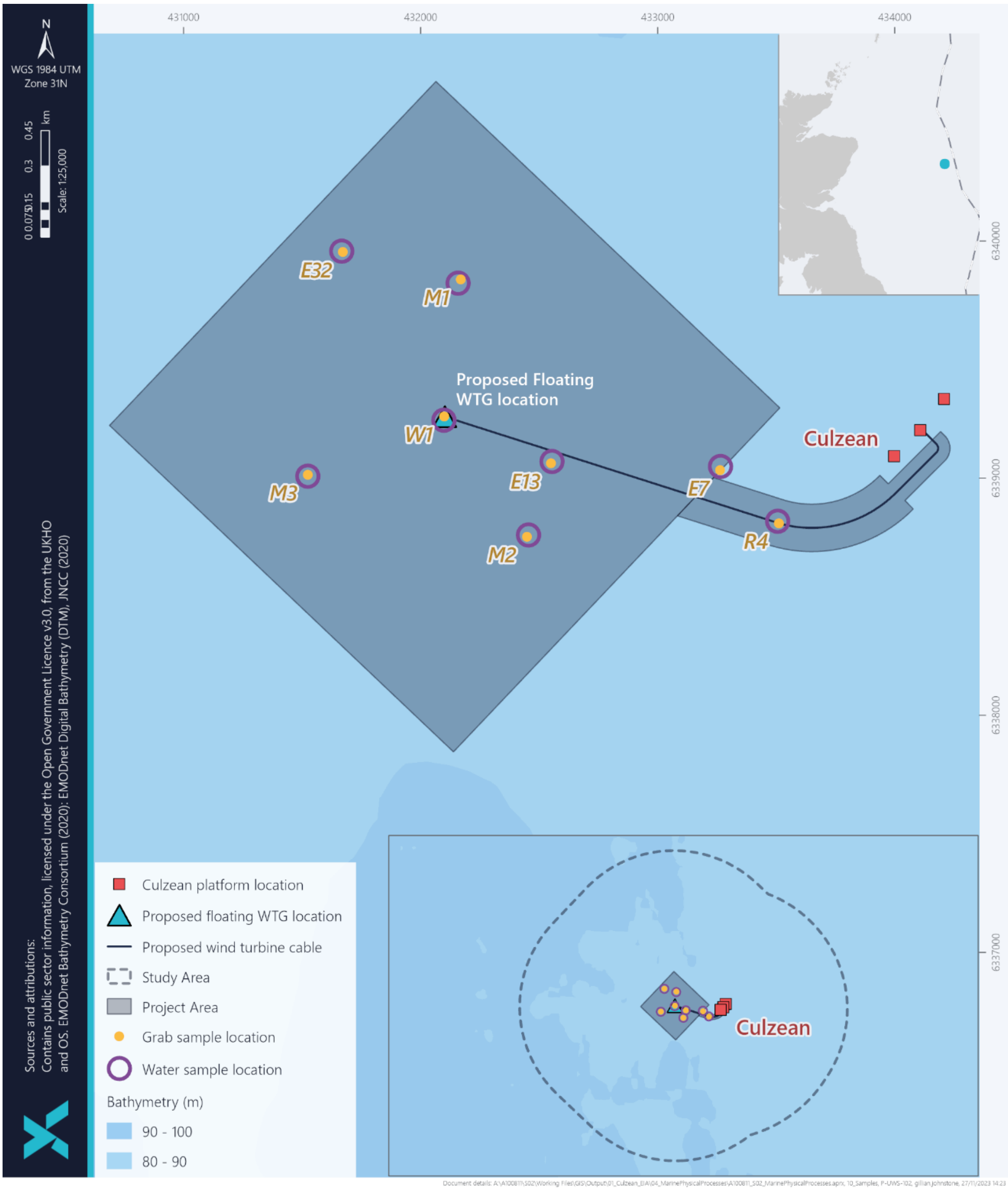

Figure 7-2 Environmental (benthic, sediment and water) sampling locations across the Project Area (Appendix D)

7.5.3 Existing baseline

A review of literature and available data sources (Section 7.5.1), augmented by consultation and Project site-specific surveys (Section 7.5.2) has been undertaken to describe the current baseline environment for the Marine Physical Processes topic.

7.5.3.1 Protected Sites

There are no offshore protected sites that overlap with the Project Area or Study Area. The closest Special Area of Conservation (SAC) is the Scanner and Braemar Pockmarks SAC located approximately 135 km and 190 km North of the project respectively. The closest MPA is the East of Gannet and Montrose MPA, which is located approximately 14 km west of the proposed Project and is designated for the presence of the long-lived bivalve Ocean Quahog (*Arctica islandica)* and offshore deep-sea muds (JNCC, 2021). Due to the intervening distance between the proposed operations and the designated interest features within the closest protected areas, as well as the scale of operations, it is considered that there is little to no pathway for interaction or impacts to designated features.

7.5.3.2 Geology

The basic structural framework of bedrock geology within the North Sea is primarily a result of Upper Jurassic/Lower Cretaceous rifting, with partial control from older structural elements (Norwegian Petroleum Directorate, 2023). The CNS has a consistent geology >12 nautical miles (nm) from the coast, with the geology within the Project Area being consistent with the surrounding CNS region. BGS (2023) characterises the bedrock geology as siliciclastic, argillaceous and sandstone of Eocene to Pliocene age (Tertiary), occurring at depths of >50 m. Overlying Quaternary deposits consist of a mixture of firm to hard interbedded sands, silts and clays, interspersed with undifferentiated mixed sediment of the same lithology characteristic of glacial till (BGS, 2023), with deposits being greater than 50 m in thickness (Figure 7-3).

The geophysical survey completed across the Project Area identified the presence of multiple geological units within the shallow geology, largely comprising Quaternary geological deposits (Appendix J), with varying presence and thicknesses across the Project Area. The shallowest, comprised a Holocene unit occurring at depths between 0 and 0.7 m below the seabed, with a patchy and variable presence across the Project Area. Also present across a large proportion of the Survey Area and cutting through several geological units, are sediments identified as part of the Upper Forth Formation, which are differentiated from the underlying geological and overlying Holocene units. Directly beneath the Upper Forth Formation is the older Lower Forth Formation, which is largely present and associated with the Upper Forth Formation. Where the Upper and Lower Forth Formations are present along the cable corridor, where present within the turbine Survey Area, the units have a combined thickness of 0 m to up to 36 m below the seabed. Other deeper geological units include the Fisher Formation occurring at depths of up to 70 m below the seabed and the Aberdeen Ground Formation, which is the deepest and oldest of the Quaternary deposits in this region of the North Sea. The Aberdeen Ground Formation is present across the entire Project Area and is at identified to begin at depths of around 40 m below the seabed and extending to depths of greater than 90 m below the seabed.

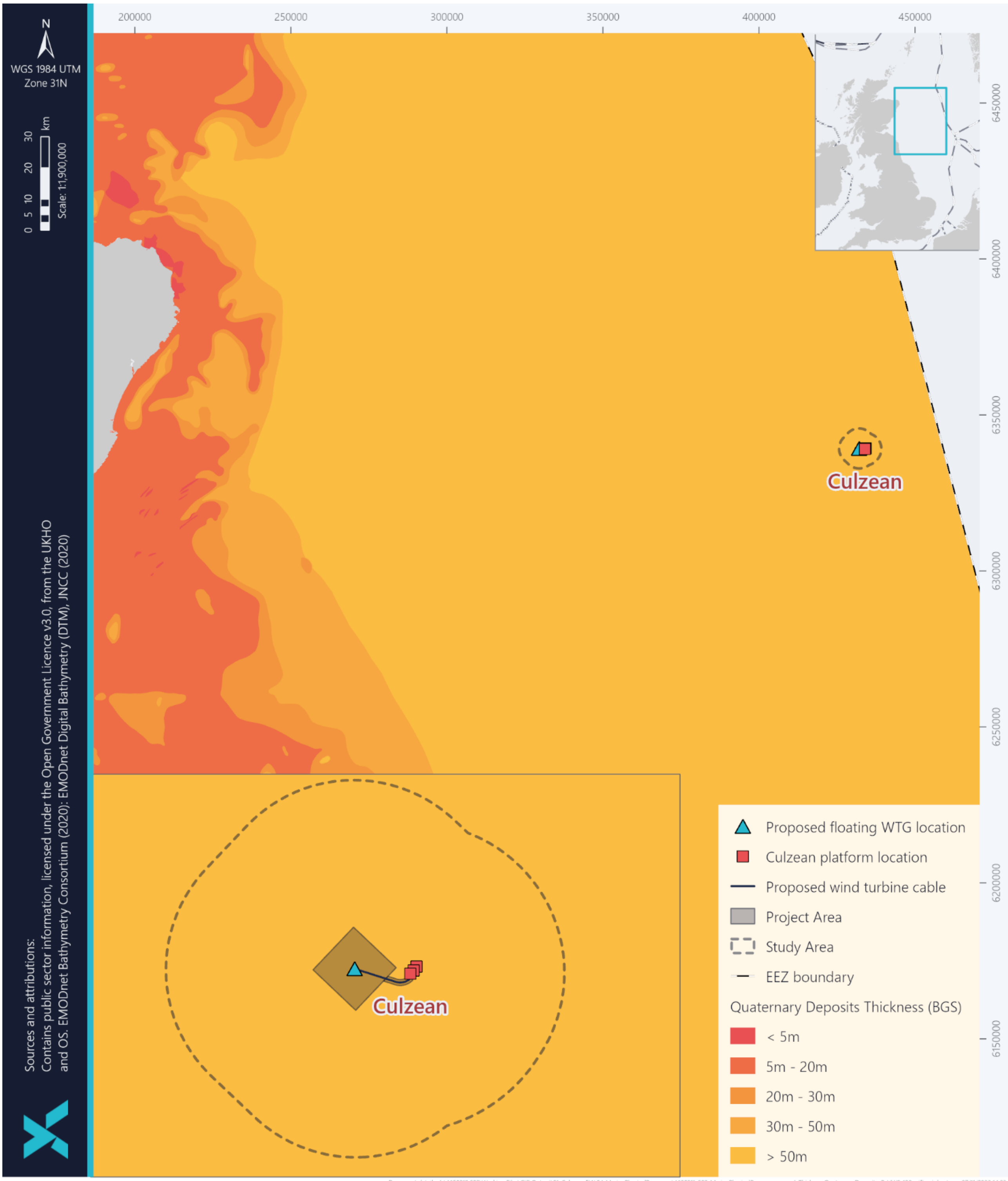

Figure 7-3 Quaternary deposit thickness across the Study Area (BGS, 2023)

7.5.3.3 Seabed Sediment

DECC (2016) reports that sand and slightly gravelly sand covers much of the seabed of the CNS region and occurs within a wide range of water depths from the shallow coastal zone to deeper locations further offshore, i.e. at water depths of up to 120 m. Sediments are considered to have a significant mud content, particularly in basins and in deeper waters to the north (JNCC, 2010; NMPi, 2023), while coastal areas in the region support a more varied range of intertidal and seabed habitats (DTI, 2001).

Interpretations of the site-specific geophysical survey data indicated the presence of the following sediment types:

- Mud: Low acoustic reflectivity with no real texture; mainly muddy sand;
- Fine Sand: Low acoustic reflectivity with a relatively smooth texture; predominately circalittoral sand, and muddy sand; and
- Coarse Sand: Low to medium acoustic reflectivity with areas of mixed sediments common; gravelly muddy sand, gravelly sand, slightly gravelly sand and sandy gravel.

Further detail as informed by the environmental survey across the Project Area indicated that the seabed is dominated by fine sand and very fine sand (Gardline, 2013; Appendix D; Appendix J; Figure 7-4). All sampled locations were classified as fine or very fine sand under the Wentworth classification and as muddy sand under the Folk classification (Table 7-4) (Appendix D; Appendix J). This is consistent with the sediment that extends throughout the Project Area as informed by BGS (2020) and NMPi (2023).

Sediment samples acquired during the environmental survey (Appendix D) indicate sediments have a dominant composition of muddy sand, which is the most frequent occurrence (Table 7-4). More specifically, the seabed sediment has a mean grain size (d50) range of approximately 115 to 190 μm. The percentage composition of different sediment fraction from the sampled locations across the Project Area (Figure 7-4) demonstrated the poorly sorted nature of the sediment (Table 7-4). In addition to the seabed sediment, the completed geophysical surveys identified the presence of infrequent boulders across the Project Area, which were all present on the surface, and none detected below the seabed surface (Appendix J).

