Sheringham Shoal and Dudgeon Offshore Wind Farm Extension Projects

Environmental Statement

Volume 1

Chapter 6 - Marine Geology, Oceanography and Physical Processes

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Glossary of Acronyms

3D	Three Dimensional
AWAC	Acoustic Wave and Current Meter
CD	Chart Datum
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CIA	Cumulative Impact Assessment
CPA	Coast Protection Act
CSCB	Cromer Shoal Chalk Beds
CSIMP	Cable Specification, Installation and Monitoring Plan
DCO	Development Consent Order
DECC	Department of Energy and Climate Change
DEP	Dudgeon Extension Project
DML	Deemed Marine Licence
DOW	Dudgeon Offshore Wind Farm
EEA	European Economic Area
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EIFCA	Eastern Inshore Fisheries and Conservation Authorities
EPP	Evidence Plan Process
ES	Environmental Statement
ETG	Expert Topic Group
FEPA	Food and Environmental Protection Act
GBS	Gravity Base Structure
HAT	Highest Astronomical Tide
HDD	Horizontal Directional Drilling
IFCA	Inshore Fisheries and Conservation Authorities
IPCC	Intergovernmental Panel on Climate Change
IPMP	In-principle monitoring plan
km	Kilometre
km^2	Kilometre Squared
LAT	Lowest Astronomical Tide
m	Metre
m^2	Metre Squared
m^3	Metre Cubed
m/s	Metres Per Second
MCZ	Marine Conservation Zone
mg/l	Milligrams Per Litre

MHWS	Mean High Water Spring
MLWS	Mean Low Water Spring
mm	Millimetre
MMO	Marine Management Organisation
MPS	Marine Policy Statement
MW	Megawatt
NPS	National Policy Statement
NSIP	Nationally Significant Infrastructure Project
OSP	Offshore Substation Platform
OWF	Offshore Wind Farm
PEIR	Preliminary Environmental Information Report
PINS	Planning Inspectorate
PSA	Particle Size Analysis
RCP	Representative Concentration Pathways
s	Second (unit of time)
SMP	Shoreline Management Plan
SAC	Special Area of Conservation
SEP	Sheringham Shoal Extension Project
SOW	Sheringham Shoal Offshore Wind Farm
SPA	Special Protection Area
S-P-R	Source-Pathway-Receptor conceptual model
SSC	Suspended Sediment Concentration
SSSI	Site of Special Scientific Interest
UKCP18	United Kingdom Climate Projections 2018
UKHO	UK Hydrographic Office

Glossary of Terms

Amphidromic point	The centre of an amphidromic system; a nodal point around which a standing-wave crest rotates once each tidal period
The Applicant	Equinor New Energy Limited
Astronomical tide	The predicted tide levels and character that would result from the gravitational effects of the earth, sun and moon without any atmospheric influences
Bathymetry	Topography of the sea bed
Beach	A deposit of non-cohesive sediment (e.g. sand, gravel) situated on the interface between dry land and the sea (or other large expanse of water) and actively 'worked' by present-day hydrodynamic processes (i.e. waves, tides and currents) and sometimes by winds
Bedforms	Features on the sea bed (e.g. sand waves, ripples) resulting from the movement of sediment over it
Bedload	Sediment particles that travel near or on the bed
Clay	Fine-grained sediment with a typical particle size of less than 0.002mm
Climate change	A change in global or regional climate patterns. Within this chapter this usually relates to any long-term trend in mean sea level, wave height, wind speed etc, due to climate change
Closure depth	The depth that represents the 'seaward limit of significant depth change', but is not an absolute boundary across which there is no cross-shore sediment transport
Coastal processes	Collective term covering the action of natural forces on the shoreline and nearshore sea bed
Cohesive sediment	Sediment containing a significant proportion of clays, the electromagnetic properties of which causes the particles to bind together
Crest	Highest point on a bedform or wave
Current	Flow of water generated by a variety of forcing mechanisms (e.g. waves, tides, wind)
Dudgeon Offshore Wind Farm Extension Project (DEP)	The Dudgeon Offshore Wind Farm Extension onshore and offshore sites including all onshore and offshore infrastructure.
DEP offshore site	The Dudgeon Offshore Wind Farm Extension consisting of the DEP wind farm site, interlink cable corridors and offshore export cable corridor (up to mean high water springs).
DEP onshore site	The Dudgeon Offshore Wind Farm Extension onshore area consisting of the DEP onshore substation site, onshore

	cable corridor, construction compounds, temporary working areas and onshore landfall area.
DEP North array area	The wind farm site area of the DEP offshore site located to the north of the existing Dudgeon Offshore Wind Farm
DEP South array area	The wind farm site area of the DEP offshore site located to the south of the existing Dudgeon Offshore Wind Farm
DEP wind farm site	The offshore area of DEP within which wind turbines, infield cables and offshore substation platform/s will be located and the adjacent Offshore Temporary Works Area. This is also the collective term for the DEP North and South array areas.
Ebb tide	The falling tide, immediately following the period of high water and preceding the period of low water
Erosion	Wearing away of the land or sea bed by natural forces (e.g. wind, waves, currents, chemical weathering)
Evidence Plan Process	A voluntary consultation process with specialist stakeholders to agree the approach to the EIA and information to support the HRA
Export cables	Cables that transmit electricity from the offshore substation platform to the onshore project substation
Flood tide	The rising tide, immediately following the period of low water and preceding the period of high water
Glacial till	Poorly-sorted, non-stratified and unconsolidated sediment carried or deposited by a glacier
Gravel	Loose, rounded fragments of rock larger than sand but smaller than cobbles. Sediment larger than 2mm (as classified by the Wentworth scale used in sedimentology)
Habitat	The environment of an organism and the place where it is usually found
High water	Maximum level reached by the rising tide
Holocene	The last 10,000 years of earth history
Hydrodynamic	The process and science associated with the flow and motion in water produced by applied forces
Infield cables	Cables which link the wind turbine generators to the offshore substation platform(s).
Interlink cable corridor	This is the area which will contain the interlink cables between offshore substation platform/s and the adjacent Offshore Temporary Works Area.
Interlink cables	Cables linking two separate project areas. This can be cables linking: 1) DEP South array area and DEP North array area 2) DEP South array area and SEP

	3) DEP North array area and SEP 1 is relevant if DEP is constructed in isolation or first in a phased development. 2 and 3 are relevant where both SEP and DEP are built.
Intertidal	Area on a shore that lies between Lowest Astronomical Tide (LAT) and Highest Astronomical Tide (HAT)
Landfall	The point at the coast at which the offshore export cables are brought onshore, connecting to the onshore cables at the transition joint bay above mean high water
Long-term	Refers to a time period of decades to centuries
Low water	The minimum height reached by the falling tide
Mean sea level	The average level of the sea surface over a defined period (usually a year or longer), taking account of all tidal effects and surge events
Megaripples	Bedforms with a wavelength of 0.6 to 10.0m and a height of 0.1 to 1.0m. These features are smaller than sand waves but larger than ripples
Neap tide	A tide that occurs when the tide-generating forces of the sun and moon are acting at right angles to each other, so the tidal range is lower than average
Nearshore	The zone which extends from the swash zone to the position marking the start of the offshore zone (~20m)
Numerical modelling	Refers to the analysis of coastal processes using computational models
Offshore	Area seaward of nearshore in which the transport of sediment is not caused by wave activity
Offshore cable corridors	This is the area which will contain the offshore export cables or interlink cables, including the adjacent Offshore Temporary Works Area.
Offshore export cable corridor	This is the area which will contain the offshore export cables between offshore substation platform/s and landfall, including the adjacent Offshore Temporary Works Area.
Offshore export cables	The cables which would bring electricity from the offshore substation platform(s) to the landfall. 220 – 230kV.
Offshore substation platform	A fixed structure located within the wind farm area, containing electrical equipment to aggregate the power from the wind turbine generators and convert it into a more suitable form for export to shore.
Offshore Temporary Works Area	An Offshore Temporary Works Area within the offshore Order Limits in which vessels are permitted to carry out activities during construction, operation and decommissioning encompassing a 200m buffer around the

	wind farm sites and a 750m buffer around the offshore cable corridors. No permanent infrastructure would be installed within the Offshore Temporary Works Area.
Pleistocene	An epoch of the Quaternary Period (between about 2 million and 10,000 years ago) characterised by several glacial ages
Quaternary Period	The last 2 million years of earth history incorporating the Pleistocene ice ages and the post-glacial (Holocene) Period
Sand	Sediment particles, mainly of quartz with a diameter of between 0.063mm and 2mm. Sand is generally classified as fine, medium or coarse
Sand wave	Bedforms with wavelengths of 10 to 100m, with amplitudes of 1 to 10m
Scour protection	Protective materials to avoid sediment being eroded away from the base of the foundations as a result of the flow of water
Sea level	Generally, refers to 'still water level' (excluding wave influences) averaged over a period of time such that periodic changes in level (e.g. due to the tides) are averaged out
Sea-level rise	The general term given to the upward trend in mean sea level resulting from a combination of local or regional geological movements and global climate change
Sediment	Particulate matter derived from rock, minerals or bioclastic matter
Sediment transport	The movement of a mass of sediment by the forces of currents and waves
Sheringham Shoal Offshore Wind Farm Extension Project (SEP)	The Sheringham Shoal Offshore Wind Farm Extension onshore and offshore sites including all onshore and offshore infrastructure.
SEP offshore site	Sheringham Shoal Offshore Wind Farm Extension consisting of the SEP wind farm site and offshore export cable corridor (up to mean high water springs).
SEP onshore site	The Sheringham Shoal Wind Farm Extension onshore area consisting of the SEP onshore substation site, onshore cable corridor, construction compounds, temporary working areas and onshore landfall area.
SEP wind farm site	The offshore area of SEP within which wind turbines, infield cables and offshore substation platform/s will be located and the adjacent Offshore Temporary Works Area.
Shore platform	A platform of exposed rock or cohesive sediment exposed within the intertidal and subtidal zones
Short-term	Refers to a time period of months to years
Significant wave height	The average height of the highest of one third of the waves in a given sea state

Silt	Sediment particles with a grain size between 0.002mm and 0.063mm, i.e. coarser than clay but finer than sand
Spring tide	A tide that occurs when the tide-generating forces of the sun and moon are acting in the same directions, so the tidal range is higher than average
Storm surge	A rise in water level on the open coast due to the action of wind stress as well as atmospheric pressure on the sea surface
Study area	Area where potential impacts from the Project could occur, as defined for each individual EIA topic
Surge	Changes in water level as a result of meteorological forcing (wind, high or low barometric pressure) causing a difference between the recorded water level and the astronomical tide predicted using harmonic analysis
Suspended sediment	The sediment moving in suspension in a fluid kept up by the upward components of the turbulent currents or by the colloidal suspension
Swell waves	Wind-generated waves that have travelled out of their generating area. Swell characteristically exhibits a more regular and longer period and has flatter crests than waves within their fetch
Thalweg	A line connecting the lowest points of successive cross-sections along the course of a valley or river.
Tidal current	The alternating horizontal movement of water associated with the rise and fall of the tide
Tidal range	Difference in height between high and low water levels at a point
Tide	The periodic rise and fall of the water that results from the gravitational attraction of the moon and sun acting upon the rotating earth
Wave climate	Average condition of the waves at a given place over a period of years, as shown by height, period, direction etc.
Wave height	The vertical distance between the crest and the trough
Wavelength	The horizontal distance between consecutive wave crests (or alternatively troughs)

6 MARINE GEOLOGY, OCEANOGRAPHY AND PHYSICAL PROCESSES

6.1 Introduction

1. This chapter of the Environmental Statement (ES) describes the potential impacts of the proposed Sheringham Shoal Offshore Wind Farm Extension Project (SEP) and Dudgeon Offshore Wind Farm Extension Project (DEP) on marine geology, oceanography and physical processes. The chapter provides an overview of the existing environment for the proposed offshore sites, followed by an assessment of the potential impacts and associated mitigation for the construction, operation, and decommissioning phases of SEP and DEP.
2. This assessment has been undertaken with specific reference to the relevant legislation and guidance, of which the primary source are the National Policy Statements (NPS). Details of these and the methodology used for the Environmental Impact Assessment (EIA) and Cumulative Impact Assessment (CIA) are presented in **Chapter 5 EIA Methodology** and **Section 6.4**.
3. The assessment should be read in conjunction with following linked ES chapters and supporting documentation:
    - **Chapter 7 Marine Water and Sediment Quality**;
    - **Chapter 8 Benthic Ecology**;
    - **Chapter 9 Fish and Shellfish Ecology**;
    - **Chapter 12 Commercial Fisheries**;
    - **Chapter 14 Offshore Archaeology and Cultural Heritage**; and
    - **Stage 1 Cromer Shoal Chalk Beds (CSCB) Marine Conservation Zone (MCZ) Assessment** (document reference 5.6).
4. Additional information to support the marine geology, oceanography and physical processes assessment includes:
    - Interpretation of survey data specifically collected for SEP and DEP including bathymetry, geophysical (shallow geology) and environmental (sediment particle size) data;
    - The existing evidence base of the effects of offshore wind farm developments on the physical environment;
    - Numerical modelling and theoretical studies undertaken for Dudgeon Offshore Wind Farm (DOW) and Sheringham Shoal Offshore Wind Farm (SOW) and their associated Environmental Statement (ES) chapters;
    - Discussion and agreement with key stakeholders; and
    - Application of both conceptual evidence-based and numerical modelling (waves) assessments by Royal HaskoningDHV.

6.2 Consultation

5. Consultation with regard to marine geology, oceanography and physical processes has been undertaken in line with the general process described in **Chapter 5 EIA Methodology** and the **Consultation Report** (document reference 5.1). The key elements to date have included scoping, the ongoing Evidence Plan Process (EPP) via the Seabed Expert Topic Group (ETG) (meetings held in August 2019, June 2020, February 2021, August 2021 and March 2022, with attendees including Natural England, the Marine Management Organisation (MMO), Centre for Environment, Fisheries and Aquaculture Science (Cefas), The Wildlife Trusts (TWT), and Eastern Inshore Fisheries and Conservation Authority (EIFCA)), and the Preliminary Environmental Information Report (PEIR).

6. Further consultation regarding marine geology, oceanography and physical processes has been conducted through consultation on the **Dudgeon and Sheringham Shoal Offshore Wind Farm Extensions Physical Processes Method Statement** (**Appendix 6.1**) submitted to the ETG in April 2020 as part of the EPP. This document provided data requirements and a method for the assessment of potential effects on the baseline marine physical processes due to SEP and DEP. **Appendix 6.1** should be considered as a historic document that reflects a point in time in the design process and therefore has not been updated with the project design iterations undertaken during production of the ES. Members provided their feedback and agreed the Method Statement via an agreement log which has been provided as part of this Development Consent Order (DCO) application.

7. The feedback received throughout this process has been considered in preparing the ES. This chapter has been updated following consultation in order to produce the final assessment submitted within the DCO application. **Table 6-1** provides a summary of the consultation responses received to date relevant to this topic, and details of how the Project team has had regard to the comment and how these have been addressed within this chapter.

8. The consultation process is described further in **Chapter 5 EIA Methodology**, with full details presented in the **Consultation Report** (document reference 5.1), which has been submitted as part of the DCO application.

Table 6-1: Consultation Responses

Consultee	Date	Comment	Project Response
Scoping Responses			
Planning Inspectorate (PINS)	November 2019	The Inspectorate agrees that the potential for the presence of construction plant and offshore infrastructure to impact upon the hydrodynamic regime during the construction phase is unlikely to result in significant effects and can therefore be scoped out of the ES.	Assessment of construction impacts on hydrodynamics are scoped out of the EIA.
PINS	November 2019	The Scoping Report states that “Due to the localised nature of these effects, it is not anticipated that such changes would give rise to significant impacts on sea bed features”. The Inspectorate disagrees with this assertion, particularly in relation to the Cromer Shoal Beds Marine Conservation Zone (MCZ) as the geological features cannot reform once damaged. Natural England’s consultation response also demonstrates concern in this regard. The Inspectorate considers that the ES [PEIR] should include an assessment of likely significant effects to sea bed features resultant from the Proposed Development.	Consideration of the potential effects on the form and function of bedload sediment transport processes due to foundation and cable installation (particularly in the MCZ) is described in **Section 6.6.5.3, Section 6.6.5.5,** and **Section 6.6.5.6**. The assessment is completed using a conceptual evidence-based approach.
PINS	November 2019	The Scoping Report considers that hydrodynamic and sedimentary impacts would be restricted to near-field change. The Applicant has not provided references to studies to back up this claim, nor has it identified a study area for this aspect chapter within which it considers effects are likely (see below). Nevertheless, having regard to the location of the Proposed Development (a minimum of 100km from any international territory boundary), the nature of the likely potential hydrodynamic and sedimentary impacts, the Inspectorate considers that transboundary impacts associated with this matter are unlikely to result in significant effects and can therefore be scoped out of the ES.	Transboundary effects associated with hydrodynamic and sedimentary processes effects are scoped out of the EIA.
PINS	November 2019	The Scoping Report states “the coast is exposed and dynamic with rapid cliff erosion occurring in places”. The potential impacts of landfall work on coastal processes, including erosion and deposition, should be assessed with appropriate cross reference to other technical reports including landscape and visual impacts. The assessment should assess potential impacts associated with climate change during the Proposed Development’s operational life and any decommissioning period, as well as the relevant Shoreline Management Plan.	**Section 6.4** discusses the approach to coastal and landfall impacts. These impacts are addressed in the ES and cross reference is made, where appropriate, to other technical reports and the Shoreline Management Plan. The United Kingdom Climate Projections 2018 (UKCP18) climate change projections have been applied in the assessment at the coast.

Consultee	Date	Comment	Project Response
PINS	November 2019	The Scoping Report refers to the use of conceptual methods to assess impacts. No details are provided as to what conceptual methods would be utilised. The ES [PEIR] should provide details of all methods used along with any assumptions and limitations and an explanation of how these have been factored into the assessment.	Justification for using conceptual methods to predict effects is provided in **Section 6.6.3**. The assessment is based on a source-pathway-receptor (S-P-R) conceptual model, whereby the source is the initiator event, the pathway is the link between the source and the receptor impacted by the effect, and the receptor is the receiving entity. The use of numerical modelling for hydrodynamics and sediment dispersion is disproportionate to the potential effect that would occur. In these cases, the S-P-R conceptual model is proportionate. Following Section 42 consultation and feedback received from Natural England and the MMO through the EPP, numerical modelling of waves has now been completed for potential operational impacts due to the presence of the foundation structures (**Appendix 6.2**).
PINS	November 2019	The ES [PEIR] should assess any likely significant effects from changes in current and wave action resulting from introduced scour protection measures.	Several scour protection options are considered and detailed within the ES and the effects on hydrodynamics and waves considered.
PINS	November 2019	The Scoping Report refers to 'previous studies' however does not reference these. The ES [PEIR] should provide clear references to any studies used to inform the approach and support its conclusions.	Cross references to previous studies are included in this ES.
PINS	November 2019	A number of desk-based data sources relating to the existing Sheringham Shoal and Dudgeon offshore wind farms are proposed be used to inform the characterisation of the existing environment. The Inspectorate considers that these will provide useful baseline information, however their limitations in terms of age of data and spatial coverage should be acknowledged within the ES [PEIR]. The Applicant should make efforts to agree with relevant consultation bodies what is an appropriate level of information to inform the baseline characterisation.	A description of new surveys that have collected data including bathymetry, sea bed texture and near-bed geology across the wind farm sites and offshore cable corridors is provided in **Section 6.4.2**. Existing metocean data collected for the existing wind farms is considered appropriate as a baseline for the ES due to their proximity to the extensions and likelihood of consistency in metocean conditions across the area occupied by all the wind farms.

Consultee	Date	Comment	Project Response
PINS	November 2019	It is unclear how the existing suspended sediment concentrations within the application site will be determined based on the existing data sources available (which do not cover the spatial extent of the SEP/DEP) and the proposed baseline surveys (which are for multibeam bathymetry, side-scan sonar and sub-bottom profiling). The ES [PEIR] should clearly identify the data sources used to inform the suspended sediment baseline.	**Section 6.4.2** details how data sources used to inform the suspended sediment concentration baseline will be identified.
PINS	November 2019	The Inspectorate is unclear as to the relevance of the 'Guidance on Environmental Impact Assessment in Relation to Dredging Applications (Office of the Deputy Prime Minister, 2001)', as no dredging has been proposed within the Scoping Report. The Applicant should ensure that all guidance utilised to inform the assessment is relevant and its relationship to the assessment is clearly explained.	All guidance quoted is relevant to the assessment.
PINS	November 2019	The Inspectorate notes that irrespective of the chosen landfall, the offshore cable route would pass through Cromer Shoal Chalk Beds MCZ and the Greater Wash Special Protection Area (SPA). The ES [PEIR] should assess the likely significant effects of changes to hydrodynamic and sedimentary processes on these receptors.	**Section 6.6.5.1** and **6.6.5.2** outline potential impacts on the hydrodynamic and sedimentary processes with regard to the Cromer Shoal Chalk Beds MCZ. A separate study of the sedimentary processes operating in the MCZ has also been carried out (**Appendix 6.3**).
PINS	November 2019	The assessment should take into the effects of climate change. Information from UKCP18 on waves, winds, storm surge and sea level rise, should be incorporated into the future baseline.	The UKCP18 climate change projections are included in the future baseline for physical processes.
Historic England	November 2019	This section discusses the assessments of the marine geology, oceanography and physical processes. We would recommend that this section includes references to how changes to these factors could impact on the historic environment by exposing or covering heritage assets. For example, it is stated in Section 2.1.2.2 that there is the potential for the development to increase sea bed scour in areas, which could result in the exposure, degradation or loss of vulnerable assets. We note that the impact of changes to the hydrodynamic and sedimentary process regimes on the historic environment are discussed in Section 2.9.2, however we would recommend that heritage is also referenced within this section of the ES.	Part of the assessment covers changes to sedimentary processes which in themselves are not necessarily impacts to which significance can be ascribed. However, such changes may indirectly impact other receptors such as the historic environment and are referenced in the ES. The significance of impacts on historic environment are made in the historic environment chapter (**Chapter 14 Offshore Archaeology and Cultural Heritage**).

Consultee	Date	Comment	Project Response
MMO	November 2019	The applicant proposes that effects on the hydrodynamic regime should be scoped out (Chapter 2.1.2.1), despite noting that there is potential for the physical presence of construction plant and offshore infrastructure to have an impact on the hydrodynamic state. The MMO suggest that the applicant scope this in, as construction activities (such as any changes at the sea bed during cable installation) could have an impact on flow and wave propagation. After the second ETG meeting in June 2020, and following consultation with our advisers, the MMO can confirm that the impact on the hydrodynamic regime during construction can be scoped out, as the impact of the monopile(s) presence will be assessed in the operational phase of the project.	Assessment of the construction impacts on hydrodynamics are scoped out of the ES.
Natural England	November 2019	The Applicant is considering a proposed cable route through the Cromer Shoal MCZ, which is predominantly designated for subtidal chalk habitat. As stated there is often a veneer of gravelly sand laid on top of the bedrock. In the case of Cromer Shoal Chalk Beds MCZ, this bedrock is chalk. Cabling through chalk could result in losing the unique 3D structures it creates in certain places. Therefore, understanding where these veneers persist and are a suitable thickness for cabling in, would allow the applicant to have greater confidence that the features of the MCZ will not be damaged	Separate reports on sedimentary processes and geology along the export cable corridor in the MCZ covering this issue have been completed (Royal HaskoningDHV, 2020; Dove and Carter, 2021). These reports are appended to the ES as supporting documentation (**Appendix 6.3** and **Appendix 6.4,** respectively).
Natural England	November 2019	Natural England agrees that the greatest potential impacts from the array upon the hydrodynamic regime would be from the constructed windfarm during operation. Therefore, we are content it can be scoped out of further consideration in relation to the construction phase.	Assessment of construction impacts on hydrodynamics are scoped out of the ES.
Natural England	November 2019	Natural England disagrees that the wind farm extensions will not give rise to significant impacts on sea bed features. This is particularly relevant to the Cromer Shoal Chalk Beds MCZ and installing cables through it. The geological features that exist in this area are unique and cannot be reformed once damaged, unlike a mobile sediment dominated area. However, the effect on coastal morphology and sediment transport itself will probably be minimal.	A separate study of the sedimentary processes operating in the MCZ has also been carried out (**Appendix 6.3**).
Natural England	November 2019	There is currently no reference to specific impacts of suspended sediment concentrations from disposal of dredged material at specific disposal	Sea-bed levelling will be carried out for interlink cable installation (between SEP and the DEP North array area, between SEP and the DEP South array

Consultee	Date	Comment	Project Response
		grounds offshore. This needs to be considered further and scoped into the assessment.	area, and within the DEP North array area and DEP South array area). Any excavated sediment due to sand wave levelling (pre-sweeping) for the infield cables would be disposed of within the project sites (the trough would be filled in to create an even sea bed) and therefore there will be no net loss of sand from the site. This impact has been addressed in **Section 6.6.4.7**.
Natural England	November 2019	Will wake effects from the turbines be considered further in the assessment?	**Section 6.6.5.2** describes how wakes caused by localised flow accelerations around the foundations and wave shadow effects attributable to individual foundations are assessed in the ES.
Natural England	November 2019	Increased concentrations of suspended sediments and release of contaminants due to ongoing scour during operation should be scoped vin. This has been recognised by the scoping in of increased suspended sediment concentrations during operation in regard to Benthic and intertidal ecology.	Several scour protection options are considered and detailed within the ES and the effects on hydrodynamics and waves considered (**Section 6.6.5.1** and **Section 6.6.5.2**).
Weybourne Parish Council	November 2019	The Parish Council are keen that Equinor consider the impact of tidal surges in their Environmental Statement. Tidal surges change the nature and character of the coastline and are predicted to increase in frequency and severity.	Tidal surges and their predicted future changes due to climate change are included in the baseline (**Section 6.5.11**) and are assessed conceptually.
Method Statement			
Natural England	June 2020	Project Description - Wind Turbine Generator Foundations This is contradictory as the various documents provided include different foundation types.	When the method statement was drafted, Gravity Base Structure (GBS) foundations had been removed from the Rochdale envelope and were therefore not included. However, this decision has since been reviewed, with the decision to reinstate GBS foundations as an option because they may be necessary for larger turbines that are not currently available in the market, but may be by the time of construction. The method statement has been revised accordingly.

Consultee	Date	Comment	Project Response
Natural England	June 2020	Project Description - Wind Turbine Generator Foundations Natural England would expect volume and area of scour protection per turbine to be included in ES.	**Section 6.6.5.4** outlines the volume and area of scour protection per Wind Turbine Generator (WTG) foundation.
Natural England	June 2020	Operation and Maintenance Strategy It is not clear what the operation life span is, i.e. 25 or 30 years	The operational lifetime of SEP and DEP is assumed to be a minimum of 40 years.
Natural England	June 2020	Impact Assessment Methodology - Using the Previous Modelling Results to Support the Conceptual Approach Considering both Dudgeon and Sheringham Shoal Offshore Wind Farm (OWF) are now built, how will the potential impacts on hydrodynamics caused by these projects be taken into consideration given the modelling undertaken for these projects (i.e. before they were built) is suggested to be used?	The existing modelling and assessments are in close proximity to the extensions projects and were very conservative given the larger number of turbines modelled in the existing wind farms compared to the number of turbines in the extensions. Therefore, the hydrodynamic modelling results are still considered to be appropriate (presented in **Sections 6.6.5.1–6.6.5.2**). Following Section 42 consultation and feedback received from Natural England and the MMO through the EPP, numerical modelling of waves has now been completed for potential operational impacts due to the presence of the foundation structures (**Appendix 6.2**). **Section 6.6.3** provides further justification for use of the previous hydrodynamic modelling.
Natural England	June 2020	Potential Impacts - Impact on Sea Bed Features due to Cable Installation and during decommissioning Natural England welcomes consideration of remove of cable protection at the time of decommissioning and if removal could be achieved, then whilst the impacts would no longer be permanent, they would still last for the lifetime of the infrastructure (25 years) and potentially longer as a residual impact. Therefore, because this impact is lasting/long term and site recovery wouldn't be assured, Natural England's view is that reasonable scientific doubt would likely remain regarding the impact of the proposals on the conservation objectives for the site. Accordingly a precautionary approach is required. Please also be advised that if it is considered that certain types of cable protection could be modified to enable a greater	Noted.

Consultee	Date	Comment	Project Response
		success of recovery/removal at decommissioning, whilst reducing wider designated site impact, then we advise that this would need to be reflected in the DCO/DML to ensure this mitigation is secured.	
Natural England	June 2020	Potential Impacts - Indentations on the Sea Bed due to Installation Vessels Please note that several windfarms (including Norfolk Vanguard and Norfolk Boreas) have recently committed to not using jack-up barges for installation due to the impact that this method has on the seabed. Natural England would therefore recommend re-considering their use at an early stage for all projects.	It is understood that Norfolk Boreas and Norfolk Vanguard have made the commitment not to use jack-up vessels within a Special Area of Conservation (SAC) and will use alternative work vessels in the SAC during the construction and operation. This commitment only applies to the export cables, and only within the SAC. The Applicant has considered whether the use of jack-up vessels could be ruled out in the MCZ however there is a potential requirement for their use at the HDD exit point and therefore they remain within the envelope and assessment.
Natural England	June 2020	Potential impacts during O&M - Approach to assessment Please note that existing data should only be used to support site specific data sets.	Noted.
Natural England	June 2020	Potential impacts during O&M - Changes to Sediment Transport due to Cable Protection Measures For any proposed cable protection Natural England expects a reasonable estimate of the amount, area impacted and pressure exerted on any designated features within MPAs. Cable protection should be considered as a last resort.	This has been assessed in **Sections 6.6.5.6** and **6.6.5.7**.
MMO	July 2020	According to the information presented in the ETG presentation on the 02 June 2020, the MMO agree that the coarse lag is effectively static.	Noted.
MMO	July 2020	The MMO confirm that data from planned and past surveys should cover the geological description of the cable corridors adequately.	Noted (see **Section 6.4.2** for Data and Information Sources used to describe offshore geology).
MMO	July 2020	The MMO agree that the proposed baseline data collection is adequate in relation to geophysical survey.	Noted.

Consultee	Date	Comment	Project Response
MMO	July 2020	The existing models described refer to OWFs with approximately three times more turbines than the SEP/DEP (so that would cover the worst-case scenario) and the sites have similar characteristics. Furthermore, the expert assessment should identify potential impacts and propose any mitigation measures accordingly.	**Section 6.6.3** provides further justification for use of the previous hydrodynamic and sediment dispersion modelling. Following Section 42 consultation and feedback received from Natural England and the MMO through the EPP, numerical modelling of waves has now been completed for potential operational impacts due to the presence of the foundation structures (**Appendix 6.2**). **Sections 6.6.4** – **6.6.6** address potential impacts during the construction, operation and decommissioning phase of SEP and DEP.
MMO	July 2020	As discussed during the ETG, it was identified that the MMO held a conflicting scoping opinion in respect of scoping in or out assessment of impacts on the hydrodynamic regime during construction. Following consultation with our advisers, the MMO can confirm that the impact on the hydrodynamic regime during construction can be scoped out, as the impact of the monopile(s) presence will be assessed in the operational phase of the project.	Noted.
MMO	July 2020	The potential projects scoped in for the cumulative impact assessment appear to be appropriate. The MMO note that cumulative impacts have been considered in relation changes to Marine Geology, Oceanography and Physical Processes arising from the proposed project alone and those arising from the proposed project cumulatively or in combination with other offshore wind farm developments and other nearby sea bed activities, including marine aggregate extraction, marine disposal, proposed seaweed farm and construction of Oil and Gas platforms. The full list of ongoing plans or projects to be included in the Environmental Statement (ES) will be developed as part of on-going consultation with technical consultees. The MMO will be able to provide further comments once this is finalised.	Noted.
ETG Meetings			

Consultee	Date	Comment	Project Response
MMO/Cefas, Natural England and TWT	ETG1 Agreement Log October 2019	Agreement that the baseline should describe tidal currents, waves and bedload sediment and transport, and suspended sediment	This is provided in **Section 6.5**
MMO/Cefas, Natural England and TWT	ETG1 Agreement Log October 2019	Agreement on the adequacy of the export cable corridor geophysical survey results to describe seabed type, shallow geology, bathymetry and seabed features/anomalies	It is noted that the survey report was shared with ETG members and results summarised in **Appendix 6.3 Sedimentary Processes in the Cromer Shoal Chalk Beds MCZ** and within the ETG2 meeting presentation. The ETG agreed that the export cable corridor geophysical survey results are adequate, but needed to review the benthic survey results separately. It is noted that since this agreement, an offshore temporary works area (see **Figures 6.1** to **6.4**) has been incorporated within the SEP and DEP offshore sites which does not include geophysical coverage however the Applicant has committed to post consent coverage of the additional areas potentially required for temporary works. See **Chapter 4 Project Description** for further details.
MMO/Cefas, Natural England and TWT	ETG2 Agreement Log June 2020	Agreement of potential impacts to be assessed and those scoped out: As described in the Scoping Report and Scoping Opinion. To include assessment of effects on seabed features, including likely significant effects of changes to hydrodynamic and sedimentary processes on designated features of the Cromer Shoal Chalk Beds MCZ, Greater Wash SPA and any other designated sites within the zone of influence. Notes: The potential impacts screened into the assessment are as agreed through the Scoping Report and Scoping Opinion and that assessment of	**Section 6.6** includes an assessment of the potential impacts as agreed through the Scoping Report and Scoping Opinion. The Cromer Shoal Chalk Beds MCZ is included as a sensitive receptor. From a physical processes perspective there would be no potential for LSE on the designated features of the Greater Wash SPA given the small scale and

Consultee	Date	Comment	Project Response
		the following potential impacts should be undertaken: seabed features, including potential impacts of changes to hydrodynamic and sedimentary processes on designated features of the Cromer Shoal Chalk Beds MCZ, Greater Wash SPA and any other designated sites within the zone of influence.	localised nature of the impacts assessed within **Section 6.6**. Potential indirect impacts through effects on offshore ornithology habitats and prey species is provided in **Chapter 12 Offshore Ornithology**.
MMO/Cefas, Natural England and TWT	ETG2 Agreement Log June 2020	Agreement that the methods for identifying the worst-case scenarios are appropriate and that the worst-case scenarios presented in the Method Statement are comprehensive and identify the elements of the project that will form the worst-case scenarios for Marine Geology, Oceanography and Physical Processes. Notes: Natural England pointed out that several wind farms have recently committed to not using jack-up barges for installation due to the impact that this method has on the seabed. Natural England would therefore recommend re-considering their use at an early stage for all projects.	Regarding ruling out the use of jack-up vessels in the offshore cable corridor, the Applicant understands that this comment was made in relation to the export cable corridor only, and only within the MCZ. The Applicant has considered this and has made the decision to retain the use of jack-up vessels in the MCZ within the design envelope because they may be required during HDD activity.
MMO/Cefas, Natural England and TWT	ETG2 Agreement Log June 2020	Agreement that a combined approach of 1.) effects (where they are manifest as impacts on other receptors) and 2.) impacts (where they are defined as directly affecting receptors which possess their own intrinsic morphological value) is acceptable.	This approach has been used within the assessment.
Natural England, MMO/Cefas	ETG4 Agreement Log August 2021	Agreed that sandbanks are to be included as a separate receptor within MGOPP assessment. The list of MGOPP receptors is therefore agreed i.e: • Cromer Shoal Chalk Beds MCZ • Coastline • Sandbanks	Sand banks have been included as a separate receptor for the relevant potential impacts in **Section 6.6.**
MMO/Cefas and Natural England	ETG4 meeting minutes August 2021	MMO/Cefas asked if the Applicant would place scour before insertion of a pile or once pile is inserted and stated adding a layer of slate before the WTG foundation is inserted doesn't allow any scour to occur. Natural England stated it would be preferred if limestone was used as it is naturally present in the area unlike slate. However, Natural England	The specific type of scour protection material to be used will be decided post consent however it is anticipated that this would likely be granite. The Applicant can also confirm that if monopiles are selected as the foundation type, then a filter layer of

Consultee	Date	Comment	Project Response
		anticipates the Equinor engineers probably could not commit to limestone due to its tendency to winnow away.	scour protection will be placed prior to monopile insertion in order to prevent scour.
Section 42 Responses			
Eastern Inshore Fisheries Conservation Authority (EIFCA)	June 2021	Chapter 8 Marine Geology Oceanography and Physical Processes We note with concern the volumes stated on pages 30/31 "Impact 3: Changes in suspended sediment concentrations due to export cable installation" and question how widespread (spatially) the impact is likely to be and for how long might this impact be present, particularly in relation to commercial and recreational fisheries species of interest?	**Section 6.6.4.5** provides an assessment of the potential impact on suspended sediment concentrations. An assessment of the potential impacts of an increase in suspended sediment concentrations on fish and shellfish ecology receptors is provided in **Section 9.6.1.2** and **9.6.2.5** of **Chapter 9 Fish and Shellfish Ecology** which includes consideration of the key commercial species of interest (also see **Section 12.6.1.5** of **Chapter 12 Commercial Fisheries**). The assessment of how widespread the plume is likely to be was based on modelling of the DOW export cable which has similarities in water depth, sediment types and metocean conditions to the SEP/DEP export cable corridor. This makes the earlier modelling studies a suitable analogue for the present assessment (see **Section 6.6.3**). The increase in suspended sediment concentrations is expected to be local and short-term. The results indicate that mud-sized material (which represents only a very small proportion of the disturbed sediment) would be advected around 10km to the west and less to the east and persist in the water column for hours to days (within one tidal excursion), with concentrations dropping to less than 1mg/l within a single flood or ebb excursion. Also, although suspended sediment concentrations will be elevated, they are likely to be lower than concentrations that

Consultee	Date	Comment	Project Response
			would develop in the water column during storm conditions.
MMO	June 2021	5 Chapter 8. Marine Geology, Oceanography and Physical Processes Observation 5.1 Section 8.4.3 paragraph 33 - 35 clearly distinguishes clearly between direct receptors (e.g morphological features) and also where a change to marine geology, oceanography and physical processes may result in a knock-on effect to a non-physical receptor, which is good practice. 5.2 MMO note that SEP and DEP are being assessed through one DCO application, but flexibility has been retained within the design/Rochdale envelope for them to be developed either in an integrated manner or as separate projects. The joint application approach should facilitate consideration of interactions between the two new proposed projects, so inter-related/cumulative impacts between the two projects has been inherently considered throughout. MMO would support the integrated approach as it would reduce overall effects compared to constructing the projects separately, particularly if it can reduce the number of cables required to pass through the Marine Conservation Zone (MCZ). 5.3 Section 8.3.3 Table 8-4 summarises embedded mitigations in project design. Other mitigation measures are detailed in the impact assessment section 8.6.	Noted
MMO	June 2021	5.4 Preference for removable scour protection in the MCZ is noted. Whilst MMO agree it is preferable to use methods which facilitate/allow removal at decommissioning stage, the potential for degradation of components which would be used for lifting/removal over the project lifetime should be accounted for in decision-making on this matter.	The **Outline CSCB MCZ Cable Specification, Installation and Monitoring Plan (CSIMP)** (document reference 9.7) provides further information on the potential cable protection requirements and material to be installed within the MCZ.
MMO	June 2021	5.5 The MMO would like to highlight that if gravity-based structures are selected, there is an option for locally derived sediment (dredged during seabed preparation activities) to be used as ballast. If this option were selected, the impact assessment would need to be updated to consider whether the removal of this sediment would have any impact on sediment transport processes and subtidal geomorphological features, such as	The potential use of locally derived sediment as ballast within GBS foundations has been removed from the project envelope.

Consultee	Date	Comment	Project Response
		Sheringham Shoal sand bank and the Cromer Knolls. Changes to such features may alter hydrodynamics and therefore alter the energy regime and the coastline.	
MMO	June 2021	Changes Required: 5.6 The use of scour protection is proposed in all areas where scour would be predicted to occur, therefore potential impacts from any sediment that would be mobilised due to erosion occurring during scour development is not assessed. The impacts of using scour protection (relating to a greater footprint of hard substrate being introduced, which may lead to habitat change/loss) should be compared to the impacts of simply designing foundations which can accommodate scour development. The resulting effects of scour (lowering of the seabed, winnowing/coarsening of sediment, plus release of sediment into the wider environment after installation) may have a lesser impact than compared to the introduction of hard substrate into the environment (particularly given that rock scour and/or cable protection is difficult to decommission).	Secondary scour effects associated with scour protection would be confined to within a few meters of the direct footprint of that scour protection material, and so the potential impact would be minimal. The loss of habitat due to the direct footprint of the scour protection is considered to be worse than the effects of scour without scour protection (or secondary scour). Hence, a scenario with no scour protection is not assessed.
MMO	June 2021	5.7 The MMO were unable to find an assessment of potential scour depths, as scour protection (as noted above in paragraph 5.6 is proposed for all areas where scour may occur. Secondary scour around the edge of scour and cable protection should be assessed and accounted for in habitat change assessments in other topic chapters as it is likely to increase the overall footprint/area of effect. 5.8 With further regard to secondary scour the MMO consider further evidence should be collected from field data/monitoring evidence from other wind farms if available, although we acknowledge that empirical assessment methodologies are less established for edge/secondary scour than they are for primary scour where no scour protection is applied. Currently, the assertion that "It is likely that any secondary scour effects associated scour protection would be confined to within a few meters of the direct footprint of that scour protection material" is not well supported by evidence or predictive assessment, and it is not clear whether its footprint is factored into project footprint estimates. Further information should be provided to support this.	Direct impact from scour protection is assessed as a worst-case. Secondary scour effects are not factored into the worst-case scenarios for footprints. Footprints for secondary scour are difficult to quantify and not directly comparable in terms of impact pathways to the use of scour protection. Therefore, it is not proposed to include a footprint of secondary scour within the ES assessments. The Applicant has reviewed the SOW and DOW post construction monitoring reports however no information on secondary scour is presented within those. The **Offshore In-Principle Monitoring Plan (IPMP)** (document reference 9.5) includes provision for monitoring of secondary scour around scour protection which would be undertaken as part general engineering and design monitoring procedures.

Consultee	Date	Comment	Project Response
MMO	June 2021	5.9 The MMO suggest that it would be beneficial if the baseline sections of Chapter 8 include a location map showing the features discussed in the text compared to the proposed development e.g. Weybourne channels, Bolney Cut, nearby and regional sand banks, other projects, etc.	Four new plates (**Plate 6.1** to **Plate 6.4**) have been added to show the depths to the base of the two uppermost units across the proposed development (Botney Cut and Bolders Bank Formations) and the position of the Weybourne Channel Deposits along the export cable corridor. The deeper geological units have less relevance. A figure showing other projects included as part of the cumulative impact assessment screening has been provided (**Figure 6.14**). All sand banks within the DEP wind farm site (there are none in the SEP wind farm site) and along the offshore cable corridors are mapped bathymetrically (see **Figures 6.1 to 6.4**). However as noted above, an offshore temporary works area has been incorporated within the SEP and DEP offshore sites which does not include geophysical coverage. The Applicant has committed to post consent coverage of the additional areas potentially required for temporary works. See **Chapter 4 Project Description** for further details.
MMO	June 2021	5.10 The MMO consider a precautionary approach to be appropriate given uncertainties around the effects of sand wave levelling on sand bank evolution. The MMO would expect to see greater detail on the extent of areas where sand wave levelling is proposed in relation to these features within the ES. This should be encompassed in determining the magnitude of the effect in Table 8.23 and impact significance in 8.6.4.8.3. Depending on the outcome of this further assessment the contents of Section 8.11 on monitoring proposed may need to be changed.	A precautionary approach to the effects of sand wave levelling (pre-sweeping) has already been adopted for cable (infield and interlink) installation. The worst-case scenario sand wave levelling volumes are presented in **Table 6-2** for each of the different scenarios and **Figure 4.9 in Chapter 4 Project Description** shows the potential locations of sand wave levelling. Cross-references to this figure are now included throughout this chapter.

Consultee	Date	Comment	Project Response
			These worst-case parameters and the existing evidence base on sand wave recovery are encompassed in defining the magnitude of effect in **Section 6.6.4.8.3**. Monitoring of sand wave recovery following their clearance is included in the **Offshore IPMP** (document reference 9.5) and see **Section 6.11**.
MMO	June 2021	5.11 The MMO do not agree with the statement made in Section 8.5.8.1 paragraph 131 that no significant difference was found in sediment composition between the Sheringham Shoal Offshore Wind Farm (SOW) export cable trenches and the control areas adjacent to the trenches. The MMO do not consider that such a strong conclusion can be drawn based on photographic data in the absence of particle size analysis. The MMO suggest this is reworded in the ES to state that results indicated no difference but acknowledge that further evidence would be needed to confirm. If subsequent assessments rely on this assertion, further evidence would be required.	The statement in (the original) Paragraph 131 (now Paragraph) has been reworded.
MMO	June 2021	5.12 Section 8.6.4.8.1 paragraph 255 states: “The dynamic nature of the sandwaves in this area means that any direct changes to the sea bed associated with sand wave levelling are likely to recover over a short period of time due to natural sand transport pathways.” The MMO request further evidence to be presented to confirm that this is the case at this site. The MMO suggest greater discussion including an assessment (see paragraph 5.10 above) of the areas where sandwave levelling will occur and their vicinity to local sand banks and morphological features is needed to provide reassurance there will be no long-term morphological effects due to sand wave levelling.	A new Construction Impact 7 (new **Section 6.6.4.9**) has been added to the chapter, which assesses the potential interruptions to bedload sediment transport due to sand wave levelling for offshore cable installation (infield and interlink cables). Evidence has been presented from pre- and post-construction monitoring at Race Bank and a sand wave study carried out for the Norfolk Projects. The areas where sand wave levelling could potentially occur are shown on **Figure 4.9 in Chapter 4 Project Description** to which cross-references are now included in this chapter. A more detailed discussion of these sand waves and their relationship to local sand banks has been added to the baseline environment (**Section 6.5.1**).

Consultee	Date	Comment	Project Response
MMO	June 2021	5.13 Further to the above comment (5.12) The PEIR should consider whether there might be impacts on nearby subtidal geomorphological features, e.g. Cromer Knoll, Sheringham Shoal sand bank. Changes to these features may influence the East Anglian Coast and/or MCZ, and therefore they should be considered as a subsection of impact assessment on these receptors, although it could also be appropriate to address them separately as their own receptor group. Any assessments need to consider the potential for direct impacts to sand banks caused by the various impacts identified to lead to indirect effects on receptors. For example, impact 6 “change in sea bed level due to offshore cable installation (infield and interlink cables)” needs to include consideration of whether nearby sand banks and morphological features could be affected by sand wave levelling activities. The MMO consider this is necessary because there is a possibility for sand bank changes to affect wave energy propagation across the site and therefore affect the wave energy at the receptors (similar to wave regime effects resulting from the presence of structures as considered in section 8.6.5.2).	A new Construction Impact 7 (new **Section 6.6.4.9**) has been added to the chapter, which assesses whether sand bank functionality is affected by sand wave levelling activities.
MMO	June 2021	5.14 The MMO note that studies on sedimentary processes and geology in the MCZ have been undertaken, although the British Geographical Survey (BGS) study is not included as an appendix to the PEIR, its title indicates it is an interim report. The MMO would welcome sight of the final report during the DCO application process at an appropriate stage.	The final BGS report is now included as **Appendix 6.4**.
MMO	June 2021	5.15 The MMO recommends that it may be beneficial if the Applicant reviews information and assessments for other projects making landfall through the MCZ e.g. Hornsea 3, as an additional source of information.	Noted
MMO	June 2021	5.16 Section 8.4.4 states that for marine geology, oceanography and physical processes, activities considered to have potential cumulative effects include construction of other OWFs and large coastal defence and protection works. While It may be that there are no other project types in the potential zone of influence, the MMO seek further reassurance that other activities which have potential to impact these receptors or processes have also been considered when screening for projects, e.g. marine aggregate extraction, telecommunications/interconnector cables.	Blythe Hub, Viking Link and AGG3 are now included in the list of projects/activities that could potentially have a cumulative impact with SEP and DEP. The potential for cumulative impacts has been assessed through the CIA screening process.

Consultee	Date	Comment	Project Response
MMO	June 2021	5.17 Section 8.7.1 states that no cumulative impact assessment is required in relation to marine geology, oceanography and physical processes. At present the MMO do not consider that enough information has been presented regarding the decision-making behind the contents of the "potential for cumulative impact" and "data confidence" columns in Table 8.35, nor that sufficient information regarding the nature of other projects is available in the Chapter to agree with this, and request that further detail and justification is provided.	Further justification to show how project screening for CIA was undertaken is now provided in the **Section 6.7**.
MMO	June 2021	5.18 The MMO query the Applicant's assertion that "Only potential impacts assessed in Section 8.6 as negligible adverse or above are included in the CIA (i.e. those assessed as 'no impact' are not taken forward as there is no potential for them to contribute to a cumulative impact)." Since effects determined to be insignificant individually can interact with other effects and lead to significant effects. The MMO suggest individual impact magnitude is a better metric on which to screen effects from further consideration.	By definition, no impact means that there will be no change to a parameter due to SEP and DEP. Hence, cumulatively, the only impact to that parameter would be from the other project or activity. Hence, there would be no cumulative impact in relation to SEP and DEP. This is standard practice within cumulative impact assessment.
MMO	June 2021	5.19 The modelling undertaken for SOW and DOW did not have existing nearby wind farms as part of its baseline. The MMO consider further justification is given to provide assurance that modelling undertaken for individual SOW/DOW wind farms encompasses a conservative enough design envelope to account for the four wind farms which will potentially co-exist (DOW, SOW, SEP and DEP) in the area, and where this is uncertain, consider additional specific modelling or consider applying a more conservative approach when drawing conclusions regarding impact significance. As an example, this would apply to operational impact 1, 2 & 3 as identified in Section 8.6.5 of this Chapter.	The justification for using the SOW/DOW theoretical work has been updated to include more detail of its use as an analogy for the wind farms co-existing (see **Section 6.6.3**). Numerical modelling of waves has now been completed for potential operational impacts due to the presence of the foundation structures. The modelling includes assessment of all four wind farms cumulatively (**Appendix 6.2**).
MMO	June 2021	5.20 The MMO would like to see further clarification to confirm that no modelling is needed. MMO note that the Hornsea 2 DCO application undertook a modelling study to determine effects on the wave climate at the shoreline, which has not been employed here, although the MMO acknowledge the wind farm is closer to shore. Please see 5.21 below for further points on this matter.	Numerical modelling of waves has now been completed for potential operational impacts due to the presence of the foundation structures. The modelling includes assessment of all four wind farms cumulatively (**Appendix 6.2**).

Consultee	Date	Comment	Project Response
MMO	June 2021	5.21 It is stated that no monitoring is proposed for physical processes, oceanography and seabed geology: this should be considered as further assessment is completed and based on the MMO's comments above and advice during examination.	Monitoring of sand wave recovery following their clearance is now included in the **Offshore IPMP** (document reference 9.5) and see **Section 6.11**.
North Norfolk Coast District Council	June 2021	Chapter 8 - Marine Geology, Oceanography and Physical Processes NNDC would defer to the advice of Natural England, Marine Management Organisation, Centre for Environment, Fisheries and Aquaculture Science (CEFAS) and other experts in respect of matters within this Chapter of the PEIR.	Noted.
Natural England	June 2021	Summary of Main Concerns for Marine Geology Oceanography and Physical Processes – Project Parameters Subject: Project Definition Comments: The baseline data provided in this chapter in support of the PEIR is insufficient to adequately inform the assessment of impacts due to the proposed development. Landfall and beach access impacts have not been considered. Not all sensitive receptors have been considered either. Recommendations: Full baseline characterisation should be provided, along with consideration of all impacts and sensitive receptors.	A full suite of geophysical and benthic surveys were completed across the wind farm sites and offshore cable corridors (excluding offshore temporary works areas) at periods between September 2019 and August 2020 to support baseline environment characterisation (**Section 6.4.2.1**). These included bathymetry (multibeam echosounder), sea bed texture (side-scan sonar), shallow geology (sub-bottom profiling), and sea bed sediments/particle size (grab sampling). Landfall and beach access does not form part of the coastal processes assessment. Sand banks have been added as a sensitive receptor. As noted above, an offshore temporary works area has been incorporated within the SEP and DEP offshore sites which does not include geophysical coverage. The Applicant has committed to post consent coverage of the additional areas potentially required for temporary works. See **Chapter 4 Project Description** for further details.
Natural England	June 2021	Subject: Worst-Case Scenario (WCS) Comments:	The worst-case scenarios for Marine Geology, Oceanography and Physical Processes were developed from the Project Design Envelope described in **Chapter 4 Project Description**. They

Consultee	Date	Comment	Project Response
		It is not clear how some of the worst-case scenario footprints and volumes have been calculated (in this chapter and Chapter 5), nor some of the project parameters, and thus, the rationale behind them. Furthermore, the worst-case scenario does not consider all receptor impacts e.g. changes to the sandbanks, wave shadow (attenuation) effect of the arrays, plume dispersion and seabed change due EC installation along the ECC, and changes to the shoreline. Recommendations: Calculations of project parameters should be clearly defined. The WCS for changes to each receptor should be evaluated. Unless this information is provided then we will be unable to provide our full nature conservation advice and there is a risk that that we will not be able to agree with your conclusions.	are defined using the Rochdale Envelope approach (**Section 6.3.2.1**), and are the worst-case scenarios for the Marine Geology, Oceanography and Physical Processes parameters that are considered (waves, tidal currents, sediment transport). In terms of impacts, changes to sand banks are now included in the assessment as a new Construction Impact 7 (see **Section 6.6.4.9**). Wave shadow effects of the arrays are implicit in the assessment of changes to waves (**Section 6.6.5.2**); plume dispersion due to export cable installation has been covered albeit through analogous studies at SOW and DOW (**Section 6.6.4.5**); sea bed change due to installation of the export cable has been addressed (**Section 6.6.4.6**); changes to the shoreline have been addressed (**Section 6.6.5.6**), although there is no impact because the cable installation at the landfall will be undertaken by long HDD).
Natural England	June 2021	Subject: NE position on WCS Comments: Natural England does not agree with all aspects of the WCS presented. Recommendations: As above.	Response as above
Natural England	June 2021	Subject: Data suitability and baseline characterisation Comments: There is significant uncertainty regarding baseline characterisation. In this case (except for some geophysical, bathymetric and sediment sample analysis), no new project-specific data have been collected. Moreover, in addition to the use of data that pre-date the construction of the existing	A full suite of geophysical and benthic surveys were completed across the wind farm sites and offshore cable corridors (excluding temporary works areas) at periods between September 2019 and August 2020 to support the baseline environment (**Section 6.4.2.1**) (see response to Project Definition comment). The surveys undertaken are in line with

Consultee	Date	Comment	Project Response
		windfarms (DOW and/or SOW), there are data gaps, and a reliance on qualitative assessments. The wave climate has not been adequately characterised for the project area over a range of wave conditions, to understand possible impacts on sediment transport processes. No wave analysis or results have been presented. There is a lack of suspended sediment concentration data. The only SSC figures quoted are 19 years old, apart from one SSC value recorded near Great Yarmouth in 2012. There is insufficient bathymetric and seismic survey data across the project area, in addition, there is a lack of mapping of seabed mobility, regional geology, Quaternary geology, sediment thickness, sediment transport pathways, coastal cells, regional sediment transport. There are no annual/biannual coastal frontage survey data. There are no scour pit model results. The nature of the sandbanks has not been characterised. DOW sediment plume dispersion model results are not presented, nether are the simulations - only qualitative assessments of this have been provided. Recommendations: Baseline characterisation needs to be fully established.	that for previous offshore wind farm projects and enable appropriate baseline characterisation for EIA purposes. As noted above, an offshore temporary works area has been incorporated within the SEP and DEP offshore sites which does not include geophysical coverage. The Applicant has committed to post consent coverage of the additional areas potentially required for temporary works. See **Chapter 4 Project Description** for further details. The justification for using a qualitative (conceptual) approach to the hydrodynamics and sediment dispersion assessments is provided in **Section 6.6.3**. The wave regimes at SOW and DOW are considered suitable analogues for the likely wave regimes at SEP and DEP. However, more detail on the characterisation of the wave climate using SOW and DOW data is now provided in the baseline environment. The assessment of impacts on waves is based on numerical modelling (**Appendix 6.2**). The use of existing suspended sediment concentration data is proportionate to the potential effects on concentrations because most of the sea bed is sand. In these environments, the potential for release of sediment into the water column as a plume is limited as the sediment is too coarse to be lifted off the bed. Also, ambient suspended sediment concentrations are unlikely to change over time and so the collection of new data would not add value and therefore use of old data is justified.

Consultee	Date	Comment	Project Response
			Sea bed mobility, sediment transport pathways and regional sediment transport are covered in **Section 6.5.8**. Quaternary geology and sediment thickness are covered in **Section 6.5.2**. Regional geology outside the bounds of the project area is not relevant for EIA. Detailed information such as coastal cells and annual/biannual coastal frontage survey data are not included as the information would not be used in the assessment because the cable landfall will be HDD. Hence, there would be no changes to the frontage over and above the natural processes. There are no scour pit model results because scour resulting from the proposed development is not assessed. This is because scour protection will be used wherever scour will occur. The bathymetries of the sand banks have been described. Paragraphs have been added to the seabed sediment distribution sub-sections that relate to the DEP North array area and DEP South array area to characterise sediment type specific to the sand banks using the particle size analyses. More details on SOW and DOW export cable corridor dispersion and deposition modelling results are now provided in **Section 6.6.3.4.1**.
Natural England	June 2021	Subject: Data gaps Comments: Additional data requirements include:	• Wave climate data – response same as for Data suitability and baseline characterisation above.

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		· Wave climate data across a range of conditions across the project area. · Assessment of the 'wave shadow' (attenuation) effect of the array(s): existing and planned. · Bathymetric and geophysical data of the sandbanks is needed, in addition to an assessment of the effects (direct and indirect) due to the proposed development. · Cliff erosion data, beach profile data, coastal erosion assessment at, and adjacent to, landfall. · Sediment plume dispersion model results and simulations should be provided for different locations along the ECC (near the array(s), midway, and near landfall). These data should also include predictions of sediment deposition thickness. · Suspended sediment concentration data across the project area. · Sediment transport process study for cable crossings/protection. · Scour assessment, scour pit and wake modelling around wind turbine and OSP structures. · Thickness of sediment units across the project area (including consolidation and change over time). · Lithology across the project area (origin, composition). See Detailed Comments for further data requirements. Recommendations: See above.	• Assessment of the wave shadow effects is implicit in the assessment of changes to the wave regime (see **Section 6.6.5.2**). Assessment is not part of the baseline. • All the sand banks within the wind farm sites and along the offshore cable corridors are mapped bathymetrically (see **Figures 6.1 to 6.4**). Changes to sand banks are now included in the assessment as a new Construction Impact 7 (see **Section 6.6.4.9**). • The presentation of cliff erosion and beach profile data, and a coastal erosion assessment at the landfall are not provided because the cable landfall will be HDD. Hence, there would be no changes to beach evolution and cliff erosion over and above the natural processes. • Justification for using previous SOW and DOW numerical modelling for suspended sediment concentration assessment is provided in **Section 6.6.3**. Bespoke sediment dispersion modelling for SEP and DEP was considered not to be required as satisfactory evidence for potential impacts was available from the SOW and DOW assessment results. Assessment is not part of the baseline. • Suspended sediment data – response same as for Data suitability and baseline characterisation.

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			• Baseline sediment transport is presented in **Section 6.5.8**. A sediment transport process study for cable crossings/protection is not part of the baseline. • Scour assessment, scour pit and wake modelling – see response for Data suitability and baseline characterisation. Assessment is not part of the baseline. • The thickness of sediment units is covered in **Section 6.5.2**. Consolidation and change over time are not relevant for EIA. • Lithology of the geological units is covered in Section 6.5.2.
Natural England	June 2021	Subject: Data analysis Comments: Chapter 8 presents a primarily qualitative approach to assessing the impacts of the proposed project scenario(s) on the receptors and pathways relevant to this chapter. This is not sufficient to provide a robust detailed baseline characterisation upon which the impact assessment can be based. Further information is also provided in the Detailed Comments. Recommendations: See above.	The Applicant requests clarification on this point because it suggests that the assessment methodology is not sufficient to provide a robust baseline characterisation. Assessment does not dictate the baseline characterisation.
Natural England	June 2021	Subject: Identified Impacts Comments: The following pressures/impacts do not appear to have been considered in this chapter. These include: · Landfall - cliff stability/beach processes · Beach access Recommendations:	Changes to the shoreline / landfall have been covered in **Section 6.6.5.6**. The impact on cliff stability and beach processes were considered but not assessed because Horizontal Directional Drilling (HDD) will be used at the landfall. Hence, there would be no changes to cliff stability and beach processes over and above the natural evolution.

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		The assessment should consider the potential effects of the landfall on cliff stability and beach processes. If beach access is required, then information should be provided on this.	Beach access does not form part of the Marine Geology, Oceanography and Physical Processes assessment.
Natural England	June 2021	Subject: Methodology Comments: Please see below. Recommendations: See below.	Noted
Natural England	June 2021	Subject: Cumulative Effect Assessment (CEA) Comments: The only cumulative impacts assessed are those between the project and Hornsea Project Three. The CEA concluded that in relation to marine geology, oceanography, and physical processes, no cumulative impacts were anticipated and were screened out of further assessment. The justification for this is not clear, neither is the methodology for the CEA. Recommendations: The CEA methodology should be clarified, and the full range of other projects, plans and activities considered in the CEA, including the ongoing impacts due to the existing wind farm turbine structures and the possible cumulative effects of the Blythe Hub, Viking Interconnector, and Aggregate Resource Area (AGG3).	Blythe Hub, Viking Link and AGG3 are now included in the list of projects/activities that could potentially have a cumulative impact with SEP and DEP (see **Section 6.7**). The potential for cumulative impacts has been assessed through the screening process along with Hornsea Project Three.
Natural England	June 2021	Subject: Overall Assessment Conclusion Comments: It is essential that the marine and coastal processes in the vicinity of the development are well understood. This is typically achieved through the analysis of new and existing field data along with existing studies and supporting numerical modelling. The data provided should be accompanied by sufficient metadata (descriptions of the data source, location, date, time, time-step, instruments used, etc). Data should also be	The marine and coastal processes in the vicinity of the development are well understood because of project-specific, detailed and accurate bathymetric, geological and sea bed sediment data collection across the wind farm sites and along the interlink and export cable corridors (excluding offshore temporary works area), and use of existing wave and modelled tidal current data established through previous assessment of SOW and DOW.

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		of a sufficiently high accuracy. Given that the proposed development is located relatively close to the East Anglian coast, an eroding coastline, potentially sensitive sandbank receptors, and the Cromer Shoal Chalk Beds MCZ, the information provided in this chapter does not allow a full conceptual understanding of the physical environment baseline of the site and surrounding area, nor of the potential impacts of the proposed development. All sensitive receptors should be included in the study. Recommendations: Full baseline characterisation is needed.	The geophysical data does have metadata, and this is presented in the chapter. More detail on the characterisation of the wave climate using SEP and DEP data is now provided in the baseline environment (**Section 6.5.5**). The project-specific data that has been collected provides a detailed conceptual understanding of the offshore sites. This is presented in **Section 6.5** as the baseline environment. Detailed reports on the geology and transport processes in the MCZ are also provided as **Appendix 6.3 and Appendix 6.4**. Hence, the baseline characterisation does allow a full conceptual understanding of the physical and sedimentary environments and is a sound basis for impact assessment. As noted above, an offshore temporary works area has been incorporated within the SEP and DEP offshore sites which does not include geophysical coverage. The Applicant has committed to post consent coverage of the additional areas potentially required for temporary works. See **Chapter 4 Project Description** for further details. The sensitive receptors relevant to Marine Geology, Oceanography and Physical Processes are included in the assessment. Within the PEIR the Cromer Shoal Chalk Beds MCZ and the East Anglian coast were assessed however as a result of comments received from stakeholders on the PEIR, sand banks have now been added as a further sensitive receptor (see **Section 6.6.1**).

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Natural England	June 2021	Volume 1 Chapter 8 Marine Geology, Oceanography and Physical Processes Section: Glossary of Terms Comment: Wavelength Recommendation: This definition is not restricted to bedforms, rather it should simply state that wavelength is the horizontal distance between two consecutive wave crests (or alternatively troughs).	This has been amended.
Natural England	June 2021	Section: 8.3.2.1 Table 8.3 Comment: Construction: Impact 7. Cable repair and reburial. Recommendation: The anchoring figures don't quite stack up. For example, for DEP in isolation, the footprint for 32 turbines + 1 OSP = 23,760m2, so 23760/33 (turbines + OSP) = 720, and 720/12 mooring lines = 60. The anchor footprint is quoted as up to 6m width. Therefore, should the anchor footprint be 60m? Please clarify this.	This has been amended. Also, since PEIR, note the maximum number of turbines for DEP has reduced from 32 to 30 and for SEP from 24 to 23.
Natural England	June 2021	Section: 8.3.2.1 Table 8.3 Comment: Operation: Impact 6: Morphological and sediment transport effects due to cable protection measures along the export cable protection measures along the export cable. Recommendation: In Chapter 8, Table 8.3, Impact 6, states that the "height of cable crossings would be 0.5m". However, it is presumed that this latter figure represents the height of the cable crossing only, it does not include the crossing height with cable protection. Section 5.4.7.7.2 in Chapter 5 Point	Changed to 1.7m.

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		173, states that the "maximum width and length of cable protection for crossings is 21m and 100m, respectively. The maximum height of cable crossings will be 1.7m." This latter figure should be brought from Chapter 5, and incorporated into Chapter 8, and Table 8.3, to inform assessment of the potential effect of the cable crossing protection on hydrodynamics, sediment transport processes, scour and seabed morphology.	
Natural England	June 2021	Section: 8.3.2.1 Table 8.3 Comment: Operation: Impact 7: Cable repair and reburial Recommendation: Where do the figures for cable repair and reburial for DEP in isolation, and SEP in isolation, come from? Also, how have the figures been calculated in the final column 'Notes and Rationale' for cable repair and cable reburial? Please clarify these issues and present calculations where relevant.	The figures for cable repair and reburial for SEP and DEP in isolation are based on the respective configurations and the types of cables needed if they are installed on their own (without the other present). These worst-cases have been updated according to the latest Project Description. Impact 7 in **Table 6-2**, has been updated to present the worst-case scenario for cable repair, replacement and reburial more clearly. These calculations are all presented in **Table 4-31** of **Chapter 4 Project Description**.
Natural England	June 2021	Section: 8.3.2.2 Point 15 Comment: The three construction scenarios' Recommendation: Technically, there are four construction scenarios: DEP in isolation, SEP in isolation, SEP and DEP concurrently, and SEP and DEP sequentially.	The description of the project development scenarios has been amended in **Section 6.3.2** as has the presentation of the worst-case scenario table (**Table 6-2**). Further detail on project development scenarios is provided in **Section 4.1.1** of **Chapter 4 Project Description**.
Natural England	June 2021	Section: 8.4.6 Point 46 Comment: No suspended sediment concentration data were collected for this application. Coastal estimates from the southern North Sea Sediment Transport Study (HR Wallingford, 2002) were extrapolated from locations	Additional and more up-to-date baseline data on suspended sediments has been added from the Cefas (2016) report - Suspended Sediment Climatologies around the UK. Hence, the uncertainty regarding suspended sediment concentrations at the coast is removed.

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		further offshore, which were the points closest to the export cable corridor (nearshore section) and landfall. 'Hence, there is uncertainty as to the validity of this extrapolation inshore'. Recommendation: NPS EN-3 states that assessment of the effects on the subtidal environment should include: 'increased suspended sediment loads during construction', and 'increased suspended sediment loads in the intertidal zone during installation'. Therefore, to minimise the uncertainty regarding SSCs in the nearshore zone, modelling of discharged dredge or trench material should have been carried out for the proposed development. This is important in terms of understanding the potential impact of SSCs on sensitive receptors such as the CSCB MCZ, EA coast, and the sandbanks. Changes in SSC during installation may also require assessment and monitoring during cable installation within, and near, the MCZ.	The Applicant has conceptually assessed increased suspended sediment due to cable installation. This was supported by the sediment dispersion modelling undertaken along the export cable route for DOW. Bespoke sediment dispersion modelling for SEP and DEP was considered unnecessary given the high level of confidence in the DOW results to provide an analogy alongside the supporting evidence base from other offshore wind farms and the aggregate industry. Justification for using the DOW results is presented in **Section 6.6.3**. Monitoring of suspended sediment concentrations during cable installation would serve no purpose as the impacts of any release into the water column would only manifest at the sea bed and not in the water column i.e. there would be no dredging during cable installation (other than for sand wave levelling purposes which is assessed separately).
Natural England	June 2021	Section: 8.5.1 Comment: Bathymetry and bedforms. Recommendation: A figure illustrating bathymetric data across the whole project area should be included as this would provide the wider regional physical context for the current assessment. Either a MBES/SBES covering the full extent of the development area, as well as the associated zone of direct impact, should be included. In addition, high resolution swath bathymetry data of the proposed extension areas, interlink cable & export cable corridors and vicinity would provide greater detail of the seabed features and a better understanding of the seabed morphology. For any areas where the bed is known to be mobile, new project-specific survey information is needed –	Project-specific multibeam bathymetry has been collected for the wind farm sites, and along the interlink and the export cable corridors (excluding temporary works areas). These data provide the baseline understanding of sea bed features and mobile bedforms. These are discussed in **Section 6.5** - baseline environment and illustrated in **Figures 6.1 to 6.4**.

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		this would also help refine the areas where sand wave or bedform levelling is deemed necessary.	
Natural England	June 2021	Section: 8.5.2 Comment: Offshore geology Recommendation: Regional geology maps should be included here, including a regional Quaternary geology map for the project and wider areas. We advise these should be included in the ES.	Regional geology outside the bounds of the project area is not relevant for EIA. Descriptions of the geology for the array sites, and along the interlink and export cable corridors are provided in **Section 6.5.2**.
Natural England	June 2021	Section: 8.5.2 Table 8.12 Comment: Geological formations present at SEP and DEP, interlink cable corridor and export cable corridor. Recommendation: Seismic survey data would enable evaluation of the characteristics and thicknesses of the sub-surface geology, including any palaeochannels that run across the project area, and the presence of the bedrock (i.e. Cretaceous Chalk). We advise this be included in the ES.	Seismic (sub-bottom profiler) data has been captured for the array sites and export cable corridor, and is presented in **Section 6.5.2**. The stratigraphy and thicknesses of geological units have also been presented. Two new plates (**Plate 6.1** and **Plate 6.4**) have been added to show the depths to the base of the two uppermost units across the project area (Botney Cut and Bolders Bank Formations) and the position of the Weybourne Channel Deposits along the export cable corridor. **Appendix 6.3** and BGS study (**Appendix 6.4**) provide more detail of the geology across the MCZ.
Natural England	June 2021	Section: 8.5.5 Point 97 Comment: Wave climate studies for this assessment were based on the Sheringham Shoal Offshore Wind Farm in 2006 and studies undertaken for Dudgeon Offshore Wind Farm between 1988 and 2004. Recommendation: PINS commented in 2019 that the use of existing data provides a useful baseline, but their limitations in terms of age and spatial coverage should	The pre-construction baseline wave data from SOW and DOW alongside other more recent wave buoy data has been used to support the SEP and DEP assessment. Bespoke wave data has not been collected as part of the assessment, and so the request to provide wave roses at different locations across the development cannot be fulfilled. The assessment of effects on waves is completed using numerical modelling calibrated using the measured waves (**Appendix 6.2**).

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		be acknowledged. These are dated and pre-construction wave studies. Therefore, more recent data or evidence should be provided to assess any changes to the hydrodynamic regime, not only due to the construction of the existing DOWF and SOWF, but also the proposed extension turbines and their foundations. It is also important to understand the baseline wave climate over a broad range of conditions including calm, intermediate and annually significant storm events which are seasonal. The wave climate study should consider a range of wave data locations to describe the broad characteristics of the wider area, including the nearshore. It is possible that the extension project structures could reduce the height and affect the period of waves passing around them, in turn this could affect the patterns and rates of sediment transport in intermediate and shallow water depths (typically <10 to 15m but potentially deeper during large storms) such as the northwest area of DEP (N) near the top of the SEP-DEP (N) interlink cable, the furthest north part of DEP (S) next to DOWF, and the most westerly part of SEP. It would be useful to present wave data for different areas of the proposed development as wave roses and figures of significant wave height variation across the study area for different percentiles of exceedance. In other words, new wave data may not be required for the new extension projects specifically, if historical records are available from other suitably located wave buoys, especially when used in conjunction with an adequately calibrated and validated hindcast dataset. Therefore, the wave data referred to in Section 8.5.5.1, which was informed through the SOWF desk study and pre-construction studies for DOWF, should be presented in the PEIR, along with the details of the parameters, methods, and their suitability/limitations. Lastly, there is no description of wave-driven currents, which should be rectified.	
Natural England	June 2021	Section: 8.5.5.5 Point 101 Comment: Export Cable Corridor (ECC). “Nearshore wave conditions along the ECC are less severe than the SEP and DEP sites due to the protection afforded by sandbanks such as Sheringham Shoal and Pollard Bank.” The other	The sea bed to the west of SEP does not contain sand banks. The sea bed is likely to be a thin Holocene unit with limited mobility which would not be impacted by the wind farm. Provision of more detailed bathymetric / geophysical data for this area (which is outside the DCO boundary) is not

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		sand banks and the generally shallower water west from the SEP site also influence wave directions closer to the coast due to refraction. Recommendation: More detailed bathymetric/ geophysical data are needed for the sandbank areas across this proposed development. This data would help provide a better understanding of the sandbank morphology, stability, and their possible alteration due to the proposed development.	considered necessary and would be disproportionate. As noted above, an offshore temporary works area has been incorporated within the SEP and DEP offshore sites which does not include geophysical coverage. The Applicant has committed to post consent coverage of the additional areas potentially required for temporary works. See **Chapter 4 Project Description** for further details.
Natural England	June 2021	Section: 8.5.6 Point 107 Comment: States that 'Predicting coastal erosion rates is critical to forecasting future problem areas…' Recommendation: Yet, this qualitative statement is not backed up by any quantitative evidence or data. This should be provided to inform the impact assessment.	The statement relates to the impact on coastal erosion of climate change only within the context of the baseline. This statement is not related to impacts due to SEP and DEP. Given the landfall will be HDD, there would be no changes to cliff erosion over and above the natural rates of erosion, so presentation of detailed cliff erosion rate data is not warranted.
Natural England	June 2021	Section: 8.5.7 Comment: Sea Bed Sediment Distribution Recommendation: Data should also be presented to show the thickness of the different Quaternary sediments across the project area. This would also show where the thickness of Quaternary sediments is zero or negligible and thus indicate any areas of exposed bedrock. In turn, these could be correlated with any sidescan sonar or similar data. These should be provided in the ES.	Sub-bottom profiler data and multibeam/side-scan interpretation have been used to describe Quaternary unit thickness and locations where bedrock may be at or close to the sea bed across the project area. This information is presented in the chapter. Two new figures (**Plates 7-2** – **7-5**) have been added to show the depths to the base of the two uppermost units across the proposed development (Botney Cut and Bolders Bank Formations) and the position of the Weybourne Channel Deposits along the export cable corridor. The MCZ study (**Appendix 6.3**) and BGS study

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			(**Appendix 6.4**) provide more detail of the Quaternary geology across the MCZ.
Natural England	June 2021	Section: 8.5.7.1 Point 109 Comment: Sample numbers do not tally with those in Figure 8.6. Point 109 states that 16 samples were recovered in DEP North and 11 samples in DEP South), but Figure 8.6 shows only 13 samples in DEP North and 8 samples in DEP South. Similarly, the number of samples quoted for the interlink cable corridors and export cable corridor do not appear to correspond with those in Figure 8.6 Recommendation: The sample numbers in Point 109 and Figure 8.6 should be the same or an explanation for the discrepancy provided.	The description of the number of samples in **Section 6.5.7.1** has been updated and an explanation has been provided to explain the apparent discrepancy.
Natural England	June 2021	Section: 8.5.7.2, 8.5.7.3, 8.5.7.4, 8.5.7.5, 8.5.7.6 Comment: Sediment sample analysis Recommendation: Please provide a description of sediment grain properties (e.g. grain size, shape, density, distribution and settling velocity).	Particle (grain) size is presented as five cumulative particle size distribution curves which are described in the chapter and illustrated as **Plate 6.14** to **Plate 6.19**. Shape and density are irrelevant for the purposes of EIA, and settling velocity is a parameter that is only relevant to suspended sediments.
Natural England	June 2021	Section: 8.5.7.4 Point 114 Comment: No sea bed sediment samples were collected in the DEP N to DEP S interlink cable corridor. Recommendation: The geophysical survey for DOW (2009) is referred to, but the sediment sample analysis relevant to this interlink cable is not included here. A map	The sediment sampling campaign undertaken by MMT in August 2018 (MMT, 2018a) has been used to characterise sediment within the DEP North array area to DEP South array area interlink cable corridor. There were six relevant samples (DOW24, DOW25, DOW26, DOW32, DOW45 and DOW54) (now presented in **Figure 8.2**).