Table 7-4 Seabed sediment properties across the Project Area (Appendix D), with sample locations as illustrated in Figure 7-2

SAMPLE ID	MEAN GRAIN SIZE (µm)	SEDIMENT CLASSIFICATION		SORTING	PERCENTAGE SEDIMENT FRACTION (%)		
		WENTWORTH	BGS (1982)		GRAVEL (>2 mm)	SAND (63-2000 µm)	MUD (<63 µm)
E13	114.7	Very Fine Sand	Muddy Sand	Poorly Sorted	0.06	72.39	27.55
E32	189.7	Fine Sand	Slightly Gravelly Muddy Sand	Poorly Sorted	3.96	81.55	14.49
E7	144.6	Very Fine Sand	Muddy Sand	Poorly Sorted	0.70	80.17	19.13
M1	118.2	Very Fine Sand	Muddy Sand	Poorly Sorted	0.10	75.29	24.61
M2	117.4	Very Fine Sand	Muddy Sand	Very Poorly Sorted	0.05	71.65	28.31
M3	131.0	Very Fine Sand	Muddy Sand	Poorly Sorted	0.11	78.06	21.83
R4	128.0	Very Fine Sand	Muddy Sand	Poorly Sorted	0.09	74.50	25.41
W1	128.9	Very Fine Sand	Muddy Sand	Poorly Sorted	0.02	75.33	24.65

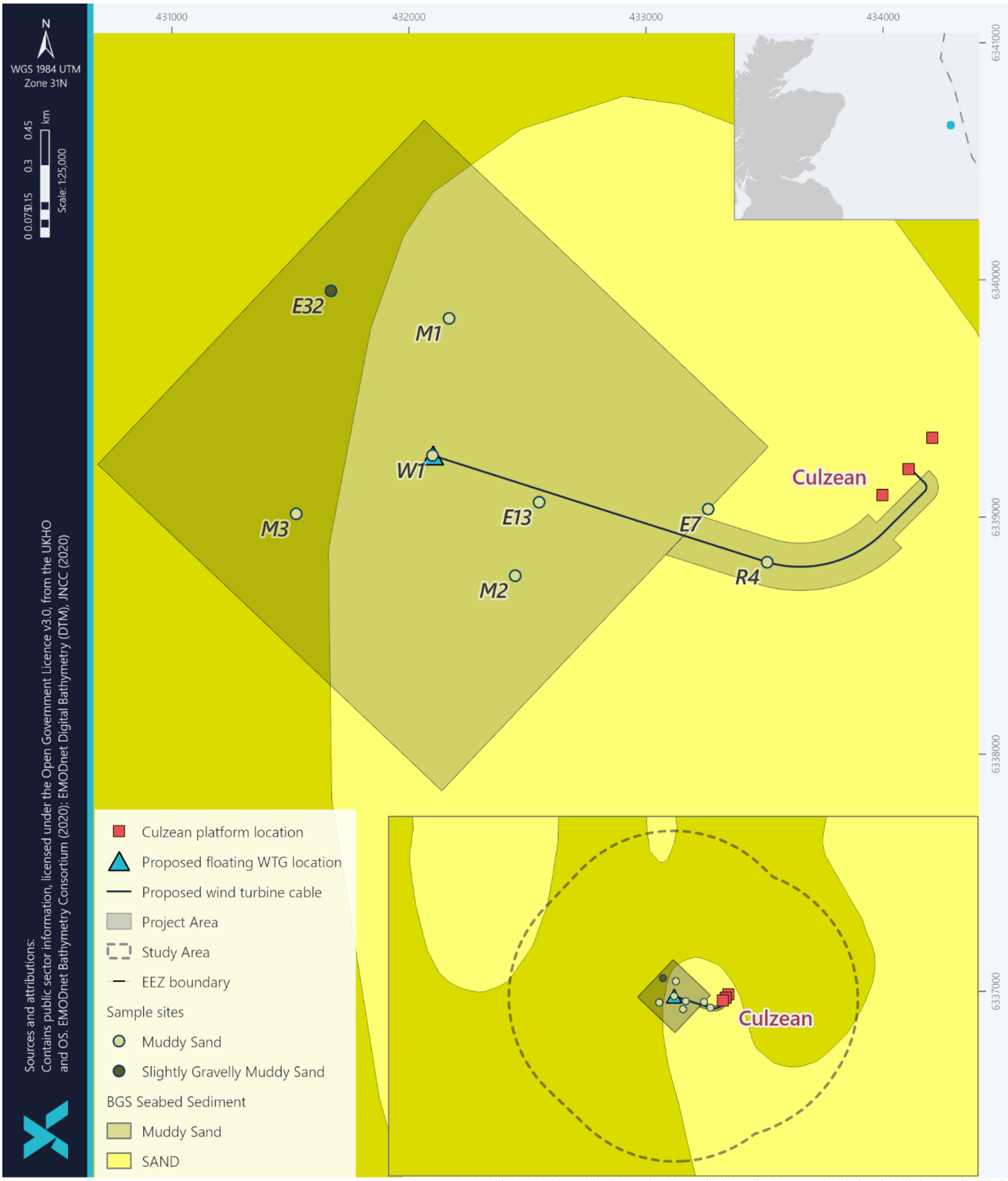

Figure 7-4 Sampled seabed sediment properties across the Project Area in relation to BGS (2023)

7.5.3.4 Bathymetry and morphology

Water depths in the CNS gradually deepen from south to north from approximately 40 m at the Dogger Bank to approximately 100 m at the Fladen/Witch Ground, (approximately 250 km and 220 km south and north of the Project Area respectively) (DTI, 2001; DECC, 2016). The main topographic features in the CNS are the Dogger Bank a large sublittoral sandbank submerged through sea-level rise, located in the southwest corner of the region, marking a division between the southern North Sea and CNS, and the Fladen/Witch Ground, a large muddy depression generally considered to define the northern extent of the CNS (DTI, 2001; DECC, 2016).

The water depth is relatively consistent across the Project Area, with the deepest depth at approximately 100 mLAT (NMPi, 2023; Figure 7-5), although, the site-specific geophysical survey indicates a depth range between 87 mLAT and 91 mLAT (Appendix J). The seabed across the Project gently deepens towards the west at a gradient of <0.5°, which is consistent with the surrounding area (Figure 7-6) and as identified in Appendix J, which states no steep gradients occur within the Project Area. The only identified morphological feature within the geophysical survey was an isolated furrow, orientated in a north northeast to south southwest direction, and was shallow at only 0.1 m deep, with evidence of rippling, indicating bottom currents (Appendix J). Otherwise, the seabed is homogenous.

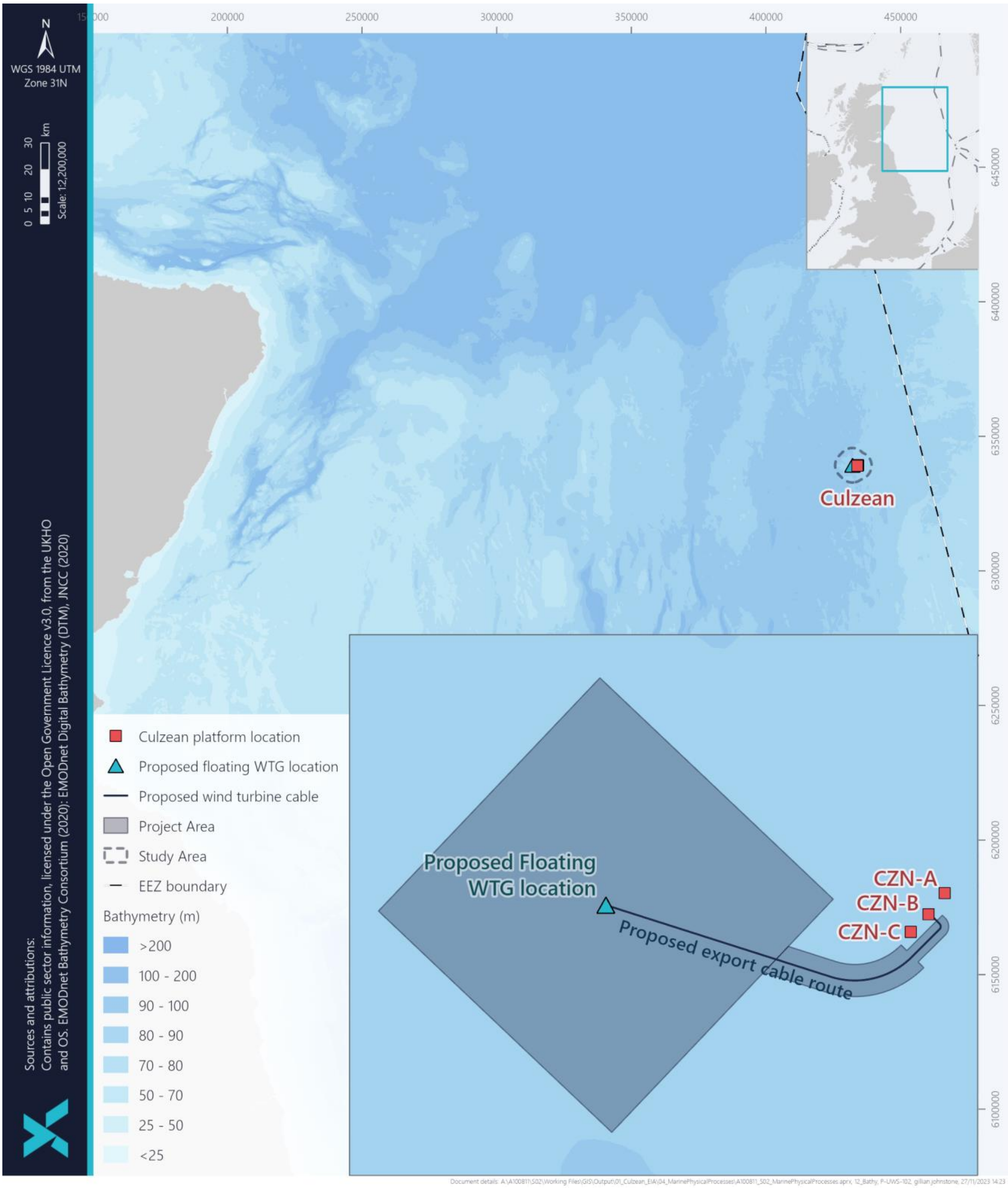

Figure 7-5 Project and Study Area bathymetry

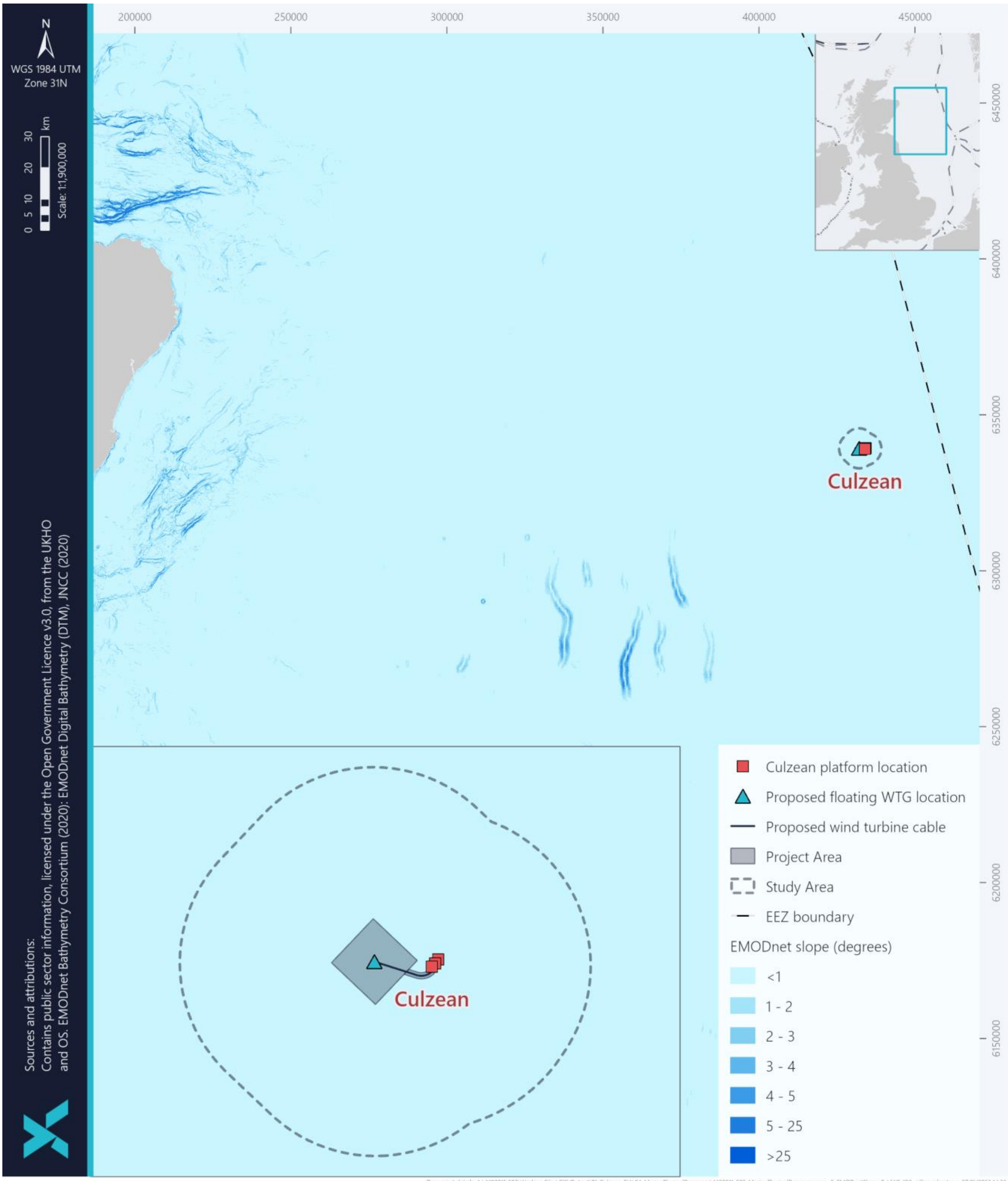

Figure 7-6 Slope within the Project and Study Areas

7.5.3.5 Hydrodynamic regime

The anti-clockwise movement of water through the North Sea and around the CNS region originates from the influx of Atlantic water, via the Fair Isle Channel and around the north of Shetland, and the main outflow northwards along the Norwegian coast (DECC, 2016). Against this background of tidal flow, the direction of residual water movement in the CNS is generally to the southeast (DTI, 2001; DECC, 2016).

Water levels

The Project Area is in a micro tidal setting, with a mean spring tidal range between 0.75 m – 1 m (Figure 7-7; ABPmer, 2008), being located in a region of relatively low tidal amplitudes, associated to its proximity to the amphidromic point off the Norwegian coast. LAT and highest astronomical tide (HAT) water levels for an offshore location within the Study Area (i.e. T024A), informed from the ATT (UKHO, 2023), indicate levels of 0.1 m and 2.2 m respectively. At Peterhead, which is the closest port, associated levels are 0.1 m and 4.4 m for LAT and HAT respectively. The mean spring and neap range at the coastal location is 3.3 m and 1.6 m respectively, with the tidal ranges decreasing offshore to levels represented within the levels illustrated in Figure 7-7, which is also in line with the distribution of co-range lines across the CNS.

Current speed

Figure 7-1 provides an indication of the orientation of tidal flows across the Project Area, based on the mean spring tidal ellipses (ABPmer, 2008), where tidal flow is orientated north – south, based on a flood flow towards the south. Spring flow speeds across the Project Area are illustrated in Figure 7-8, with current speeds of between 0.26 and 0.5 m/s (ABPmer, 2008). Neap flow rates for the same region from ABPmer (2008) indicate speeds between 0.10 m/s and 0.25 m/s. Information from tidal diamonds surrounding the Project and Study Area from ATT (i.e. SN025E, SN025F, SN0241 and SN024J) indicate mean spring speeds ranging between 0.05 m/s and 0.36 m/s, compared with a neap range ranging between 0.00 m/s and 0.21 m/s (UKHO, 2023), which is consistent with the understanding for the area.

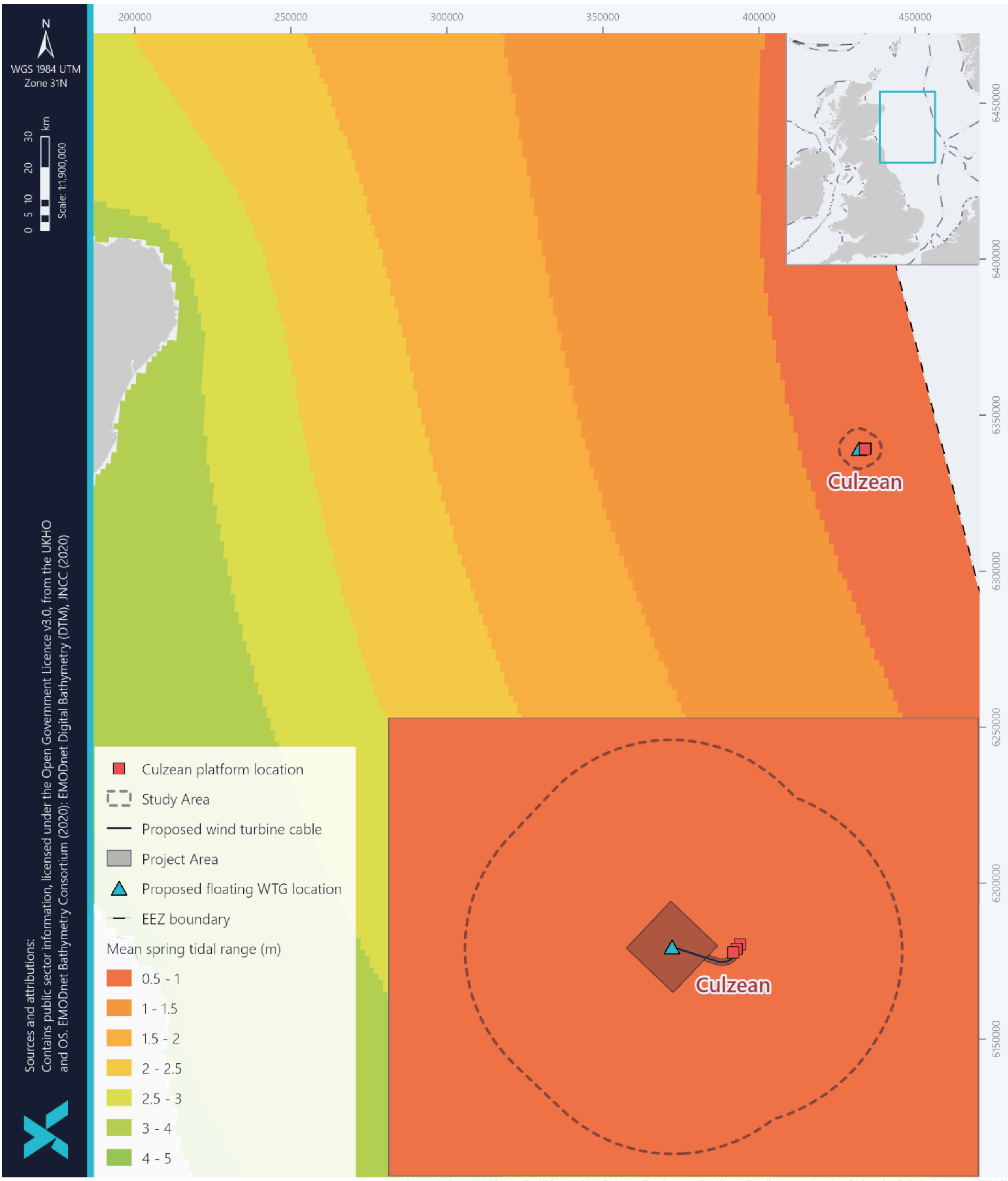

Figure 7-7 Mean spring tidal range (m) across the Project and Study Areas

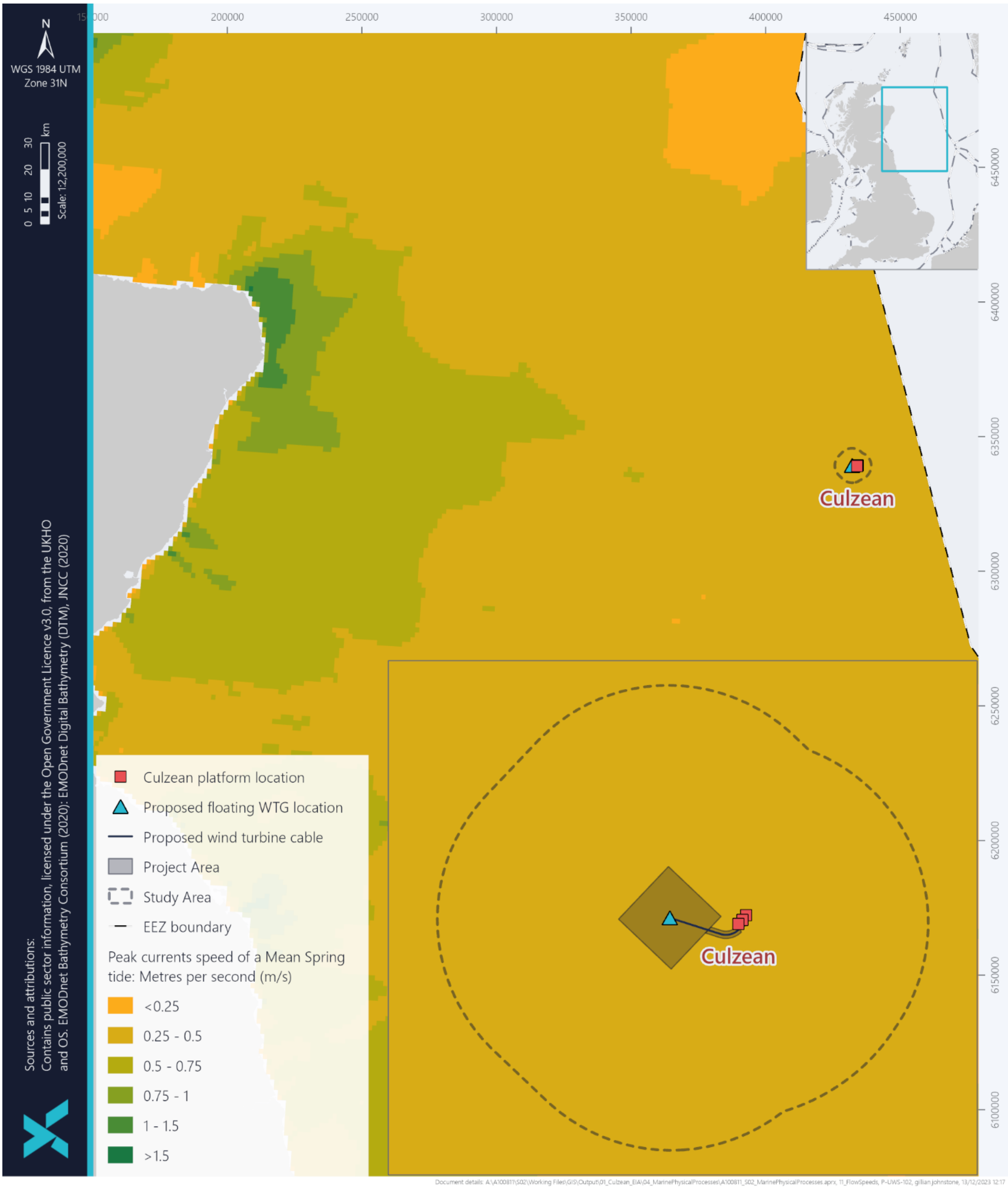

Figure 7-8 Mean spring flow speed (m/s) across the Project and Study Areas

7.5.3.6 Wave regime

The annual mean wave height in the CNS region follows a gradient decreasing from the northern area of the Fladen/Witch Ground to the southern area of the Dogger Bank. In the north, the mean wave height ranges from 1.51 m – 2.40 m whilst in the south it ranges from 1.51 m – 2.10 m (NMPi, 2023).

Figure 7-9 and Figure 7-10 respectively show the recorded significant wave height (Hs) and zero-crossing period (Tz), between January 2022 and May 2023 at the nearby Eastern Trough Area Project (ETAP) platform, located 16 km northwest of the Project Area. At the ETAP platform, Hs of around 1 m are observed over the summer months, compared with around 3 m during the winter (Figure 7-9). Similarly, the wave period in the summer is typically around 5 seconds compared with 7 seconds for the winter months (Figure 7-10), characteristic of a locally generated wind wave regime. Larger wave events are observed to occur within the presented timeframe, with significant wave of over 6 m (Figure 7-9), with an associated period of 10 seconds (Figure 7-10), more representative of swell waves propagating in from the other areas of the North Sea. The dominant wave approach direction is from the north (ABPmer, 2018).

Modelled Hs, from the UK Renewables Atlas (ABPmer, 2008) covering the Project Area, show that the Hs typically range between 2.01 m - 2.25 m throughout the year, with a seasonal variation as represented in the ETAP platform measurements. In the summer, the Hs covering the Project Area ranges between 1.00 m and 2.5 m, compared with a Hs between 2.76 m and 3 m in the winter months (ABPmer, 2008). Although, no site-specific information is available from the Project Area, the wave properties from the nearby ETAP platform are considered to be a good representation of conditions that are likely to occur within the Project and Study Areas.

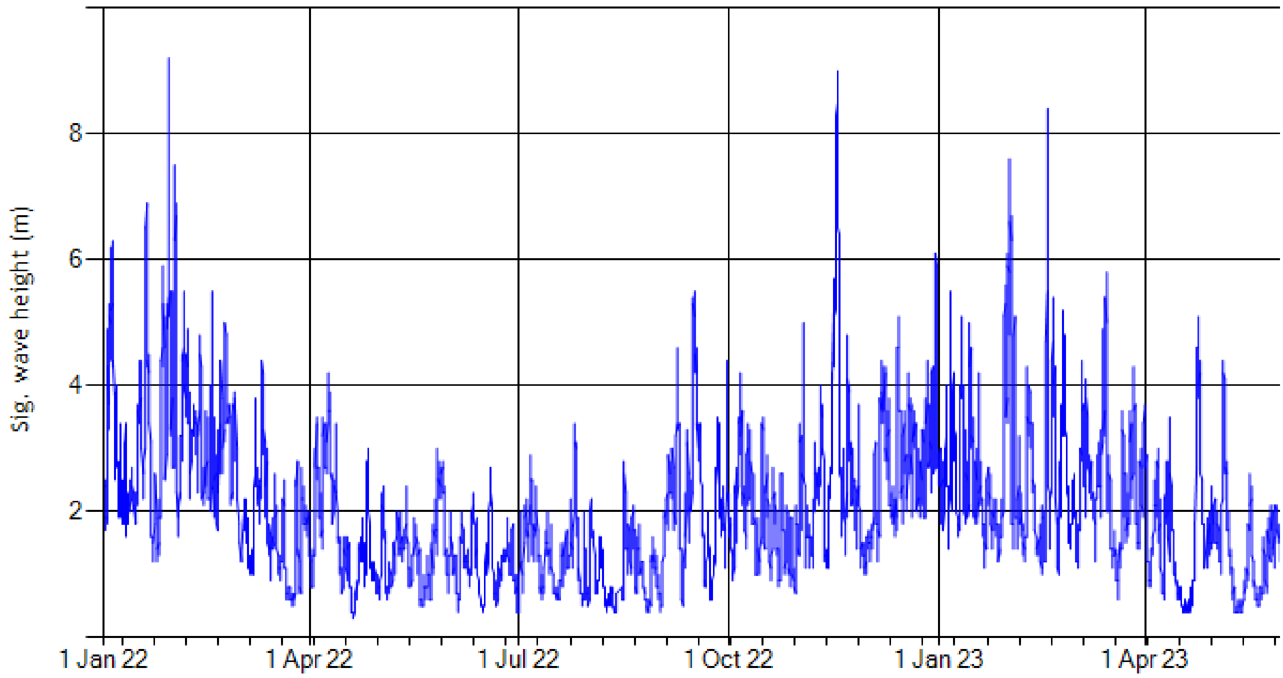

Figure 7-9 Average significant Wave height at the ETAP platform between January 2022 and May 2023 (Cefas, 2023)