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		showing where the DOW (2009) samples were obtained should be included also. Furthermore, these data are now old (12 years) and from pre-construction surveys. It is therefore advisable to include more recent data.	
Natural England	June 2021	Section: 8.5.8 Point 123 Comment: "Between these opposing directions of transport is a bedload transport parting." Recommendation: Please could a schematic be provided showing coastal sediment transport pathways including sediment cells, net drift directions, sediment sinks, parting zones etc? Points 123 & 124 are largely based on the Norfolk Boreas Environmental Statement Chapter 8, Page 42.	**Section 6.5.10** describes sediment transport at the coast/landfall whereas **Section 6.5.8** covers bedload transport in the marine environment. The title of this section has been changed to 'Offshore Bedload Sediment Transport' and a new plate added from Kenyon and Cooper (2005) to illustrate.
Natural England	June 2021	Section: 8.5.8 Point 123 Comment: "Regional sediment transport pathways in the southern North Sea…" Recommendation: A regional sediment transport map should be provided.	A new plate from Kenyon and Cooper (2005) has been added as illustration.
Natural England	June 2021	Section: 8.5.8 Point 124 Comment: "Tidal currents are the main driving force of sediment transport…" Recommendation: This is not true for all areas of the proposed development and should be clarified. Near-bed tidal currents may dominate bedload transport offshore, in the deeper water sites, but within the nearshore and at the coastline, bedload transport is primarily wave-driven. It would be useful to include a sediment mobility study/map that compares bathymetric surveys to determine historic migration rates and the directions of the sandwaves	The Applicant agrees that wave transport at the coast is driven by waves and this is covered in **Section 6.5.10**. **Section 6.5.8** is about bedload sediment transport in the offshore. The title of this section has been changed to 'Offshore Bedload Sediment Transport'. The Applicant does not have and is not aware of any historic bathymetry data within the SEP and DEP offshore sites with which to compare the recent project-specific data, and so this analysis cannot be undertaken.

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		within the SEP & DEP site. This would help inform sandwave levelling requirements and recoverability of the bedforms.	A new Construction Impact 7 (new **Section 6.6.4.9**) has been added to the chapter, which assesses the potential interruptions to bedload sediment transport due to sand wave levelling for offshore cable installation (infield and interlink cables).
Natural England	June 2021	Section: 8.5.8.1 Point 125 Comment: Seabed mobility across the ECC in the CSCB MCZ Recommendation: Seabed mobility should also be shown on a map across this area, as well as described qualitatively in the text.	Maps of sea bed sediment distribution across the MCZ in the ECC are presented in **Appendix 6.3**. More details on sediment transport in the MCZ is presented there. The chapter itself provides a summary of that data.
Natural England	June 2021	Section: 8.5.8.1 Point 126 Comment: Comparison of SOW ECC geophysical pre- and post-construction surveys are described in the text. No figures have been provided. Recommendation: A figure should be provided to show the differences in seabed elevation between pre- and post-construction, to back up the qualitative description in the text.	All the data is in **Appendix 6.3** including figures comparing different aged bathymetries which this chapter provides a summary of.
Natural England	June 2021	Section: 8.5.8.1 Point 127 Comment: Discussion of the range of sediment transport potentials across the stratigraphic units mapped along the SEP and DEP cable corridor (Royal HaskoningDHV, 2020). Recommendation: If these have been mapped, please could the map be provided?	See **Appendix 6.3**.

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Natural England	June 2021	Section: 8.5.8.1 Point 131 Comment: “However, no significant difference was found in sediment composition between the trenches and the control areas adjacent to the trenches.” Recommendation: The 2020 survey involved random stills, photographic stills, and video. As discussed in our formal response (29 March 2021), photographic stills cannot provide a measure of the sediment thickness and should have been compared with accompanying geophysical/bathymetric survey data. The type of surficial sediments may be apparent in the photographic stills, and the trenches may not be apparent in the photographs, but the depth of infilling within the trenches cannot be gauged from the photographic stills. Therefore, there may still be a depression present which cannot be observed by photographic evidence alone.	There was no geophysical data collected in 2020 with which to support this type of analysis. Only benthic surveys were undertaken at this time as part of the post-construction monitoring for the SOW export cable. This is the interpretation based on the data that was available, and was purely a comparison of sea bed sediment types, not bathymetry.
Natural England	June 2021	Section: 8.5.9 Point 132 Comment: Suspended sediment transport. “Typical mean summer suspended sediment concentrations across SEP and DEP are less than 10mg/l whereas mean winter concentrations are 30mg/l…” Recommendation: The summer and winter SSC figures quoted are attributed to the HR Wallingford et al (2002) study. These figures are 19 years old. Moreover, Carroll et al (2010) refer to the same HR Wallingford report and quote SSC of 8 to 128mg/l during summer months, and 16 to 128mg/l during winter months for the Lynn and Inner Dowsing area. Carroll et al also quote EA data for Lynn and Inner Dowsing coastal water monitoring data that indicate a SSC range of 5 to 525mg/l, with an average of 129mg/l. More recently, Norfolk Vanguard East SSC measurements recorded values of 0.3 to 108mg/l over a period of a year. Baseline SSCs across Norfolk Boreas were estimated to vary between 0 to 100mg/l. The values	The suspended sediment climatologies calculated by Cefas (2016) have been added to the baseline to update those of HR Wallingford et al (2002) (**Section 6.5.9**). This provides a more recent and longer time-series of data and is a robust estimate of the baseline suspended sediment concentration environment at SEP and DEP.

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		quoted for SEP and DEP would appear low in comparison to Boreas, Vanguard and Lynn and Inner Dowsing. Whilst Boreas and Vanguard are further offshore, and Lynn and Inner Dowsing is closer inshore, their relative SSC values could be used to adjust those quoted for SEP and DEP. This is important as the SSC figures used by SEP and DEP will provide an indication of background SSCs across the project area.	
Natural England	June 2021	Section: 8.5.10 Comment: Coastal Processes at the Weybourne (Muckleburgh Estate) Landfall Recommendation: This section should consider regional coastal characterisation, such as coastal cells.	Detailed information on regional coastal cells is not included as the information would not be used in the assessment. However, a reference to the sub-cell in which the landfall sits has been added.
Natural England	June 2021	Section: 8.5.10 Point 133 Comment: "The coast to the east of the landfall is exposed to waves and cliff erosion is occurring in places." The predicted net sediment transport rates in the region quoted are from the HR Wallingford 2002 study. Recommendation: This statement is vague. Please provide information where cliff erosion is occurring and consider any coastal defences along this stretch of coast. Photographs of the frontage would help provide context. It might be worth looking for more recent and more specific estimates of sediment transport rates.	More specific information has been added. A photograph of the cliffs has been added as a plate (**Plate 6.21**). The numbers for transport quoted in the HR Wallingford (2002) work are reproduced in the Shoreline Management Plan (SMP) 2 for this coast and so are considered 'the most recent'. Indeed, a search found no other estimates.
Natural England	June 2021	Section: 8.6.1 Point 136 Comment: "The principal receptors with respect to marine geology, oceanography and physical processes are those features with an inherent geological or geomorphological value or function which may potentially be affected by SEP and DEP."	The sand banks in the DEP North and DEP South array areas are now included as receptors and potential impacts on them have been assessed. An assessment of landscape scale stability of the sand banks would be disproportionate to the potential impacts and would not aid the assessment

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		Recommendation: The sandbanks across the DEP&SEP project area are themselves receptors and as such, should be included in the list of impact receptors. Potential impacts on these receptors due to the proposed development should therefore be assessed. Changes to the sandbanks may come about directly through installation of project infrastructure, or indirectly through changes to a pathway. The stability of the sandbanks should be assessed as part of the impact assessment, through examination of historic charts. Impacts may also be exacerbated by projects acting cumulatively or in-combination.	of potential changes due to the wind farm. It would provide information on broad-scale historical evolution but would not be used in the assessment of future change to the system, which is based on changes to driving processes not long-term form.
Natural England	June 2021	Section: 8.6.1.2 Point 141 Comment: East Anglian Coast – shoreline retreat rates Recommendation: Natural England queries the source of the figures. Is the reference AECOM (2013)? Also, we note that no beach profiles have been included. Consideration should be given to the potential long-term effects of the project on shoreline erosion and beach lowering, and vice versa (implications for project infrastructure, cable burial etc). Therefore, a study of historic and more recent trends in morphological change at the coast should be carried out.	Yes – the reference is AECOM 2013. Beach profile data at the landfall are not presented because the cable landfall will be HDD. Hence, there would be no changes to beach evolution over and above the natural processes. Natural processes will continue unabated during both construction and operation of the landfall. The Applicant has made statements about potential future erosion and roll-back based on AECOM 2013, but a bespoke detailed analysis of historic beach profile data is not considered to be warranted here. It would not provide any further evidence to support the assessment over and above the published existing work. In addition, **Appendix 3.2 Cable Landfall Concept Study** of **Chapter 3 Site Selection and Assessment of Alternatives** provides further information on erosion rates and how these would factor into the final HDD design.
Natural England	June 2021	Section: 8.6.3 Points 144 & 145	Further details on the methods and results of the modelling and theoretical work at SOW and DOW

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		Comment: Justification for use of a conceptual approach for the project. “Previous numerical modelling and theoretical work has been undertaken specifically for the SOW and DOW located in close proximity to SEP and DEP to assess the potential effects of the extensions on the marine geology, oceanography and physical processes”. “Justification for using the modelling results from SOW and DOW as the principal evidence of potential effects or impacts at SEP and DEP…” Recommendation: PINS (2019) commented that the ‘ES [PEIR] should provide details of all methods used along with any assumptions and limitations and an explanation of how these have been factored into the assessment’. Without the details of the modelling theoretical work undertaken for the SOW and DOW projects, it is not possible to agree with the justification to use them. Therefore, these details should be provided in, or as an appendix to, the ES.	have been added to **Section 6.6.3**. The new information has essentially been taken from the tidal currents impact assessment section for operation and the suspended sediment concentration impact assessment section for construction of the export cable. Numerical modelling of waves has now been completed for potential operational impacts due to the presence of the foundation structures (**Appendix 6.2**).
Natural England	June 2021	Section: 8.6.3 Point 149 Comment: Sea bed sediments at all sites are similar. Recommendation: Similar in places, but not the same. As discussed previously, a sediment distribution map across the study area would back this up.	A map showing SOW, DOW, SEP and DEP sediment fractional composition is now included as **Figure 8.2** of **Chapter 8 Benthic Ecology** for context.
Natural England	June 2021	Section: 8.6.3 Point 151 Comment: ‘post-construction geophysical and environmental survey data for SOW and DOW has been used to retrospectively ‘ground-truth’ the pre-construction numerical modelling and theoretical results for the existing wind farms to provide confidence in their use…’	It was carried out as part of the EIA process and details are included in the relevant impact assessment sections (**6.6.4.9, 6.6.5.1, 6.6.5.2**, and particularly **6.6.5.3**).

Consultee	Date	Comment	Project Response
		Recommendation: Where and how has this 'ground-truthing' been carried out? This needs to be provided in the coastal process chapter of the ES.	
Natural England	June 2021	Section: 8.6.4.2.1 Point 167 Comment: "It is estimated that the maximum number of foundations that would require drilling would be 5%..." Recommendation: Please provide evidence that 5% is a realistic worst-case scenario for the number of foundations which would require drilling.	This is the maximum percentage determined through examination of the available ground condition information. This is the worst-case scenario assessed – i.e. it is the Rochdale Envelope for drilled foundations.
Natural England	June 2021	Section: 8.6.4.3.1 Comment: Impact 2a. Changes in sea bed level due to sea bed preparation for foundation installation Recommendation: This section does not state what the seabed preparation would entail, however, based in the details in Section 8.6.4.1 and Table 8.3, it is assumed that this would involve dredging (using a trailer suction hopper dredger and installation of a bedding and levelling layer) up to a sediment depth of 5m. These details should be provided alongside the impact assessment.	As stated in the Natural England response, they are provided in **Section 6.6.4.1** and **Table 6-2**. It is considered that it would be duplication and unnecessary to include again here.
Natural England	June 2021	Section: 8.6.4.3.1 Points 178 & 180 Comment: "The resulting mound would be a measurable protrusion above the existing sea bed (likely to be tens of centimetres to a few metres high)" and "the overall change in elevation of the seabed is small compared to the absolute depth of water…" Recommendation:	The **Offshore IPMP** (document reference 9.5) includes proposals for monitoring of any mounds of sediment created during sea bed preparation for GBS foundations in water less than 15m deep, if required.

Consultee	Date	Comment	Project Response
		In the deeper water locations, the overall change in elevation of the seabed would be small compared to the absolute depth of water. However, in shallow water depth areas, for example, 11m in SEP and 14m in DEP with disposal mounds 'a few metres high' this could potentially give rise to secondary effects depending on the persistence of the mounds. Therefore, the reduced water depth could be as much as 30% or more. This would not be within the natural change to the bed caused by sand waves and hence the blockage effect on physical processes would not be negligible. Whilst, it is likely, that the disposal mounds (unless comprised of clay or chalk aggregates) will be redistributed by waves and tidal currents, it would seem sensible to confirm this through monitoring, particularly for those mounds in shallower depths.	
Natural England	June 2021	Section: 8.6.4.5.1 Point 210 Comment: Impact 3: Change in suspended sediment concentrations due to ECC installation "No sandwave levelling is expected in a SEP in isolation scenario." Recommendation: Please could this be expanded upon with justification.	The statement reflects the fact that there are no sand waves along the export cable corridor for SEP in isolation. Text has been added to clarify.
Natural England	June 2021	Section: 8.6.4.5.1 Point 210 Comment: SEP or DEP in isolation - sandwave levelling. "Sandwave levelling may be required at the northern end of the export cable corridor DEP North…" Recommendation: No details have been provided in Chapter 8 for the estimated area of seabed disturbed by sandwave levelling in terms of depth or width. However, Chapter 5 (Section 5.4.7.1) discusses pre-sweeping requirements for cable installation which is based on analysis of the 2020 geophysical survey. This identified four areas requiring pre-sweeping: two	Estimates of the volumes and areas of sediment that would be dredged by sand wave levelling for cable installation are provided in **Table 6-2**. Detailed geophysical surveys have been undertaken which has informed the worst-case scenario estimates for sand wave levelling. Gardline (2020a), Gardline (2020b) and the Benthic Characterisation Reports (**Appendices 8.1** and **8.2** of **Chapter 8 Benthic Ecology**) provide detailed information on seabed sediment and sand waves

Consultee	Date	Comment	Project Response
		at DEP (N), one south of DOW, and one within DEP (S). How does the value for the cable route pre-sweeping footprint in Table 5-4 (Chapter 5) relate to the volumes of sediment disturbed provided in Table 8.3 (Chapter 8)? If detailed geophysical surveys are carried out across the whole project area, then this would identify the areas of large-scale bedforms and thus inform a more precise understanding of the requirement for seabed levelling. A map detailing seabed sediment and sandwaves (and other large-scale bedforms) across the project areas should be provided. Asymmetry of sandwaves should be identified. The likely dredger capacity should also be estimated and considered. All possible efforts should be made to avoid areas of sandwaves where possible or minimise the need for clearance by applying micrositing the cable. If sandwaves need to be crossed, then this should be carried out at a high crossing angle to minimise dredge volumes. An estimation of the proposed timescales of post-levelling bedform recovery should also be provided.	throughout SEP and DEP. Heights and orientations of sand waves are described in **Section 6.5.1**. The dredger capacity would not be known until post consent and would not feed into the assessment of potential impact. As described in **Table 6-3,** micro-siting around sand waves and mega ripples as far as possible would be undertaken and would be considered during detailed design and on which the relevant SNCBs would be consulted. Additionally, the **Offshore IPMP** (document reference 9.5) includes provision for the monitoring of any levelled sand waves.
Natural England	June 2021	Section: 8.6.4.5.1 Point 214 Comment: i. Reference is made to the results from DOW ECC modelling and 'conceptual evidence-based assessment' ii. It is 'anticipated' that changes in SSC due to EC installation would be less than those that have been assessed in relation to the disturbance of near-surface sediments during foundation installation activities. Recommendation: (i) The results from the modelling at the DOW ECC are referred to, but not presented. The model results should be included in the ES if they are being used as supporting evidence. (ii) The relative magnitudes of GBS foundation installation and ECC installation sediment disturbance volumes are not comparable. Worst-Casevolume of sediment that would be disturbed for 102km of EC installation is 195,900m3. Whereas, the total worst-case seabed	(i) More details on SOW export cable corridor dispersion modelling results are now provided in **Section 6.6.3**. (ii) This statement is considered to provide a useful comparison of the relative magnitudes of volumetric disturbance for both activities and provides an indication that foundation disturbance is much larger than cable disturbance and hence a better metric for the worst-case scenario. It should also be noted that the 14MW turbine is no longer within the design envelope. The lowest capacity turbine being considered is 15MW.

Consultee	Date	Comment	Project Response
		preparation volume for 56 conical GBS foundations for 14MW turbines is 929,126m3. This is not a useful statement and should be amended.	
Natural England	June 2021		These values are not known as no bespoke measurements were made at the time of the storm surge. A reasoned argument regarding relative contribution to the suspended sediment load from a storm and jetting is already included in **Section 6.6.4.5.1**.
Natural England	June 2021	Section: 8.6.4.5.1 Point 216 Comment: "It is likely that the increase in concentrations would be greatest in the shallowest sections of the offshore cable corridor…", "with values up to 170mg/l recorded in the vicinity of the coast at Great Yarmouth (ABPmer, 2012). Recommendation: We assume this point is referring to SSCs. Also, it is presumed that this coastal SSC value provides a background level of SSC against which elevated SSC due to cable installation in the nearshore could be compared. However, there are no comparative values presented for the SEP and DEP ECC in the nearshore. Further evidence is needed to support this conclusion.	It is referring to background SSCs. The predicted concentrations in the plume from export cable installation (up to 20mg/l) modelled for SOW apply universally along the cable including the nearshore. These values are low compared to the ambient nearshore concentrations.
Natural England	June 2021	Section: 8.6.4.5.1 Point 217 Comment: "It should be noted that the modelled results are only applicable to the nearshore area where chalk or other competent beds are exposed or have only a thin layer of mobile sediment." Recommendation: This would suggest that the DOW (2009) suspended sediment plume dispersion modelling results are not valid for the mobile sand regions of the CSCB MCZ, but would be applicable to the coarse lag and exposed	The results are applicable to all areas of the MCZ where there is mobile sediment that can be transported in the water column. Mobile sand would move as bedload which is a different process to movement in the water. Bedload is not covered in this impact – it is restricted to suspended sediment.

Consultee	Date	Comment	Project Response
		chalk bed regions (depending on suitability of the DOW model results generally to the proposed development options – see Point 2.41 below).	
Natural England	June 2021	Section: 8.6.4.6 Comment: Impact 4: Changes in seabed elevation due to deposition from the suspended sediment plume during EC installation within the offshore cable corridor. Plume modelling simulations for DOW. Recommendation: The DOW plume modelling simulations should be provided in the ES, along with details of the different scenarios modelled to demonstrate the suitability of these data for the DEP in isolation, SEP in isolation, SEP & DEP integrated options. Furthermore, it needs to be shown that the DOW simulations are representative of sediment plumes that would arise due to EC installation at different locations along the ECC i.e. near the arrays, midway along the ECC, and near landfall. Limitations of using the DOW (2009) sediment plume dispersion modelling results also need to be discussed, and an analysis of how the DOW (2009) pre-construction model parameters relate to those for the proposed project options provided.	More details on the SOW export cable corridor dispersion and deposition modelling results are provided in **Section 6.6.3**.
Natural England	June 2021	Section: 8.6.4.6.1 Point 231 Comment: Plume modelling simulations for DOW show that sand-sized material would settle out of suspension within less than 20m from the point of installation. Recommendation: This statement raises several questions that it would be useful to clarify. What depth was the discharge of dredged or trenched material within the water column, i.e. close to the sea surface, or close to the sea bed? What were the quantities of disturbed seabed sediment used in the DOW model simulations? How do these quantities compare with those for	The plume was generated from the sea bed as the trench was excavated. More details on the SOW export cable corridor dispersion and deposition modelling results are provided in **Section 6.6.3**. The deposit of sand would be similar in composition to the existing adjacent sea bed given that only a small proportion of the fines will be lost into suspension. The width of this deposit along the line of the cable is likely to be less than 20m and so the area would be extremely small compared to the area

Consultee	Date	Comment	Project Response
		DEPN/DEPS/SEP/DEP&SEP? Point 231 describes the settling out of sand-sized material within less than 20m from the point of EC installation, however, it does not give an indication of the thickness of the deposit – this needs to be included and an assessment of how this would impact on the interest features of CSCB MCZ.	of the entire MCZ. There would be negligible impact on the interest features from both habitat and footprint perspectives.
Natural England	June 2021	Section: 8.6.4.8 Comment: Impact 6: Change in seabed level due to offshore cable installation (infield and interlink cables) Recommendation: There does not appear to be a similar section for changes in seabed level due to offshore cable installation for the export cables. Where cable routes cross sandbanks, the impact on the sandbanks in terms of hiatus or disruption to sediment transport processes will need to be considered for infield, interlink and export cables.	**Section 6.6.4.6** provides an assessment of change in sea bed level due to deposition from the suspended sediment plume during export cable installation within the offshore cable corridor (Impact 4). The lengths of cable that cross sand banks is limited. Where they do, they will be buried and there will be a rapid infilling of the trench and return to natural sediment transport processes.
Natural England	June 2021	Section: 8.6.4.9.2 & 8.6.4.9.4 Point 270 Comment: Impact 7: Indentations on the seabed due to installation vessels – HDD exit point within Cromer MCZ Recommendation: Any cable installation activities within the MCZ have the potential to (temporarily or permanently) damage or change the nature of the seabed within the MCZ. In turn, this may hinder the conservation objectives of the MCZ and put pressure on the designated features (e.g. increased suspended sediments, deposition, temporary and/or permanent habitat loss).	Noted. Potential impacts on the MCZ during cable installation are assessed for the relevant impacts in **Section 6.6**.
Natural England	June 2021	Section: 8.6.5.4.1 Comment:	No scour assessment has been carried out. An assumption has been made for the worst-case scenario that scour protection will be used wherever

Consultee	Date	Comment	Project Response
		Impact 4: Loss of seabed area due to the footprint of wind turbines and OSP foundation structures Recommendation: No scour assessment has been carried out. Predictions of the size and shape of scour pits and wakes should be provided for the wind turbine and OSP foundation structures, as this would inform the need for scour protection and the appropriate type of scour protection. Scour assessments are particularly important to those foundation structures in relatively shallow water where scour volumes are likely to be greatest. Secondary scour effects of scour protection need to be considered.	scour will occur, reducing sediment release to negligible quantities. A conservative worst-case scenario of all foundations having scour protection is considered for footprint loss. Secondary scour effects associated with scour protection would be confined to within a few meters of the direct footprint of that scour protection material, and so the potential impact would be minimal. The loss of habitat due to the direct footprint of the scour protection is considered to be worse than the effects of scour without scour protection (or secondary scour). The **Offshore IPMP** (document reference 9.5) includes provision for monitoring of secondary scour around scour protection.
Natural England	June 2021	Section: 8.6.5.2 Comment: Impact 2: Changes to the wave regime due to the presence of structures on the seabed (wind turbine and OSP foundations). Wave sheltering effects due to presence of foundation structures could create a wave shadow zone typically up to several tens of kilometres from the site along the axis of wave approach. Recommendation: What is the WCS for a wave shadow zone extending several kilometres from the site along the axis of wave approach? Given that the closest point from SEP OWF to the coast is 13.6km, this could impinge on the coastal hinterland to SEP & SOW (which would have a combined wave sheltering effect). The closest point from the DEP OWF site to the coast would be 24.8km which is still within ‘several tens of kilometres’ of each other. This needs to be quantified. The spatial extent of projected changes	Numerical modelling of waves has now been completed for potential operational impacts due to the presence of the foundation structures (**Appendix 6.2**). The main driver of sand bank morphology is tidal currents with secondary influence of waves where the crest is shallow or during storm conditions. The change in wave height is local to each turbine with little change further afield where these sand banks are located. These very small magnitudes of change in wave height will have little impact on sand bank morphology.

Consultee	Date	Comment	Project Response
		to the wave regime downwind of the array(s) need to be understood, and the potential reductions in significant wave height at the adjacent coastline and the impacts on morphological processes be assessed. Furthermore, what is the potential WCS impact of this 'wave shadow' effect and reduced tidal flow speed (Section 8.6.5.1) on the sandbanks close to the array(s) (e.g. Sheringham Shoal, Pollard Bank, Cromer Knoll)? For example, how would a 1-2% reduction in average tidal flow speed and 'typically less than 10% of baseline wave heights near each wind turbine', translate as a percentage change in nearshore sediment transport, accretion or erosion, or coastal erosion?	
Natural England	June 2021	Section: 8.6.5.6 Comment: Impact 6: Morphological and sediment transport effects due to cable protection measures within the offshore cable corridor (export cables) Recommendation: There are no specifications for potential cable crossings with the DEP/SEP or DEP&SEP projects within Chapter 8, apart from an overall lifetime footprint. Neither is there an evaluation of the potential impacts of the different cable crossings on morphological and sediment transport processes. A list of potential cable crossings has been provided in Chapter 5 (Section 5.4.7.7.4). Chapter 18 (Section 18.6.1.3), assesses the potential impacts of the SEP & DEP project(s) on subsea cables and pipelines are considered. However, to assess the potential impacts of cable protection within the ECC on marine and coastal receptors and pathways, specific details should be provided in Chapter 8. For example, a map showing the location of all potential cable crossings across the project area, anticipated cable crossing protection parameters such as width, length, height, distance of cable crossings from the coastline, as well as a robust study into the likely impacts of the cable crossings/protection on the marine and coastal receptors and pathways.	A description of the cable crossings along the export cable which is considered to be sufficient for the purposes of the impact assessment in this chapter is provided in **Table 6-2**. It was not considered necessary to repeat that information in the assessment section. To describe the specifications of every potential cable crossing along the length of the export cable would be disproportionate and unnecessary. Instead, standard practice of providing and assessing the worst-case total footprint of cable crossings has been undertaken. **Chapter 16 Petroleum Industry and Other Marine Users** is working to a different set of worst-case scenarios and impact pathways compared to this chapter and is not considered to be relevant. In this chapter the morphological effects of all the cable protection including cable crossings is evaluated. Crossings are not extracted individually for their own impact assessment because they are too small, relative to the entire length of cable, to warrant this.
Natural England	June 2021	Section: 8.6.5.6.2, Table 8.31	The assessment looks at all potential cable protection, not just cable crossings. Crossings are

Consultee	Date	Comment	Project Response
		Comment: Magnitude of effect on seabed morphology and sediment transport under the worst-case scenario for cable protection measures for export cables. Recommendation: What is the rationale behind the assessment of these magnitudes of effect? There could be particular concern regarding the cable crossings shoreward of SEP, for example, where the Hornsea Project Three EC crosses the SEP & DEP EC, and where the Hornsea Project Three EC crosses the SEP EC, and the SOW EC.	integral to the assessment but they are not singled out for individual attention. This would be disproportionate as the crossings are likely to be only a small percentage of the potential protection that will be installed. It is not clear in the comment as to why there is a particular concern at the two crossings mentioned. The rationale for the magnitudes of effects is presented in the text prior to **Table 6-36**.
Natural England	June 2021	Section: 8.6.5.6.3, Point 343 Comment: Cable protection within Cromer MCZ Recommendation: Reference should also be made here to our response to the MEEB proposals (20 April 2021). Neither DOW nor SOW required cable protection within the MCZ. Therefore, thorough consideration should be given to the need for cable protection within the CSCB MCZ. Any cable protection placed, its installation activities, and cable maintenance activities would hinder the conservation objectives of the MCZ and put pressure on the designated features (e.g. increased suspended sediments, deposition, temporary and/or permanent habitat loss).	The quantities of cable protection assessed within this chapter have been refined as far as possible and are based on the Rochdale Envelope approach. This approach provides flexibility in the consent in the absence of detailed ground investigations which are required to enable detailed design decisions such as these to be made. A commitment has been made to only use cable protection at the HDD exit point and up to a maximum of 100m for each of the two export cables inside the MCZ (1,800m^2 in total). A geotechnical survey campaign was undertaken in October 2021, the results of which have fed into the **Outline CSCB MCZ CSIMP** (document reference 9.7)
Natural England	June 2021	Section: 8.6.5.7 Comment: Impact 7: Cable repairs and reburial Recommendation: We query whether the number of cable repairs and reburials quoted are	See response directly above.

Consultee	Date	Comment	Project Response
		realistic, for example, one export cable every ten years, one interlink cable every ten years, two infield cable repairs every ten years etc See also comment to Point 343 above on the Cromer MCZ.	
Natural England	June 2021	Section: 8.1.1, Point 372 Comment: Potential Monitoring Requirements Recommendation: Are there Environment Agency surveys which could provide annual/biannual coastal frontage data to ensure no unexpected changes to the beach? Ideally bathymetric & geophysical surveys around sandbanks, near and across the MCZ to ensure that there are no unexpected changes, especially to sensitive receptors. High-resolution swathe bathymetry surveys of scour pits and associated scour protection measures should be undertaken to identify the extent, volume and integrity of any scour protection used. Wave climate (local to regional climate) should be monitored post-construction to understand spatial extent of any changes or to ensure that any changes are as predicted. Sand wave clearance areas along the ECC particularly those near the MCZ and across sandbanks should be monitored (e.g. MBES and/or side scan sonar) to assess cable burial state and to assess recovery of the seabed morphology.	The monitoring requirements are defined in the **Offshore IPMP** (document reference 9.5) submitted alongside the DCO application and will be further developed and agreed with the MMO and Natural England prior to construction. Monitoring of sand wave recovery and secondary scour have been included. Also, as stated, a range of geophysical surveys including bathymetry will be carried out both before and after construction to support other topics, but would also have value in monitoring sedimentary processes/sand bank morphology. There will be no need for bespoke beach profiles as the landfall is not affected because of installation using long HDD. Even so, the Environment Agency is likely to continue their annual surveys close to the landfall into the future. Numerical modelling of waves has been completed for potential operational impacts due to the presence of the foundation structures (**Appendix 6.2**). The results show that SEP and DEP are predicted to have only a localised impact on wave climate, where reflection from the wind turbines results in a slight reduction in wave conditions, up to 0.05m significant wave height. There is no impact on the nearshore wave conditions along the East Anglian coast. Therefore, the Applicant considers that there is no requirement for wave climate monitoring as the main wave effect will be local to turbines. Any wider

Consultee	Date	Comment	Project Response
			effects (wave shadow) will be within the range of natural variability.
Natural England	June 2021	Section: 8.12, Table 8.39 Comment: Summary of potential impacts on marine geology, oceanography, and physical processes Recommendation: Potential impacts include: • Modification of adjacent or nearby sandbanks • Changes to the wave regime downwind of the array(s), reduction in significant wave height at adjacent coastlines, and concomitant changes to morphological processes • Potential scour around foundations and cable crossings and the need for scour protection • Plume dispersal of suspended sediments • Adverse effect on the integrity of the CSCB MCZ.	An assessment of potential impacts on nearby sand banks is now included for the relevant impacts (see **Section 6.6**). Other impacts mentioned are already assessed, apart from scour for the reasons stated in individual responses to comments above.
Natural England	June 2021	Volume 3 Appendix 8.1 Physical Processes Method Statement Section: 8.1.4.2.1 | Point 36 Comment: 'Sediment plume dispersion (particularly the release of chalk fines) during cable installation was also modelled...' Recommendation: These model results should be presented in Chapter 8.	An interpretation of the SOW and DOW sediment plume dispersion modelling results has been provided in **Section 6.6.3.4.1**.
Natural England	June 2021	Volume 3 Appendix 8.1 Physical Processes Method Statement Section: 8.1.4.2.1 | Point 36 Comment: Numerical modelling of waves and tidal currents with the arrays in place was not carried out.	See response to 8.5.5 Point 97 above.

Consultee	Date	Comment	Project Response
		Recommendation: See comment for 8.5.5 Point 97 in Chapter 8 above.	
Natural England	June 2021	Volume 3 Appendix 8.1 Physical Processes Method Statement Section: 8.1.5.3, Point 62 Comment: "Seabed sediments at all sites are similar". Recommendation: See comment for 8.5.7 in Chapter 8. A sediment distribution map should be provided across the entire project area. Whilst there may be considerable areas of medium to coarse sand, sandy gravel, and gravely sand, there are also areas where clay, or clay-rich, sediments are present. A detailed and accurate characterisation of the sediments across the project area is essential for understanding the sedimentary, erosional and accretional effects of the project, and the potential for sediment dispersion due to construction and operation activities. Therefore, a sediment distribution map should be provided for the study area.	A map showing SOW, DOW, SEP and DEP sediment fractional composition is now included as **Figure 8.2** and **8.3** of **Chapter 8 Benthic Ecology** for context.
Natural England	June 2021	Volume 3 Appendix 8.1 Physical Processes Method Statement Section: 8.1.5.3 | Point 63 Comment: Regional suspended sediment concentrations. Concentrations may increase significantly during storm events. Recommendation: Natural England queries the source of the figures. A reference should be provided. The comment regarding suspended sediment concentrations (SSCs) during storms, is vague and needs quantifying. No suspended sediment concentration (SSC) data were measured. Ideally, simultaneous records of SSC, water levels, currents and waves over several tidal cycles would have been collected. Alternatively, modelling of the plume dispersion of dredged or trenched material should have been carried out at different locations along the proposed ECC. For example, close to the	See individual responses to Natural England comments on section 8.4.6, Point 46, and section 8.5.9, Point 132 above. Note chapter number has changed to 6 and so the first number of section references is now 6.

Consultee	Date	Comment	Project Response
		array, midway along the ECC (perhaps near Sheringham Shoal sandbank), and close to landfall. This comment ties in with those for Chapter 8, 8.4.6, Point 46, and 8.5.9, Point 132.	

6.3 Scope

6.3.1 Study Area

9. The SEP and DEP wind farm sites are located in the southern North Sea. The DEP wind farm site is split into two array areas i.e. the DEP North array area and the DEP South array area which together encompass a sea bed area of approximately 114.75km^2. SEP is approximately 97.0km^2 in area. The DEP North and DEP South array areas are adjacent to and north and south of DOW, respectively. SEP is adjacent to and north of SOW. SEP is closest to the coast and is located approximately 15.8km from the nearest point on the coast of Norfolk. An offshore export cable corridor joins the SEP and DEP wind farm sites to the landfall at Weybourne (Muckleburgh Estate). In addition, interlink cable corridor options have been defined between the DEP North array area and SEP wind farm site, between the DEP South array area and SEP wind farm site and between the DEP North array area and DEP South array area depending on the project development scenario (see **Section 4.1.1** of **Chapter 4 Project Description** for more details). The offshore infrastructure required for SEP and DEP is outlined in **Section 6.3.2**.

10. The assessment of effects on marine geology, oceanography and physical processes considers the direct footprint of SEP and DEP (near-field) and the wider areas of sea bed and coast that potentially could be affected (far-field).

6.3.2 Realistic Worst-Case Scenario

6.3.2.1 General Approach

11. The final design of SEP and DEP will be confirmed through detailed engineering design studies that will be undertaken post-consent to enable the commencement of construction. In order to provide a precautionary but robust impact assessment at this stage of the development process, realistic worst-case scenarios have been defined in terms of the potential effects that may arise. This approach to EIA, referred to as the Rochdale Envelope, is common practice for developments of this nature, as set out in Planning Inspectorate Advice Note Nine: Rochdale Envelope (v3, 2018). The Rochdale Envelope for a project outlines the realistic worst-case scenario for each individual impact, so that it can be safely assumed that all lesser options will have less impact. Further details are provided in **Chapter 5 EIA Methodology**.

12. The realistic worst-case scenarios for the marine geology, oceanography and physical processes assessment are summarised in **Table 6-2**. These are based on the project parameters described in **Chapter 4 Project Description**, which provides further details regarding specific activities and their durations.