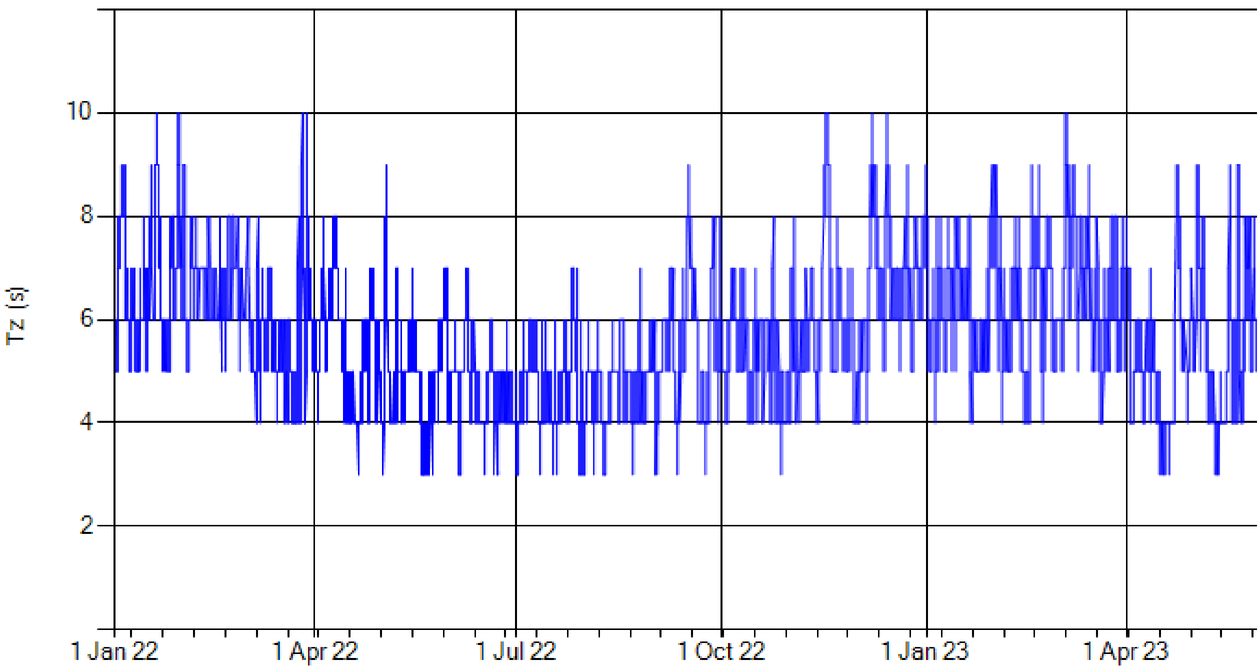

Figure 7-10 Average wave period at the ETAP platform between January 2022 and May 2023 (Cefas, 2023)

7.5.3.7 Sediment transport

Coarse sediment fraction

Sediment movement throughout the Project Area is influenced by the prevailing hydrodynamic and metocean processes in addition to the surrounding bathymetry and seabed characteristics. The interaction of the seabed with wave and tidal processes determines how often unconsolidated surficial sediments become mobilised and the way they are transported (i.e. bed load transport and/or suspended load transport). Section 7.5.3.3 provides an overview of the seabed sediment distribution across the Study Area, which is used in association with tidal and wave properties described in Sections 7.5.3.5 and 7.5.3.6, to inform the sediment transport potential, which is calculated based on Soulsby (1997).

The seabed sediment across the Project Area consists of muddy sand, with a mean grain size range of approximately between 115 μm and 190 μm (Table 7-4). However, the sediment is noted as being poorly sorted, with up to gravel sized material (i.e. >2 mm) being present (Table 7-4), therefore, the assessment of sediment transport potential is completed for up to the gravel sediment fraction. Based on the range of d50 sediment grain sizes across the Project Area (Section 7.5.3.3), a mean value of 135 μm, equating to fine sand is used to represent the seabed sediment. Applied current speeds are based on the slowest, medium, and fastest flow speed under spring and neap conditions as described for the Project Area in Section 7.5.3.5. This equates to speeds of 0.26 m/s, 0.35 m/s and 0.50 m/s under spring conditions respectively and 0.11 m/s, 0.18 m/s and 0.25 m/s under neap conditions respectively. The above flow conditions are assessed in relation to summer wave properties (i.e. Hs of 1.0 m and Tz of 5 seconds) and winter wave properties (i.e. Hs of 3.0 m and Tz of 7 seconds). A water depth of 90 m, which is characteristic to the Project Area is used in estimating the sediment transport potential, for which results are presented in Table 7-5.

The results of the sediment transport potential indicates that currents are the principal driving force behind sediment mobility, with no mobility occurring in relation to the locally wind generated wave regime characteristic to the Project Area (Table 7-5). Under currents, sediment mobility is determined to occur only associated with spring flow speeds at medium and fastest speeds, i.e. at speeds at and above 0.35 m/s (Table 7-5). At the medium spring speeds of 0.35 m/s, sediment up to fine sand would be mobilised at the water depths which occur within the Project Area. At the fastest flow speeds of up to 0.5 m/s at the seabed, sediment up to coarse sand could be disturbed and mobilised. As even slower flows speeds (i.e. < 0.35 m/s) occur under neap conditions, no sediment mobility is estimated under such conditions (Table 7-5).

Table 7-5 Sediment mobility potential calculated for the Project Area

SCENARIO			SEDIMENT MOBILITY POTENTIAL				
WAVES	FLOW CONDITIONS (m/s)		VERY FINE SAND	FINE SAND	MEDIUM SAND	COARSE SAND	VERY FINE GRAVEL
Winter (Hs = 3.0 m, Tz = 7 s)	Spring	0.26	N	N	N	N	N
		0.35	Y[1]	Y[1]	N	N	N
		0.5	Y[1]	Y[1]	Y[1]	Y[1]	N
	Neap	0.11	N	N	N	N	N
		0.18	N	N	N	N	N
		0.25	N	N	N	N	N
Summer (Hs = 1.0 m, Tz = 5 s)	Spring	0.26	N	N	N	N	N
		0.35	Y[1]	Y[1]	N	N	N
		0.5	Y[1]	Y[1]	Y[1]	Y[1]	N
	Neap	0.11	N	N	N	N	N
		0.18	N	N	N	N	N
		0.25	N	N	N	N	N

Sediment transport potential estimated based on a water depth of 90 m characteristic to the Project Area.

N - No sediment mobility occurring under and condition, i.e. currents or waves along and combined currents and waves scenario.

Y[1] - Sediment is mobile under currents along and combined currents and waves scenario. No mobility occurs under waves alone for the assessed wave properties.

Fine sediment fraction

The sediment type across the Project Area is dominated by sand and mud (Section 7.5.3.3). For the Project and Study Area, Table 7-5 above demonstrates that coarser sediments are mobile as a bedload transport in response to tidal currents and only during spring conditions. When finer sediments (i.e., silts and muds) are mobilised they are typically carried in suspension, contributing to higher concentrations of SSC or Sediment Particulate Matter (SPM), thereby increasing the turbidity of water column until the material settles out. Due to the offshore location of the Project Area, any turbidity would be in relation to seabed sources mixing throughout the water column. Suspended sediment concentrations in the water column is principally governed by tidal currents, with fluctuations observed across the spring-neap cycle and across the different tidal stages (high water, peak ebb, low water, peak flood). SSC are also intensified during wind-driven storm events, which increases mixing throughout the water column. During these high-energy storm events, SSC can increase considerably, both near the seabed and extending into the water column. Following storm events, SSC levels will gradually decrease to baseline conditions, regulated by the ambient regional tidal regimes. The seasonal nature and frequency of storm events in the central North Sea, therefore, support a broadly seasonal pattern for SSC levels.

Long-term (1998 to 2015) monthly average concentration of sea surface SPM have been deduced from satellite data (Cefas, 2016). In general, SPM concentrations across the Study Area are considered to be very low (<1 mg/l) (Figure 7-11). This is attributed to the limited seabed sediment mobility, deep water depths, offshore location and distance from coastal or terrestrial sediment sources. At the offshore location of the Project Area, only marginally higher levels of SSC are assessed to occur in the winter months (Cefas, 2016).

As introduced in Section 7.5.2.3, water sampling for TSS was completed as part of the site-specific environmental sampling to provide information on the water column SSC (Appendix D). Samples were acquired from eight locations across the Project Area (Figure 7-2), with sampling occurring at two water depths for each location, i.e. at the surface and bottom (Section 7.5.2.3). Results of the TSS from the sampled locations are set out in Table 7-6. Across the Project Area, TSS ranged from <5 mg/l to 28 mg/l, with most samples having concentrations of <5 mg/l, below the level of detection, thereby indicating little to low levels of SSC. The measured levels of TSS is in line with the general understanding of the region and assumed to be approximately representative of background levels. Measurements of over 10 mg/l were recorded within the Project Area, albeit for individual samples at a given locations. The marginally higher concentrations were observed for location E13 (surface and bottom), E7 (bottom only) and M2 (surface only), all located within the turbine surveyed area (Figure 7-2). Despite the localised higher TSS measurements, the Project Area is generally considered to have low SSC properties in line with that represented by the Cefas (2016) dataset in Figure 7-11, as the water sample results largely indicate concentrations below the level of detection (Table 7-6).

Table 7-6 Total suspended solids within the Project Area (Appendix D), with sample locations as illustrated in Figure 7-2

SAMPLE ID AND LOCATION	TOTAL SUSPENDED SOLIDS (mg/l)
E13 Surface	17
E13 Bottom	26
E7 Surface	7
E7 Bottom	28
M2 Surface	22
M2 Bottom	<5
M3 Surface	<5
M3 Bottom	<5
R4 Surface	<5
R4 Bottom	<5
W1 Surface	<5
W1 Bottom	<5
E32 Surface	10
E32 Bottom	<5
M1 Surface	<5
M1 Bottom	<5

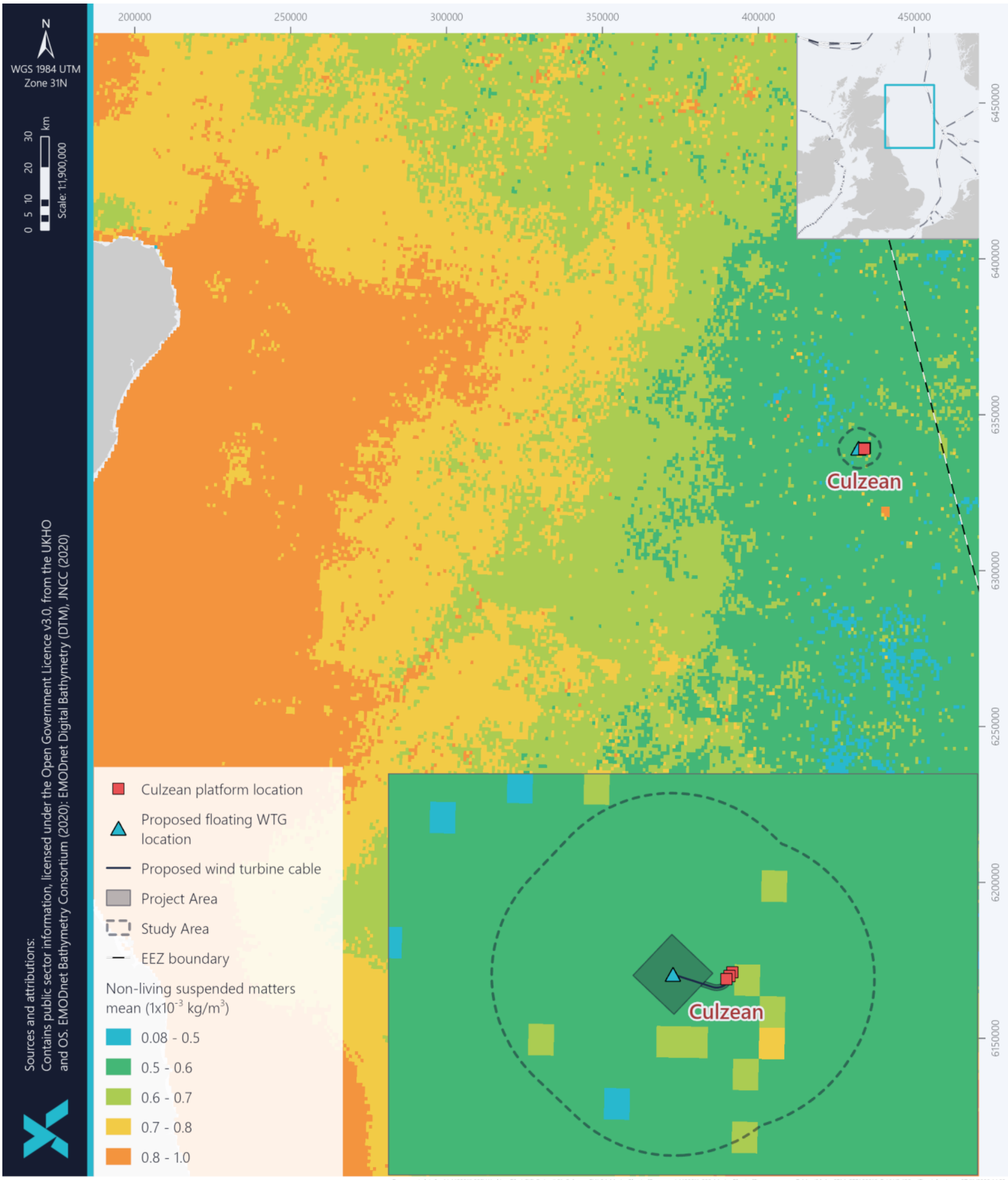

Figure 7-11 Non-living suspended particulate matter after Cefas (2016)

7.5.3.8 Fronts and stratification

Across the Project Area, the mean annual surface temperature is approximately 9.6°C (based on climatology data of the north-west European continental shelf for 1971-2000) (NMPi, 2023). The annual mean near-bed temperatures across the Project are approximately 7°C (NMPi, 2023). Fronts are one of five large-scale features included on the list of MPA search features. Scottish Natural Heritage (SNH) (2014) (now NatureScot) utilised front detection and aggregation techniques to high resolution satellite ocean colour data to describe frequently occurring fronts near to the Scottish coast. The key frontal zones were selected through detailed analysis of the seasonal chlorophyll and thermal front distributions. Based on the regional information covering the Project Area, the Project does not coincide with any area of strong frontal activity.

The potential for stratification was assessed based on work completed by Miller and Christodoulou (2014), which provided seasonally averaged front frequency map based on an interpretation of ten years of satellite data (1998 to 2008). Figure 7-12 shows that fronts were most likely in the spring and summer months, with up to 20 to 40% likelihood of a front developing in the spring and summer respectively, compared with <10% for the autumn and winter months (Miller and Christodoulou, 2014). A review of the summer front frequency potential covering the Project and Study Areas is illustrated in Figure 7-13 and shows a long-term summer potential of between 7% and 30% for fronts occurring. However, the potential is not consistent and is variable within the Study Area, so the Project Area is in a region of limited frontal and stratification activity. As a result of the above and the small scale of the Project, the assessment for potential impacts on fronts and stratification was scoped out in the Culzean Floating Wind Pilot Scoping Report (TotalEnergies, 2023), as agreed by consultees during scoping (MD-LOT, 2023) (Table 7-2).

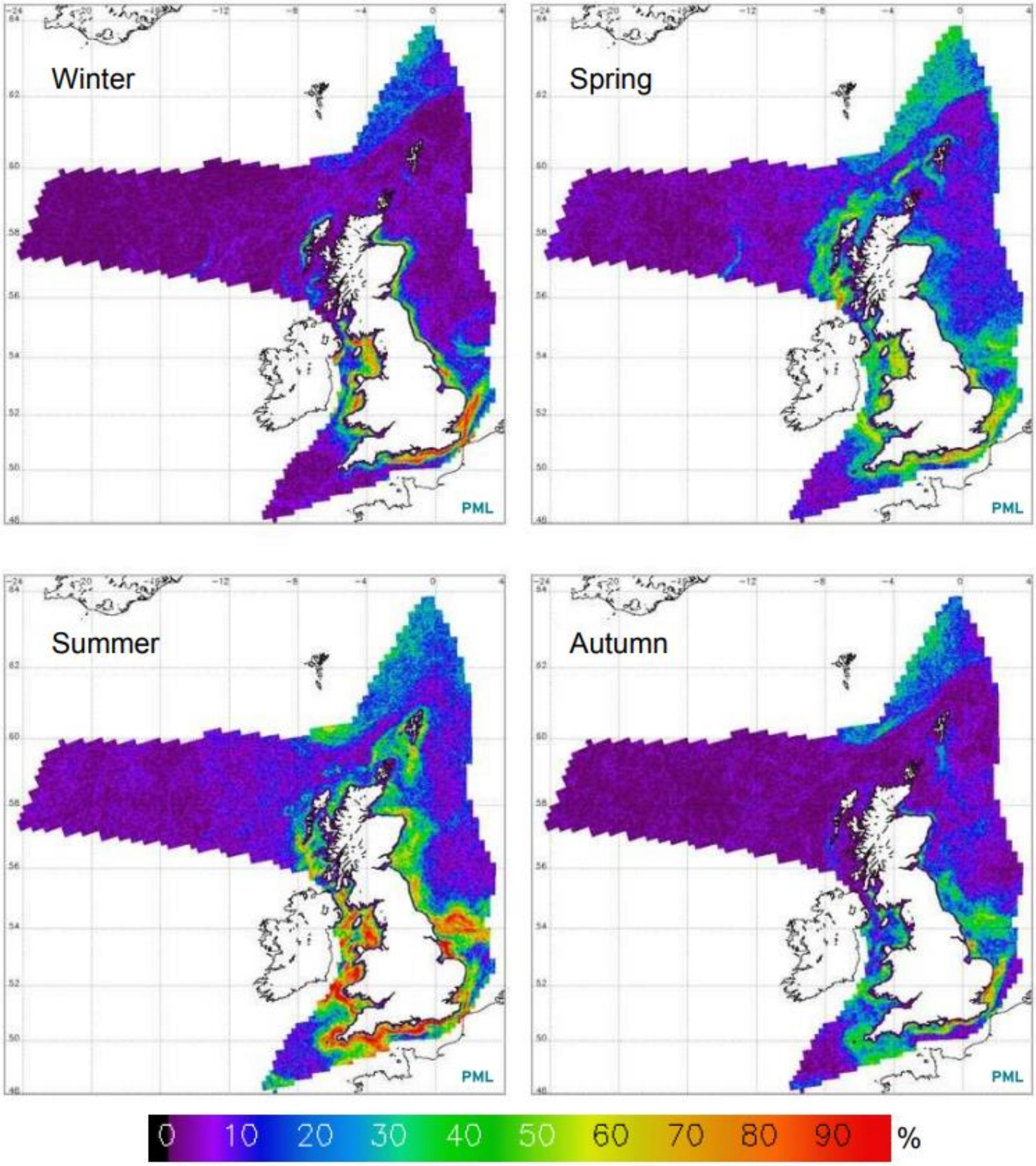

Figure 7-12 Seasonal frequent front maps, indicating the percentage of time a strong front was observed within the UKCS (1999-2008) (Miller and Christodoulou, 2014)

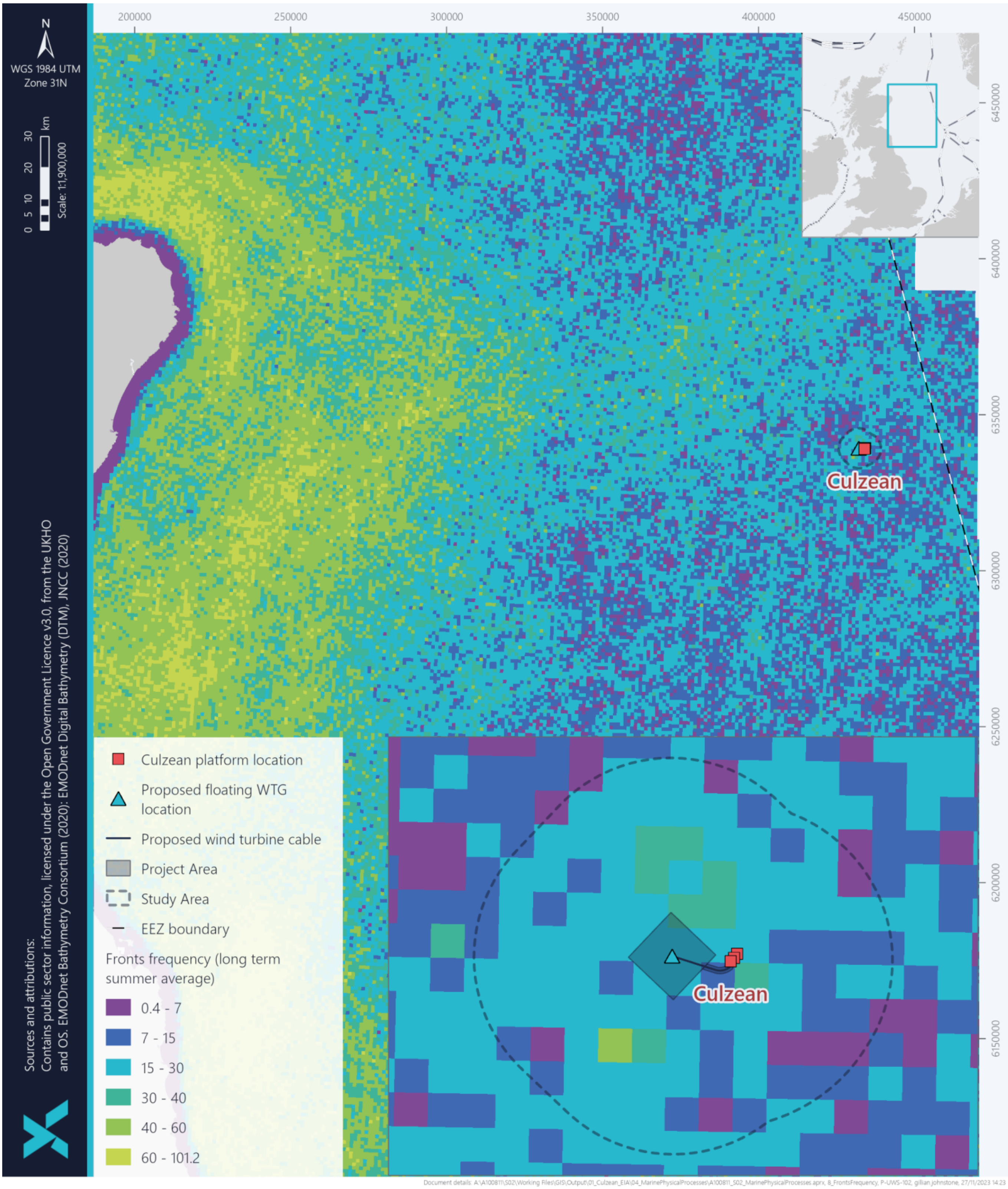

Figure 7-13 Long term averaged summer frequency of occurrence of fronts (Miller and Christodoulou, 2014)

7.5.3.9 Wind regime

The prevailing winds in the CNS are from the southwest. Wind strengths in winter are typically in the range of Beaufort scale force 4 – 6 (6 m/s – 11 m/s) with higher winds of force 8 – 12 (17 m/s – 32 m/s) being much less frequent. Winds of force 5 (8 m/s) and greater are recorded 60% – 65% of the time in winter and 22 – 27% of the time during the summer months (DECC, 2016).

The wind speeds within the Project Area are presented as a 30-year average. Across the Project, the average wind speed is recorded as between 10.1 m/s – 10.5 m/s, with seasonal variations showing faster wind speeds throughout the autumn, winter, and spring months between September to March (ABPmer, 2008). Figure 7-14 highlights winds across the Project Area are largely from the south to the northwest, and marginally from the southwest to northerly sectors. The yearly mean average wind dominant direction in relation to the Project location is from the southwest (ABPmer, 2018) with mean average wind speeds of 10 m/s – 10.5 m/s (ABPmer, 2008).

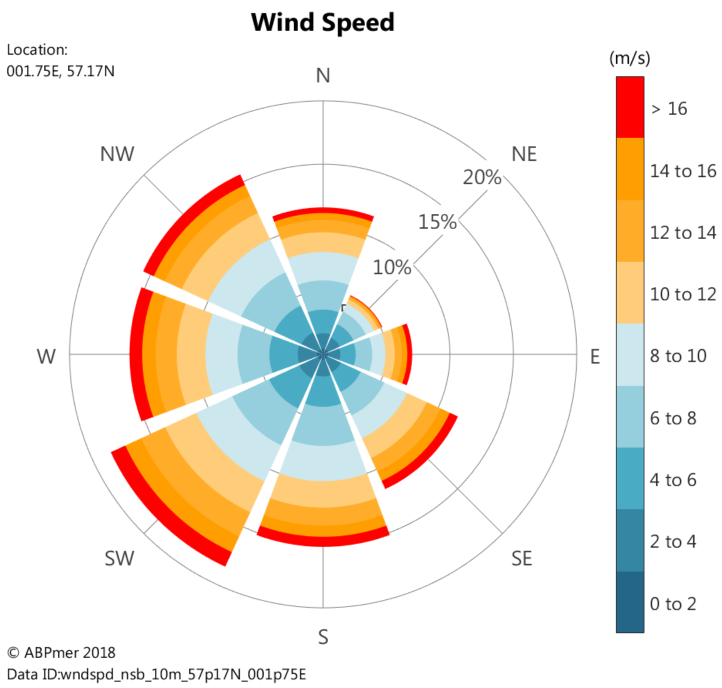

Figure 7-14 Wind speed for a location within the Project Area (ABPmer, 2018)

7.5.4 Future Baseline

Aspects of the Marine Physical Processes baseline are likely to change over time, largely due to climate change. However, the degree of change is uncertain. Certain features of the physical environment, such as the bedrock geology and subsurface sediments, will remain unchanged over time. These features have been consistent within the Project Area for millennia and will continue to be so into the future. In contrast, metocean regimes within the Project Area are likely to be influenced over time by the changing climate. This may have consequences for other dependant physical features and properties such as fronts, sediment transport etc.

7.5.4.1 Bathymetry and morphology

There is not anticipated to be any change to the seabed bathymetry or morphology in the long term. The absence of bedforms, the deep-water depths and the limited transport potential means there is little mechanism for change.