13. In addition to the design parameters set out in **Table 6-2**, consideration is also given to:

- How SEP and DEP will be built out as described in **Section 6.3.2.2** to **Section** below. This accounts for the fact that whilst SEP and DEP are the subject of one DCO application, it is possible that only one Project could be built out (i.e. build SEP or DEP in isolation) or that both of the Projects could be developed. If both are developed, construction may be undertaken either concurrently or sequentially.
- A number of further development options which either depend on pre-investment or anticipatory investment, or that relate to the final design of the wind farms.
- Whether one OSP or two OSPs are required.
- The design option of whether to use all of the DEP North and DEP South array areas, or whether to use the DEP North array area only.

14. In order to ensure that a robust assessment has been undertaken, all development scenarios and options have been considered to ensure the realistic worst-case scenario for each topic has been assessed. Further details are provided in **Chapter 4 Project Description**.

15. In relation to the different OSP scenarios where both SEP and DEP are built (i.e. where there are one or two OSPs), each scenario has been presented, however only the overall realistic worst-case for each impact has been assessed in **Section 6.6**. The worst-case parameter for each activity / footprint in the SEP and DEP one or two OSP scenario has been denoted with an asterisk and underlined in **Table 6-2**. In addition, cells have been shaded grey to indicate which scenario represents the worst-case in relation to each of the impacts assessed.

6.3.2.2 Construction Scenarios

16. In the event that both SEP and DEP are built, the following principles set out the framework for how SEP and DEP may be constructed:

- SEP and DEP may be constructed at the same time, or at different times;
- If built at the same time both SEP and DEP could be constructed in four years;
- If built at different times, either Project could be built first;
- If built at different times, each Project would require a four year period of construction;
- If built at different times, the offset between the start of construction of the first Project, and the start of construction of the second Project may vary from two to four years;
- Taking the above into account, the total maximum period during which construction could take place is eight years for both Projects; and
- The earliest construction start date is 2025.

17. The impact assessment for benthic ecology considers the following development scenarios in determining the worst-case scenario for each topic:

- Build SEP or build DEP in isolation – one OSP only; and
- Build SEP and DEP concurrently or sequentially – with either two OSPs, one for SEP and one for DEP, or with one OSP only to serve both SEP and DEP

18. For each of these scenarios it has been considered whether the build out of the DEP North and DEP South array areas, or the build out of the DEP North array area only, represents the worst-case for that topic. Any differences between SEP and DEP, or differences that could result from the manner in which the first and the second projects are built (concurrent or sequential and the length of any gap) are identified and discussed where relevant in the impact assessment section of this chapter (**Section 6.6**). For each potential impact, where necessary, only the worst-case construction scenario for two Projects is presented, i.e. either concurrent or sequential. The justification for what constitutes the worst-case is provided, where necessary, in **Section 6.6**.

6.3.2.3 Operation Scenarios

19. Operation scenarios are described in detail in **Chapter 4 Project Description**. Where necessary, the assessment considers the following three scenarios:

- Only SEP in operation;
- Only DEP in operation; and
- The two Projects operating at the same time, with a gap of two to four years between each Project commencing operation.

20. The operational lifetime of each Project is expected to be 40 years.

6.3.2.4 Decommissioning Scenarios

21. Decommissioning scenarios are described in detail in **Chapter 4 Project Description**. Decommissioning arrangements will be agreed through the submission of a Decommissioning Programme prior to construction, however for the purpose of this assessment it is assumed that decommissioning of SEP and DEP could be conducted separately, or at the same time.

Table 6-2: Summary of Realistic Worst-case Scenarios

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP		Notes and Rationale
			Two OSPs (one in SEP wind farm site and one in DEP North array area)	One OSP (located in SEP wind farm site)	
Construction					
Impact 1a: Changes in suspended sediment concentrations due to sea bed preparation for foundation installation	Sea bed preparation for 24 conical GBS foundations for 18MW turbines. Total worst-case sea bed preparation volume: **407,150m³**	Sea bed preparation for 19 conical GBS foundations for 18MW turbines. Total worst-case sea bed preparation volume: **322,327m³**	Sea bed preparation for up 43 conical GBS foundations for 18MW turbines. **Total** worst-case sea bed preparation volume = **<u>729,477m³*</u>**		The worst-case for a single 18 MW GBS foundation with a 60m base plate diameter = 16,964.60m³. Worst-Case for a single 15MW GBS foundation with a 45m base plate diameter = 9,543m³. Therefore, the overall worst-case is associated with 24 18MW GBS foundations at DEP and 19 18MW GBS foundations at SEP. Sea bed preparation (dredging using a trailing suction hopper dredger and installation of a bedding and levelling layer) may be required up to a sediment depth of 5m. The worst-case scenario represents the greatest potential for increased SSC across the study area as a result of changes to physical processes which could result in impacts on fish and shellfish ecology receptors.
Impact 1b: Changes in suspended sediment concentrations due to drill arisings for foundation installation of piled foundations for wind turbines and OSPs	Drill arisings at 2 15MW wind turbines = 11,946m³ Drill arisings at 1 OSP = 425m³ **Total = 12,371m³**	Drill arisings at 2 15MW wind turbines = 11,946m³ Drill arisings at 1 OSP = 425m³ **Total = 12,371m³**	Drill arisings at 4 15MW wind turbines = 23,892m³ Drill arisings at 2 OSPs = <u>850m³*</u> **<u>Total = 24,742m³*</u>**	Drill arisings at 4 15MW wind turbines = 23,892m³ Drill arisings at 1 OSP = 425m³ **Total = 24,292m³**	For wind turbine monopile foundations, the maximum percentage anticipated to require drilling is 5%. As a precautionary worst-case, up to two 15MW wind turbines each for SEP and DEP are considered to require drilling. An average drill penetration depth for the 15MW wind turbine of 45m and a maximum drill diameter of 13m is assumed. This equates to 5,973m³ of drill arisings per 15MW wind turbine. OSPs jacket foundations would have up to 8 legs, 1 of which could be drilled. An average drill penetration depth of 60m and a maximum drill diameter of 4m is assumed
Impact 2a: Changes in sea bed level due to sea bed preparation for foundation installation	As Construction Impact 1a.	As Construction Impact 1a.	As Construction Impact 1a.	As Construction Impact 1a.	As Construction Impact 1a.
Impact 2b: Changes in sea bed level due to drill arisings for installation of piled foundations for wind turbines and OSPs	As Construction Impact 1b	As Construction Impact 1b	As Construction Impact 1b	As Construction Impact 1b	As Construction Impact 1b.
Impact 3: Changes in suspended sediment concentrations due to export cable installation	<u>Displaced sediment during export cable installation</u> Export cable = 31,000m³	<u>Displaced sediment during export cable installation</u> Export cable = 20,000m³	<u>Displaced sediment during export cable installation</u> Export cable = <u>51,000m³*</u>	<u>Displaced sediment during export cable installation</u> Export cable = 40,000m³	Offshore export cables would be buried up to 1m below the sea bed. Calculations are based on an indicative sediment displacement width of 1m for jetting and assume a v-shaped trench.

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP		Notes and Rationale
			Two OSPs (one in SEP wind farm site and one in DEP North array area)	One OSP (located in SEP wind farm site)	
	HDD exit point = 650m³ (600m³ initial exit point trench and 50m³ further transition zone) Sand wave levelling = 144,200m³ **Total = 175,850m³**	HDD exit point = 650m³ (600m³ initial exit point trench and 50m³ further transition zone) Sand wave levelling = 0m³ **Total = 20,650m³**	HDD exit point = 700m³ (600m³ initial exit point trench and 100m³ further transition zone) Sand wave levelling = <u>144,200m³*</u> <u>**Total = 195,900m³***</u>	HDD exit point = 700m³ (600m³ initial exit point trench and 100m³ further transition zone) Sand wave levelling = 0m³ **Total = 40,700m³**	For the HDD exit pit, if SEP and DEP are both built it is assumed that both export cables are within the same initial trench meaning the volume of disturbance is the same as SEP or DEP in isolation scenarios. However, for the transition zone it assumes two trenches and therefore the area of disturbance is double the SEP or DEP in isolation scenarios. Sand wave levelling (pre-sweeping) is potentially required in particular areas prior to infield and interlink cable installation (**Figure 4.9** of **Chapter 4 Project Description**). Any excavated sediment due to sand wave levelling would be disposed of within the vicinity of the removal location, meaning there will be no net loss of sediment from the site(s). The WCS is based on a two OSP scenario and is estimated based on analysis of existing geophysical data to determine where sand wave clearance is likely to be required (details provided in **Chapter 4 Project Description**). No sand wave levelling (pre-sweeping) is required in SEP as no sand waves are present.
Impact 4: Change in sea bed level due to deposition from the suspended sediment plume during export cable installation within the offshore export cable corridor	As Construction Impact 3	As Construction Impact 3	As Construction Impact 3	As Construction Impact 3	As Construction Impact 3.
Impact 5: Changes in suspended sediment concentrations due to offshore cables installation (infield and interlink cables)	<u>Displaced sediment during infield and interlink cable installation</u> Infield = 151,875m³ Interlink = 74,250m³ Sand wave levelling = 232,200m³ (216,000m³ infield and 16,200m³ interlink) **Total = 458,325m³**	<u>Displaced sediment during infield and interlink cable v</u> Infield = 101,250m³ Interlink = 0m³ Sand wave levelling = 0m³ **Total = 101,250m³**	<u>Displaced sediment during infield and interlink cable installation</u> Infield = 253,125m³ Interlink = 74,250m³ Sand wave levelling = 232,200m³ (216,000m³ infield and 16,200m³ interlink) **Total = 559,575m³**	<u>Displaced sediment during infield and interlink cable installation</u> Infield = 253,125m³ Interlink = <u>160,875m³*</u> Sand wave levelling = <u>360,200m³*</u> (216,000m³ infield and 144,200m³ interlink) <u>**Total = 774,200m³***</u>	As above for sand wave levelling (pre-sweeping) Infield and interlink cables would be buried up to 1.5m below the sea bed. Calculations are based on an indicative sediment displacement width of 1m for jetting and assume a v-shaped trench.
Impact 6: Change in sea bed level due to offshore cable installation (infield and interlink cables)	As Construction Impact 5	As Construction Impact 5	As Construction Impact 5	As Construction Impact 5	As Construction Impact 5.
Impact 7: Interruptions to bedload sediment transport due to sand wave levelling for offshore cable installation (infield and interlink cables)	Sand wave levelling (pre-sweeping) in infield and interlink cable corridors: **232,200m³** over an area of **929,719m²**	No sand wave levelling (pre-sweeping)	Sand wave levelling (pre-sweeping) in infield and interlink cable corridors: **232,200m³** over an area of **929,719m²**	Sand wave levelling (pre-sweeping) in infield and interlink cable corridors: <u>**360,200m³***</u> over an area of **758,821m²**	The primary pathway for impact relates to the volume of sediment removed and therefore the worst-case scenario is linked to the scenario with the greatest volume of dredged sediment rather than the area over which sand wave levelling occurs.

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP		Notes and Rationale
			Two OSPs (one in SEP wind farm site and one in DEP North array area)	One OSP (located in SEP wind farm site)	
Impact 8: Indentations on the sea bed due to installation vessels	Jack up vessels • Up to two jack-up deployments at each turbine/OSP (30 15MW wind turbines + one OSP: **74,400m²**) Anchoring • Turbines (30) and OSP (1) installation vessel anchoring (up to 12 lines per location) = **22,320m²** • Export cable installation vessel anchoring (seven lines) (62km) = **26,040m²** • Interlink cable (**66km**) installation vessel anchoring (seven moorings) = **27,720m²** **Total** sea bed disturbance footprint from vessels for DEP in isolation = **150,608m²**.	Jack up vessels • Up to two jack-up deployments at each turbine/OSP (23 15MW turbines + one OSP: **57,600m²**) Anchoring • Turbines (23) and OSP (1) installation vessel anchoring (up to 12 lines per location) = **17,280m²** • Export cable installation vessel anchoring (seven lines) (40km) = **16,800m²** • No interlink cables **Total** sea bed disturbance footprint from vessels for SEP in isolation = **91,808m²**	Jack up vessels • Up to two jack-up deployments at each turbine/OSP (53 15MW turbines + two OSPs: **132,000m²***) Anchoring • Turbines (53) and OSP (2) installation vessel anchoring: (up to 12 lines per location) **39,600m²**. • Export cable installation vessel anchoring (seven lines) (62km + 40km) = **42,840m²** • Interlink cable (**66km**) installation vessel anchoring (seven moorings) = **27,720m²** **Total** sea bed disturbance footprint from vessels = **242,416m²**	Jack up vessels • Up to two jack-up deployments at each turbine/OSP (53 15MW turbines + one OSPs: **129,600m²**) Anchoring • Turbines (53) and OSP (1) installation vessel anchoring: (up to 12 lines per location) **38,880m²**. • Export cable installation vessel anchoring (seven lines) (40km + 40km) = **33,600m²** • Interlink cable (**154km**) installation vessel anchoring (seven moorings) = **64,680m²*** **Total** sea bed disturbance footprint from vessels = **267,016m²***	Worst-case scenario is a jack-up barge with six legs per barge (200m² per leg) equating to a total footprint of 1,200m² per installation (for wind turbines and OSPs). Individual anchor footprint = 30m². Up to two anchor deployments required at each wind turbine and OSP location.
Operation					
Impact 1: Changes to the tidal regime due to the presence of structures on the sea bed	Worst-Case sea bed obstruction footprint • 24 x 18MW GBS wind turbine foundations (60m base diameter plus scour protection of 180m diameter) with a minimum spacing of 3.3km: **610,726m²** • One OSP with four-leg jacket and suction buckets (12m diameter per leg) and a maximum bucket spacing of 40m: **4,225m²**	Worst-Case sea bed obstruction footprint • 19 x 18MW GBS wind turbine foundations (60m base diameter plus scour protection of 180m diameter) with a minimum spacing of 3.3km: **483,491m²** • One OSP with four-leg jacket and suction buckets (12m diameter per leg) and a maximum bucket spacing of 40m: **4,225m²**	Worst-Case sea bed obstruction footprint • 43 x 18MW GBS wind turbine foundations (60m base diameter plus scour protection of 180m diameter) with a minimum spacing of 3.3km: **1,094,217m²** • Two OSPs with four-leg jackets and suction buckets (12m diameter per leg) and a maximum bucket spacing of 40m: **8,450m²***	Worst-Case sea bed obstruction footprint • 43 x 18MW GBS wind turbine foundations (60m base diameter plus scour protection of 180m diameter) with a minimum spacing of 3.3km: **1,094,217m²** • One OSP with four-leg jackets and suction buckets (12m diameter per leg) and a maximum bucket spacing of 40m: **4,225m²**	GBS for wind turbines and jackets on suction buckets for OSPs are the worst-case foundation types for effects on tidal currents. This is based on GBS OSP jackets on suction buckets having the greatest cross-sectional area within the water column (compared to other foundation types) representing the greatest physical blockage to tidal currents. Therefore, a larger number of GBS with minimum wind turbine spacing is the worst-case scenario. Individual GBS footprints including scour protection are 14,313.8m² and 25,446.9m² for a 15MW and 18MW wind turbine respectively and therefore the worst-case across the wind farm sites is associated with the 18MW wind turbines (based on maximum numbers of 15MW turbines of 23 and 30 at SEP and DEP respectively). The diameter of the 18MW wind turbine GBS foundation base at the sea bed would be 60m, narrowing to 14m at the sea surface. The worst-case scenario for changes to the tidal regime does not include effects caused by cable protection. This is because, although flows would tend to accelerate over the protection and then decelerate on the 'down-flow' side, they would

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP		Notes and Rationale
			Two OSPs (one in SEP wind farm site and one in DEP North array area)	One OSP (located in SEP wind farm site)	
					return to baseline values a very short distance from the structure. Hence, the effect on tidal currents would be very small.
Impact 2: Changes to the wave regime due to the presence of structures on the sea bed (wind turbines and offshore substation foundations)	30 x GBS wind turbine foundations Wind turbine spacing = 1.05km	23 x GBS wind turbine foundations Wind turbine spacing = 1.05km	53 x GBS wind turbine foundations Wind turbine spacing = 1.05km	53 x GBS wind turbine foundations Wind turbine spacing = 1.05km	GBS are the worst-case foundation types for effects on waves due to the height of the foundation above the sea bed. Specific GBS foundation dimensions which were inputted to the wave climate model, as simulated by the DIFFRACT model, are shown in Figure 6-2 of **Appendix 6.2**.
Impact 3: Changes to the sediment transport regime due to the presence of structures on the sea bed (wind turbines and offshore substation foundations)	As Operational Impact 1	As Operational Impact 1	As Operational Impact 1	As Operational Impact 1	GBS are the worst-case foundation types for effects on the sediment transport regime due to the height of the foundation above the sea bed.
Impact 4: Loss of sea bed area due to the footprint of wind turbine and offshore substation foundation structures	As Operational Impact 1	As Operational Impact 1	As Operational Impact 1	As Operational Impact 1	GBS are the worst-case foundation types for loss of sea bed area due to the size of the base that will be present on the sea bed.
Impact 5: Morphological and sediment transport effects due to cable protection measures within the SEP and DEP wind farm sites and interlink cable corridor	Subsea cable surface protection • **Infield cables** up to **1km** of cable protection **4m** wide = **4,000m²** • **Interlink cables** up to **1.5km** of cable protection **6m** wide = **9,000m²**. Crossings Each crossing has a 2,100m² footprint (21m width x 100m length) • **Infield: 7** crossings **= 14,700m²** • **Interlink**: **6** crossings = **12,600m²** **Total** area for all types of cable protection = **40,300m²***	Subsea cable surface protection • **Infield cables** up to **1km** of cable protection **4m** wide = **4,000m²** Crossings **No interlink or infield cable** crossing protection material is required for a SEP in isolation scenario. **Total** area for all types of cable protection = **4,000m²**	Same as DEP in isolation scenario	Same as DEP in isolation scenario	Cable protection for crossings will be up to 21m wide and 100m long and consist of either concrete mattressing or rock dumping. **SEP and DEP worst-case crossing locations** • Infield cables: up to seven crossings (three in the DEP North array area at Durango-Waveney pipeline, up to four in the DEP South array area) • Interlink cables, up to six crossings (three cables from the DEP South array area crossing two Dudgeon export cables)
Impact 6: Morphological and sediment transport effects due to cable protection measures along the export cable	Subsea cable surface protection • **Export cables** up to **0.5km** (including 100m in the MCZ) of cable protection 6m wide = **3,000m²**. Crossings • **Export**: **4** crossings = 8,400m² HDD Exit point	Same as for a DEP in isolation scenario	Subsea cable surface protection Same as for a DEP in isolation scenario Crossings **Export: 8** crossings = **16,800m²**	Same as for two OSP scenario	Export cable protection for crossings will be up to 21m wide and 100m long and consist of either concrete mattressing or rock dumping. **SEP and DEP worst-case crossing locations** • Export cable, up to four crossings (two at Dudgeon export cables, two for Hornsea Three export cables). One disused subsea cable crosses the export cable, but no crossing required.

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP		Notes and Rationale
			Two OSPs (one in SEP wind farm site and one in DEP North array area)	One OSP (located in SEP wind farm site)	
	• HDD exit transition zone (100m x 3m): **300m^2** **Total** area for all types of cable protection = **11,700m^2**		HDD Exit point • HDD exit transition zone (100m length x 3m width for up to 2 export cables) = **600m^2** **Total** area for all types of cable protection = **20,400m^{2*}**		All crossings will be outside the Cromer Shoal Chalk Beds MCZ.
Impact 7: Cable repairs and reburial	Volumes of Sediment Disturbed *Cable repair or replacement* • One export cable repair every 10 years, up to 800m, = **800m^3** • One interlink cable repair every 10 years, up to 800m = **1,800m^3** • Two infield cable repairs every 10 years, up to 5km each, = **22,500m^3.** *Cable reburial* • Up to 200m of export cable subject to reburial works every 10 years, 1m width of sediment displacement with jetting and 1m maximum burial depth = **200m^3**. • Reburial of 1% of up to 66km of interlink cabling every 10 years (0.66km), 1.5m width of sediment displacement with mechanical cutting and 1.5m maximum burial depth = **1,485m^3** • Reburial of 1% of 135km (90km in DEP North array area and 45km in DEP South array area) of infield cabling every 10 years (1.35km), 1.5m width of sediment displacement with mechanical cutting and 1.5m maximum burial depth = **3,038m^3**. **Total = 29,823m^3 per 10 year period**	Volumes of Sediment Disturbed *Cable repair or replacement* • One export cable repair every 10 years, up to 800m = **800m^3** • Two infield cable repairs every 10 years, up to 5km each, = **22,500m^3.** *Cable reburial* • Up to 200m of export cable subject to reburial works every 10 years, 1m width of sediment displacement with jetting and 1.5m maximum burial depth = **200m^3**. • 0m^3 for interlink cables since there are no interlink cables for SEP in isolation. • Reburial of 1% of 90km of infield cabling every 10 years (0.90km), 1.5m width of sediment displacement with mechanical cutting and 1.5m maximum burial depth = **2,025m^3**. **Total = 25,525m^3 per 10 year period** Worst-Case scenario disturbance footprint within CSCB MCZ on average per 10 year period: **1,500m^2** (0.0005% of MCZ)	Volumes of Sediment Disturbed *Cable repair or replacement* • One export cable repair every 10 years, up to 800m = **800m^3** • One interlink cable repair every 10 years, up to 800m, = **1,800m^3** • Two infield cable repairs every 10 years, up to 5km each, 1.5m width of sediment displacement with mechanical cutting and 1.5m maximum burial depth = **22,500m^3.** *Cable reburial* • Up to 200m per export cable subject to reburial works every 10 years, 1m width of sediment displacement with jetting and 1m maximum burial depth = **400m^3**. • Reburial of 1% of up to 66km of interlink cabling every 10 years (0.66km), 1.5m width of sediment displacement with mechanical cutting and 1.5m maximum burial depth = **1,485m^3**. • Reburial of 1% of 225km of infield cabling every 10 years (2.25km), 1.5m width of sediment displacement with mechanical cutting and 1.5m maximum burial depth = **5,063m^3**. **Total = 32,048m^3 per 10 year period**	Volumes of Sediment Disturbed *Cable repair or replacement* • Same as for a two OSP scenario *Cable reburial* • Up to 200m per export cable subject to reburial works every 10 years, 1m width of sediment displacement with jetting and 1m maximum burial depth = **400m^3**. • Reburial of 1% of up to 143km of interlink cabling every 10 years (1.43km), 1.5m width of sediment displacement with mechanical cutting and 1.5m maximum burial depth = **3,218m^{3*}.** • Reburial of 1% of 225km of infield cabling every 10 years (2.25km), 1.5m width of sediment displacement with mechanical cutting and 1.5m maximum burial depth = **5,063m^{3*}**. **Total = 33,781m^3* per 10 year period** Worst-Case scenario disturbance footprint within CSCB MCZ on average per 10 year period: **3,600m^2** (0.001% of MCZ)	Up to 10 jack-up movements per year for each of SEP and DEP (i.e. 20 in total). Jack-up vessel with a sea bed footprint of 1,200m^2 (up to four legs, each with a footprint of up to 300m^2). 1m width of sediment displacement with jetting and 1m maximum burial depth is assumed for export cable repair, replacement or reburial. 1.5m width of sediment displacement with mechanical cutting and 1.5m maximum burial depth is assumed for interlink and infield cable repair, replacement or reburial. Further detail on maximum temporary O&M footprints in the wind farm sites and cable corridors is provided in **Table 4-9** of **Chapter 4 Project Description.** Export cable repair and reburial would be undertaken using a jetting cable burial method. The worst-case repair and reburial method for infield and interlink cables is mechanical cutting. SEP and DEP have an operational design life of 40 years.

Impact	DEP in Isolation	SEP in Isolation	SEP and DEP		Notes and Rationale
			Two OSPs (one in SEP wind farm site and one in DEP North array area)	One OSP (located in SEP wind farm site)	
	Worst-Case scenario disturbance footprint within CSCB MCZ on average per 10 year period: **1,500m^2** (0.0005% of MCZ)		Worst-Case scenario disturbance footprint within CSCB MCZ on average per 10 year period: **3,600m^2** (0.001% of MCZ)		
Decommissioning					
Impact 1: Changes in suspended sediment concentrations due to foundation removal	No decision has yet been made regarding the final decommissioning policy for the offshore project infrastructure. It is also recognised that legislation and industry best practice change over time. However, the following infrastructure is likely be removed, reused or recycled where practicable: • Turbines including monopile, steel jacket and GBS foundations; • OSPs including topsides and steel jacket foundations; and • Offshore cables may be removed or left *in situ* depending on available information at the time of decommissioning. The following infrastructure is likely to be decommissioned *in situ* depending on available information at the time of decommissioning: • Scour protection; • Offshore cables may be removed or left *in situ*; and • Crossings and cable protection. The detail and scope of the decommissioning works will be determined by the relevant legislation and guidance at the time of decommissioning and will be agreed with the regulator. For the purposes of the worst-case scenario, it is anticipated that the impacts will be no greater than those identified for the construction phase.				Decommissioning arrangements will be detailed in a Decommissioning Programme, which will be drawn up and agreed with the Department for Business, Energy and Industrial Strategy (BEIS) prior to construction.
Impact 2: Changes in sea bed level due to foundation removal					
Impact 3: Changes in suspended sediment concentrations due to removal of parts of the export cable					
Impact 4: Changes in sea bed level due to removal of parts of the export cable					
Impact 5: Changes in suspended sediment concentrations due to removal of parts of the infield and interlink cables					
Impact 6: Changes in sea bed level due to removal of parts of the infield and interlink cables					
Impact 7: Indentations on the sea bed due to decommissioning vessels					

6.3.3 Summary of Mitigation Embedded in the Design

22. This section outlines the embedded mitigation relevant to the marine geology, oceanography and physical processes assessment, which has been incorporated into the design of SEP and DEP (**Table 6-3**). Where other mitigation measures are proposed, these are detailed in the impact assessment (**Section 6.6**).

Table 6-3: Embedded Mitigation Measures

Parameter	Mitigation Measures Embedded into the Design of SEP and DEP
Turbine spacing	A minimum separation distance of up to 1.05km has been defined between adjacent wind turbines within each row and between rows, minimising the potential for interaction between adjacent wind turbines with respect to marine physical process.
Foundations	The selection of appropriate foundation designs and sizes at each wind turbine location will be made following pre-construction surveys within the wind farm sites.
	For piled foundation types, such as monopiles and jackets with pin piles, pile-driving will be used in preference to drilling where it is practicable to do so (i.e. where ground conditions allow). This would minimise the quantity of sub-surface sediment released into the water column from the installation process.
	Micro-siting will be used where possible to minimise the requirements for sea bed preparation prior to foundation installation.
Cables	The Applicant will make reasonable endeavours to bury cables, minimising the requirement for cable protection measures and thus effects on sediment transport. Use of external cable protection would be minimised in all cases and in the nearshore is only included for potential use at the HDD exit point.
	Route selection and micro-siting of the cables will be used to avoid areas of sea bed that pose a significant challenge to their installation, including for example areas of sand waves and megaripples. This will minimise the requirement for sea bed preparation (levelling) and the associated sea bed disturbance. This is reflected in the allowances that have been made for these works as described in **Table 6-2**, based on the information from the geophysical surveys conducted to date.
Landfall	HDD will be used to install the cables at the landfall, exiting approximately 1,000m offshore. Cables will be buried at sufficient depth to have no effect on coastal erosion. Erosion would continue as a natural phenomenon driven by waves and subaerial processes, which would not be affected by SEP and DEP. Natural coastal erosion throughout the lifetime of the project has been considered within the project design by ensuring appropriate set back distances from the coast for the onshore HDD entry point.

6.4 Impact Assessment Methodology

6.4.1 Policy, Legislation and Guidance

6.4.1.1 National Policy Statements

23. The assessment of potential impacts upon marine geology, oceanography and physical processes has been made with specific reference to the relevant National Policy Statements (NPS). These are the principal decision making documents for Nationally Significant Infrastructure Projects (NSIPs). Those relevant to SEP and DEP are:

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

24. The specific assessment requirements for marine geology, oceanography and physical processes, as detailed in the NPS, are summarised in **Table 6-4** together with an indication of the section of the ES chapter where each is addressed.
25. It is noted that the NPS for Energy (EN-1) and the NPS for Renewable Energy Infrastructure (EN-3) are in the process of being revised. Draft versions were published for consultation in September 2021 (Department for Business Energy and Industrial Strategy (BEIS), 2021a and BEIS 2021b respectively). A review of these draft versions has been undertaken in the context of this ES chapter.
26. **Table 6-4** includes a section for the draft version of NPS (EN-1 and EN-3) in which relevant additional NPS requirements not presented within the current NPS (EN-1 and EN-3) have been included. A reference to the particular requirement's location within the draft NPS and to where within this ES chapter or wider ES it has been addressed has also been provided.
27. Minor wording changes within the draft version which do not materially influence the NPS (EN-1 and EN-3) requirements have not been reflected in **Table 6-4**.

Table 6-4: NPS Assessment Requirements

NPS Requirement	NPS Reference	ES Reference
NPS for Energy (EN-1)		
'where relevant, applicants should undertake coastal geomorphological and sediment transfer modelling to predict and understand impacts and help identify relevant mitigating or compensatory measures'	Section 5.5, paragraph 5.5.6	The approach adopted in this ES for all impacts apart from waves is conceptual and evidence-based using data from SOW and DOW post-construction monitoring as a suitable analogue (see **Section 6.6.3**). This was agreed in general terms through the Method Statement and Seabed ETG. Numerical modelling of waves has now been completed for potential operational impacts due to the presence of the foundation structures (**Appendix 6.2**).
'the ES should include an assessment of the effects on the coast. In particular, applicants should assess: • The impact of the proposed project on coastal processes and geomorphology, including by taking account of potential impacts from climate change. If the development will have an impact on coastal processes the applicant must demonstrate how the impacts will be managed to minimise adverse impacts on other parts of the coast	Section 5.5, paragraph 5.5.7	The assessment of potential construction and operation and maintenance impacts are described in **Section 6.6** and **Section 6.7**, respectively SEP and DEP will not affect the Shoreline Management Plan and allowance has been made for predicated erosion rates during SEP and DEP design (further detail is provided in **Chapter 3 Site Selection and Assessment of Alternatives**). Embedded mitigation to minimise potential impacts at the coast of cable

NPS Requirement	NPS Reference	ES Reference
• The implications of the proposed project on strategies for managing the coast as set out in Shoreline Management Plans (SMPs) and any relevant Marine Plans (Objective 10 of the East Inshore and East Offshore Marine Plans is "To ensure integration with other plans, and in the regulation and management of key activities and issues, in the East Marine Plans, and adjacent areas" this therefore refers back to the objectives of the SMPs)… and capital programmes for maintaining flood and coastal defences • The effects of the proposed project on marine ecology, biodiversity and protected sites • The effects of the proposed project on maintaining coastal recreation sites and features • The vulnerability of the proposed development to coastal change, taking account of climate change, during the Project's operational life and any decommissioning period'		installation and operation are described in **Section 6.3.3.** Effects on marine ecology biodiversity and protected sites are assessed in **Chapter 8 Benthic Ecology, Chapter 9 Fish and Shellfish Ecology, Chapter 10 Marine Mammal Ecology** and **Chapter 11 Offshore Ornithology**. Effects on recreation are assessed in **Chapter 19 Land Use, Agriculture and Recreation**. As described above, SEP and DEP have been designed so that they are not vulnerable to coastal change or climate change.
'the applicant should be particularly careful to identify any effects of physical changes on the integrity and special features of Marine Conservation Zones, candidate marine Special Areas of Conservation (SACs), coastal SACs and candidate coastal SACs, coastal Special Protection Areas (SPAs) and potential SCIs and Sites of Special Scientific Interest (SSSI)' [1]	Section 5.5, paragraph 5.5.9	The potential receptors to morphological change are Cromer Shoal Chalk Beds MCZ, the East Anglian coast and sandbanks. The potential to affect their integrity is assessed with respect to changes in sea bed level caused by foundation and cable installation (**Section 6.6.4.1** – **Section 6.6.4.8**) and interruption to bedload sediment transport by cable protection (**Section 6.6.5.5** and **Section 6.6.5.6**).
NPS for Renewable Energy Infrastructure (EN-3)		
'The assessment should include predictions of physical effect that will result from the construction and operation of the required infrastructure and include effects such as the scouring that may result from the proposed development'	Section 2.6, paragraph 2.6.193 and 2.6.194	Each of the impacts in **Section 6.6.5.1** – **Section 6.6.5.3** cover the potential magnitude and significance of the physical (waves, tides and sediments) effects upon the baseline conditions resulting from the construction and operation of SEP and DEP. Scour

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

NPS Requirement	NPS Reference	ES Reference
		resulting from the proposed development is not assessed because scour protection will be used wherever scour will occur, reducing sediment release to negligible quantities.
'where necessary, assessment of the effects on the subtidal environment should include: • Loss of habitat due to foundation type including associated sea bed preparation, predicted scour, scour protection and altered sedimentary processes • Environmental appraisal of inter-array and cable routes and installation methods • Habitat disturbance from construction vessels extendible legs and anchors • Increased suspended sediment loads during construction • Predicted rates at which the subtidal zone might recover from temporary effects'	Section 2.6, paragraph 2.6.113	See above for scour. The quantification and potential impact of sea bed loss due to the footprints of SEP and DEP infrastructure is covered in **Section 6.6.5.4**. A worst-case scenario of all foundations having scour protection is considered to provide a conservative assessment. The worst-case scenario cable-laying techniques are jetting, ploughing or cutting and are considered in all the cable construction assessments. The disturbance to the subtidal sea bed caused by indentations due to installation vessels is assessed in **Section 6.6.4.10.** The potential increase in suspended sediment concentrations and change in sea bed level is assessed in **Section 6.6.4.1** – **Section 6.6.4.8**. The recoverability of receptors is assessed for all the relevant impacts, particularly those related to changes in sea bed level due to export cable installation (**Section 6.6.4.6**) and morphological and sediment transport effects due to cable protection measures for export cables (**Section 6.6.5.6**).
'an assessment of the effects of installing cable across the intertidal zone should include information, where relevant, about: • Any alternative landfall sites that have been considered by the applicant during the design phase and an explanation of the final choice • Any alternative cable installation methods that have been considered by the applicant during the design phase and an explanation of the final choice • Potential loss of habitat • Disturbance during cable installation and removal (decommissioning)	Section 2.6, paragraph 2.6.81	HDD will be used to install the export cables at the landfall, with the HDD exit point located approximately 1,000m offshore. Therefore, there will be no direct impacts on the intertidal zone. Landfall Site Selection and Assessment of Alternatives are provided in **Chapter 4 Site Selection and Assessment of Alternatives** A range of cable installation methods are required, and these are detailed in **Chapter 4 Project Description**. The worst-case scenario for marine geology,

NPS Requirement	NPS Reference	ES Reference
• Increased suspended sediment loads in the intertidal zone during installation • Predicted rates at which the intertidal zone might recover from temporary effects'		oceanography and physical processes is provided in **Section 6.3.2.** Assessment of the potential disturbance and increased suspended sediment concentrations in the nearshore (including the intertidal zone) due to cable installation is provided in **Section 6.6.5.6.** The recoverability of the coastal receptor (East Anglian coast) is assessed for morphological and sediment transport effects due to cable protection measures at the coast (**Section 6.6.5.6**).
Draft Overarching NPS for Energy (EN-1) (BEIS, 2021a)		
the ES should include an assessment of the effects on the coast. In particular, applicants should assess: • how coastal change could affect flood risk management infrastructure, drainage and flood risk	Section 5.6, paragraph 5.6.7	As described above, SEP and DEP have been designed so that the Projects are not vulnerable to coastal change or climate change. Potential flood risk impacts are considered in **Chapter 18 Water Resources and Flood Risk.**
Draft NPS for Renewable Energy Infrastructure (EN-3) (BEIS, 2021b)		
Assessment of the effects on the subtidal environment should include: • environmental appraisal of inter-array and export cable routes and installation/maintenance methods, including predicted loss of habitat due to predicted scour and scour protection • impacts on protected sites (e.g. HRA sites and MCZs) • potential impacts from EMF on benthic fauna	Section 2.30, Paragraph 2.30.2	An assessment of the potential impacts of the installation and maintenance of cable infrastructure (including consideration of the potential impact of cable protection measures) is undertaken for the relevant construction and operation impacts in **Section 6.6.4** and **6.6.5** respectively. The Cromer Shoal Chalk Beds MCZ has been included as a receptor within this chapter and so potential impacts on protected sites has been considered. Also, refer to the **Stage 1 CSCB MCZ Assessment** (document reference 5.6). The topic of EMF is not relevant to marine geology, oceanography and physical processes. However, this is considered in **Chapter 9 Fish and Shellfish Ecology**.
An assessment of the effects of installing cable across the intertidal zone should follow The Crown Estate's cable route protocol and include information, where relevant, about:	Section 2.21, Paragraph 2.27.3	HDD will be used to install the export cables at the landfall, with the HDD exit point located approximately 1,000m offshore. Therefore, there will be no direct impacts on the intertidal zone.

NPS Requirement	NPS Reference	ES Reference
• disturbance during cable installation, maintenance/repairs and removal (decommissioning) • increased suspended sediment loads in the intertidal zone during installation and maintenance/repairs • Protected sites (e.g. HRA sites, MCZs and SSSIs)		Assessment of the potential disturbance and increased suspended sediment concentrations in the nearshore (including the intertidal zone) due to cable installation is provided in **Section 6.6.5.6.** Potential disturbance impacts from cable repair and maintenance are provided in **Section 6.6.5.7** and decommissioning in **Section 6.6.6**. The recoverability of the coastal receptor (East Anglian coast) is assessed for morphological and sediment transport effects due to cable protection measures at the coast (**Section 6.6.5.6**). The Cromer Shoal Chalk Beds MCZ has been included as a receptor within this chapter and so potential impacts on protected sites has been considered. Also, refer to the **Stage 1 CSCB MCZ Assessment** (document reference 5.6).