7.5.4.2 Hydrodynamic regime

Water Levels

Over the last approximately hundred years (i.e. 1900 to 2011), the long-term absolute mean sea level rise is estimated to be 1.53 mm ± 0.16 mm/yr for the entire North Sea region (Wahl *et al.*, 2013). This is partly attributable to the ongoing isostatic emergence of the Scottish land mass after the effects of glaciation due to the thawing of the Scottish Ice Sheet (Dawson *et al.*, 2013). This isostatic adjustment will continue in tandem with the predicted rise in sea level attributed to changes in the climate described above. Sea level changes associated with isostatic adjustment are slow and part of an ongoing process which will continue beyond the lifetime of the Project.

Further changes in water level would be in relation to global sea level rise associated with climate change. With regards to changes in water level, the UKCP provide details of climate change projections for mean sea level at sites around the UK coastline (Lowe *et al.*, 2018) along with the marine report (Palmer *et al.*, 2018). The projections extend to 2100 for various scenarios (representative concentration pathways, RCP) at locations around the UK mainland. Under RCP8.5 (the high emissions scenario), climate change is expected to contribute a 1 mm – 2 mm increase in the sea level rise per year in the UK. Under the high-emissions scenario by 2100, in proximity to Peterhead, sea levels would have risen by approximately 0.97 m, based on the 95th percentile estimate, which would mean a landward advance of high water. At the offshore location of the Project Area, similar levels could be expected to occur. However, such increases in sea levels are not in relation to the Project, with little to no influence on the Project properties. Furthermore, Ramsay and Brampton (2000) states that the net sea level rise around the Scottish coast will be up to 30 cm, with nearly a third of the coastline experiencing a 10 cm rise some areas will experiencing larger increases. The variations reflect the differences in the rate of crustal uplift which will either moderate or exacerbate the sea level rise. The future rises coupled with an increase in extreme tidal levels and an increase in tidal surges would be expected to increase the probability of waves overtopping sea defences at the coast but would not be noticeable further out to sea (Ramsay and Brampton, 2000).

Current Speed

There is not expected to be any change to tidal flows and current speeds in the future. The tidal properties within the Project Area are associated with much larger regional scale tidal movement. Tidal flows are additionally independent of wind and wave conditions.

7.5.4.3 Wave Regime

Due to naturally high inter-annual variability in the wave climate and low confidence in future climate change projections, there is presently no clear consensus on future wave climates affecting the north coast of Scotland (Wolf *et al.*, 2020; Bircheno *et al.*, 2023), although it is expected that natural variability will continue to contribute to the trends observed in the frequency and intensity of waves and storms within the North Atlantic. The most recent Marine Climate Change Impacts report card suggests that there is likely to be an overall reduction in mean significant wave height in the north of the UK (compared to an increase in the south; Bircheno *et al.*, 2023). Any change attributable to ongoing climate change will occur on timescales beyond the operational life of the Project.

7.5.4.4 Sediment transport

Given that there are not expected to be any changes to the regional scale tidal properties, and only natural variation to the wave climate in response to climate change is likely to occur, there is not anticipated to be any variation to the sediment transport characteristics in the future (beyond existing natural variability), especially within the Project lifespan.

7.5.4.5 Stratification and fronts

There is little evidence to suggest that fronts or stratification are consistently (even seasonally) present within the region, which is considered to be the case into the future. Any changes to the frequency of occurrence or properties of fronts or stratification within the wider CNS, will be dictated by regional mesoscale processes and changes to the water column, which would also be influenced by climate change, based on the conditions described in previous sections.

7.5.4.6 Wind regime

Any changes to the wind regime in the future will primarily be attributable to ongoing climate change, which will occur on timescales beyond the operational life of the Project.

7.5.5 Summary and Key Issues

Table 7-7 Summary and key issues for Marine Physical Processes

SUMMARY AND KEY ISSUES	PROJECT AREA
	Bedrock geology is likely consistent across the whole offshore Project Area and constitutes firm to hard interbedded sandstone of Eocene to Pliocene age (Tertiary). Seabed sediments are mostly classified as muddy sand. Water depths within the Project Area range between approximately 87 mLAT and 91 mLAT (Gardline, 2013; Appendix J), with little to no morphological features present.
	The Project Area is in a micro tidal setting, with a mean spring range between 0.5 m – 1 m. Mean spring current speeds within the Project Area ranges between 0.26 m/s – 0.5 m/s, with neap speeds between 0.11 m/s – 0.25 m/s. Waves primarily approach from the north, with a Hs of 1 m and Tz of 5 seconds in summer months and 3 m and 7 seconds in winter months. Larger wave events occur with Hs over 6 m and an associated Tz of 10 seconds.
	Sediment transport potential across the Project Area is primarily driven by currents, with mobility occurring associated with spring flow speeds of around 0.35 m/s and above. No mobility occurs in relation to the summer or winter wave conditions identified for the Project Area. Sediment up to coarse sand is mobilised associated with the fastest current speeds of 0.5 m/s, while mobility of fine sand occurs associated with flow speeds of around 0.35 m/s. The Project Area is determined to be in a region of low SSC, characterised by regional information from Cefas (2016) and corroborated by site-specific water sampling, which indicated the area largely had TSS below the level of detection, i.e. at <5 mg/l.
	The Project Area is in a region of little to frontal and stratification activity.
	The offshore location of the Project Area means that there is no interaction with the coast.

7.5.6 Data Gaps and Uncertainties

Whilst good overall understanding is achieved there remains some data gaps across the Project Area in the quantification of measured flows and waves, which places reliance on existing datasets to provide these details. Datasets, such as that of the ATT (UKHO, 2023), ABPmer (2008) and NMPi (2023) have been used within this EIAR and are appropriate to support a robust impact assessment.

7.6 Key Parameters for Assessment

As detailed in Chapter 4: Project Description, this assessment considers a Project Design Envelope (PDE), which encompasses a Maximum Design Scenario (MDS) or a worst-case scenario. The MDS scenario represents, for any given receptor and potential impact on that receptor that would result in the greatest potential for change.

Given that the MDS is based on the design option (or combination of options) that represents the greatest potential for change, confidence can be held that development of any alternative options within the design parameters will give rise to no worse effects than assessed in this impact assessment. Table 7-8 presents the worst-case scenario for potential impacts on Marine Physical Processes during construction, operation and maintenance and decommissioning.

Table 7-8 Worst case scenario specific to Marine Physical Processes receptor impact assessment

<table>
<tr><th>POTENTIAL IMPACT</th><th>WORST CASE SCENARIO</th><th>JUSTIFICATION</th></tr>
<tr><td colspan="3">Construction</td></tr>
<tr><td>Loss / alteration of seabed morphology (bathymetry and sediment type)

Increase in suspended sediments</td><td>Moorings: catenary
Maximum number of moorings is six per substructure / Wind Turbine Generator (WTG) (three catenary mooring lines, three taut or semi-taut mooring lines);
Catenary moorings:
Maximum length of each catenary mooring line is 600 m (1,800 m total);
Maximum length of catenary mooring that may come into contact with the seabed is 490 m per line (1,470 m total);
Accounting for a maximum 10 m wide lateral movement zone of the catenary mooring lines, the worst-case area of impact is expected to be 14,700 m^2 or 0.0147 km^2.
Taut / semi-taut moorings:
Maximum length of each taut / semi-taut mooring line is 610 m (1,830 m total);
Maximum length of taut / semi-taut mooring that may come into contact with the seabed is 110 m per line (330 m total);
Accounting for a maximum 10 m wide lateral movement zone of the semi-taut mooring lines, the worst-case area of impact is expected to be 3,300 m^2 or 0.00033 km^2.
Maximum area of seabed where lateral movement of mooring line can occur is 18,000 m^2/ 0.018 km^2 in total for all six mooring lines;
Up to 11 clump weights will be attached to each catenary mooring line, the footprint of which is included within the 10 m lateral movement zone; and
Total duration of offshore operations is one month associated with turbine, substructure, moorings and cable Installation activities.</td><td>This covers the largest spatial area of impact associated with seabed activities including installation of the seabed anchors and substructure mooring line, export cable and any required scour protection measures.</td></tr>
</table>

POTENTIAL IMPACT	WORST CASE SCENARIO	JUSTIFICATION
	Anchors • Worst case seabed disturbance and alteration is expected from drag anchors; • Up to six anchors per substructure / WTG (i.e. one per mooring line); • Maximum anchor size 11.2 m by 11.2 m by 6 m (length, width and height respectively) per anchor; • Maximum seabed footprint per anchor 125 m^2 (up to 750 m^2 for all six anchors); • Maximum seabed disturbance drag length 50 m per anchor; • Maximum seabed disturbance footprint from drag length is 560 m^2 per anchor (up to 3,360 m^2 for all six anchors); • Maximum total seabed disturbance loss / alteration (combined anchor footprint and drag length footprint) is 4,110 m^2 / 0.00411 km^2 for all six anchors. Seabed preparation (boulder removal, seabed levelling etc) will be completed within the same area; • Maximum scour protection footprint 70 m^2 per anchor (up to 420 m^2 / 0.00042 km^2 for all six anchors); • Maximum scour protection height is 1 m; and • Total duration of offshore operations is one month associated with turbine, substructure, moorings and cable Installation activities. Export cable • A maximum of one export cable will be applied; • Maximum cable length is 2,500 m; • Maximum cable length in water column is 500 m; • Maximum cable length on seabed is 2,045 m; • Cable installation (lay and burial) operations using a jetting tool; • Maximum trench width 3 m and maximum trench depth 1.5 m; • Trenching rate 120 m/hr; • Approximately 50% of the offshore export cables (1,000 m) may not reach target burial depth and may require remedial cable protection. Remedial cable protection may be up to 7 m wide and be protrude by up to 1 m above the seabed, resulting in a total area of 7,000 m^2;	

POTENTIAL IMPACT	WORST CASE SCENARIO	JUSTIFICATION
	• Maximum width of cable corridor 15 m (seabed disturbance, not trench width). Seabed preparation including boulder removal, seabed levelling etc. will take place within this corridor; • Seabed preparation to be completed along 100% of cable corridor; • Maximum seabed preparation footprint = 30,675 m^2/ 0.03 km^2 (15 m by 2,045 m); • Maximum volume of 7,000 m^3 cable protection for export cables; and • Total duration of offshore operations is one month associated with turbine, substructure, moorings and cable Installation activities.	
Operation and Maintenance		
Introduction of scour	Anchors • Up to six anchors per substructure / WTG (i.e. one per mooring line); • Maximum anchor size 11.2 m by 11.2 m by 6 m (length, width and height respectively) per anchor; • Maximum scour protection footprint 70 m^2 per anchor (up to 420 m^2 for all six anchors); and • Maximum scour protection height is 1 m.	Local scouring could occur around the base of the anchors and protection.
Decommissioning		
The MDS for decommissioning will be the same or less than during construction.		

7.7 Methodology for Assessment of Effects

An assessment of potential impacts is provided separately for the construction, operation and maintenance and decommissioning stages. The assessment for Marine Physical Processes is undertaken following the principles set out in Chapter 6: EIA Methodology. The sensitivity of the receptor is combined with the magnitude to determine the impact significance. Topic-specific sensitivity and magnitude criteria are assigned based on professional judgement, as described in Table 7-9 and Table 7-10.

Table 7-9 Sensitivity criteria

SENSITIVITY OF RECEPTOR	DEFINITION
High	Receptor is of very high importance and is protected under national and international legislation. Receptor with no or very low capacity to accommodate a particular effect with no or low ability to recover or adapt
Medium	Receptor is of high importance and is protected under national and international legislation. Receptor with low capacity to accommodate a particular effect without significantly altering character. Receptor has moderate ability to recover or adapt.
Low	Receptor is of moderate importance, but with no associated designation. The receptor is considered tolerant to change without significant detriment to its character; some limited or minor change may occur. Receptor has some tolerance to accommodate a particular effect and a high ability to recover or adapt.
Negligible	Receptor of very low importance, with no associated designations. Receptor is generally tolerant and can accommodate a particular effect without the need to recover or adapt and without effect on its fundamental character.

Table 7-10 Magnitude criteria

MAGNITUDE CRITERIA	DEFINITION
High	Impact occurs over a large spatial extent resulting in widespread, long term or permanent changes in baseline conditions or affecting a large proportion of the receptor. The impact is very likely to occur and /or will occur at a high frequency or intensity.
Medium	Impact occurs over a local to medium extent, with short to medium term change to baseline conditions or affecting a moderate proportion of the receptor. The impact is likely to occur and/ or will occur at a moderate frequency or intensity.
Low	Impact is localised and temporary or short term, leading to detectable change in baseline conditions or noticeable effect on small proportion of the receptor. The impact is unlikely to occur or may occur but at low frequency or intensity.
Negligible	Impact is highly localised and short term with full rapid recovery expected to result in very slight or imperceptible changes to baseline conditions or the receptor. The impact is very unlikely to occur and if it does will occur at very low frequency or intensity.

The consequence and significance of effect is then determined using the matrix provided in Chapter 6: EIA Methodology.

7.8 Embedded Mitigation

As described in Chapter 6: EIA Methodology, certain measures have been adopted as part of the Project development process to reduce the potential for impacts to the environment, as presented in Table 7-11. These have been accounted for in the assessment presented below. The requirement for additional mitigation measures (secondary mitigation) will be dependent on the significance of the effects on Marine Physical Processes receptors.

Table 7-11 Embedded mitigation measures relevant to Marine Physical Processes

MITIGATION MEASURE	DESCRIPTION	FORM (PRIMARY OR TERTIARY)	HOW MITIGATION WILL BE SECURED
Application of scour protection	The potential scale and requirement for scour protection will be informed by ongoing inspection surveys and the selected anchor solution. Requirements outlined within the Construction Method Statement (CMS).	Primary	Secured within conditions attached to the Marine Licence.
Cable Plan (CaP) and Cable Burial Risk Assessment (CBRA)	A CaP will be provided for the Project which will detail the location/route and cable laying techniques of export cable and detail the methods for cable surveys during its operational life. A CBRA will also be undertaken and included within the CaP.	Primary	Secured within conditions attached to the Marine Licence.
Micro-siting offshore infrastructure.	The Project will micro-siting the WTG and associated offshore infrastructure (including cable route) to avoid sensitive features. The final Project layout will be presented within the CaP and Development Specification and Layout Plan (DLSP).	Primary	Secured within conditions attached to the Marine Licence.
Environmental Management Plan (EMP)	The EMP will provide the over-arching framework for on-site environmental management during the phases of development as follows: • All construction as required to be undertaken before the commissioning of the Project • The operational lifespan of the Project from Commissioning until the cessation of electricity generation (environmental management during decommissioning is addressed by the Decommissioning Programme). The EMP will be in accordance with the "Application" insofar as it relates to environmental management measures. The EMP will set out the roles, responsibilities and chain of command in respect of environmental management for the protection of environmental interests during the	Tertiary	Secured within conditions attached to the Marine Licence.

MITIGATION MEASURE	DESCRIPTION	FORM (PRIMARY OR TERTIARY)	HOW MITIGATION WILL BE SECURED
	construction and operation of the Project. It will address (but not be limited to) the following overarching requirements for environmental management during construction: • Mitigation measures as identified in the "Application", pre-consent and pre-construction monitoring or data collection; • A pollution prevention and control method statement, including contingency plans; • Management measures to prevent the introduction of Invasive Non-Native Species (INNS); • A site waste management plan (dealing with all aspects of waste produced during the construction period), including details of contingency planning in the event of accidental release of materials which could cause harm to the environment. Wherever possible the waste hierarchy of reduce, reuse and recycle will be referred to; and • The reporting mechanisms that will be used to provide the Scottish Ministers and relevant stakeholders with regular updates on construction activity, including any environmental issues that have been encountered and how these have been addressed. The EMP will be regularly reviewed by the Company at intervals agreed by the Scottish Ministers and will be updated based on current information on construction methods and operations.		
Project Environmental Monitoring Programme (PEMP)	A Project Environmental Monitoring Programme (PEMP) to provide further evidence to support these conclusions of the EIA and provide information for future offshore wind farm developments.	Tertiary	Secured within conditions attached to the Marine Licence.
Construction Method Statement (CMS)	A CMS will be developed in accordance with the EMP and detail how project activities and plans identified within the EMP will be carried out, whilst also highlighting any possible dangers / risks associated with specific Project activities. The CMS will include the Code of Construction Practice (CoCP) which will set out the approach to how construction activities will be managed and controlled in order to deliver the commitments and mitigation arising from Project.	Tertiary	Secured within conditions attached to the Marine Licence.

7.9 Assessment of Impacts

7.9.1 Potential Effects During Construction

7.9.1.1 Loss or alteration of seabed morphology (bathymetry and sediment type)

Localised changes to seabed morphology may arise through construction activities. Although impacts are only likely to be minimal due to the small scale of the Project, there is potential for the loss / alteration of seabed morphology as a result of the following:

- Seabed preparation activities (boulder removal, seabed levelling etc.);
- Placement of mooring lines (catenary and taut / semi-taut), including their movement on the seabed (and inclusive of the clump weights on the catenary moorings);
- Anchor installation and presence;
- Placement of scour protection at anchors;
- Installation of export cable; and
- Placement of rock protection along the export cable.

Seabed sediments across the Project Area are characterised as predominantly muddy sand and the seabed is described as relatively featureless and flat (Sections 7.5.3.3 and 7.5.3.4). Infrequent boulders were identified on the surface of the seabed during the survey (Appendix D, Appendix J) and none were in the Project Area. it is therefore likely that boulder clearance activities will be limited. Boulder clearance will result in some minor disturbance to the seabed corresponding to the direct site of the clearance activity. However, this removal of boulders is a discrete activity which will not result in overall changes to seabed levels, as boulders would be relocated to adjacent areas where similar features exist. Consequently, this activity is not likely to give rise to significant effects and is therefore not considered further in the context of changes to seabed levels. Furthermore, in practical terms, boulders will only be moved a short distance from their original location. The movement of boulders would inherently change the characterisation of the immediate area; however, the overall characteristics of the seabed in the Project Area will remain the same. Seabed preparation activities inclusive of boulder clearance lead to displacement and disturbance of the seabed and have the potential to create sediment plumes and lead to increased suspended sediments in the water column, the potential for which is addressed in full in Section 7.5.4.4.

Depending on the exact seabed conditions and presence of morphological bedforms in the Project Area, further site preparation (specifically, seabed levelling) may be required to ensure suitably flat and stable conditions for installation of the Project infrastructure. This can be performed using varying methods. Considering the nature of the seabed across the Project Area, seabed levelling is more likely to be undertaken by a Pre-Lay Grapnel Run (PLGR). All seabed preparation activities will occur within a 15 m corridor, centred on the export cable route. The maximum length of export cable which will be on the seabed is 2,045 m. The total area of disturbance attribute to seabed preparation will be 0.03 km^2 (see Table 7-8).

Catenary and taut / semi-taut moorings will be applied, one for each of the (up to) six anchors, may be used to hold the substructure in place. Each catenary mooring line has a maximum length of 600 m, of which 490 m may come into contact with the seabed. Each taut / semi-taut mooring line has a maximum length of 610 m, of which 110 m may come into contact with the seabed. Using the parameters stated in Table 7-8 (Section 7.6) and accounting for lateral movement of the mooring line on the seabed, up to 0.018 km^2 of seabed may be affected across all mooring lines. The footprint associated with the clump weights will be within the corridor accounting for lateral movement of the mooring lines. While this impact is assessed here as part of construction, this impact will be ongoing over the course of the Project lifetime. This disturbance will be dependent on weather conditions, however sediments disturbed by the movement of the mooring lines will likely only be resuspended for a short while local to the area of disturbance. With regards to the greatest source of seabed disturbance, trenching of the export cable corridor will have the greatest impact.

Trenching and burial of the export cable will most likely be undertaken by jetting. Trenching 100% of the export cable which comes into contact with the seabed represents the worst-case from a sediment disturbance point of view. Jetting aims to minimise sediment loss so keeps the largest proportion of sediment within the trench. Therefore, a disturbance height of 1 m has been assumed in the following analysis. Based on typical flow speeds within the Project Area (0.3 m/s), the maximum trench parameters (as stated in Table 7-8), and an assumed jetting speed of approximately 120 m/hour, deposition extents as illustrated in Table 7-12 were calculated.

Deposition extent and thickness are inversely linked – the further settlement travels when disturbed, the thinner the deposit. Table 7-12 presents several outcomes based on different sediment fractions which are found to a greater or lesser extent in the Project Area.

Table 7-12 Distance travelled and thickness of sediment deposits as a result of jetting

SEDIMENT	RESETTLEMENT DURATION (s)	DISTANCE TRAVELLED (m)	DEPOSITION THICKNESS (m)
Fine Gravel	3.45	1.03	2.77
Coarse Sand	7.14	2.14	0.08
Medium Sand	20.00	6.00	0.07
Fine Sand	100.00	30	0.10
Coarse Silt	1,000.00	300	0.001

The Project Area consists predominantly of finer sediments, so deposition distance from the site of disturbance (jetting) for silt material will be up to 300 m, with a corresponding thickness of approximately 0.001 m. The fine and highly dispersed sediment will be rapidly reincorporated into the local sediment transport regime on subsequent tidal cycles. The relocation of existing sediment substrate displaced during trenching will not to lead to a noticeable change in sediment properties or seabed characteristics in the Project Area. The seabed in the Project Area is relatively consistent and featureless, therefore, any deposited sediment would be indiscernible from the existing seabed sediment. The time for resettlement is also shown in Table 7-12, with longer resettlement times typical of finer sediments. This is also related to sediment plumes and suspended sediments, which are considered further in Section 7.9.1.2.

The extent of disturbance and deposition associated with seabed preparation (boulder clearance, seabed levelling) and the catenary mooring lines, would be less than the deposition associated with trenching (jetting), as described above and shown in Table 7-12. Overall, the disturbance and deposition of sediment would not ultimately lead to a change in sediment type or properties, as sediment would largely be deposited in proximity to the disturbance and would be of the same sediment type.

Surveys within the Project Area identified that Holocene deposits reach a depth of 0.7 m below the seabed. Below this, other interbedded Quaternary deposits reach a depth of approximately 70 m (Section 7.5.3.2). Even in areas where the uppermost surficial sediments are absent (Section 7.5.3.3 notes their patchy presence within the Project

Area), with the mix of sediments across the Project Area being consistent. Therefore, all sediment types are represented across the Project Area. The intention is to trench and bury the export cable, with a maximum trench depth of 1.5 m. Therefore, cable burial is not expected to reach any units of subsurface geology. Similarly, installation of the five anchors will involve penetration of the seabed. However, this will be limited to surficial seabed sediments and the process of installing the anchors will not bring up sediment. Overall, the construction activities for the Project infrastructure are not expected to introduce any new or alternative sediment types, beyond that which already occurs as seabed sediment, which will all be limited to the footprint of seabed preparation activities (quantified above).

In addition to the above activities, which will be temporary and transient in nature, the footprint of the anchors, associated scour protection, and rock protection along the export cable will constitute a loss of seabed as a new hard substrate is introduced. The areas associated with these activities are detailed in Table 7-13.

Table 7-13 Construction footprints which constitute a loss of seabed

PARAMETER	MAXIMUM HEIGHT (m)	FOOTPRINT AREA (km^2) [2]
Anchors	6 (each for six anchors)	0.00075 (for all six anchors)
Anchor scour protection	1	0.00042 (for all six anchors)[3]
Remedial cable protection	1	0.007
Total	-	0.00817

A total of 0.00817 km^2 of seabed area will be lost due to the presence of anchors and rock. The inclusion of this hard substrate as part of the Project has the potential to change seabed levels. Should cable protection and anchor scour protection be required, this protection would be installed to a maximum berm height of 1 m which will present a change to a hitherto flat and featureless seabed.

In summary, the above discussion has quantified and contextualised the area of disturbance associated with the construction stage of the Project. The seabed is characterised as being relatively flat and featureless, with infrequent boulders; therefore, it is not expected that there will be a need for extensive seabed preparation. Consequently, trenching and burial of the export cable will likely have the most notable effect on the seabed. However, this still allows for recovery once construction activities have ceased. Consequently, the sensitivity of the receptor is considered low.

The area of deposition associated with sediments disturbed through construction activities reaches a maximum of 300 m from the site of disturbance (jetting) associated with the disturbance and movement of fine sediment (i.e. silt sediment fraction). All other activities will have a more limited extent. The area of seabed lost due to installation of hard substrate is 0.00817 km^2. Overall, these areas are highly localised in the context of wider muddy sand sediment within the CNS, therefore the magnitude of impact is low.

[2] Please refer to Table 7-8 for the worst-case scenario parameters.

[3] This area of anchor scour protection is separate to/does not include the footprint of the anchors themselves.

Evaluation of significance

Taking the low sensitivity of the seabed morphology and the low magnitude of the impact, the overall effect of alteration or loss of seabed morphology during construction is considered to be negligible and not significant in EIA terms.

SENSITIVITY	MAGNITUDE OF IMPACT	CONSEQUENCE
Low	Low	Negligible
Impact significance - NOT SIGNIFICANT		

7.9.1.2 Increase in suspended sediments

There are multiple mechanisms by which seabed disturbance during construction may lead to an increase in suspended sediments. This, in turn, can have implications for the local sediment transport regime and smothering of local benthos (considered in other topic chapters). While impacts are only likely to be minimal due to the scale of the Project, there is the potential for localised increases in suspended sediments associated with the following construction activities:

- Placement of catenary moorings, including their movement on the seabed;
- Anchor installation and presence; and
- Installation of export cable.

Seabed preparatory measures, such as seabed levelling are not expected to be extensively required as the geophysical survey did not identify any macroscale bedforms (e.g. sandwaves), instead any levelling would most likely be implemented through PLGR, with limited disturbance. Furthermore, the extent of disturbance and suspended sediment will be highly localised, and more limited in scale than the impact associated with trenching of the export cable. Consequently, seabed preparation activities have not been directly estimated as export cable trenching results in the greatest levels of disturbance and suspended sediments, which is quantified and assessed below.

The mooring line for the floating substructures would periodically come in contact with the seabed with the rise and fall of the tide. It is anticipated that during the periods when the mooring may be touching down or lifting off the seabed, there is likely to be some seabed disturbance and a very localised and short-term increase in suspended sediment of any finer particles present (i.e. silts). The substructure will be held in place by catenary mooring lines with a maximum length of 600 m each and by taut / semi-taut mooring lines with a maximum length of 610 m each. As detailed in Table 7-8, the maximum length of each catenary mooring that could come in contact with the seabed is 490 m per line, and for the taut / semi-taut moorings is 110 m per line. In total, the six mooring lines are expected to move over an approximate sweep area of approximately 0.018 km^2. The degree of disturbance and increase in suspended sediment will be variable in relation to the speed of touch down or lift off (associated with the change in water level from high to low water and vice versa) along with the flow speed.

For any disturbance that occurs, it would be gradual and transient along the mooring, being localised to the mooring line spatially and within a few metres of the seabed vertically. The coarser fraction within the disturbed sediment would quickly be redeposited back on the to seabed, whilst the silt fraction may be advected away by the near-bed flow. The sediments across the Project Area are generally finer (Section 7.5.3.3) so will take longer to disperse.