6.4.1.2 Other

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

- The Marine Policy Statement (MPS, HM Government, 2011; discussed further in **Chapter 3, Policy and Legislative Context**) provides the high-level approach to marine planning and general principles for decision making that contribute to achieving this vision. It also sets out the framework for environmental, social and economic considerations that need to be considered in marine planning. Regarding the topics covered by this chapter the key reference is in section 2.6.8.6 of the MPS which states:

  "*…Marine plan authorities should not consider development which may affect areas at high risk and probability of coastal change unless the impacts upon it can be managed. Marine plan authorities should seek to minimise and mitigate any geomorphological changes that an activity or development will have on coastal processes, including sediment movement.*"

- The MPS is also the framework for preparing individual Marine Plans and taking decisions affecting the marine environment. The Marine Plans relevant to the Project are the East Inshore and the East Offshore Marine Plans (HM Government, 2014; discussed further in **Chapter 3 Policy and Legislative Context**). Objective 6 "*To have a healthy, resilient and adaptable marine ecosystem in the East Marine Plan areas*" is of relevance to this Chapter as this covers policies and commitments on the wider ecosystem, set out in the MPS including those to do with the Marine Strategy Framework Directive and the Water Framework Directive (see **Chapter 3 Policy and Legislative Context**), as well as other environmental, social and economic considerations. Elements of the ecosystem considered by this objective include: "*coastal processes and the hydrological and geomorphological processes in water bodies and how these support ecological features".*

29. In addition to NPS, MPS and East Inshore and East Offshore Marine Plans, guidance on the generic requirements, including spatial and temporal scales, for marine physical processes studies associated with offshore wind farm developments is provided in seven main documents:
    - Offshore wind farms (OWFs): guidance note for Environmental Impact Assessment in respect of Food and Environmental Protection Act (FEPA) and Coast Protection Act (CPA) requirements: Version 2 (Cefas, 2004).
    - Coastal Process Modelling for Offshore Wind Farm Environmental Impact Assessment (Lambkin et al., 2009).
    - Review of Cabling Techniques and Environmental Effects applicable to the Offshore Wind Farm Industry (BERR, 2008).
    - General advice on assessing potential impacts of and mitigation for human activities on MCZ features, using existing regulation and legislation (JNCC and Natural England, 2011).
    - Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects (Cefas, 2011).
    - East Inshore and East Offshore Marine Plan Areas: Evidence and Issues (MMO, 2012).
    - The Crown Estate, 2019, Plan-Level Habitats Regulations Assessment for the 2017 Offshore Wind Farm Extensions, Cable Route Protocol (TCE, 2019).

30. Further detail where relevant is provided in **Chapter 2 Policy and Legislative Context**.

6.4.2 Data and Information Sources

6.4.2.1 Site Specific Surveys

31. In order to provide site-specific and up-to-date information on which to base the impact assessment, studies of sedimentary processes and geology in the Cromer Shoal Chalk Beds MCZ were completed by Royal HaskoningDHV (2020)

(**Appendix 6.3**) and Dove and Carter (2021) (**Appendix 6.4**), and specifically along the export cable corridor for the SEP and DEP.

32. A geophysical (multibeam echosounder for bathymetry, side-scan sonar for sea bed texture and sub-bottom profiling for shallow geology) survey (excluding offshore temporary works area) of the DEP wind farm site, SEP wind farm site and the interlink cable corridors was completed in March to May 2020 (Gardline, 2020a, b). The geophysical survey of the offshore export cable corridor (excluding offshore temporary works area) was completed between September and December 2019 (Gardline, 2019). A benthic survey of SEP and DEP offshore sites, which collected data on sea bed sediments and particle size, was completed between 11th and 18th August 2020 (Fugro, 2020). The results of these surveys are described in **Table 6-5** and are used to help characterise the existing environment in this chapter.

33. In April 2022, the Applicant conducted a targeted consultation exercise following the addition of an offshore temporary works area to the SEP and DEP wind farm sites and offshore cable corridors. The offshore temporary works area is shown on **Figure 6.1 to 6.4** and consists of a 750m buffer either side of the area in which the offshore export and interlink cables will be installed and a 200m buffer around the area in which wind turbines, OSPs and infield cables will be installed. Further details on the offshore temporary works area are provided in **Chapter 4 Project Description**.

34. The Applicant has committed to post consent geophysical survey coverage of the additional areas potentially required for temporary works.

Table 6-5: Site-Specific Surveys (Excluding Offshore Temporary Works Area)

Dataset	Spatial coverage	Year	Notes
Geophysical survey	DEP North array area	March to May 2020	High-resolution sea bed bathymetry, sea bed texture, morphological features and shallow geology
Geophysical survey	DEP South array area	March to May 2020	High-resolution sea bed bathymetry, sea bed texture, morphological features and shallow geology
Geophysical survey	Interlink cable corridor	March to May 2020	High-resolution sea bed bathymetry, sea bed texture, morphological features and shallow geology
Geophysical survey	SEP	March to May 2020	High-resolution sea bed bathymetry, sea bed texture, morphological features and shallow geology
Geophysical survey	Export cable corridor	September to December 2019	High-resolution sea bed bathymetry, sea bed texture, morphological features and shallow geology
Grab sample survey	DEP North array area	August 2020	16 grab samples and particle size at selected sites
Grab sample survey	DEP South array area	August 2020	11 grab samples and particle size at selected sites
Grab sample survey	Interlink cable corridor	August 2020	23 grab samples and particle size at selected sites

Dataset	Spatial coverage	Year	Notes
Grab sample survey	SEP	August 2020	17 grab samples and particle size at selected sites
Grab sample survey	Export cable corridor	August 2020	31 grab samples and particle size at selected sites

6.4.2.2 Numerical Modelling of Waves

35. To investigate waves and provide a baseline for prediction of changes due to SEP and DEP, a wave model was run. Wave conditions were simulated using the spectral model MIKE21-SW. The model simulates the growth, decay and transformation of wind-generated waves and swell in offshore and coastal areas. MIKE21-SW is a state-of-the-art numerical tool for prediction and analysis of wave climates in offshore and coastal areas (**Appendix 6.2**).

36. The wave model has been successfully calibrated against measured data recorded at waverider buoys Dudgeon 1, Dudgeon 2, and Blakeney Overfalls (data and locations are provided in **Appendix 6.2**). For each of these waverider buoys, the four biggest storm events were selected for the model calibration. The worst potential impacts in terms of wave direction are considered to be waves from the north and northeast; hence two storm events for each of these directions were selected.

6.4.2.3 Other Available Sources

37. Information to support this ES has also been drawn from a series of data collection exercises and associated studies, including desk-top assessment and numerical modelling, which were undertaken to inform the SOW and DOW ESs (HR Wallingford, 2006, 2009) (**Table 6-6**):

- collection of metocean data (wind, waves, water levels and currents) at the existing wind farms;
- a desk study to determine the existing wave, tidal and sedimentary processes within the wind farm site and surrounding sea area, along the export cable corridor and at the adjacent coast;
- an assessment of the effects on the physical environment resulting from the construction, operation and decommissioning of the existing wind farms, including the effects of the turbines foundations on waves, tidal currents and sediment transport; and
- modelling of baseline tidal currents and sediment plume dispersion during cable installation and assessment of foundation scour potential for different areas of the wind farms.

38. In addition to the site-specific surveys for SEP and DEP and the data collected for SOW and DOW, a range of other data sources is available including:

- National Tide and Sea Level Forecasting Service;
- Extreme sea levels database (Environment Agency, 2018);

- UK Hydrographic Office (UKHO) tidal diamonds;
- British Oceanographic Data Centre;
- UKCP18 (Met Office, 2018);
- Admiralty Charts and UK Hydrographic Office survey data.
- Southern North Sea Sediment Transport Study; and
- Shoreline Management Plans.

Table 6-6: Existing Data Sources used in the ES

Data source	Date	Data contents
SOW ES and associated technical supporting documents (Scira Offshore Energy)	2006	All marine geology, oceanography and physical processes information and data related to the existing offshore wind farm
SOW: Coastal and sea-bed processes (HR Wallingford)	2006	Hydrodynamic modelling of the existing offshore wind farm
DOW ES and associated technical supporting documents (Dudgeon Offshore Wind)	2009	All marine geology, oceanography and physical processes information and data, including numerical modelling, related to the existing wind farm
Post construction geophysical monitoring of SOW	2013-18	Bathymetry and sea-bed character
Post construction environmental monitoring of SOW	2012-20	Sea-bed sediment and particle size
Post construction geophysical monitoring of DOW	2018	Bathymetry and sea-bed character
Post construction environmental monitoring of DOW	2018	Sea-bed sediment and particle size
Post-construction environmental monitoring of the SOW export cables	2013-20	Sea-bed sediment

6.4.3 Impact Assessment Methodology

39. **Chapter 5 EIA Methodology** provides a summary of the general impact assessment methodology applied to SEP and DEP. The following sections confirm the methodology used to assess the potential impacts on marine geology, oceanography and physical processes.

40. The assessment of effects on tidal current and sediment transport processes are predicated on a S-P-R conceptual model, whereby the source is the initiator event, the pathway is the link between the source and the receptor impacted by the effect, and the receptor is the receiving entity. An example of the S-P-R conceptual model is provided by cable installation which disturbs sediment on the sea bed (source). This sediment is then transported by tidal currents until it settles back to the sea bed (pathway). The deposited sediment could change the composition and elevation of the sea bed (receptor). Numerical modelling of these processes effects of SEP and DEP would be disproportionate to the potential impact and a conceptual evidence-based assessment is preferred (see further details in **Section 6.6.3**). However, numerical modelling of waves has been completed for potential operational impacts due to the presence of the foundation structures (**Appendix 6.2**).

41. Consideration of the potential effects of SEP and DEP on the marine geology, oceanography and physical processes is carried out over the following spatial scales:

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

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

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

44. In addition to identifiable receptors, the second type of assessment covers changes to marine geology, oceanography and physical processes which in themselves are not necessarily impacts to which significance can be ascribed. Rather, these changes (such as a change in the wave climate, a change in the tidal regime or a change in suspended sediment concentrations) represent effects which may manifest themselves as an impact upon other receptors, most notably marine water and sediment quality, benthic ecology, and fish and shellfish ecology (e.g. in terms of increased suspended sediment concentrations, or erosion or smothering of habitats on the sea bed). Hence, the two approaches to the assessment of marine geology, oceanography and physical processes are:

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

6.4.3.1 Definitions of Sensitivity, Value and Magnitude

45. For each effect, the assessment identifies receptors sensitive to that effect and implements a systematic approach to understanding the impact pathways and the

level of impacts on given receptors. The sensitivity of a receptor is dependent upon its:

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

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

- Scale (i.e. size, extent or intensity);
- Duration;
- Frequency of occurrence; and
- Reversibility (i.e. the capability of the environment to return to a condition equivalent to the baseline after the effect ceases).

47. The sensitivity and value of discrete morphological receptors and the magnitude of effect will be assessed using evidence-based judgement and described with a standard semantic scale. The definitions of sensitivity, value and magnitude for the purpose of the marine geology, oceanography and physical processes assessment are provided in **Table 6-7, Table 6-8 and Table 6-9**, respectively. These evidence-based judgements of receptor sensitivity, value and magnitude of effect will be closely guided by the conceptual understanding of baseline conditions.

Table 6-7: Definitions of sensitivity for a morphological receptor

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

Table 6-8: Definitions of value for a morphological receptor

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

Table 6-9: Definition of magnitude for a morphological receptor

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

6.4.3.2 Impact Significance

48. In basic terms, the potential significance of an impact is a function of the sensitivity of the receptor and the magnitude of the effect (see **Chapter 5 EIA Methodology** for further details). The determination of significance is guided by the use of an impact significance matrix, as shown in **Table 6-10**. Definitions of each level of significance are provided in **Table 6-11**.

49. Potential impacts identified within the assessment as major or moderate are regarded as significant in terms of the EIA regulations. Potential impacts should be described using impact significance, followed by a statement of whether the impact significance is significant in terms of the EIA regulations, e.g. "*minor adverse impact, not significant in EIA terms / moderate adverse impact, significant in EIA terms*".

Appropriate mitigation has been identified, where possible, in consultation with the regulatory authorities and relevant stakeholders. The aim of mitigation measures is to avoid or reduce the overall impact in order to determine a residual impact upon a given receptor.

Table 6-10: Impact Significance Matrix

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

Table 6-11: Definition of Impact Significance

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

6.4.4 Cumulative Impact Assessment Methodology

50. The cumulative impact assessment (CIA) considers other plans, projects and activities that may impact cumulatively with SEP and DEP. As part of this process, the assessment considers which of the residual impacts assessed for SEP and/or DEP on their own have the potential to contribute to a cumulative impact, the data and information available to inform the cumulative assessment and the resulting confidence in any assessment that is undertaken. **Chapter 5 EIA Methodology** provides further details of the general framework and approach to the CIA.

51. For marine geology, oceanography and physical processes, these activities include construction of other OWFs and large coastal defence/ protection works.

6.4.5 Transboundary Impact Assessment Methodology

52. The transboundary assessment considers the potential for transboundary effects to occur on marine geology, oceanography and physical processes receptors as a

result of SEP and DEP; either those that might arise within the Exclusive Economic Zone (EEZ) of European Economic Area (EEA) states or arising on the interests of EEA states e.g. a non UK fishing vessel. **Chapter 5 EIA Methodology** provides further details of the general framework and approach to the assessment of transboundary effects.

53. For marine geology, oceanography and physical processes, the potential for transboundary effects were considered in the Scoping Report and it was concluded that “transboundary impacts are unlikely to occur or are unlikely to be significant” (Royal HaskoningDHV, 2019, PINS, 2019). The conclusion of the Scoping Report was accepted in the Scoping Opinion, and therefore, transboundary impacts are scoped out and are not considered further in this chapter.

6.4.6 Assumptions and Limitations

54. Due to the large amount of data that has been collected for the site-specific surveys, SOW and DOW, as well as other available data, there is a good understanding of the existing marine geology, oceanography and physical processes environment at the Project and its adjacent areas.

6.5 Existing Environment

6.5.1 Bathymetry and Bedforms

6.5.1.1 SEP and DEP

55. Water depths at the SEP and DEP wind farm sites range from 11m below Lowest Astronomical Tide (LAT) along a sand bank in the northwest of DEP South array area to 36m below LAT in the sea bed adjacent to a sand bank in the northwest of the DEP North array area (**Figure 6.1** and **Figure 6.2**) (Gardline, 2020a, b). The sea bed gradient across SEP and DEP is generally less than 1°, although gradients of greater than 10° are observed on the flanks of sand waves (Gardline, 2020 a,b).

56. Sand waves are prevalent across SEP and DEP, particularly in the northwest of DEP North array area and northwest of DEP South array area where they are associated with northwest to southeast oriented sand banks (Gardline, 2020 a,b). The largest sand waves, with crests trending northeast to southwest, reach heights of approximately 2-4m (with wavelengths of 250m), although they are more commonly 1-1.5m (Gardline, 2020 a,b).

57. Ripples trending northeast to southwest are present across SEP and DEP and are approximately 0.8m in height, with wavelengths less than 1m. Further minor ripples (less than 0.5m high) are found sporadically across the surveyed areas (Gardline, 2020 a,b).

6.5.1.2 Interlink Cable Corridors

58. Water depths along the interlink cable corridors are between 10m below LAT and 35m below LAT (**Figure 6.3**) (Gardline, 2020b). The sea bed gradient is generally less than 1° along the routes, although gradients reach greater than 10° on the flanks of megaripples (Gardline, 2020b). The bathymetry shallows moving northwest along the interlink corridor between the DEP South and DEP North array areas from approximately 23-24m below LAT to 11-13m below LAT (DOW, 2009).

59. Sand waves oriented northeast to southwest are found predominantly at the northern ends of the SEP to DEP North array area, and DEP North array area to DEP South array area interlink cable corridors, and at the northwestern end of the DEP South array area to DEP North array area interlink cable corridor reaching heights of up to 3m (Gardline, 2020b) (see **Figure 4.9** of **Chapter 4 Project Description**). Minor ripples less than 0.5m high are present along all interlink cable routes (Gardline, 2020b).

6.5.1.3 Export Cable Corridor

60. Water depths within the offshore portion of the export cable corridor, in the region of the SEP wind farm site, are typically 25-27m below LAT (**Figure 6.4**). Water depths decrease progressively to 0m LAT at the coast (Gardline, 2019). The 5m below LAT contour is typically 200-300m from the coast (Gardline, 2019).

61. Superimposed on the general reduction in water depth shoreward is the eastern tip of Sheringham Shoal sand bank, where the bathymetry shallows to about 16m below LAT (Gardline, 2019). Secondary bedforms within the export cable corridor include areas of megaripples (including the flanks of the sand bank) up to 0.5m high with crests typically oriented north-south or north-northeast to south-southwest (Gardline, 2019).

62. The export cable corridor passes through the Cromer Shoal Chalk Beds MCZ. Three geophysical surveys completed across the MCZ for Cefas between 2012 and 2014 provide a general bathymetric overview (**Appendix 6.3**) (Royal HaskoningDHV, 2020). **Appendix 6.3** includes information relevant to an offshore export cable corridor making landfall near Bacton. However, since the report was produced the Weybourne landfall option has been selected as described in **Chapter 3 Site Selection and Assessment of Alternatives.** The bathymetry slopes seaward from about 5m below LAT close to the coast to about 20m below LAT at its seaward boundary (**Figure 6.4**). Details of how variations in bathymetry relate to the underlying geology, sea bed sediment distribution and bedload sediment transport are provided in **Sections 6.5.7.6** and **6.5.8.1**.

6.5.2 Offshore geology

63. The geology of SEP and DEP generally consists of Holocene deposits overlying a series of Pleistocene sands and clays, with a bedrock of Upper Cretaceous Chalk (**Table 6-12**).

Table 6-12: Geological formations present at SEP and DEP, interlink cable corridor and export cable corridor (Gardline, 2020a,b; British Geological Survey, 2020)

Formation	Geophysical description	Expected geological conditions
Botney Cut Formation	Five units varying from chaotic to conformable acoustic facies.	Sand-rich or organic-rich sandy mud channel infills, glaciolacustrine laminated silt and sandy clay, and glaciofluvial sand
Bolders Bank Formation	Three units, typically with a chaotic acoustic character.	Sub-glacial diamicton composed of firm to very stiff clay.
Egmond Ground Formation	Acoustically raised amplitude well layered even reflectors.	Very dense fine sand

Formation	Geophysical description	Expected geological conditions
Sand Hole or Upper Swarte Bank Formation	Two units. Upper unit with conformably-banded horizons with some prograding strata. Lower unit of disturbed conformable reflectors.	Basinal, quiescent (clay-rich) sedimentation (lower unit) and sand-rich deposition (upper unit)
Swarte Bank Formation	Five units of acoustically chaotic/massive reflectors.	Sub-glacial diamicton composed of hard clay with occasional chalk, gravel and flint
Cretaceous Chalk	Acoustically high amplitude very well layered broadly undulating reflections.	Weak to moderately weak low to medium density chalk

6.5.2.1 SEP

64. The bedrock under SEP is dominated by Upper Cretaceous Chalk, the top of which lies in excess of 180m below the sea bed and as shallow as 3m below the sea bed at the far southeast fringes of the site where the Botney Cut Formation rests directly on the chalk (Gardline, 2020b).The Chalk is incised by large channels filled with Swarte Bank Formation (**Plate 6.1**). The base of the largest channel is 180m below the sea bed in the west of the site.

65. The Bolders Bank Formation overlies the Swarte Bank Formation as a blanket deposit across most of the site, although it is frequently cut by Botney Cut Formation in channels. These channels are oriented northeast to southwest and are up to 70m below the sea bed at their bases (Gardline, 2020b).

66. The Holocene sediments are generally up to 1.5m thick, but sand banks are present in the southeast and northwest of the site (Gardline, 2020b).

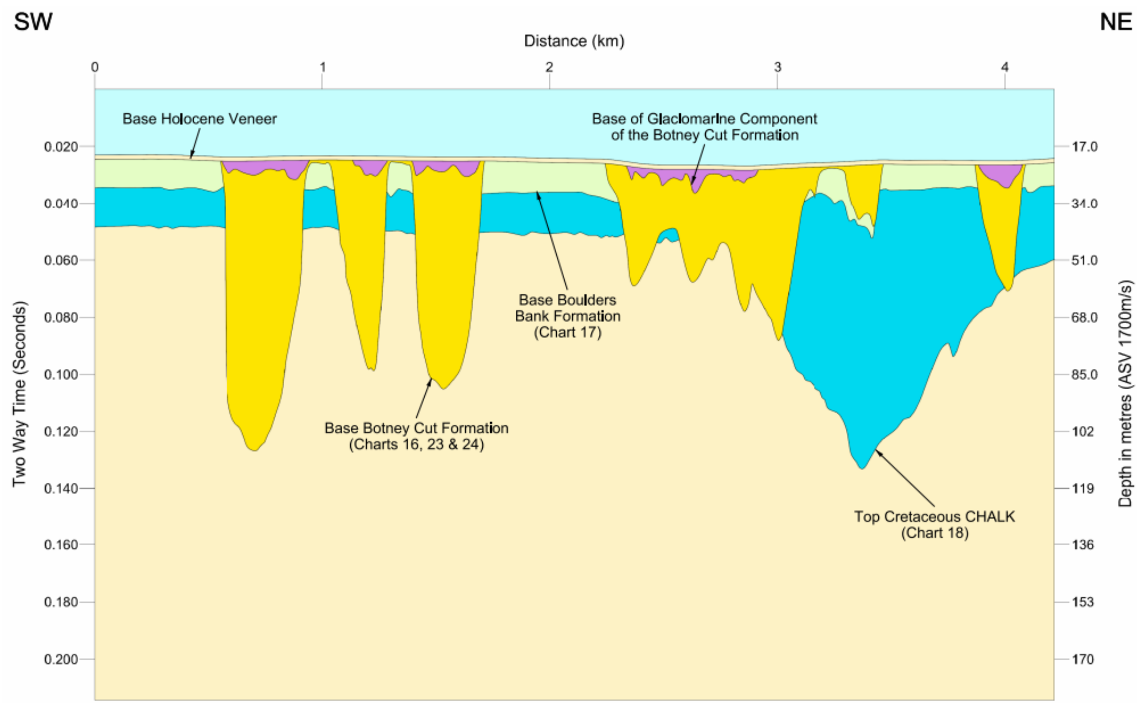

Plate 6.1: Schematic of the shallow geology of SEP (Gardline, 2020b)

6.5.2.2 DEP North Array Area

67. The bedrock across the DEP North array area is dominated by Cretaceous Chalk. The top of the formation is between 4m and 80m below the sea bed (Gardline, 2020a). The chalk is incised by large northwest to southeast oriented channels which are infilled by the Swarte Bank Formation.

68. A blanket deposit of the Egmond Ground Formation overlies the Swarte Bank Formation (**Plate 6.2**). However, this is extensively incised by channelling and infilling with Botney Cut Formation and Bolders Bank Formation. Bolders Bank Formation overlies the Egmond Ground Formation although much has been removed by Botney Cut channelling (Gardline, 2020a). A significant Botney Cut channel incises the underlying units through to the Chalk at approximately 80m below LAT in the southeast of the site.

69. Holocene deposits are present up to 9m below the sea bed overlying the Botney Cut Formation and in places, the Bolders Bank Formation (Gardline, 2020a). In localised areas, pockets of underlying formations are exposed where Holocene sands are absent (Gardline, 2020a).

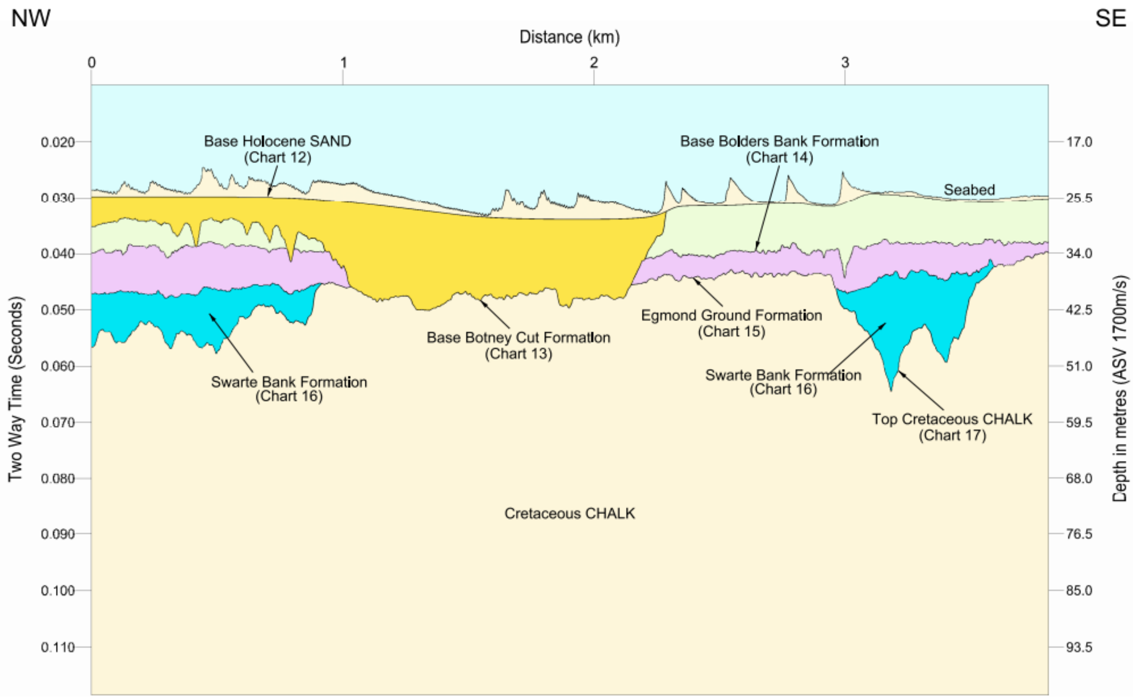

Plate 6.2: Schematic of the shallow geology of the DEP North array area (Gardline, 2020a)

6.5.2.3 DEP South Array Area

70. The underlying bedrock in the DEP South array area is dominated by Upper Cretaceous Chalk, the top of which is typically in excess of 50m below the sea bed to within 13m of the sea bed in the east and far northwest (Gardline, 2020a). The Chalk is extensively faulted, although vertical displacement rarely exceeds 10m.

71. The chalk is overlain by the Swarte Bank Formation across most of the site, except in the northeast where it has been removed by channelling and infilled with Botney Cut Formation (**Plate 6.3**). In the northwest, the chalk is incised by a large channel down to 200m below the sea bed infilled with Swarte Bank Formation. The Swarte Bank Formation is overlain by a thin layer of Egmond Ground Formation, thickening in the east and west and absent through the centre of the site. The Bolders Bank Formation, up to 8m thick, forms a blanket deposit across almost the entire site and is only absent where Botney Cut Formation is present in channels (Gardline, 2020a). A prominent channel filled with Botney Cut Formation is present in the west of the site, extending up to 18m below the sea bed along the channel thalweg (Gardline, 2020a).

72. The Holocene sediment is composed of loose fine to medium sand with shell fragments and is up to 11m thick. The mobile sea bed sediments include a 4m-thick sand bank in the northwest of the site.

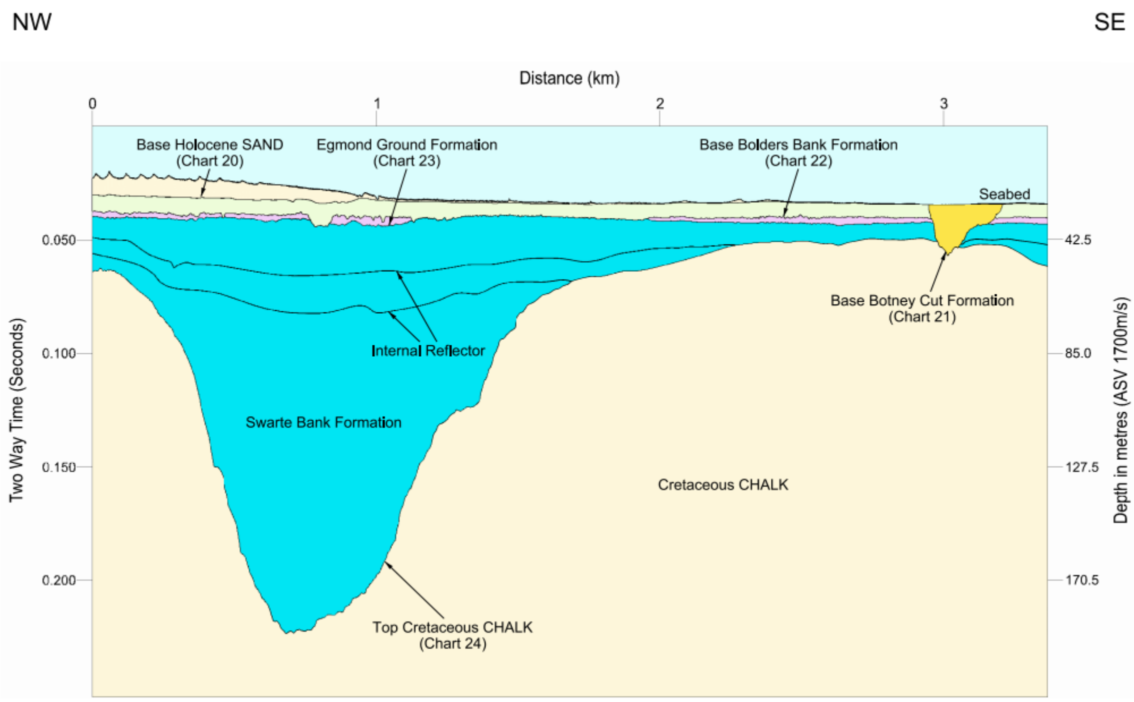

Plate 6.3: Schematic of the shallow geology of DEP South array area (Gardline, 2020a)

6.5.2.4 Interlink Cable Corridor

6.5.2.4.1 SEP or DEP North Array Area

73. Progressing north-northeast from SEP towards the DEP North array area, the underlying geology exhibits Bolders Bank Formation up to 10m thick along the majority of the route. This is cut by Botney Cut Formation channels in places (Gardline, 2020b). A large Botney Cut channel infill oriented northeast to southwest is located beneath the Holocene veneer at approximately 16km from SEP (Gardline,

2020b). The Holocene veneer thickens rapidly at 16km (reaching up to 7m), forming a sand bank with superimposed sand waves up to 3m high (Gardline, 2020b).

74. At the DEP North array area end of the cable corridor, the Botney Cut Formation is up to 30m thick and overlain by a thin (1m) deposit of Holocene sediment (Gardline, 2020b).

6.5.2.4.2 SEP or DEP South Array Area

75. Progressing northeast from SEP towards DEP South array area, conditions are similar to that seen along the SEP to DEP North array area route; a thin veneer of Holocene sediment overlies the Bolders Bank Formation, which is intermittently cut by Botney Cut Formation channels (Gardline, 2020b).

76. At approximately 11km from SEP, a high-standing feature composed of a well layered sequence of sediments with a flat base is observed. This has been interpreted as the Botney Cut Formation (Gardline, 2020b).

6.5.2.4.3 DEP North Array Area to DEP South Array Area

77. Progressing northeast from DEP South array area to DEP North array area, Holocene sands overlie the Bolders Bank Formation. A minor channel is observed incising into the underlying Bolders Bank Formation infilled with the Botney Cut Formation. In the central survey area, the Bolders Bank Formation is underlain by a sub-crop of the Upper Chalk Formation, whilst in other survey areas it is underlain by the Egmond Ground Formation (Gardline, 2007).

6.5.2.5 Export Cable Corridor

78. The bedrock along the export cable corridor is dominated by Upper Cretaceous Chalk (Cameron *et al*., 1992; Gardline, 2019; Dove and Carter, 2021). Along most of the southern part of the corridor to south of Sheringham Shoal sand bank, the chalk is either exposed at the sea bed (within the landward 500m of the corridor) or sub-cropping beneath alternating zones of thin gravelly sand/gravel and Holocene sand.

79. About 1-2km from the coast, the chalk is dissected by a deep infilled channel cut through the chalk to -17m LAT filled with Weybourne Channel deposits (**Plate 6.4**). These are likely to be a mix of older sand and gravel overlain by laminated silts and sands (Chroston *et al*., 1999).

80. From south of Sheringham Shoal sand bank to the SEP wind farm site, the geology is dominated by Pleistocene Botney Cut Formation (and some Swarte Bank Formation) overlying chalk. Where the Botney Cut and Swarte Bank Formations are absent the chalk sub-crops at the sea bed beneath a thin unit of sand and gravel. About 10km from the coast, the Pleistocene units are overlain by the Sheringham Shoal sand bank (and associated megaripples), which is up to 6m thick along the cable corridor.

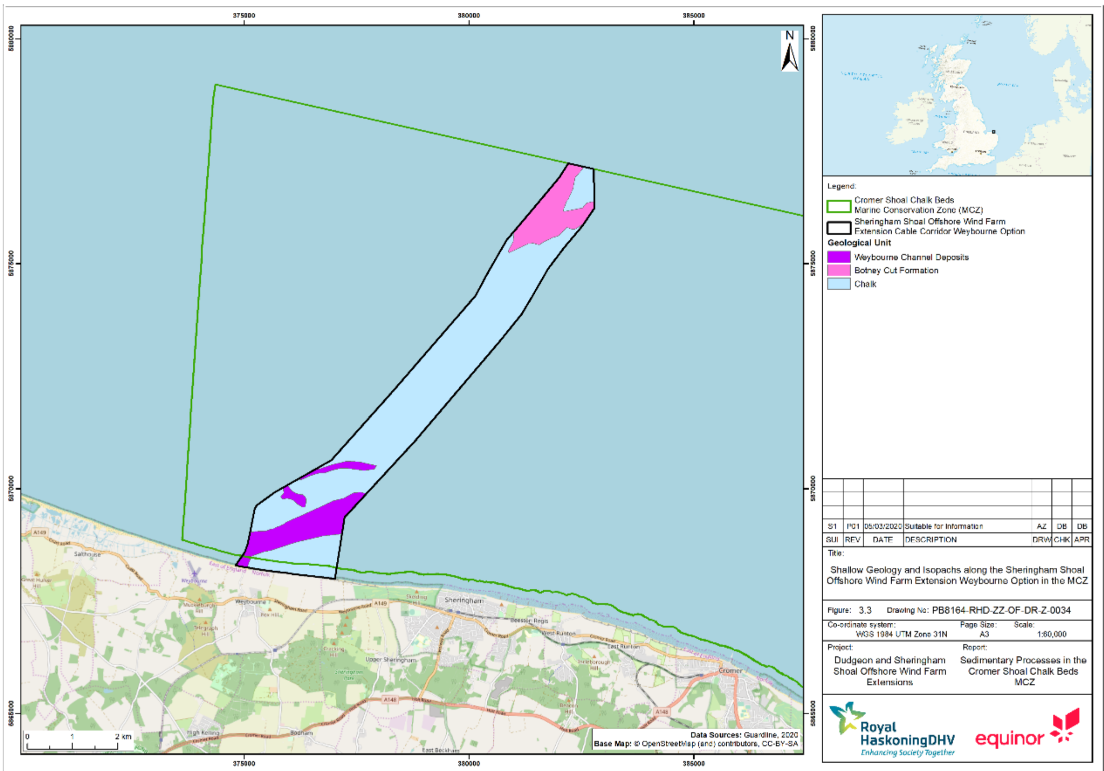

Plate 6.4: Shallow geology of export cable corridor in the Cromer Shoal Chalk Beds MCZ showing the location of the Weybourne Channel deposits (Royal HaskoningDHV, 2020)

6.5.2.6 Cromer Shoal Chalk Beds MCZ

81. The export cable corridor passes through the western end of the Cromer Shoal Chalk Beds MCZ. It extends about 10km offshore and covers an area of about 321km^2 (Royal HaskoningDHV, 2020). The bedrock geology across the MCZ is dominated by chalk which is around 400m thick across the site (Cameron *et al.*, 1992). In the western part of the MCZ close to the landfall, subtidal chalk is exposed at the sea bed close to the intertidal zone, extending further offshore in the southeast portion of the site (Royal HaskoningDHV, 2020).

82. The sea bed and the shallow sediment layers beneath the sea bed of the Cromer Shoal Chalk Beds MCZ in the vicinity of the proposed cable corridor are characterised geologically and geomorphologically in several different ways (Royal HaskoningDHV, 2020; Dove and Carter, 2021). These are:

- Outcropping chalk at the sea bed with no overlying sediment;
- Subcropping chalk covered by a thin lag of coarse sand and gravel;
- Pleistocene glacial sediments covered by a thin lag of coarse sand and gravel;
- Chalk (or chalk with lag) overlain by Holocene sand; and
- Pleistocene glacial sediments overlain by Holocene sand.

83. The Cromer Shoal Chalk Beds MCZ encompasses important sea bed geological features including the best examples of subtidal chalk beds in the North Sea (Royal

HaskoningDHV, 2020). The shallow inshore part of the MCZ out to 10m water depth features infralittoral rock which extends for almost the entire length of the site. This area of hard, stable substrate provides a suitable habitat for attached and mobile epifauna. Extending offshore from the infralittoral rock into deeper water is a band of circalittoral rock with more epifauna. The areas of infralittoral and circalittoral rock in the MCZ are comprised of subtidal chalk, as well as other rock types. It is not possible to accurately differentiate between different types of rock using geophysical data, and so areas mapped as the subtidal chalk are likely to overlap with areas mapped as circalittoral and infralittoral rock.

84. Spray and Watson (2011) reported the results of 111 dives to the nearshore sea bed between Cley and Trimingham. Chalk was encountered on every dive with no dives recording only sand or sediment. The exposed chalk has a variety of characters with a continuum from low, irregular plains with scattered flints, through mounded chalk to a rugged sea bed with 1-2m-deep gullies (with partial sediment infill) and ridges, pinnacles and arches. This indicates that where the chalk outcrops at the sea bed it is complex and displays micro-variations in bathymetry (over distances of metres) (Royal HaskoningDHV, 2020).

6.5.2.7 Landfall

85. The coast of north to northeast Norfolk to the east of the landfall is an almost continuous line of glacial till cliffs with a short length of chalk cliffs at Weybourne. The cliffs are fronted by a steep shingle beach. To the west, the cliffs disappear and are replaced by areas of lower ground at Weybourne Gap and Kelling Hard. The beach is formed into a shingle ridge fronting a low-lying coastal fringe with tidal inlets and saltmarsh.

6.5.3 Water levels

6.5.3.1 Regional summary

86. The astronomical tidal range in the southern North Sea and along the East Anglian coast varies according to the position of an amphidromic point between East Anglia and the Netherlands. At the amphidromic point, the tidal range is near zero and then increases with radial distance from this point. Due to the regional tidal regime being influenced by the amphidromic point, the tidal range gradually increases with progression west across the study area (**Figure 6.5**).

6.5.3.2 SEP

87. SEP is in an area subject to a macrotidal regime, with a mean spring tidal range varying from about 4.0m at its eastern boundary to 4.6m at its western boundary.

6.5.3.3 DEP North Array Area

88. The DEP North array area experiences a macrotidal regime with a mean spring tidal range (difference in water levels between mean high water spring (MHWS) and mean low water spring (MLWS)) of about 3.7m at its eastern boundary and 4.1m at its western boundary.

6.5.3.4 DEP South Array Area

89. The mean spring tidal range at DEP South array area ranges from about 3.5m at its eastern boundary to about 3.7m at its western boundary.

6.5.3.5 Interlink Cable Corridor

90. The interlink cable corridors experience a mean spring tidal range of about 3.7m to 4.2m.

6.5.3.6 Export Cable Corridor

91. Along the export cable corridor, the tidal range is about 4.0m at its northern end increasing to about 4.7m at the landfall.

6.5.3.7 Cromer Shoal Chalk Beds MCZ

92. The Cromer Shoal Chalk Beds MCZ begins about 200m offshore from the north Norfolk coast with a western boundary just west of Weybourne and an eastern boundary at Happisburgh. This means the tidal range varies from about 3.0m towards its eastern end to about 4.5m towards its western end.

6.5.3.8 Storm Surge

93. The North Sea is particularly susceptible to storm surges, and water levels at SEP and DEP could become elevated several metres by these meteorological effects. The coast can also be subject to significant surge activity which may raise water levels above those of the predicted tide. Predicted extreme water levels can exceed predicted mean high-water spring levels by more than 1m. Environment Agency (2018) calculated one in one-year water levels of 3.15m above MHWS at Weybourne. The 1 in 50-year water levels are predicted to be 4.13m above MHWS at Weybourne.

6.5.4 Tidal Currents

94. SEP and DEP is located adjacent to the existing SOW and DOW. Measured and modelled hydrodynamic data exist for these operational assets and are used here to support the tidal current baseline for SEP and DEP.

6.5.4.1 Regional summary

95. Regional tidal current velocity and direction are influenced by the presence of the amphidromic point (**Section 6.5.3**) and the anti-clockwise circulation around it. HR Wallingford *et al*. 2002a developed a regional tidal flow model (using TELEMAC), which was used to predict tidal current vectors in the southern North Sea. The model predicted regional spring tide flows closer to the north Norfolk coast that are approximately parallel to the coast turning towards west-northwest (flood tide) and east-southeast (ebb tide) close to SEP and DEP and then northwest and southeast further offshore. Predicted offshore current velocities are around 1m/s reducing to about 0.7m/s closer to the coast.

96. DOW (2009) used the regional TELEMAC model (HR Wallingford *et al*., 2002a), validated against local Acoustic Wave and Current Meter (AWAC) data and information from Admiralty Chart tidal diamonds, to simulate tidal currents at and adjacent to DOW. The simulated data covers the southern area occupied by the DEP North array area, the majority of the area occupied by the DEP South array area and the eastern half of the area occupied by the interlink cable corridor.

97. The predicted peak flood flow and peak ebb flow vectors for spring tides at DOW are shown in **Plate 6.5** and **Plate 6.6**, respectively. Predicted peak flood flow and peak ebb flow vectors for neap tides at DOW are shown in **Plate 6.7** and **Plate 6.8** respectively.

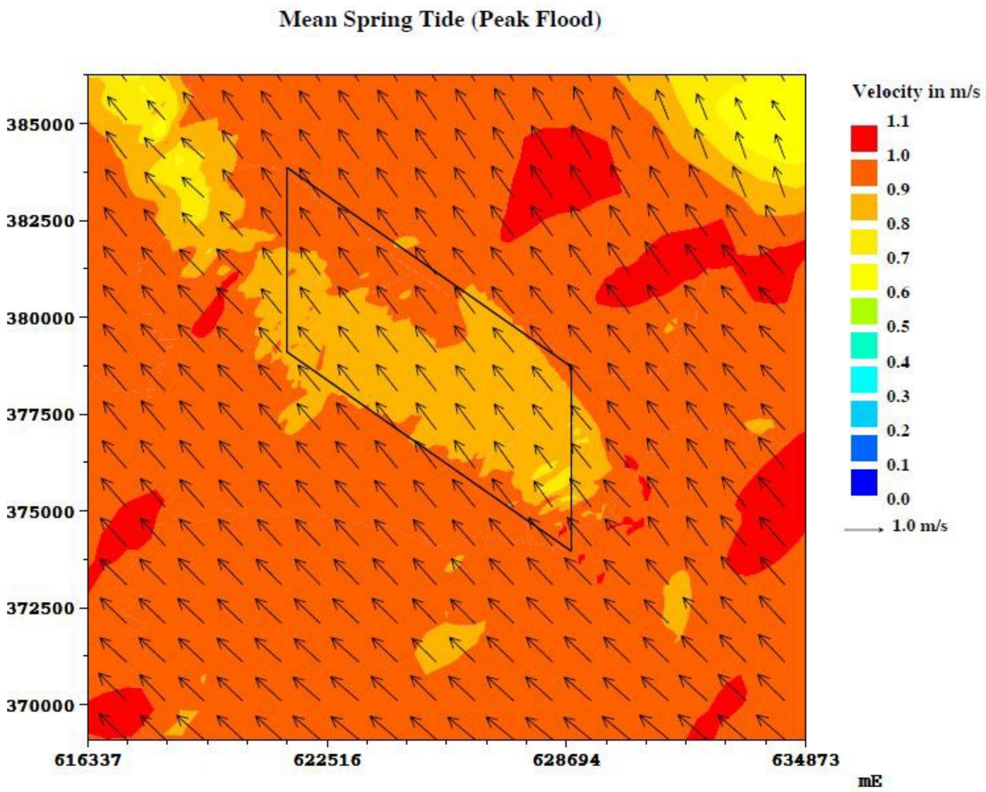

Plate 6.5: Peak flood flow vector for spring tide at DOW (DOW, 2009).

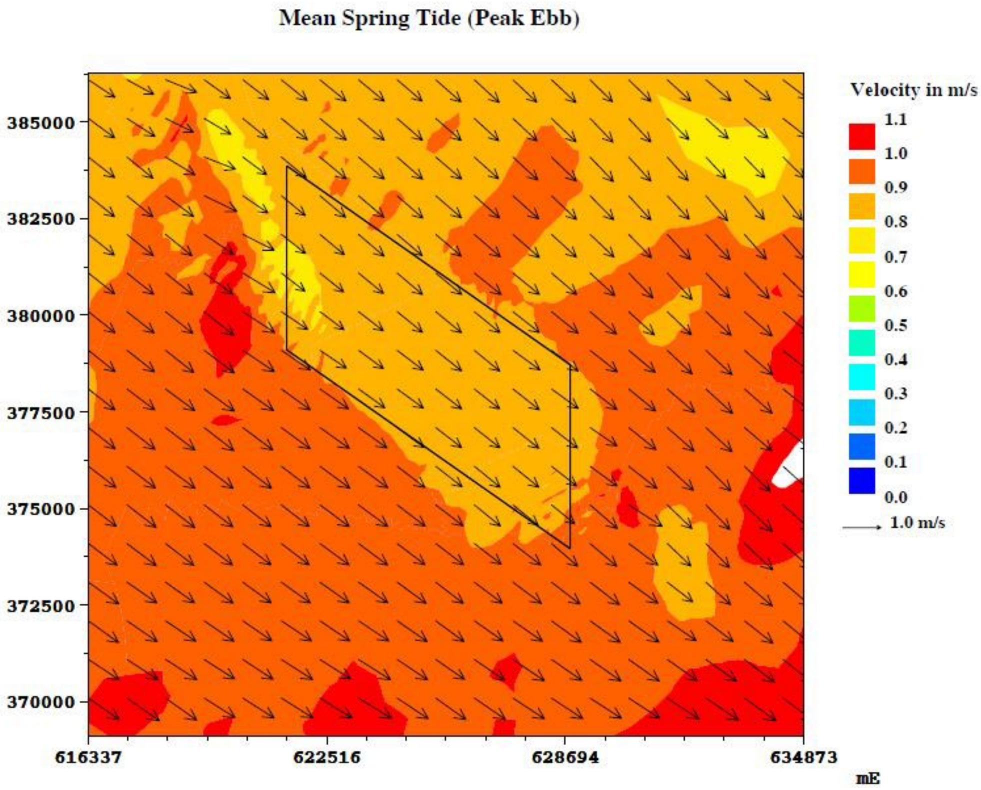

Plate 6.6: Peak ebb flow vector for spring tide at DOW (DOW, 2009).

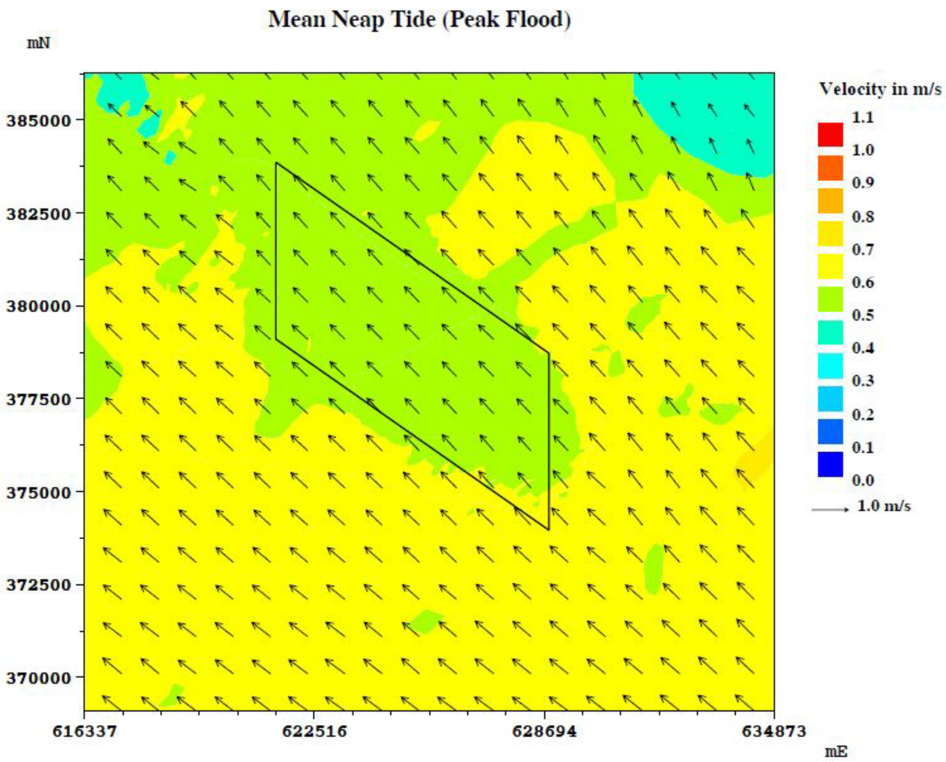

Plate 6.7: Peak flood flow vector for neap tide at DOW (DOW, 2009)

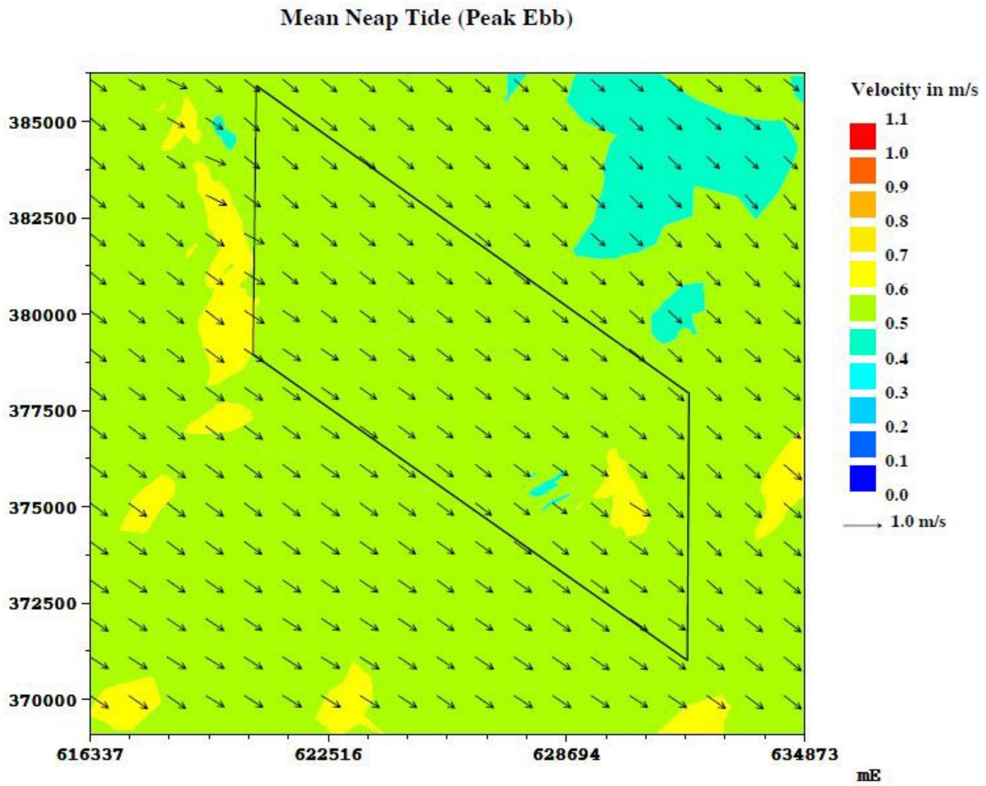

Plate 6.8: Peak ebb flow vector for neap tide at DOW (DOW, 2009)

98. Scira (2006) used the regional TELEMAC model (HR Wallingford *et al*., 2002a), validated against local AWAC data and information from Admiralty Chart tidal diamonds, to simulate tidal currents at and adjacent to SOW. The predicted peak flood flow and peak ebb flow vectors for spring tides are shown in **Plate 6.9** and **Plate 6.10**, respectively. Predicted peak flood flow and peak ebb flow vectors for neap tides are shown in **Plate 6.11** and **Plate 6.12**, respectively. The simulated data covers the area occupied by SEP and also covers the area between the SEP and DEP wind farm sites and the coast.

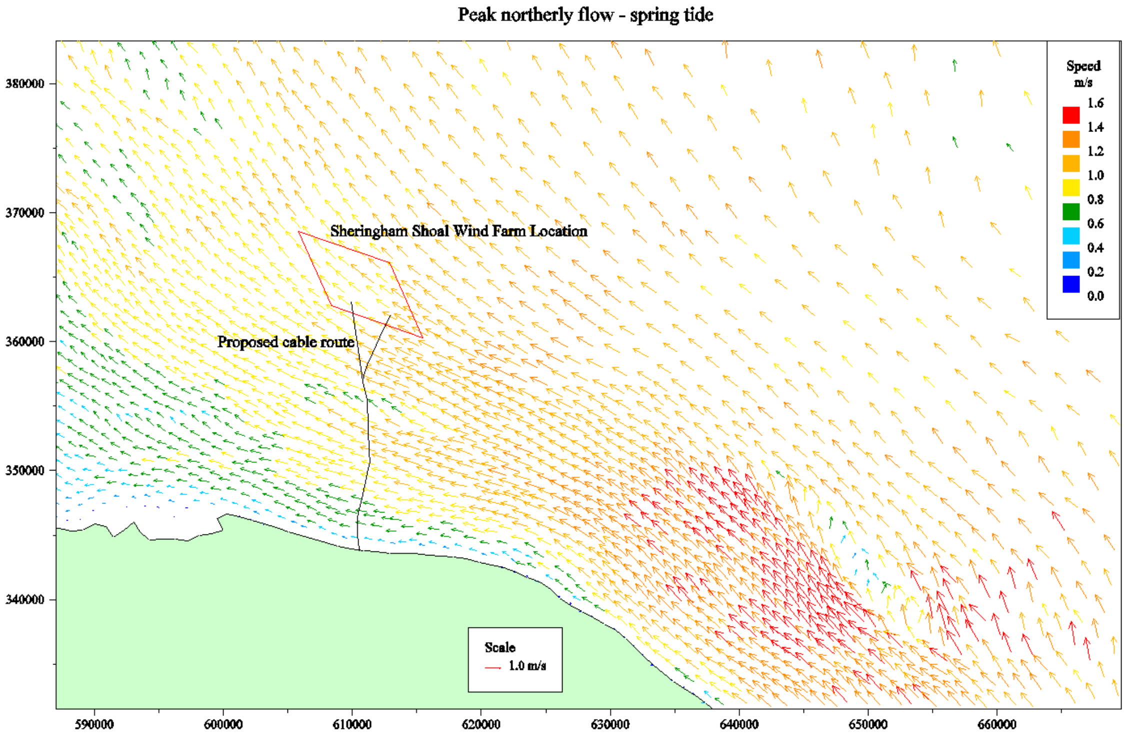

Plate 6.9: Peak flood flow vector for spring tide at SOW (Scira, 2006)

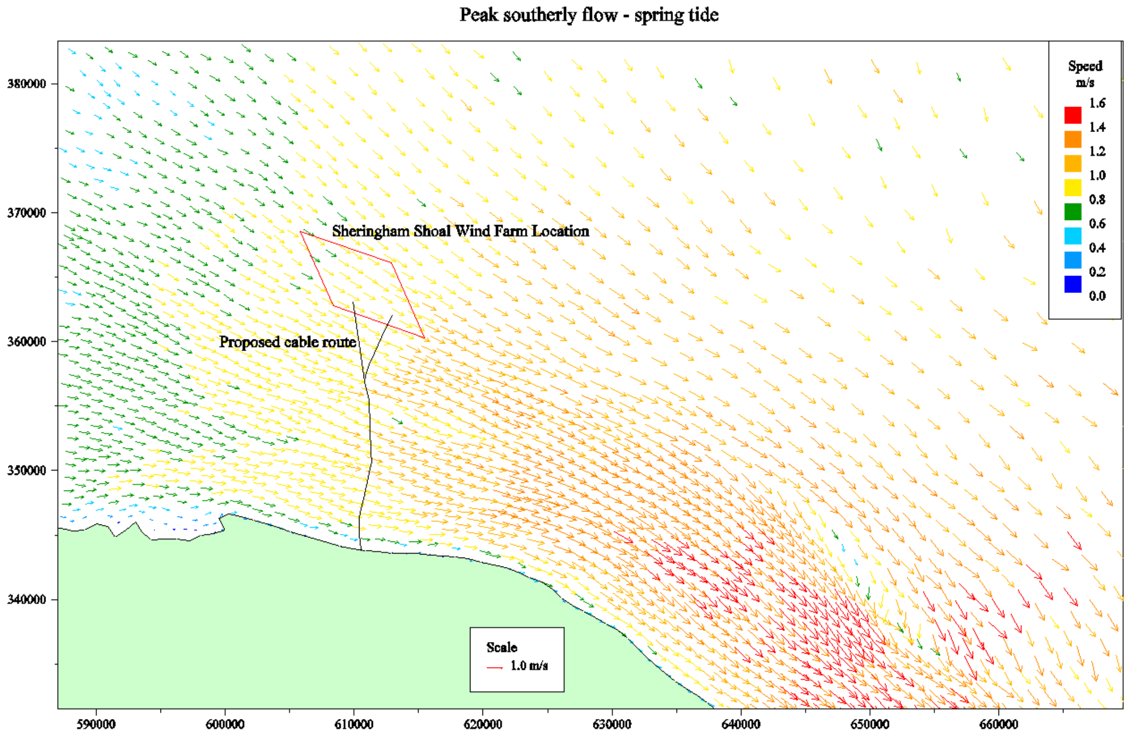

Plate 6.10: Peak ebb flow vector for spring tide at SOW (Scira, 2006)

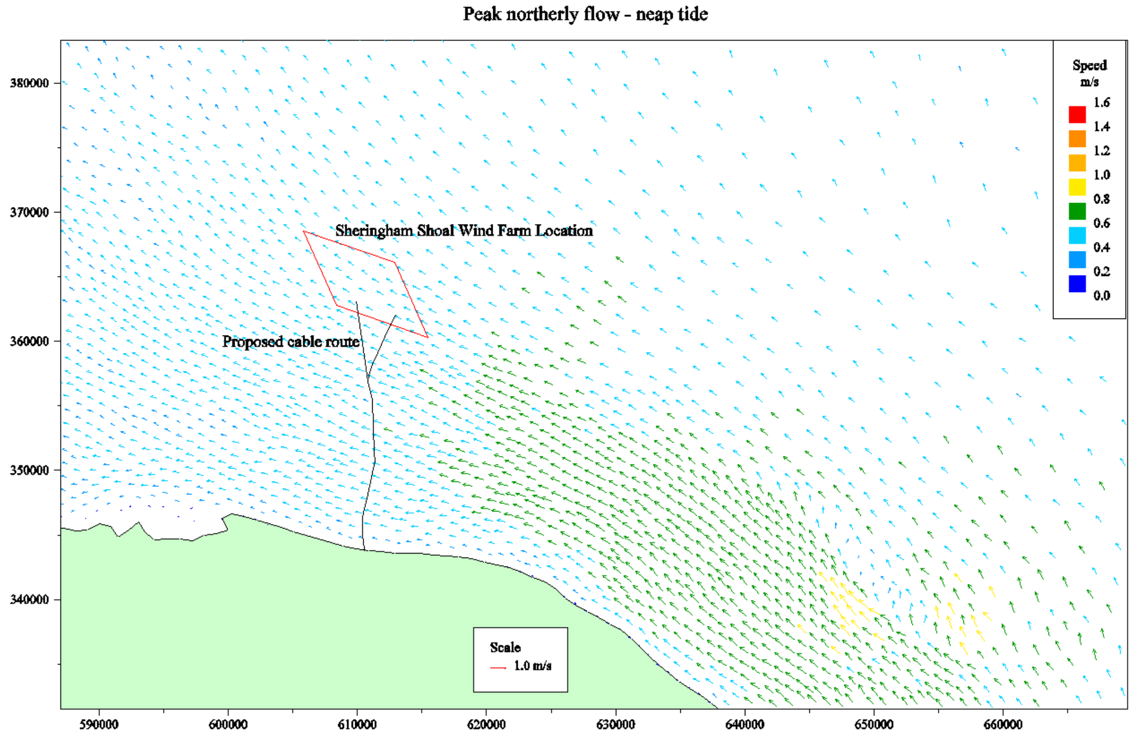

Plate 6.11: Peak flood flow vector for neap tide at SOW (Scira, 2006)

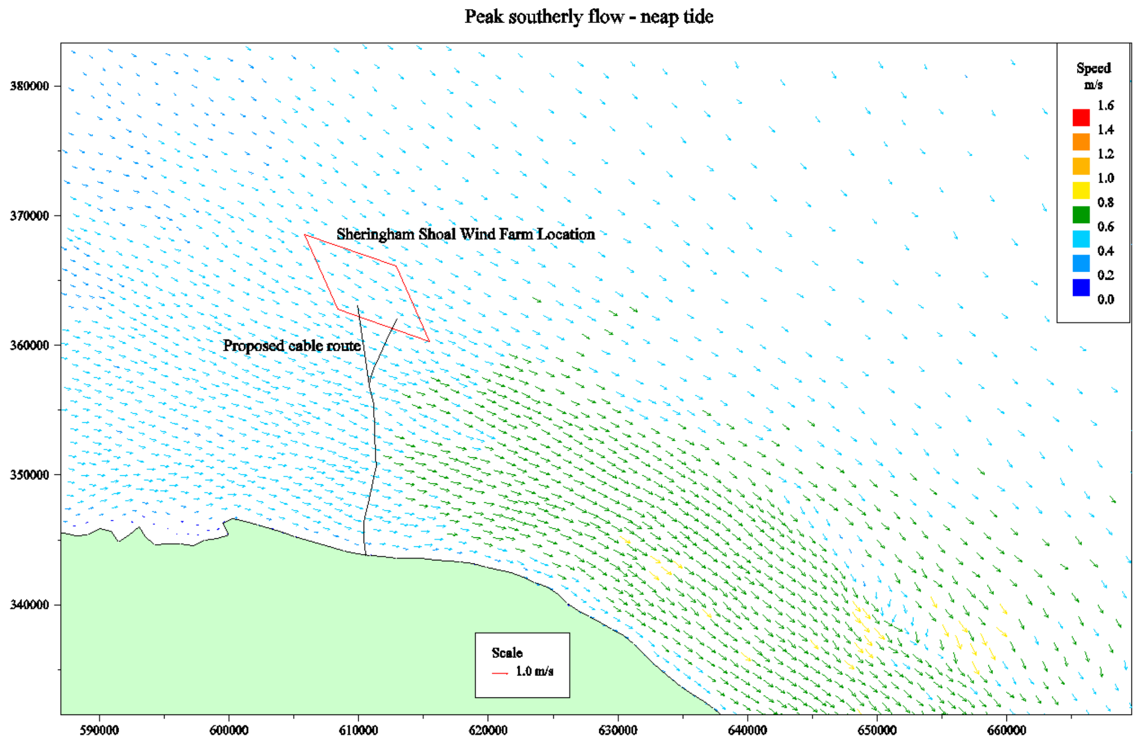

Plate 6.12: Peak ebb flow vector for neap tide at SOW (Scira, 2006)

6.5.4.2 SEP

99. The spring tide peak flows across the SEP wind farm site are predicted to be between 0.8m/s and 1.2m/s to the northwest on a flood tide and between 0.6m/s

and 1.2m/s to the southeast on an ebb tide. Peak neap tide flows are predicted to be about 0.4-0.6m/s on both flood and ebb tides.

6.5.4.3 DEP North Array Area

100. The spring tide peak flows across the DEP North array area are predicted to be between 0.6m/s and 1.0m/s to the northwest on a flood tide and between 0.8m/s and 1.1m/s to the southeast on an ebb tide. Peak neap tide flows are predicted to be about 0.4-0.7m/s on both flood and ebb tides.

6.5.4.4 DEP South Array Area

101. Peak spring tide flows across the DEP South array area are predicted to be about 0.8-1.1m/s on both flood and ebb tides and peak neap tide flows are predicted to be about 0.5-0.7m/s on both flood and ebb tides.

6.5.4.5 Interlink Cable Corridors

102. Peak spring tide flows across the interlink cable corridors are predicted to be about 0.7-1.1m/s on both flood and ebb tides and peak neap tide flows are predicted to be about 0.5-0.7m/s on both flood and ebb tides.

6.5.4.6 Export Cable Corridor

103. Along most of the export cable corridor, the spring tide peak current flows are predicted to be 0.8-1.2m/s on both flood and ebb tides. Currents are directed west-northwest on a flood tide and east-southeast on an ebb tide. Neap tide peak current flows are predicted to be 0.4-0.8m/s on both flood and ebb tides. Within 1km of the coast the predicted spring tidal current flows reduce to less than 0.6m/s and re-orient to westerly on a flood tide and easterly on an ebb tide (coast-parallel).

6.5.5 Waves

6.5.5.1 Regional summary

104. The regional wave climate is composed of a combination of swell waves generated offshore and locally generated wind-waves. Waves from the southwest through northwest with relatively low heights (less than 1m) are most frequent followed by higher waves from the northwest to northeast sector. Offshore waves above 4m are relatively common during winter storms.

105. The wave regimes at the SEP and DEP wind farm sites are informed through a desk study undertaken for SOW (Scira, 2006) and relevant data sources from previous studies (e.g. HR Wallingford, 1988, 1990, 2002a, 2002b, 2004) at DOW.

6.5.5.2 SEP

106. SEP is exposed to wave conditions generated within the North Sea, with the most severe conditions arriving from the north and northeast due to fetch lengths of over 500km. Significant wave heights greater than 1m are generated from these directions. The most frequent waves are driven by winds blowing over the much

shorter fetches from the southwest to northwest sector. Significant wave heights are relatively small (generally less than 1m).

6.5.5.3 DEP North and DEP South Array Areas

107. DEP North and DEP South array areas are exposed to waves generated across the North Sea but modified by the numerous sand banks present in the Greater Wash SPA area. The most frequent waves are driven by winds from the south and west. However, fetch lengths between the coast and the DEP North (38.6m) and DEP South array areas (30.4m) are short, resulting in small waves with maximum significant wave heights of about 2m (DOW, 2009). The largest waves experienced at the DEP North and DEP South array areas are from the northwest to northeast sector, however, these waves are less frequent.

6.5.5.4 Interlink Cable Corridors

108. The interlink cable corridors are located between the DEP North and DEP South array areas, DEP North array area and SEP, and DEP South array area and SEP. The baseline wave regime is similar to those outlined above.

6.5.5.5 Export Cable Corridor

109. Nearshore wave conditions along the offshore export cable corridor are less severe than the SEP and DEP wind farm sites due to the protection afforded by sand banks such as Sheringham Shoal and Pollard Bank. This influence is most apparent at low tide when the shallower water depths over Sheringham Shoal cause significant wave breaking, and a reduction in wave heights from the seaward to landward side of the bank. The other banks and the generally shallower water west from the SEP wind farm site also influence wave directions closer to the coast due to refraction. These effects will vary in intensity with wave direction and nearshore location.

6.5.6 Climate Change and Sea-level Rise

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

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

112. The rate of global mean sea-level rise during the 21st century is likely to exceed the rate observed between 1993 and 2010. Church *et al*. (2013) developed projections of global sea-level rise for four emissions scenarios of future climate change, called

the Representative Concentration Pathways (RCP). In this analysis, the median projection of the worst-case emissions scenario (RCP8.5) is used. For RCP8.5, the rise by 2100 is 0.74m (range 0.52 to 0.98m) with a predicted sea-level rise rate during 2081–2100 of 8 to 16mm/year.

113. As the indicative design life of SEP and DEP is 40 years, and offshore infrastructure is set far enough away from the coast, this rise in sea level will not change significantly through the design life of the project.

114. With respect to waves, climate projections indicate that wave heights in the southern North Sea will only increase by between 0m and 0.05m by 2100. There is predicted to be an insignificant effect on storm surges over the lifetime of SEP and DEP (Lowe *et al*., 2009).

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

6.5.7 Sea-bed Sediment Distribution

6.5.7.1 Regional summary

116. The regional sea bed and coast have been strongly influenced by deposition of sediment during the Pleistocene and Holocene periods (**Section 6.5.2**). Large quantities of sediment were deposited on the underlying chalk by retreating glaciers and associated rivers. The sediment was reworked by fluvial processes while sea level was low, and then by waves and currents during the Holocene (last 10,000 years) rise in sea level and up to the present day creating numerous bedforms including megaripples, sand waves and sand banks.

117. A site-specific grab sampling campaign (particle size analysis (PSA) and macrofaunal sampling) at 75 locations across the SEP and DEP wind farm sites was completed by Fugro from 11th to 18th August 2020. Samples were recovered from the following areas (**Figure 6.6**):

- SEP (17 sample locations); and
- DEP (13 sample locations in the DEP North array area and 8 sample locations in DEP South array area).

118. Interlink cable corridors (10 sample locations from the part of the interlink cable corridor between DEP North array area and SEP and 9 sample locations from the part of the interlink cable corridor between DEP South array area and SEP):

- Export cable corridor (18 sample locations[2]. There were seven sample location within the Cromer Shoal Chalk Beds MCZ).

[2] Note that at five sample locations (EC_03, EC_04, EC_18, EC_24 and EC_25), no macrofaunal samples were acquired due to repeat failure of the grabbing tool however PSA samples were acquired.

- At a number of grab sample stations within the DEP wind farm site, the interlink cable corridors and export cable corridor (i.e. D-03, D-04, D_26, CC_09, EC_09 and EC_23), triplicate samples were taken which has fed into the cumulative particle size distribution curves presented in **Plate 6.14** to **Plate 6.18**. Further information on the specific sample stations and the sampling technique employed at each can be found in Section 4.1.3 of Appendix 9.2)
- No grab samples were taken within the DEP North array area to DEP South array area interlink cable corridor as this option was put forward after the sampling campaign outlined above had been undertaken. Therefore, a post-construction monitoring sediment sampling campaign undertaken by MMT in August 2018 (MMT, 2018a) for SOW was used to characterise sediment within the DEP North array area to DEP South array area interlink cable corridor. There were six relevant samples (DOW24, DOW25, DOW26, DOW32, DOW45 and DOW54) (**Figure 8.2**).

6.5.7.2 SEP

119. The predominant sediment type in SEP is sandy gravel. Median particle sizes (d50) range between 0.54mm and 7.16mm (coarse sand to fine gravel) (Plate 6.13). Mud content is less than 5% in 59% of samples and less than 10% in 88% of samples, with two samples in the northwest of SEP containing 17% and 13% mud (SS_19 and SS_23, respectively).

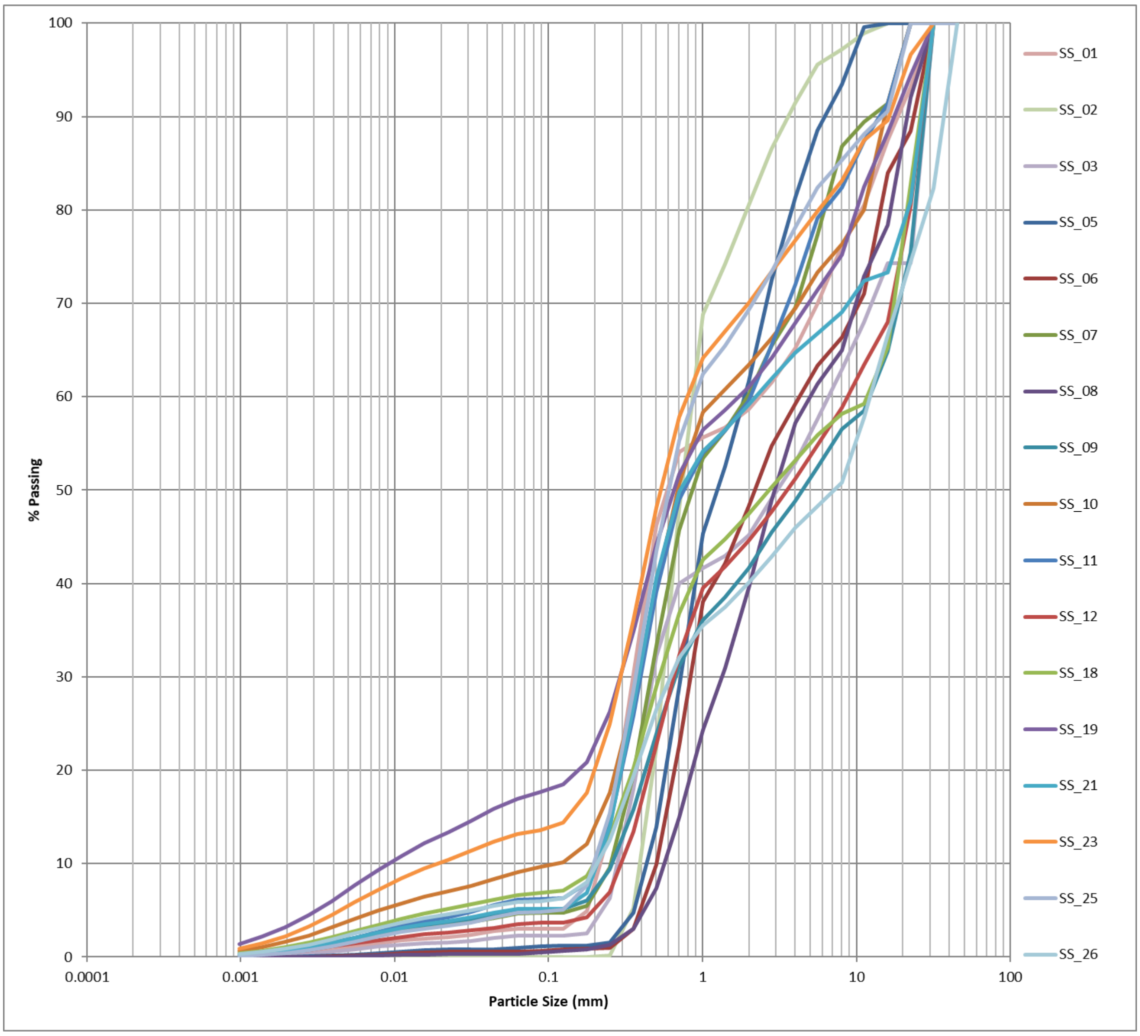

Plate 6.13: Cumulative particle size distribution curves of the 17 sea bed sediment samples collected in SEP

6.5.7.3 DEP North Array Area

120. The dominant sediment type in the DEP North array area is medium sand (23-68% content in all samples) with median particle sizes (d_{50}) between 0.34mm and 0.71mm (medium to coarse sand) (**Plate 6.14**). The mud content is less than 5% in 69% of the samples and less than 10% in 100% of the samples.