However, finer sediments have a tendency to flocculate when present in large volumes, leading to increased and quicker sedimentation. Overall, any disturbance would remain close to the seabed and is not expected to alter water column sediment concentrations above background levels.

Installation of the anchors will involve a drag length of approximately 50 m per anchor to ensure each anchor has been securely installed into the seabed. This will result in an area of 0.00336 km^2 being disturbed for all six anchors. Although it is not possible to exactly quantify the increase in suspended sediment, it is anticipated that the scale of sediment disturbance associated with the mooring lines and anchor installation would be minimal. The greatest disturbance is associated with trenching of the export cable. Consequently, suspended sediments will be highest associated with this activity.

As discussed in Section 7.9.1.1, trenching will likely be undertaken by jetting, which aims to keep the bulk of the of sediment within the trench. Assuming this method of installation, analysis of suspended sediments was undertaken using the following parameters:

- Grain sizes of 150 µm and 50 µm, representative median values of fine sand and coarse silts respectively (characteristic to the Project Area; Section 7.5.3.3);
- Water levels and spring and neap flow speeds as presented in Section 7.5.4.2;
- Assumed settling velocity associated with representative grain sizes of 150 µm and 50 µm; and
- Assumed release of sediments near-bed (at 1 m above the seabed).

Under typical flow speeds, in the immediate wake of trenching, the maximum instantaneous concentration of suspended sediments will be on the order of millions of milligrams per litre based on the entire sediment fraction. However coarser material on the order of medium sand and larger would settle out very quickly on the order of seconds to minutes and only being moved metres. Associated with the quick sedimentation, would be the fast reduction of instantaneous concentrations by orders of magnitude to hundreds of milligrams per litre. Fine sands will then settle out of suspension on the order of minutes after the activity has occurred. These sediments will be deposited in the range of tens of metres from the site of trenching activity. The thickness of the deposits will be very thin (as discussed above in Section 7.9.1.1). Coarse silts will settle out of suspension in the region of a few hours after the disturbance activity has ceased. These silts may travel in the range of kilometres from the source of disturbance, albeit at low concentrations that would be mainly at the seabed and within the background levels characteristic to the Project Area (see Section7.5.3.7).

Under faster flow speeds, the duration for settlement of sediments is not affected. However, the distance of settlement is increased under faster flows, although the distance travelled by fine sediments is still within the range of kilometres from the site of disturbance. The direction of travel will be dependent on ebb/flow conditions. The tidal ellipse characteristic of the Project Area is less than 5 km. Therefore, the extent of sediment deposition would be constrained to this distance. However, the above analysis determined that sediments will be comfortably deposited within a tidal cycle.

Given silts make up a significant component of sediments across the Project Area, it can be assumed that sediments will disperse within kilometres of the site of trenching. As described in Section 7.5.3.3, the sediments across the whole Project Area and wider region are relatively consistent. Therefore, sedimentation will occur in areas of similar seabed substrate, which is considered in full in Section 7.9.1.1.

Overall, suspended sediment concentrations associated with all other construction activities will be less than those caused by trenching (jetting). Dispersal and deposition of these suspended sediments will occur relatively rapidly, within a tidal cycle, and within a matter of kilometres from the site of disturbance. Consequently, the magnitude of impact will be low.

The increase in suspended sediments has the potential to increase localised deposition. However, the seabed sediments are consistent across the Project Area, therefore the seabed does not stand to be affected by increased suspended sediments. Therefore, the potential for the increase in suspended sediments has been assessed to be of low sensitivity.

Evaluation of significance

Taking the low sensitivity of the seabed morphology and the low magnitude of the impact, the overall effect of increased suspended sediments during construction is considered to be negligible and not significant in EIA terms.

SENSITIVITY	MAGNITUDE OF IMPACT	CONSEQUENCE
Low	Low	Negligible
Impact significance - NOT SIGNIFICANT		

7.9.2 Potential Effects During Operation and Maintenance

7.9.2.1 Introduction of Scour and Secondary Scour

Based on the embedded mitigation detailed for the Project (Table 7-11) including the burial of the export cable and installation of external cable and crossing protection and anchor scour protection where necessary at the construction stage, negates the development of scour in the first place, it was proposed to scope out this potential impact in the Scoping Report (TotalEnergies, 2023). However, following comments received from stakeholders (in particular NatureScot) and within the Scoping Opinion (MD-LOT, 2023), this impact has been taken forward into the impact assessment as introduced in Table 7-2. In particular, investigation of the potential for formation of secondary (edge) scour as a result of the applied protection was requested and is completed in this section.

Turbulent wakes formed by floating structures would tend to remain in surface waters without any capacity to influence the seabed, noting total water depths are at least 87 m across Project Area based on site specific geophysical surveys (Appendix J). However, a similar wake effect can also occur on the seabed – in this instance around the anchors, but only in the absence of scour protection. Embedded mitigation for the Project (Table 7-11 in Section 7.8) aims to prevent formation of scour through installation of scour protection around the anchors. The requirement for scour protection will be informed by scour assessment studies and the selected anchor solution, which will be undertaken as part of Front-End Engineering Design (FEED) and detailed design. On the assumption that some level of protection may be required, this has been captured in the worst-case scenario for assessment in Table 7-8, with up to 70 m^2 of protection being included in the Project design.

The use of external protection along the export cable and at the anchors where necessary at the construction stage, mitigates against the development of scour in the first instance. However, the use of these protection materials presents the potential for secondary (edge) scour as a result of the applied protection. The introduction of scour, and secondary scour is addressed in the remainder of the section. Therefore, the following analyses are only in relation to secondary (edge) scour.

Analyses undertaken to quantify the potential for edge scour formation around the cable protection and anchor scour protection is based on empirical formulae as presented in Petersen (2014) and Petersen *et al*. (2015a; 2015b). In the above studies, the edge scour properties primarily relate to the rock size applied, which normalises the scour depth. Key assumptions applied during the analysis are as follows:

- A mean seabed sediment grain size of 135 µm, representative of fine sand characteristic to the Project Area (Section 7.5.3.3) and as applied in the estimation of the sediment transport potential (Section7.5.3.7);
- At the time of writing, the size of rock to be used as protection is not available, so a nominal grain size of 67 mm is applied (this is representative of boulder sized rock);
- Water levels and spring and neap flow speeds as presented in Section 7.5.3.5 and as applied in Section7.5.4.4;
- Water depth of 90 m LAT; and
- Independent variable coefficients taken from Petersen (2014) and a friction factor of 0.5 based on a median value between 0 and 1.

Based on the applied water depths, the assumed rock size and the representative spring and neap flow speeds that occur across the Project Area, there is no development of edge scour under any conditions. Even under current speeds which would be considered extreme within the Project Area (1 m/s), scour formation was negligible, on the scale of millimetres. This would be indiscernible from natural variation in the area.

Overall, the potential for edge scour is considered unlikely with respect to the representative environmental conditions characteristic to the Project Area. Owing to the low potential of scour formation, the sensitivity of the receptor is considered to be low. In addition, owing to the virtually undetectable scale of which scour formation, the magnitude of impact is considered negligible.

Evaluation of significance

Taking the low sensitivity of the seabed and the negligible magnitude of the impact, the overall effect of scour formation during construction is considered to be negligible and not significant in EIA terms.

SENSITIVITY	MAGNITUDE OF IMPACT	CONSEQUENCE
Low	Negligible	Negligible

Impact significance - NOT SIGNIFICANT

7.9.3 Potential Effects During Decommissioning

The targeted scenario for decommissioning is a clear seabed. It should be noted that the decommissioning options for the export cable removal will be subject to comparative assessment of options at the end of the installation life. This will involve assessing the potential removal of artificial hard structures associated with the Project.

A Decommissioning Programme will be developed pre-construction to address the principal decommissioning measures for the Project and will be written in accordance with applicable guidance. The Decommissioning Programme will detail the environmental management, and schedule for decommissioning and will be reviewed and updated throughout the lifetime of the offshore Project to account for changing best practices.

Given the nature of the decommissioning activities, which will largely be a reversal of the installation process, the impacts during decommissioning are expected to be similar to or less than those assessed for the construction stage. Therefore, the magnitude of impacts assigned to Marine Physical Processes receptors during the construction stage are also applicable to the decommissioning stage. It is also assumed that the receptor sensitivities will not materially change over the lifetime of the Project. Therefore, the decommissioning effects are not expected to exceed those assessed for construction.

7.9.4 Summary of Potential Effects

A summary of the outcomes of the assessment of potential effects from the construction, operation and maintenance and decommissioning of the Project is provided in Table 7-14.

No significant effects on Marine Physical Processes receptors were identified. Therefore, no further mitigation measures are required beyond the Project embedded mitigation measures already listed in Table 7-11 (Section 7.8).

Table 7-14 Summary of potential effects

POTENTIAL EFFECT	RECEPTOR	SENSITIVITY OF RECEPTOR	MAGNITUDE OF IMPACT	CONSEQUENCE (SIGNIFICANCE OF EFFECT)	SECONDARY MITIGATION REQUIREMENTS	RESIDUAL CONSEQUENCE (SIGNIFICANT OF EFFECT)
Construction and Decommissioning						
Increase in suspended sediment	Seabed levels, sediment properties and suspended sediment concentrations	Low	Low	Negligible (not significant)	None required above existing embedded mitigation measures.	Negligible (not significant)
Loss or alteration of seabed morphology (bathymetry and sediment type)	Offshore morphology	Low	Low	Negligible (not significant)	None required above existing embedded mitigation measures.	Negligible (not significant)
Operation and Maintenance						
Scour and secondary scour	Seabed sediment and offshore morphology	Low	Negligible	Negligible (not significant)	None required above existing embedded mitigation measures.	Negligible (not significant)

7.10 Proposed Monitoring

With consideration of the embedded mitigation measures for the Project, the assessment has concluded no significant impacts to Marine Physical Processes, and therefore no further monitoring is proposed beyond the Project embedded mitigation measures already listed in Table 7-11 (Section 7.8). TEPSNUK will conduct post-installation surveys using a Remotely Operated Vehicle (ROV) to monitor the seabed throughout the Project lifecycle.

This chapter has used the best available evidence to inform the assessment of potential effects on Marine Physical Processes receptors. The Project will implement a scientific Research and Development (R&D) Programme in conjunction with the Technical University of Denmark (DTU) and the Marine Alliance for Science and Technology for Scotland (MASTS). This Programme will provide knowledge and experience on offshore wind turbine construction, integration, installation, operations and maintenance. In line with NatureScot (2022) Guidance on securing positive effects for biodiversity from local development, this project will also provide vital information to inform Nature Inclusive Design (NID) and the impacts on the biodiversity around WTGs and cable routes.

The Programme provides an opportunity for real-time environmental monitoring in the offshore environment and will provide a basis from which to assess the functionality of the floating WTG and the overall design of the project in the environmental setting of the CNS, which will inform similar developments in the future.

7.11 Cumulative Effects Assessment

Any potential impacts from the offshore Project could interact with impacts from other developments, plans and activities, resulting in a cumulative effect on Marine Physical Processes receptors. The general approach to the cumulative effects' assessment is described in Chapter 6: EIA Methodology and further detail is provided below.

The Marine Physical Processes Zone of Influence (ZoI) has been defined by a 10 km buffer around the Project. The ZoI is double the Study Area extent to capture any potential buffer of impacts from other surrounding developments.

The closest offshore development to the Project will be the Central North Sea Electrification (CNSE) Project, located approximately 11 km from the proposed operations. Any potential impacts of the Project would be highly localised and temporary, occurring within the tidal excursion distance used to define the Study Area; therefore, the tidal excursion ellipses associated with the Project location, would not overlap with that from other projects. Therefore, there is no pathway for effects to occur and no potential cumulative effects.

7.12 Inter-Related Effects

Inter-relationships are defined as the interaction between the impacts assessed within different topic assessment chapters on a receptor. The other chapters and impacts related to the assessment of potential effects on Marine Physical Processes are provided in Table 7-15.

Table 7-15 Marine Physical Processes inter-relationships

CHAPTER	IMPACT	DESCRIPTION
Chapter 8: Benthic Ecology	Impacts of suspended sediments and deposition on benthic species and habitats	Impacts on benthos could directly and indirectly impact sessile infauna. This is assessed within the Benthic Ecology chapter.
Chapter 9: Fish and Shellfish Ecology	Impacts on fish and shellfish species and biodiversity.	Impacts on fish and shellfish could impact biodiversity via the direct impacts on demersal and benthic spawning species. This is assessed within the Fish and Shellfish Ecology
Chapter 12: Commercial fisheries	Impacts on commercially important fish and shellfish species.	Impacts on fish and shellfish could indirectly impact fisheries. By the direct impacts on demersal and benthic spawning species. This is assessed within the Commercial Fisheries chapter.
Chapter 15: Marine Archaeology	Impacts of suspended sediments and deposition on archaeological sites of interest	The impact pathway of suspended sediment and deposition is characterised within the marine archaeology chapter.

Inter-related effects (e.g., multiple aspects which may affect the same receptor) have been considered through the impacts in Section 7.9. For instance, loss or alteration of seabed morphology and increased suspended sediments are all addressed in Section 7.9.1; ultimately these aspects all affect various features of the seabed. Therefore, the combined effect has already been considered.

7.13 Summary of Impacts and Mitigation Measures

No secondary mitigation, over and above the embedded mitigation measures proposed in Table 7-11 (Section 7.8) is either required or proposed in relation to the potential effects of the Project on Marine Physical Processes as no significant impacts are predicted.

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