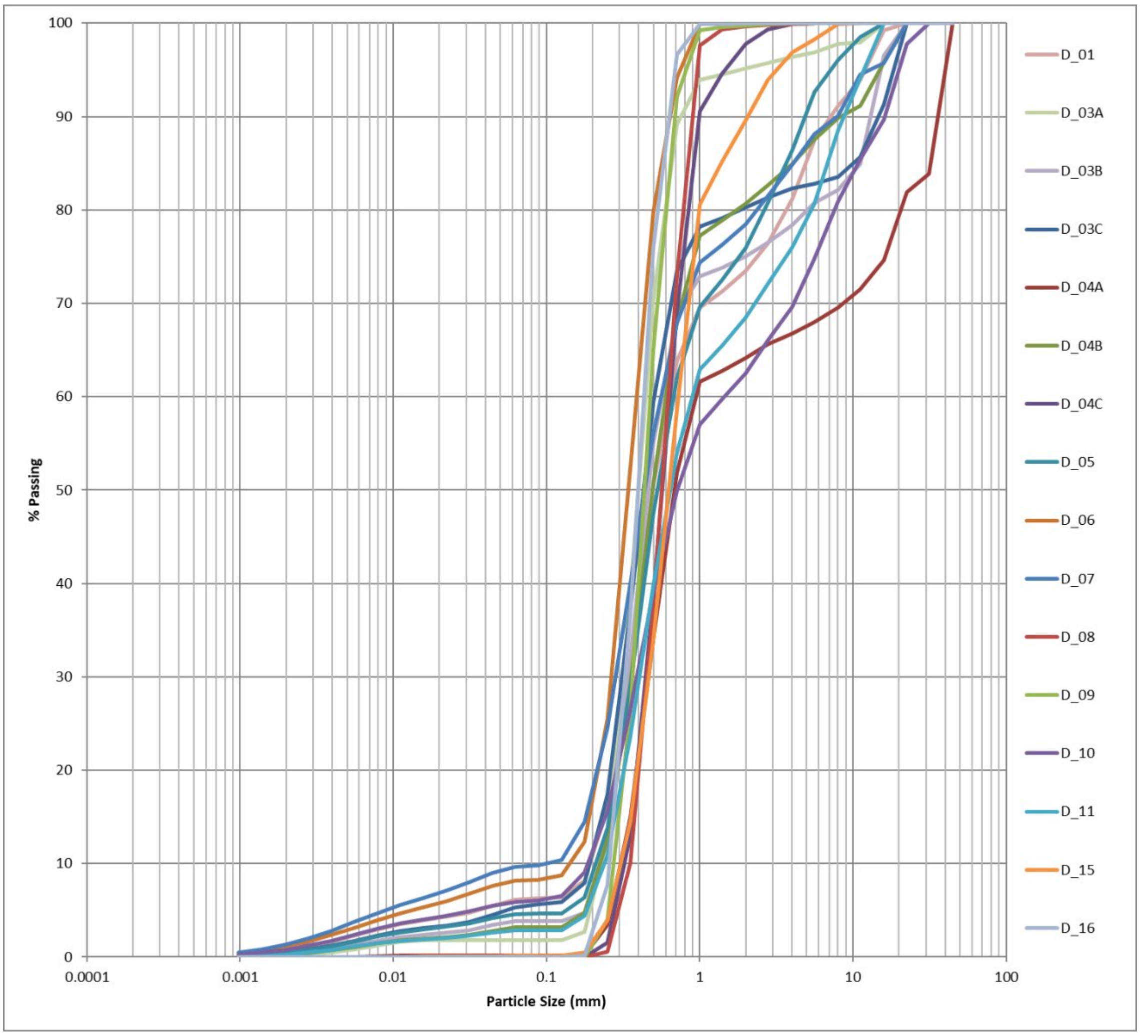

Plate 6.14: Cumulative particle size distribution curves of the 16 sea bed sediment samples collected in DEP North

6.5.7.4 DEP South Array Area

121. The dominant sediment type in the DEP South array area is also medium sand (22.2-75.2% content in all samples) with median particle sizes between 0.30mm and 0.81mm (medium to coarse sand) (**Plate 6.15**). Samples from the DEP South array area have a particularly high sand content, with 82% of samples containing greater than 75% sand. Mud content is less than 5% in 82% of the samples and less than 10% in 100% of the samples.

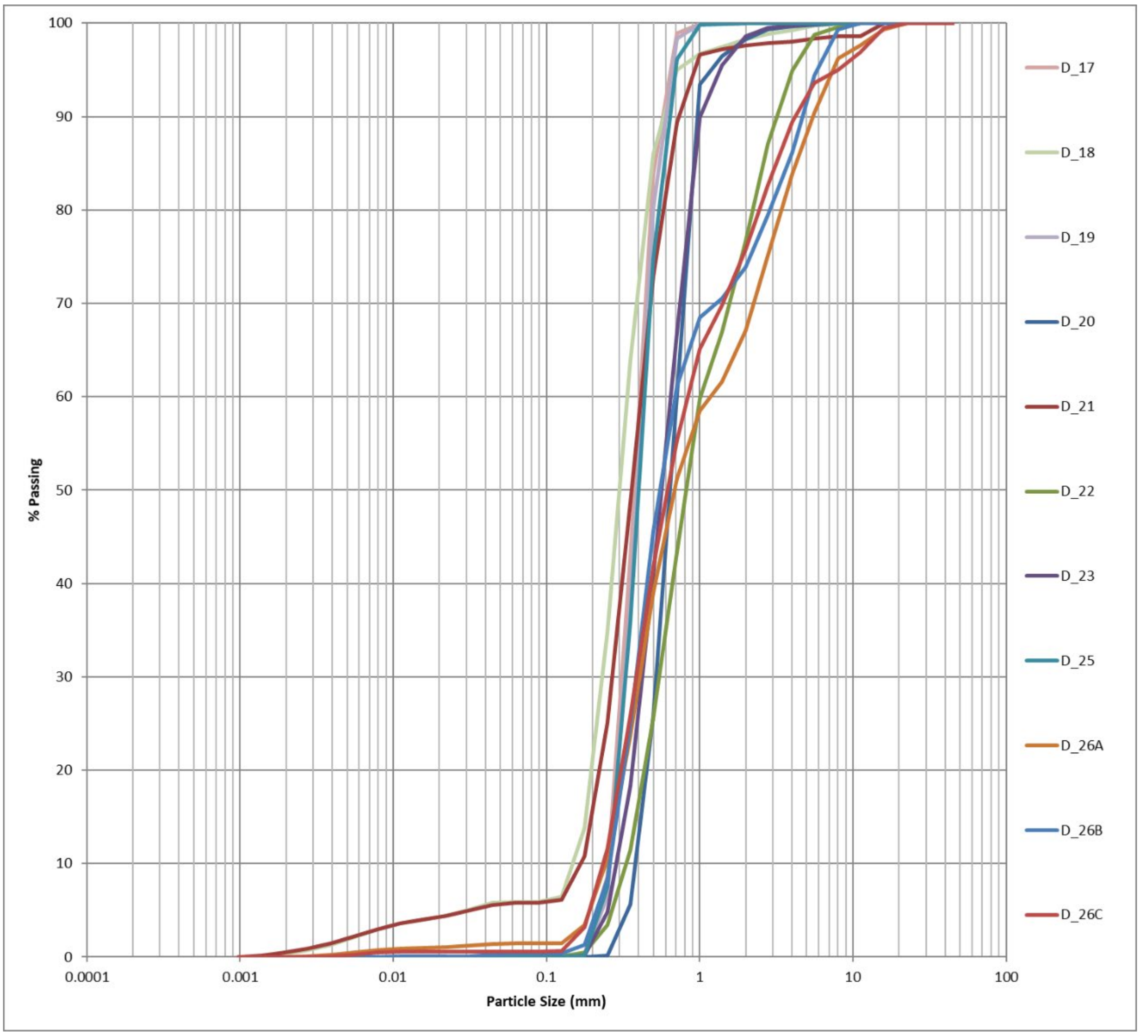

Plate 6.15: Cumulative particle size distribution curves of the 11 sea bed sediment samples collected in the DEP South array area

6.5.7.5 Interlink Cable Corridors

122. The DEP North array area to SEP part of the interlink cable corridor is characterised by coarser sediment than the corridor between the DEP North and DEP South array areas, with the majority of samples composed primarily of medium to coarse sand (**Plate 6.16**). Three samples located at each end and in the middle of the corridor contain a high percentage of gravel (48-57%). Median particle sizes range between 0.55-4.2mm (coarse sand to fine gravel) and mud content is low (less than 5% in 75% of samples and less than 10% in 100% of samples).

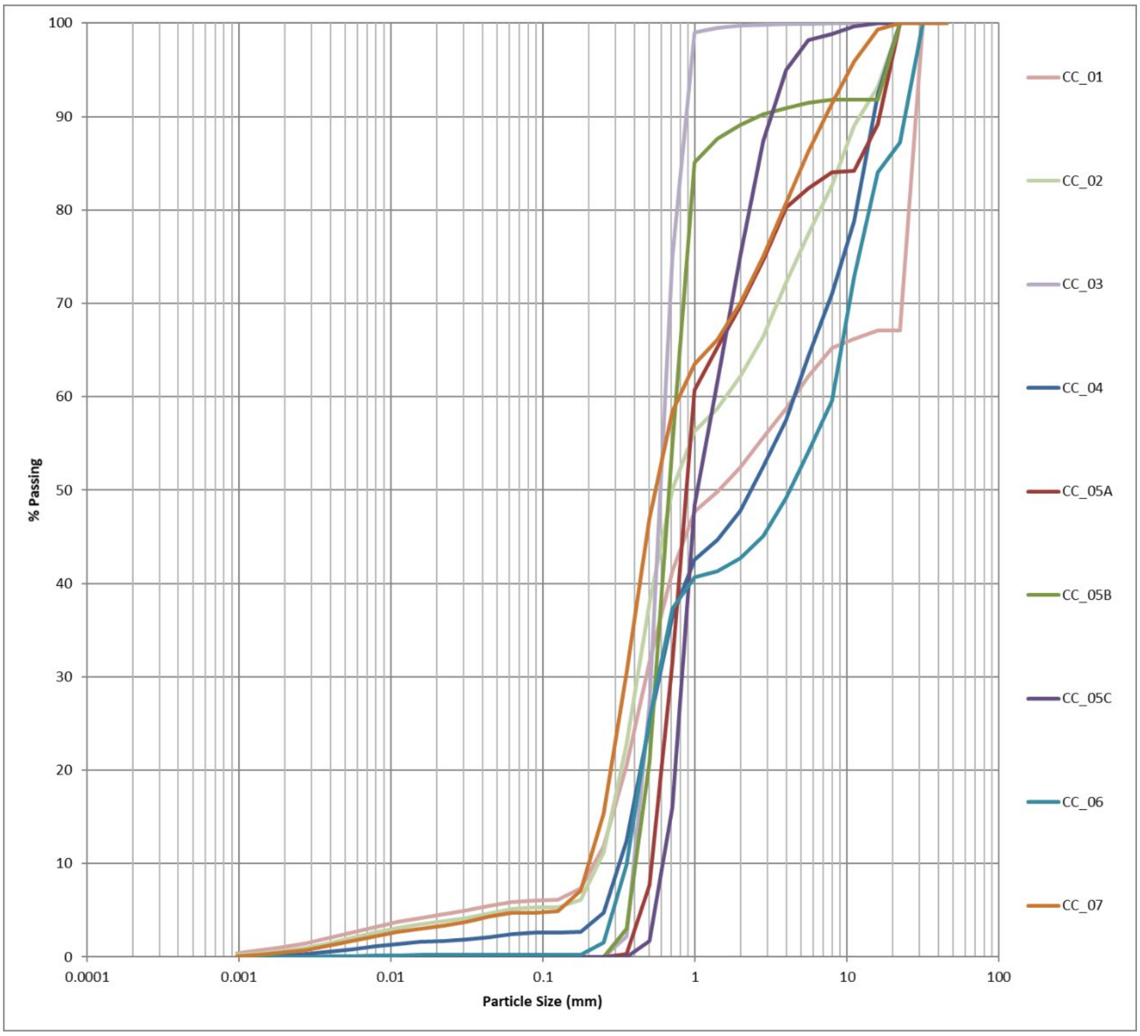

Plate 6.16: Cumulative particle size distribution curves of the nine sea bed sediment samples collected in the northern interlink cable corridor

123. The DEP South array area to SEP part of the interlink cable corridor is dominated by medium sand (15-71% content in all samples) (**Plate 6.17**). The median particle diameter (d_{50}) falls between 0.27mm and 8.65mm (predominantly medium sand with patches of fine to medium gravel). Mud content is less than 5% in 71% of samples and less than 10% in 100% of samples. Samples from the western portion of the southern corridor have a greater range of sediment size compared to samples in the east, which are more homogenous.

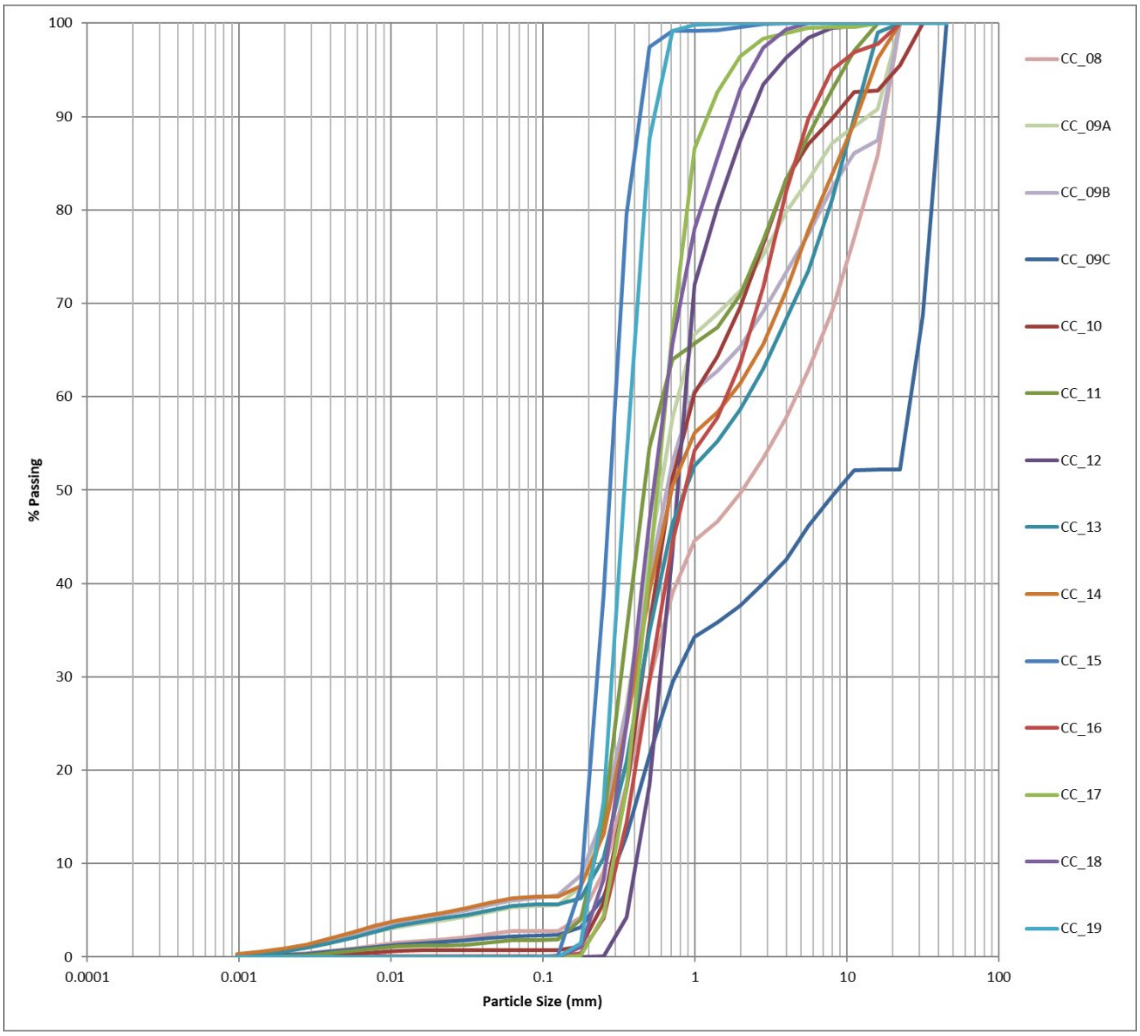

Plate 6.17: Cumulative particle size distribution curves of the 14 sea bed sediment samples collected in the southern interlink cable corridor

124. The DEP North array area to DEP South array area interlink cable corridor is dominated by sandy gravel (66% of samples). Sand proportion ranges from 56% (DOW26 in the south of the interlink cable corridor) to 99% (DOW32 in the north of the interlink cable corridor). Mud content is less than 5% in 83% of samples and below 6% in 100% of samples. DOW26 contains the highest proportion of gravel (43%).

6.5.7.6 Export Cable Corridor

125. The sea bed of the landward 500m of the export cable corridor is mainly outcropping chalk (**Figure 6.7**) (Royal HaskoningDHV, 2020). This part of the corridor is predominantly chalk at sea bed (with patches of thin sand and gravel in places) potentially sculpted into the complex geo-structures photographed during the nearshore dives of Spray and Watson (2011). This is supported by the complex irregular bathymetry recorded across this area. The seaward boundary of the outcropping chalk is in water depths of about -6m LAT at the western end to -9.5m LAT at the eastern end. The bathymetry of the seaward boundary gradually shallows

from east to west. The area of the outcropping chalk within the corridor is about 812,000m^2 (**Figure 6.8**).

126. From 500m to 4.5km offshore along the export cable corridor, the sea bed is composed of alternating zones of gravelly sand/gravel and Holocene sand across a less complex bathymetry than further inshore. The gravelly sand/gravel is interpreted to be a lag deposit created by erosion of Pleistocene units (likely to have been mainly Bolders Bank Formation) that used to overlie the chalk (Royal HaskoningDHV, 2020). It is likely to be less than 1m thick (Dove and Carter, 2021) with sub-cropping eroded chalk (although it is difficult to define the true thickness based on the geophysical data) and not mobile under existing tidal conditions.

127. The Holocene sand is up to 3m thick and rests mainly on chalk and lag. Most of the sand surface is sculpted into megaripples, indicating mobility under existing tidal conditions. If the Holocene sand is mobile, gross migration is likely to be along an approximately east-west axis (given the crest orientations of the bedforms). The smoother bathymetry in this zone indicates that exposed chalk is absent and where it sub-crops it is more regular in elevation.

128. From 4.5km from the coast to SEP the sea bed is gravelly sand or gravel. This wide zone is a continuation of the gravelly sand/gravel sea bed further landward which passes beneath the Holocene sands. The overlying mobile Holocene sands do not occur in this zone. The gradually sloping bathymetry suggests that the sub-cropping chalk surface in this zone is an eroded surface and is relatively flat and regular.

129. About 10km offshore, the sea bed is composed of sand forming the eastern end of Sheringham Shoal sand bank. The bank is up to 6m thick and covered in a field of megaripples (5-10m wavelength with crests oriented north-south).

130. Sediment samples from within the export cable corridor and outside the MCZ show the dominant sediment size is medium sand (19-62% content in all samples) (**Plate 6.18**). Median particle sizes within the export cable corridor outside the MCZ are 0.43-3.39mm (medium sand to very fine gravel). Mud content is less than 5% in 80% of samples and less than 10% in 90% of samples, with one sample (sample EC_16 located approximately 12km from the coast) containing 22% mud.

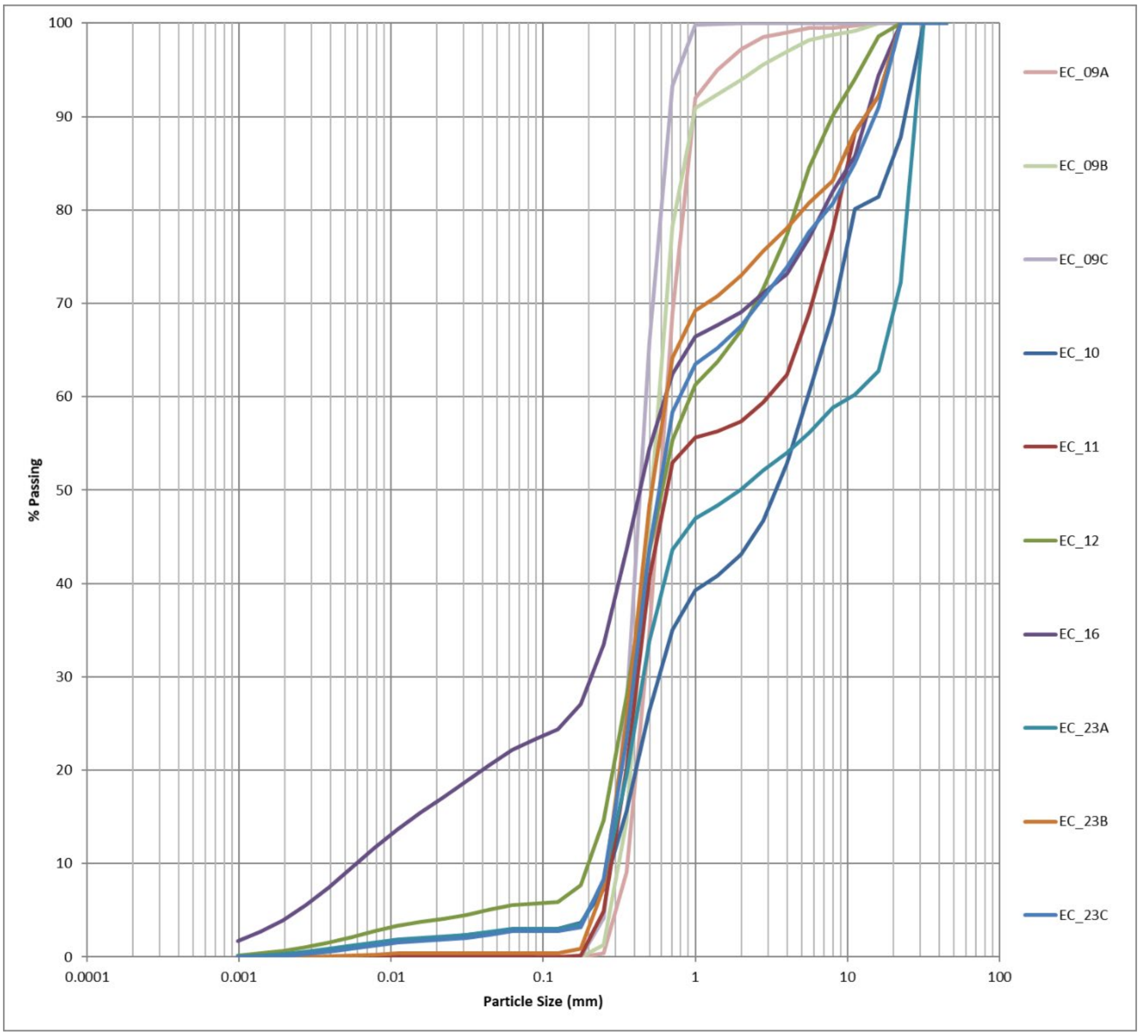

Plate 6.18: Cumulative particle size distribution curves of the ten sea bed sediment samples collected in the export cable corridor outside the MCZ

131. Sediment samples collected within the export cable corridor and inside the MCZ are predominantly composed of medium sand to coarse gravel (**Plate 6.19**). Many samples closer to the coast contain greater than 56% gravel and the majority of samples contain 0% mud.

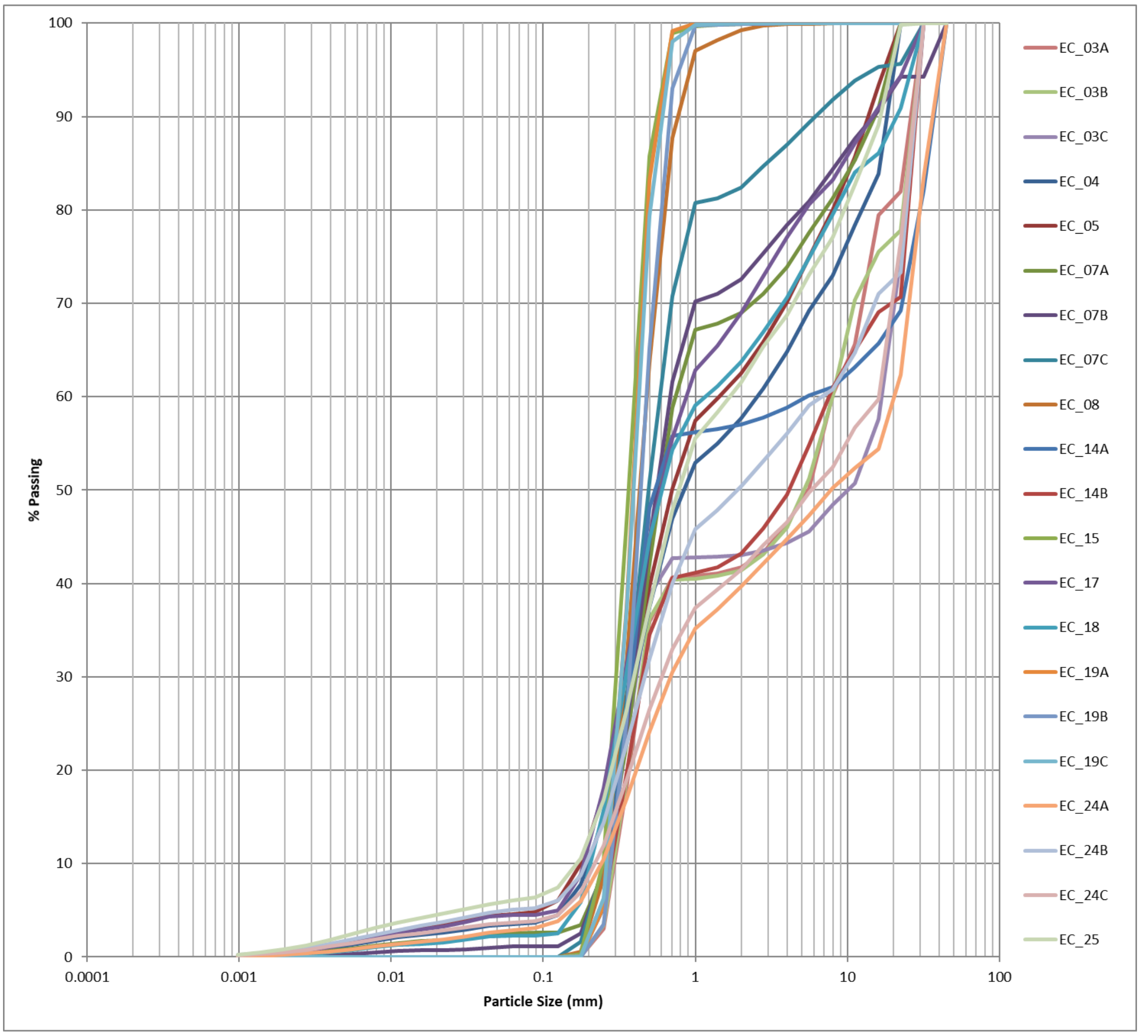

Plate 6.19: Cumulative particle size distribution curves of the 21 sea bed sediment samples collected in the export cable corridor inside the MCZ

132. Sediment sampling has also been completed across the MCZ by Cefas (2014), at 72 stations. Details of the locations of these samples are provided in **Figure 6.9**. The samples describe a variety of sea bed compositions. Similar to the samples recovered by Fugro (2020), most of the samples are composed of sand and gravel. About half the samples contain greater than 25% gravel (25-69%) and are defined as sandy gravel or gravelly sand. About 25% of the samples are greater than 90% sand with four samples predominantly mud (72-90%) with subordinate sand (Royal HaskoningDHV, 2020).

6.5.8 Offshore Bedload Sediment Transport

133. Regional bedload sediment transport pathways in the southern North Sea have been investigated by Kenyon and Cooper (2005). They analysed the results of modelling studies and bedform indicators and showed that tidal currents are the dominant mechanism responsible for bedload transport. The dominant regional bedload transport vectors are to the east and east-southeast across SEP and DEP and to the west and northwest further offshore (**Plate 6.20**). Between these opposing directions of transport is a bedload transport parting. There are very few

transport vectors directed to the south either near SEP and DEP or between SEP and DEP, and the coast.

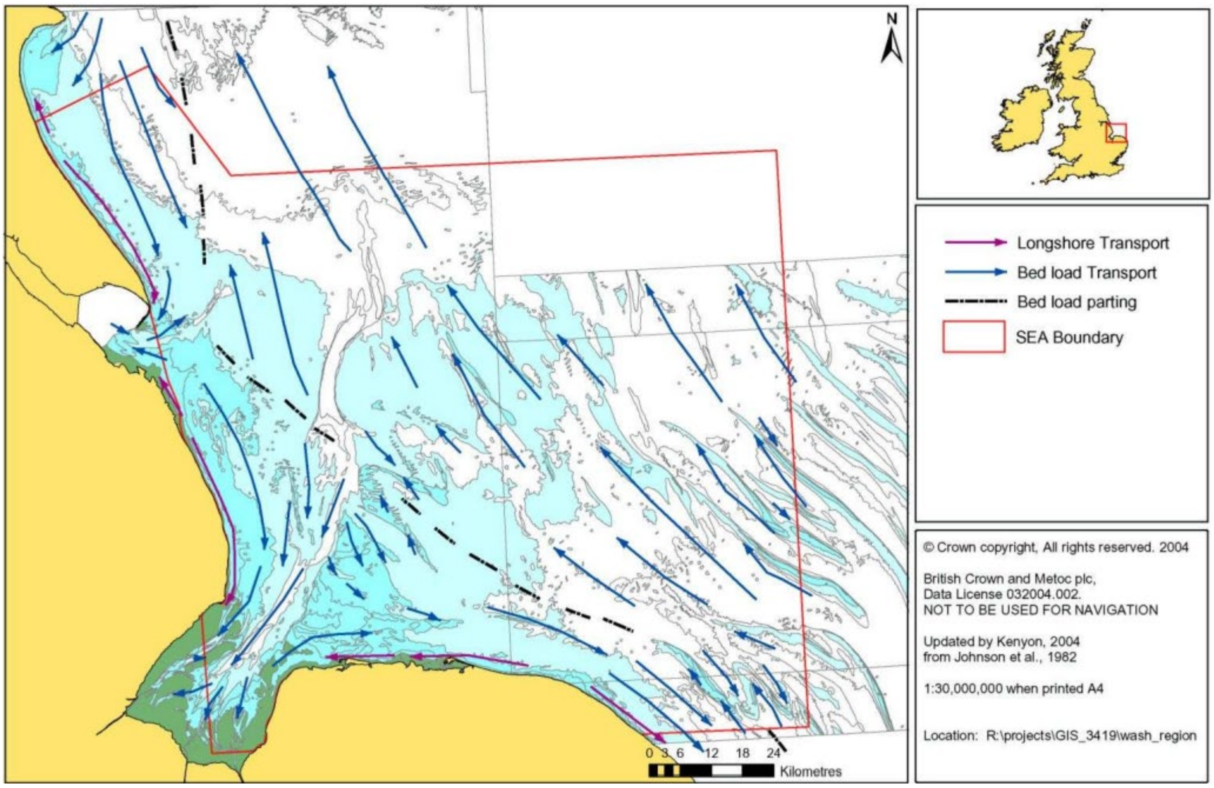

Plate 6.20: Net sand transport pathways in the southern North Sea (Kenyon and Cooper, 2005)

134. Sediment transport pathways within the SEP and DEP offshore sites have been analysed using the orientation of bedforms. Sand waves and ripples are present across parts of the DEP North and DEP South array areas (being particularly prevalent in the northern site), SEP, the interlink cable corridors and export cable corridor. Sand waves in these areas exhibit a consistent northeast – southwest orientation that indicates a net direction of transport to the southeast. Tidal currents are the main driving force of sediment transport and as a result, move sediments in a southeasterly direction. The net direction of sediment transport across areas that are not characterised by migrating bedforms will be in the same but at lower rates due to the smaller volumes of sediment available for transport.

6.5.8.1 Cromer Shoal Chalk Beds MCZ

135. Geophysical surveys from 2013 (Fugro, 2014a) and 2018 (MMT, 2018a, b) have been completed along the DOW export cable corridor within the Cromer Shoal Chalk Beds MCZ. Where these surveys overlap, they have been used as a basis for comparison to understand potential sediment transport across the MCZ (Royal HaskoningDHV, 2020) (**Appendix 6.3**). Along most of the overlapping cable route, bathymetric change has been less than 0.25m. This is effectively a non-mobile bed given that the vertical accuracy of the multibeam echosounder is +/-0.2m. This supports the interpretation of a predominantly gravelly sand sea bed as a thin static

lag deposit resting on chalk. Elevation change greater than 0.25m occurred in two locations where mobile bedforms are present. These are the Holocene sand areas 3.2km to 4.2km offshore along the corridor and at the boundary of the MCZ.

136. A similar comparison was completed for the SOW export cable corridor through the MCZ. A pre-construction survey in 2008 (EMU, 2008) was compared with post-construction surveys in winter 2013 (Fugro EMU, 2014), winter 2015/2016 (Fugro EMU, 2016), and winter 2018 (Fugro, 2019). The main difference in sea bed elevation along the cables is the discontinuous presence of the trenches in which they sit, which persisted through to 2018 (Royal HaskoningDHV, 2020). Preservation of the trenches indicates that in these areas, sediment transport is limited. This is the sea bed occupied by a lag of gravelly sand resting on chalk. Other parts of the trench are filled with sediment indicating transport is active. For example, the trenches were not visible over Pollard Bank or across the inshore 2km of the cable routes to the landfall where mobile sand is present. Apart from the trenches, most of the bathymetric differences recorded between 2008 and 2018 along the export cable corridor were less than 0.25m indicating a non-mobile sea bed. The vertical accuracy of the multibeam echosounder is +/-0.2m.

137. There is a range of sediment transport potentials across the stratigraphic units mapped along the SEP and DEP cable corridor (Royal HaskoningDHV, 2020) (**Appendix 6.3**). The chalk and the Pleistocene geological units that fill channels in the chalk (e.g. Botney Cut Formation and Weybourne Channel Deposits) are static (and can only be eroded), whereas the surface of the Holocene sand is mobile under existing tidal conditions, and so can erode, transport and deposit depending on the physical processes. The mobility of the Holocene sand is supported by the existence of megaripples across its surface in places (mainly along the Weybourne option). This indicates that there is a possibility that movement of this sediment may result in exposure or burial of the underlying geological units. Given the thickness of the Holocene sands, it would only be possible for movement of the feather edges (where the sediment is thin and could all move), to generate new sea bed substrate. In areas where the sand is thicker, the movement of the surface layer would only result in exposure of further sand deeper in the sediment column.

138. Between the chalk or Pleistocene geological units and the sea bed or overlying Holocene sand is a layer of gravelly sand/sandy gravel. This coarse-grained layer is interpreted as a lag deposit created by erosion of Pleistocene units that were originally present on the sea bed (e.g. Bolders Bank Formation). The transport potential of this sediment layer is zero or very low (Royal HaskoningDHV, 2020).

139. There have also been three post-construction benthic surveys of the SOW export cables with a focus on the MCZ; benthic grab sampling in Year 1 (December 2012), Year 2 (April/May 2014) and most recently in August 2020 (video transects of the trenches and adjacent areas in the MCZ). Post-construction geophysical surveys have been completed at least every two years. The benthic monitoring in 2012 and 2014 showed only slight differences in sea bed sediment distribution from the pre-construction sediment distribution. These small variations are likely due to natural inter-annual fluctuations in a dynamic environment.

140. The objective of the 2020 survey was to obtain photographic data to establish whether there is a difference in the sea bed sediments and epifaunal communities

between the export cable trenches and adjacent sea bed at ten sites along the cable route within the MCZ. A total of 30 transects, three per survey site, were collected. Each transect was chosen to cross the export cable corridor (described as the impacted area) where trenches were evident and two control areas (control east and control west) located at a minimum of 60m from the noticeable edge of the trenches, to a maximum of 120m. Photographic stills and video were successfully acquired at all proposed transects.

141. The photographic analysis showed significant differences between transects reflecting the naturally occurring differences in the sediment composition along the cable route (Royal HaskoningDHV, 2020). However, the results indicated no significant difference in sediment composition between the trenches and the control areas adjacent to the trenches, although it is acknowledged that further evidence (such as particle size analysis of grab samples) would be needed to confirm this conclusion.

6.5.9 Suspended Sediment Transport

142. According to HR Wallingford *et al*. (2002), typical mean summer suspended sediment concentrations across SEP and DEP are less than 10mg/l whereas mean winter concentrations are 30mg/l, although concentrations may increase significantly during storm events.

143. More recently, Cefas (2016) published average suspended sediment concentrations between 1998 and 2015 for the seas around the UK (**Figure 6.10**). They showed that over this time period, the average suspended sediment concentrations across SEP and DEP were 5-10mg/l.

6.5.10 Coastal Processes at the Weybourne (Muckleburgh Estate) Landfall

144. The landfall at Muckleburgh Estate is located towards the eastern end of coastal littoral sub-cell 3a, which stretches from Sheringham in the east to Snettisham in the west. The coast for about 5km to the east of the landfall is composed of cliffs with a fronting beach (**Plate 6.21**) exposed to waves and erosion is occurring in places. There are no coastal defences.

Plate 6.21: Eroding cliffs east of the Muckleburgh Estate landfall

145. The predicted net sediment transport rates in the region range from 160,000m^3/year to 200,000m^3/year (HR Wallingford *et al.*, 2002) directed to the west. These transport rates are for sand and are potential rates rather than actual rates).

146. The Shoreline Management Plan (AECOM, 2013) states that the intended management at Weybourne is No Active Intervention (NAI) over the next 100 years. The long-term plan for the frontage is to promote a naturally-functioning coast, with minimal human interference. This will lead to a loss in cliff top land, which includes agricultural land and part of a golf course.

6.5.11 Climate Change and Natural Trends

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

6.6 Potential Impacts

6.6.1 Impact Receptors

148. The principal receptors with respect to marine geology, oceanography and physical processes are those features with an inherent geological or geomorphological value or function which may potentially be affected by SEP and DEP. These are the Cromer Shoal Chalk Beds MCZ, sand banks (and associated sand waves) and the East Anglian coast (gravel and sand beaches, dunes and cliffs). The projects and interlink cable corridor are located north of the MCZ, but the export cable corridor passes through it, and the landfall is at Weybourne on the north Norfolk coast. Sand banks and sand waves are present in the northwest parts of the DEP North array area and in the DEP South array area (**Figure 6.1**).

149. The specific features defined within these three receptors as requiring further assessment at the EIA stage for SEP and DEP are listed in **Table 6-13**.

Table 6-13: Marine Geology, Oceanography and Physical Processes Receptors Relevant to the Projects

Receptor Group	Extent of Coverage	Description of Features	Distance from SEP and DEP
Cromer Shoal Chalk Beds MCZ (waves, tidal currents and sediment transport)	Weybourne to Happisburgh	• Moderate energy infralittoral rock; • high energy infralittoral rock; • moderate energy circalittoral rock; • high energy circalittoral rock; • subtidal chalk; • subtidal coarse sediment; • subtidal mixed sediments; • subtidal sand, peat and clay exposures; and • north Norfolk coast (subtidal geological feature)	Export cable corridor passes through the MCZ
Sand banks (and associated sand waves)	Northwest parts of DEP North array area and in DEP South array area and in the north of the cable corridor between DEP North array area and SEP	Sand banks and sand waves	Bedforms are within the boundaries of the DEP North and DEP South array area and in the north of the cable corridor between the DEP North array area and SEP
East Anglian coast (waves and sediment transport)	King's Lynn to Felixstowe	Gravel and sand beaches, dunes and cliffs	16km from the nearest point of SEP with the export cable making landfall at Weybourne

150. The impact assessment sections (**Sections 6.6.4** and **6.6.5**) assess the significance of potential impacts on the wave and/or current and/or sediment transport regimes on the receptor groups of the sensitive Cromer Shoal Chalk Beds MCZ and East Anglian coast.

6.6.1.1 Cromer Shoal Chalk Beds MCZ

151. Cromer Shoal Chalk Beds MCZ was designated in January 2016. It is located 200m off the north Norfolk coast, covering an area of 321km^2, with maximum depth of about 20m. The conservation objectives for the MCZ's protected features are that they are 'maintained in favourable condition if they are already in favourable condition, or be brought into favourable condition if they are not already in favourable condition'. The export cable passes through the MCZ.

6.6.1.2 East Anglian Coast

152. The East Anglian Coast, encompassing the landfall at Weybourne, falls under SMP 6 (AECOM, 2013). The cliffs between Kelling Hard and Sheringham has the highest proportion of shingle for the north Norfolk cliffs, representing an important source of shingle to the sediment regime both to the east and west, although some of it remains locally.

153. The beach along this section does not appear to have been affected by the steepening trend seen elsewhere along this frontage (AECOM, 2013). Cliff erosion is linear and gradual but is exacerbated by occasional slumping events. Over the next 100 years, the shoreline is expected to retreat between 10 and 50m (assuming an unconstrained coast), with the shingle ridge at Weybourne likely to roll back due to adjacent cliffline erosion.

6.6.2 Effects

154. As explained in **Section 6.4**, in addition to the receptor groups listed in **Table 6-13**, there are other potential changes (effects) to marine geology, oceanography and physical processes associated with SEP and DEP which may manifest themselves as impacts upon a wider grouping of receptors. These include marine water and sediment quality, benthic ecology, fish and shellfish ecology, commercial fisheries, and offshore archaeology and cultural heritage.

155. In respect of these effects, the marine geology, oceanography and physical processes assessment only defines the magnitude of change. The assessments of the significance of impacts arising from these effects or changes on other receptors are made within the relevant chapters of this ES pertaining directly to those receptor types.

6.6.3 Justification for why a conceptual approach is appropriate for tidal currents and sediment transport

156. Previous numerical modelling (sediment dispersion) and theoretical work (tidal currents) have been undertaken specifically for the SOW and DOW projects which are located in very close proximity to SEP and DEP and therefore offer a suitable analogue for the assessment of the potential effects of SEP and DEP on the identified marine geology, oceanography and physical processes receptors. The results of the modelling and theoretical approaches from the existing OWFs are used as part of the conceptual evidence-based assessment of potential construction and O&M effects or impacts of SEP and DEP. Also, numerical modelling of waves has been completed for potential operational impacts due to the presence of the foundation structures (**Appendix 6.2**).

6.6.3.1 Physical environment basis

157. The physical basis for using the modelling and theoretical results for tidal currents and sediment transport is that the SOW and DOW designs and marine geology, oceanography and physical processes operating at the sites are like SEP and DEP and therefore provide suitable evidence (and are suitable analogues) to support the assessment of effects or impacts at SEP and DEP.

158. Justification for using the modelling results from SOW and DOW as the principal evidence of potential effects or impacts at SEP and DEP is provided below, which includes the similarities (and dissimilarities) of the existing physical and sedimentary conditions (water depths, tidal currents, sea bed sediments, and suspended sediment) at each of the sites.

159. Water depths at SOW (15-22m below Chart Datum (CD)) and DOW (17-24m below CD) are comparable to those at SEP (14-25m below CD) and DEP (11-23m below CD).

160. Tidal currents demonstrate similar directions and velocities on the flood tide and ebb tide. At all sites, flood and ebb tidal currents flow west-northwest/northwest and east-southeast/southeast, respectively. Spring tide peak current velocities of between 0.6m/s and 1.2m/s occur across all the sites, giving rise to bed transport and the formation of mobile bed features such as sand waves and megaripples. Lower velocities (less than 1.0m/s) occur closer to the coast across the export cable corridors and directions are approximately shore parallel.

161. Sea bed sediments and particle size copmposition at all sites are similar (see **Figure 8.2**). The sea bed at SOW and DOW comprise mainly superficial gravelly sands or sandy gravels derived from the reworking of the underlying glacial till. The sea bed sediment across SEP and DEP wind farm sites also comprise a thin veneer of gravelly sand resting on till. Chalk is exposed at the sea bed closer to the coast along the export cable corridor.

162. Regional average suspended sediment concentrations vary from 5mg/l to 10mg/l. Concentrations may increase significantly during storm events.

6.6.3.2 Design basis

163. SOW comprises 88 turbines and DOW comprises 67 turbines, whereas SEP and DEP will have up to 23 and 30 turbines, respectively. Hence, the results of the modelling and theoretical assessments of the SOW and DOW designs are conservative compared to the SEP and DEP designs. Whilst it is recognised that there are small differences in physical and sedimentary conditions and project parameters between the sites, the conservative nature of the numerical modelling conducted for SOW and DOW allows for these differences in the effect that may arise due to these factors. In addition, the post-construction geophysical and environmental survey data for SOW and DOW has been used to retrospectively ‘ground-truth’ the pre-construction numerical modelling and theoretical results for the existing wind farms to provide confidence in their use in the assessment of SEP and DEP.

164. The assessments for the existing OWFs were completed when the area occupied by the export cable corridors was not designated as an MCZ. Although the export

cable corridor of SEP and DEP now passes through the Cromer Shoal Chalk Beds MCZ (designated in January 2016), the use of conceptual evidence-based assessment is still considered proportionate. This is because the existing modelling of the export cable corridors was conservative and the results are representative of the worst-case for SEP and DEP through the MCZ, and are therefore suitable analogies.

6.6.3.3 Theoretical model basis

6.6.3.3.1 Tidal currents

165. Tidal currents in the vicinity of SEP and DEP are rectilinear, with peak speeds of 0.8-1.0m/s on mean spring tides and 0.5-0.6m/s on mean neap tide (Scira, 2006, DOW, 2009). A theoretical desk-based assessment of impacts to the tidal regime at SOW considered a worst-case scenario of 108 large structures set out with spacings of 660m in the approximate direction of the strongest currents (west-northwest to east-southeast) and 570m in the approximate direction of largest waves (north-northeast to south-southwest). No significant changes to the broad scale flow regime were concluded, with a reduction in the overall flow within SOW of 1-2% and an increase in flow locally around each structure (Scira, 2006). These changes were considered to be insignificant within SOW. The substation location and foundation types were not considered in the theoretical assessment. However, it was concluded that this would still not result in a significant reduction in overall flow (Scira, 2006).

166. At SEP, a worst-case scenario of 23 x 15MW GBS foundations set out with a spacing of 1.05km (the layout of the wind turbines will be defined post consent) and one OSP with four legs of 12m diameter) is being considered. The result of the theoretical assessment of the SOW design is conservative compared to the result for the SEP design, and would be similar to the result of the SEP design in combination with the actual number of turbines installed for SOW (118 in total).

167. A theoretical assessment of impacts to the tidal regime at DOW considered a worst-case scenario of 168 GBS foundations separated at least 360m in the dominant flow direction. A previous assessment of large GBS foundations for a similar area of the Greater Wash SEA area (HR Wallingford, 2006) showed a reduction in average flow speed of 1-2%. Therefore, any change to the flow regime was anticipated to be negligible.

168. At DEP, a worst-case scenario of 30 x 15MW GBS foundations set out with spacings of 1.05km (the layout of the wind turbines will be defined post consent) and one OSP with four legs of 12m diameter is being considered. The result of the theoretical assessment of the DOW design (168 GBS foundations) is conservative compared to the result for the DEP design, and the result of the DEP design in combination with the actual number of turbines installed for DOW (90 in total).

6.6.3.4 Numerical model basis

6.6.3.4.1 Suspended sediment

169. Scira (2006) completed sediment dispersion modelling to define the extent of plume dispersion due to SOW export cable installation and the extent of the depositional

footprint. Given the similar positions of the SOW export cable corridor and the SEP and DEP export cable corridor, the modelling of the SOW installation is a suitable analogy for the potential effect of the installation of the SEP and DEP cable.

170. Suspended load for disturbed mud (at a level above 1mg/l) during ploughing of the SOW cables is predicted to extend as a plume over a distance of less than 2km in either direction before either settling out of suspension or dispersing to a level of less than 1mg/l. The deposited sediment can be re-suspended as the tidal flows flood and ebb. The modelling predicted maximum suspended concentrations of up to 20mg/l.

171. DOW (2009) also completed sediment dispersion modelling for DOW export cable laying, to simulate the potential increase in suspended sediment concentrations above background levels. The model predicted a spring tide footprint for silt which extended less than 1km from the cable with maximum concentrations less than 5mg/l.

172. For both SOW and DOW, the footprint of mud deposition was found to extend over a wide area, but at an unmeasurable rate. Even under slack water conditions, the maximum rate of deposition over a six-tide simulation was less than 0.5mm in the areas of greatest deposition, and in most of the footprint area the rate was much less. This result was anticipated as the deposited fines would be re-suspended on each tide, with no measurable sediment left in place.

6.6.4 Potential Impacts During Construction

173. During the construction phase of SEP or DEP, there is the potential for foundations and cable installation activities to disturb sediment, potentially resulting in changes in suspended sediment concentrations and/or sea bed levels or, in the case of nearshore cable installation, shoreline morphology due to deposition or erosion. These potential effects are considered as construction Impacts 1 to 8.

174. The worst-case layout scenario (discussed in **Section 6.3.2**) is assessed for construction of SEP or DEP in isolation, and SEP and DEP.

6.6.4.1 Impact 1a: Changes in suspended sediment concentrations due to sea bed preparation for foundation installation (wind farm site)

6.6.4.1.1 SEP or DEP in Isolation

175. Sea bed sediments and shallow near-bed sediments within SEP or DEP would be disturbed during dredging activities to create a suitable base prior to foundation installation. The worst-case scenario assumes that sediment would be dredged and returned to the water column at the sea surface as overflow from a dredger vessel. This process would cause localised and short-term increases in suspended sediment concentrations both at the point of dredging at the sea bed and, more importantly, at the point of its discharge back into the water column. The disposal of any sediment that would be disturbed or removed during foundation installation would occur within SEP and DEP disposal sites (see **Disposal Site Characterisation Report** (document reference 9.13).

176. Mobilised sediment from these activities may be transported by wave and tidal action in suspension in the water column. The disturbance effects at each wind

turbine location are likely to last for no more than a few days, within an overall foundation installation programme of approximately 6 months in total if the projects are built sequentially, or 4 months if both projects are built concurrently.

177. The median particle sizes of sea bed sediments are predominantly 0.30mm to 0.81mm (medium to coarse grained sand) across DEP and 0.54mm to 7.16mm (coarse sand to fine gravel) across SEP. Most sea bed samples contained less than 10% mud. As outlined in **Section 6.5.9**, typical mean summer suspended sediment concentrations at SEP and DEP are typically less than 10mg/l, whereas mean winter concentrations are 30mg/l. These concentrations may increase significantly during storm events (HR Wallingford et al., 2002).

178. For the total volume released during the construction phase, the worst-case scenario is associated with the maximum number of 18MW GBS foundations (24 at DEP, 19 at SEP) dredged to 5m (**Table 6.5.9**).

179. Conceptual evidence-based assessment suggests that, due to the predominance of medium and coarse grained sand across SEP and DEP offshore sites, the sediment disturbed by the drag head of the dredger at the sea bed would remain close to the bed and settle back to the bed rapidly. Most of the sediment released at the water surface from the dredger vessel would fall rapidly (minutes or tens of minutes) to the sea bed as a highly turbid dynamic plume immediately upon its discharge (within a few tens of metres along the axis of tidal flow).

180. Some of the finer sand fraction from this release and the very small proportion of mud that is present are likely to stay in suspension for longer and form a passive plume which would become advected by tidal currents. Due to the sediment sizes present, this is likely to exist as a measurable but modest concentration plume (tens of mg/l) for around half a tidal cycle (up to six hours). Sediment would eventually settle to the sea bed in proximity to its release (within a few hundred metres up to around a kilometre along the axis of tidal flow) within a short period of time (hours to days). Whilst lower suspended sediment concentrations would extend further from the dredged area, along the axis of predominant tidal flows, the magnitudes would be indistinguishable from background levels.

181. This conceptual evidence-based assessment is supported by the findings of a review of the evidence base into the physical impacts of marine aggregate dredging on sediment plumes and sea bed deposits (Whiteside et al., 1995; John et al., 2000; Hiscock and Bell, 2004; Newell et al., 2004; Tillin et al., 2011; Cooper and Brew, 2013).

6.6.4.1.2 Magnitude of Effect – SEP or DEP in Isolation

182. The worst-case changes in suspended sediment concentrations due to sea bed preparation for GBS foundation installation are likely to have the magnitudes of effect shown in **Table 6-14**.

Table 6-14: Magnitude of effect on suspended sediment concentrations under the worst-case scenario for GBS foundation installation

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field*	High	Negligible	Negligible	Negligible	Medium
Far-field	Low	Negligible	Negligible	Negligible	Low

*The near-field effects are confined to a small area, likely to be up to a kilometre from each foundation location.

6.6.4.1.3 Impact Significance – SEP or DEP in Isolation

183. These effects on suspended sediment concentrations due to foundation installation within SEP or DEP do not directly impact upon the identified receptor groups for marine geology, oceanography and physical processes. This is because the receptors are dominated by processes that are active along the sea bed and not affected by sediment suspended in the water column. However, there may be impacts arising from subsequent deposition of the suspended sediment on the sea bed and these are discussed under Construction Impact 2b (**Section 6.6.4.4**). Hence, there is **no impact** on the identified receptor groups associated with the suspended sediment generated by SEP and DEP.

184. The effects do have the potential to impact upon other receptors and therefore the assessment of impact significance is addressed within the relevant chapters of this ES (**Section 6.9**).

6.6.4.1.4 SEP and DEP

185. The worst-case scenario and impacts associated with foundation installation at SEP and DEP will be comparable to those outlined in **Section 6.6.4.1.1**. Similar to SEP or DEP in isolation, the larger release volume (**Table 6-2**) due to construction of both projects concurrently may combine to result in higher concentrations. However, this is unlikely because the plumes would not overlap as the tidal currents would drive the plumes in similar directions at both sites with a significant distance between SEP and DEP (the plumes would be parallel to each other).

6.6.4.1.5 Impact Significance – SEP and DEP

186. The worst-case changes in suspended sediment concentrations due to installation of the maximum number of 18MW GBS foundations across SEP and DEP will have the same magnitude as those outlined in **Section 6.6.4.2.2**. Hence, there is **no impact** on the identified receptors groups associated with SEP and DEP.

6.6.4.2 Impact 1b: Changes in suspended sediment concentrations due to drill arisings for installation of piled foundations for wind turbines and OSPs

6.6.4.2.1 SEP or DEP in Isolation

187. Sediments below the sea bed within SEP or DEP would become disturbed during any drilling activities that may be needed at the location of piled foundations. The

ambient suspended sediment concentrations across SEP and DEP of less than 10mg/l to about 30mg/l (**Section 6.5.9**) mean that the transient impact of sediment plumes arising from installation of the wind farm foundations may be significant (although temporally limited) under specific circumstances. The disposal of any sediment that would be disturbed or removed during foundation installation would occur within the SEP or DEP disposal sites (see the **Disposal Site Characterisation Report** (document reference 9.13) in close proximity to each foundation. The worst-case scenario for a release from an individual wind turbine assumes a monopile foundation for the 15MW wind turbine. In this case, a 13m drill diameter would be used from the sea bed to a depth of 45m, releasing a maximum of 5,973m^3 of sediment per foundation into the water column.

188. It is estimated that the maximum number of foundations that would require drilling would be 5%. Taking a precautionary worst-case approach it has therefore been assumed that two 15MW wind turbines in SEP and DEP each would require drilling.

189. Piled foundations with 3.5m diameter pin piles would represent the worst-case scenario for the OSP. The drill arisings per foundation are 425m^3 of sediment for SEP or DEP (up to one per project) **Table 6-2** summarises the total volume of drill arisings.

190. The drilling process would cause localised and short-term increases in suspended sediment concentrations at the point of discharge of the drill arisings at two locations only. Released sediment may then be transported by tidal currents in suspension in the water column. Due to the small quantities of fine-sediment released (most of the sediment will be sand or aggregated clasts, see **Section 6.5.7**), the fine-sediment is likely to be widely and rapidly dispersed. This would result in only low suspended sediment concentrations and low changes in sea bed level when the sediments ultimately come to deposit. The disturbance effects at each wind turbine location are only likely to last for a few days of construction activity within the overall construction programme lasting up to 6 months in total if the projects are built sequentially, or 4 months if both projects are built concurrently.

191. The conceptual evidence-based assessment suggests that away from the immediate release locations, elevations in suspended sediment concentration above background levels for only two foundations would be very low (less than 10mg/l) and within the range of natural variability. Net movement of fine-grained sediment retained within a plume would be to the northwest or southeast, depending on state of the tide at the time of release. Sediment concentrations arising from one foundation installation are unlikely to persist for sufficiently long for them to interact with subsequent operations, and therefore no cumulative effect is anticipated from multiple installations.

6.6.4.2.2 Magnitude of Effect – SEP or DEP in Isolation

192. The worst-case changes in suspended sediment concentrations due to the installation of the maximum number of 18MW monopile foundations (one in each of SEP and DEP and one OSP in each of SEP or DEP) are likely to have the following magnitudes of effect (**Table 6-15**).

Table 6-15: Magnitude of effect on suspended sediment concentrations under the worst-case scenario for piled foundation installation

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field*	Medium	Negligible	Negligible	Negligible	Negligible
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

* The near-field effects are confined to a small area likely to be up to a kilometre from each foundation location, and would not cover the SEP or DEP wind farm site.

6.6.4.2.3 Impact Significance – SEP or DEP in Isolation

193. The effects on suspended sediment concentrations due to foundation installation for the proposed SEP or DEP projects do not directly impact upon the identified receptor groups for marine geology, oceanography and physical processes, so there is **no impact** associated with the proposed SEP or DEP projects.

194. However, the effects have the potential to impact upon other receptors and the assessment of impact significance is addressed within the relevant chapters of this ES (see **Section 6.9**).

6.6.4.2.4 SEP and DEP

195. The worst-case scenario and impacts associated with foundation installation at SEP and DEP will be comparable to those outlined in **Section 6.6.4.2.1**. Similar to SEP or DEP in isolation (two foundations in each and two substations), the larger release volume (**Table 6-2**) (but still only four foundations and two substations) may combine to result in larger concentrations above background levels (but likely to still be less than 10mg/l). As outlined in **Section 6.6.4.2.1**, sediment concentrations arising from one foundation installation are unlikely to persist for a sufficiently long period of time for them to interact with subsequent operations, and therefore no cumulative effect is anticipated from multiple installations. Therefore, the construction of SEP and DEP would not result in a worse impact than SEP or DEP in isolation.

6.6.4.2.5 Impact Significance – SEP and DEP

196. The worst-case changes in suspended sediment concentrations due to installation of the maximum number of 18MW monopile foundations and two substations across SEP and DEP will have the same magnitude as those outlined in **Section 6.6.4.2.1**. Hence, there is **no impact** on the identified receptors groups associated with the proposed SEP and DEP.

6.6.4.3 Impact 2a: Changes in sea bed level due to sea bed preparation for foundation installation

6.6.4.3.1 SEP or DEP in Isolation

197. The increased suspended sediment concentrations associated with construction Impact 1a (**Section 6.6.4.2.1**) have the potential to deposit sediment and raise the sea bed elevation slightly.

198. The conceptual evidence-based assessment suggests that coarser sediment disturbed during sea bed preparation would fall rapidly to the sea bed (minutes or tens of minutes) as a highly turbid dynamic plume immediately after it is discharged. Deposition of this sediment would form a 'mound' local to the point of release. Due to the coarser sediment particle sizes observed across the site (predominantly medium-grained sand), a large proportion of the disturbed sediment would behave in this manner.

199. The resulting mound would be a measurable protrusion above the existing sea bed (likely to be tens of centimetres to a few metres high) but would remain local to the release point. The geometry of each of these produced mounds would vary across SEP and DEP, depending on the prevailing physical conditions, but in all cases the sediment within the mound would be like (but not exactly the same as) both the sea bed that it has replaced and the surrounding sea bed. Given the shallow nature within some areas of SEP and DEP, the **Offshore IPMP** (document reference 9.5) includes proposals for monitoring of any mounds of sediment created during sea bed preparation for GBS foundations in water less than 15m deep, if required. The baseline particle size distribution data for the DEP North array area and the DEP South array area shows that the sea bed is dominated by medium sand with overall compositional variations related to the volumes of coarser sand and gravel. Mud content is always less than 10%. This would mean that there would be a small but insignificant change in sea bed sediment type, likely to be caused by differences in the volume of the coarser fraction in the mound compared to the natural sea bed.

200. The sea bed across SEP is dominated by sandy gravel with a wider range of compositions than DEP. However, for the most part, mud content is less than 10%. There is greater likelihood of differences in mound and sea bed composition in SEP. However, the overall composition of the sea bed once the mound has been placed would still be dominated by a mix of medium to coarse sand and gravel (and so would have little effect on the benthic communities that inhabit this type of coarse granular sea bed).

201. Also, the overall change in elevation of the sea bed is small compared to the absolute depth of water (up to 36m below LAT in the northwest of the DEP North array area). The change in sea bed elevation is within the natural change to the bed caused by sand waves and sand ridges and hence the blockage effect on physical processes would be negligible.

202. The mound will be mobile and be driven by the physical processes, rather than the physical processes being driven by it. This means that over time the sediment comprising the mound will gradually be re-distributed by the prevailing waves and tidal currents.

203. In addition to localised mounds, the very small proportion of mud would form a passive plume and become more widely dispersed before settling on the sea bed. The worst-case thickness of sediment deposited from the plume would not likely exceed a maximum of 1mm and be less than 0.1mm over larger areas of the sea bed.

204. This assessment is supported by an extended evidence-base obtained from research into the physical impacts of marine aggregate dredging on sediment

plumes and sea bed deposits (Whiteside et al., 1995; John et al., 2000; Hiscock and Bell, 2004; Newell et al., 2004; Tillin et al., 2011; Cooper and Brew, 2013).

6.6.4.3.2 Magnitude of Effect – SEP or DEP in Isolation

205. The changes in sea bed levels due to foundation installation under the worst-case sediment dispersion scenario are likely to have the magnitudes of effect shown in **Table 6-16**.

Table 6-16: Magnitude of effects on sea bed level changes due to deposition under the worst-case scenario for sediment dispersion following GBS foundation installation

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field*	Medium	Negligible	Negligible	Negligible	Low
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

*The near-field effects are confined to a small area of sea bed likely to be up to a kilometre from each foundation location and would not cover the whole of SEP or DEP.

206. Importantly, sand bank receptors are located in the north-west of the DEP North array area and DEP South array area and in the north of the cable corridor between the DEP North array area and SEP. The sensitivity and value of the receptor is presented in **Table 6-17**.

Table 6-17: Sensitivity and value assessment of sand bank receptors

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Sand banks (and associated sand waves)	Negligible	Negligible	Negligible	High	Negligible

6.6.4.3.3 Impact Significance – SEP or DEP in Isolation

207. The overall impact of sea bed preparation for foundation installation activities for SEP and DEP under a worst-case scenario on sea bed level changes for the East Anglian Coast and Cromer Shoal Chalk Beds MCZ is considered to be **negligible adverse** impact. This is because there is a separation distance of at least 17km (DEP South array area) and 6.2km (SEP) between the nearest sediment release point and the Cromer Shoal Chalk Beds MCZ or the East Anglian coast.

208. The overall impact of sea bed preparation for foundation installation activities for the project under a worst-case scenario on sea bed level changes for the sand banks within the DEP North and DEP South array areas is considered to be **negligible adverse** impact. This is because the predicted thickness of sediment resting on the sea bed would only amount to a maximum of 1mm. After this initial deposition, this sediment will be continually re-suspended to reduce the thickness even further to a point where it will be effectively zero. This will be the longer-term outcome once the sediment supply from foundation installation has ceased.

209. The worst-case scenario assumes that sea bed preparation activities would be the maximum for the given water depth. In practice, the volumes of sediment released would be lower than the worst-case at many wind turbine locations because the

detailed design process would optimise the foundation type and installation method to the site conditions.

210. The effects on sea bed level have the potential to impact upon other receptors and the assessment of impact significance is addressed within the relevant chapters of this ES (see **Section 6.9**).

6.6.4.3.4 SEP and DEP

211. The change in sea bed level due to the foundation installation at the wind farm site for a SEP and DEP will be similar to that outlined for SEP or DEP in isolation (**Section 6.6.4.3.1**).

6.6.4.3.5 Impact Significance – SEP and DEP

212. The change in sea bed levels due to foundation installation under the worst-case sediment dispersion scenario for SEP and DEP are likely to have the same magnitudes of effect as shown in **Table 6-16**. Hence, the overall impact of foundation installation activities for the project under a worst-case scenario on sea bed level changes for the East Anglian coast and the Cromer Shoal Chalk Beds MCZ is **negligible adverse** impact, and for the sank banks receptor is **negligible adverse** .

6.6.4.4 Impact 2b: Changes in sea bed level due to drill arisings for installation of piled foundations for wind turbines and OSPs

6.6.4.4.1 SEP or DEP in Isolation

213. The combined increases in suspended sediment concentrations and creation of aggregated clasts of mud associated with construction Impact 1b (see **Section 6.6.4.2**) have the potential to deposit sediment and raise the sea bed elevation.

214. Drilling of piled foundations could potentially occur through five different geological units (**Table 6-12**); Holocene deposits potentially overlying a series of four Pleistocene units comprised of consolidated clay and sand resting on Upper Cretaceous Chalk. The coarser sediment fractions (medium and coarse sands and gravels) and aggregated 'clasts' of mud of the Bolders Bank Formation would settle out of suspension in proximity to each foundation location.

215. The coarser sediment sand/gravel would be deposited near to the point of release up to thicknesses of approximately 3cm over a sea bed area local to each foundation (within 200m). For the most part, the deposited sediment layer across the wider sea bed area would be very thin, and confined to a maximum of two foundations in DEP and two foundations in SEP.

216. If the drilling penetrates underlying mud deposits, then a worst-case scenario is considered whereby the sediment released from the drilling is assumed to be wholly in the form of larger aggregated 'clasts' which would settle rapidly. These clasts would remain on the sea bed (at least initially), rather than being disaggregated into individual fine-grained sediment components immediately upon release. Under this scenario, the worst-case scenario assumes that a 'mound' would reside on the sea bed near the site of its release.

217. For an individual wind turbine, the worst-case is associated with an 18+MW monopile and assumes that each mound would contain a maximum volume of 10,053m^3 of sediment (assumes that all the drill arisings are in the form of aggregated clasts). An individual 15MW monopile mound would contain a maximum volume of 5,973m^3.

218. For drill arisings from the SEP or DEP project as a whole, the worst-case is for two x 15MW monopile foundations in each of SEP and DEP and one OSP per site (**Table 6-2**). These mounds would be composed of sediment with a different particle size and would behave differently (they would be cohesive) to the surrounding sandy sea bed, and therefore represent the worst-case scenario for mound formation during construction.

219. The method for calculating the footprint of each mound follows that which was developed and agreed with Natural England for earlier major offshore wind projects at Dogger Bank Creyke Beck (Forewind, 2013), Dogger Bank Teesside (Forewind, 2014), East Anglia THREE (East Anglia Three Limited (EATL), 2015), Norfolk Vanguard (Royal HaskoningDHV, 2017) and Norfolk Boreas (Royal HaskoningDHV, 2018). The methodology involves the following stages:

- Calculate the maximum potential width of a mound (for the given volume) based on the diameter of an assumed idealised cone on the sea bed. This was based on simple geometric relationships between volume, height, radius and side-slope angle of a cone. The latter parameter was taken as 30°, which is a suitable representation for an angle of friction of clasts of sediment.
- Calculating the maximum potential length of the mound (for the given volume and maximum potential width). The assumed height of the mound was ‘fixed’ in the calculation as being equivalent to the average height of the naturally occurring sand waves on the sea bed within the site. This calculation was based on simple geometric relationships between volume, height, width and length and assumed that, when viewed in side elevation, the mound would be triangular in profile but that its length is greater than its width, thus forming a ‘ramp’ shape.
- Based on the newly-calculated width and length of the mound, a footprint area on the sea bed could then be calculated.

220. Based on this approach, the footprint of an individual 2m-high mound arising from the installation of a 15MW wind turbine monopile would be 5,973m^2 (or 12,371m^2 SEP and DEP each, assuming a worst-case scenario of two 15MW wind turbines in each and one OSP per site is drilled).

221. Because of their potential size, future transport of the aggregated clasts would be limited, and most would remain static within the mound. However, over time the flow of tidal currents over the mound would gradually winnow (there would be a gradual disaggregation of the clasts into their constituent particle sizes) topmost clasts and over time the mound would lower through erosion. No specific calculations have been undertaken to understand how long it would take for the mounds to fully erode.

6.6.4.4.2 Magnitude of Effect – SEP or DEP in Isolation

222. The changes in sea bed levels due to foundation installation under the worst-case sediment dispersion scenario and sediment mound scenario are likely to have the magnitudes of effect shown in **Table 6-18** and **Table 6-19**, respectively.

Table 6-18: Magnitude of Effects on Sea Bed Level Changes due to Deposition Under the Worst-Case Scenario for Sediment Dispersion Following Piled Foundation Installation

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field*	Low	Low-Medium	Low-Medium	Negligible	Low
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

*The near-field effects are confined to a small area of sea bed likely to be up to a kilometre from each foundation location and would not cover the whole of SEP or DEP.

Table 6-19: Magnitude of Effects on Sea Bed Level Changes due to Deposition Under the Worst-Case Scenario for Sediment Mound Creation Following Piled Foundation Installation

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field+	Low	Low-Medium	Low-Medium	Medium	Low
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

+The near-field effects are confined to a small area of sea bed (likely to be immediately adjacent to each wind turbine location), and would not cover the whole of SEP or DEP.

223. Importantly, sand bank receptors are located in the north-west of the DEP North array area and DEP South array area and in the north of the cable corridor between the DEP North array area and SEP. The sensitivity and value of the receptor is presented in **Table 6-20**.

Table 6-20: Sensitivity and Value Assessment of Sand Bank Receptors

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Sand banks (and associated sand waves)	Negligible	Negligible	Negligible	High	Negligible

6.6.4.4.3 Impact Significance – SEP or DEP in Isolation

224. As the impacts are restricted to the near field impacts of dispersion and the potential formation of mounds, the overall impact of foundation installation activities for the proposed project under a worst-case scenario on sea bed level changes for the East Anglian Coast and Cromer Shoal Chalk Beds MCZ is considered to be **no impact**.

This is because there is a separation distance of at least 17km (DEP South array area) and 6.2km (SEP) between the nearest sediment release point and the Cromer Shoal Chalk Beds MCZ or the East Anglian coast. Also, transport of the aggregated clasts in the mounds would be limited, and so there would be no pathway between the source (mounds) and the receptors (MCZ and coast).

225. The layout of turbines will be decided post consent, however, as outlined in **Table 6-3**, foundations will be micro-sited to minimise the requirement for sea bed preparation and therefore sand bank features within the array sites will largely be avoided. In the event that sand banks are in proximity to foundation installation, the overall impact associated with sediment dispersion would be **negligible adverse** as the deposited sediment layer across the wider sea bed area (approximately 3cm over a sea bed area local to each foundation (within 200m)) could potentially deposit on a sand bank. After this initial deposition, this sediment will be continually re-suspended to reduce the thickness even further to a point where it will be effectively zero. This will be the longer-term outcome, once the sediment supply from foundation installation has ceased. The worst-case scenario assumes that piles would be drilled to their full depth for the given water depth. In practice, the volumes of sediment released would be lower than the worst-case because the detailed design process would optimise the foundation type and installation method to the site conditions.

226. The effects on sea bed level have the potential to impact upon other receptors and the assessment of impact significance is addressed within the relevant chapters of this ES (see **Section 6.9**).

6.6.4.4.4 SEP and DEP

227. The change in sea bed level due to the foundation installation at the wind farm site and OSP for a SEP and DEP will be similar to that outlined for SEP or DEP in isolation (**Section 6.6.4.3.1**).

228. For drill arisings from SEP and DEP as a whole, the worst-case is for four x 15MW monopile foundations and two OSPs (**Table 6-2**).

229. Based on the approach outlined in **Section 6.6.4.4.1**, the footprint of an individual 2m-high mound arising from the installation of a 15MW wind turbine monopile would be 10,053m^2. Two foundation installations and two OSPs would have a total mound area of 24,742m^2. When compared to the total area of SEP and DEP combined (196.10km^2 (excluding offshore temporary works area)), the worst-case mound footprint is only 0.01% of the sea bed within the SEP and DEP wind farm sites.

6.6.4.4.5 Impact Significance – SEP and DEP

230. The change in sea bed levels due to foundation installation under the worst-case sediment dispersion scenario and sediment mound scenario are likely to have the same magnitudes of effect as shown in **Table 6-18** and **Table 6-19**, respectively.

231. As the impacts are restricted to the near field impacts of the dispersion and the formation of the mounds, the overall impact of foundation installation activities for the proposed project under a worst-case scenario on sea bed level changes for the MCZ and East Anglian coast is considered to be **no impact**. This is because there

is a separation distance of at least 6.2km between the nearest sediment release point and the Cromer Shoal Chalk Beds MCZ or the East Anglian coast. Also, transport of the aggregated clasts in the mounds would be limited, and so there would be no pathway between the source (mounds) and the receptors (MCZ and coast). Similarly, there would be **no impact** from foundation installation activities associated with sediment mound creation as they will be remote from sand bank receptors. The overall impact associated with sediment dispersion scenario on sand banks would be **negligible adverse** as the deposited sediment layer across the wider sea bed area would be approximately 3cm over a sea bed area local to each foundation (within 200 metres), which could potentially deposit on a sand bank in proximity to the foundation. After this initial deposition, this sediment will be continually re-suspended to reduce the thickness even further to a point where it will be effectively zero. This will be the longer-term outcome, once the sediment supply from foundation installation has ceased.

6.6.4.5 Impact 3: Change in suspended sediment concentrations due to export cable installation

232. The assessment of changes in suspended sediment concentrations during export cable installation has been considered separately from those for the infield and interlink cables because parts of the offshore cable corridor are in shallower water and closer to the identified morphological receptor groups.

6.6.4.5.1 SEP or DEP in Isolation

233. The detail of the export cabling is dependent upon the final project design, but present estimates are that the maximum length of export cable could be up to 62km for DEP and 40km for SEP. The worst-case cable laying technique is considered to be jetting due the greater width of disturbance compared to ploughing.

234. Sand wave levelling (pre-sweeping) may be required at the northern end of the export cable corridor at the DEP North array area prior to export cable installation (**Figure 4.9** of **Chapter 4 Project description**). No sand wave levelling is expected for a SEP in isolation scenario because there are no sand waves along the export cable corridor. The worst-case scenario assumes that sediment would be dredged and returned to the water column at the sea surface as overflow from a dredger vessel. This process would cause localised and short-term increases in suspended sediment concentrations both at the point of dredging at the sea bed and, more importantly, at the point of its discharge back into the water column.

235. Mobilised sediment from these activities may be transported by wave and tidal action in suspension in the water column. The sediment released at any one time would depend on the capacity of the dredger. Any sediment excavated during sand wave levelling would be disposed of within the export cable corridor, meaning there will be no net loss of sand from the site.

236. The installation of the export cables has the potential to disturb the sea bed down to a sediment thickness of up to 1.0m (depending on the area) and a width of up to 1.0m. A trench will also be required at the HDD exit location, located approximately 1,000m offshore. **Table 6-2** summarises the worst-case scenario sediment releases.

237. The types and magnitudes of effects that could be caused have previously been assessed within an industry best-practice document on cabling techniques (BERR 2008 and The Crown Estate/RPS, 2019). This document has been used in the conceptual evidence-based assessment of site conditions to inform the below.

238. It is anticipated using conceptual evidence-based assessment and the results from modelling at the SOW and DOW export cable corridors (Section **6.6.3.4.1**) that the changes in suspended sediment concentration due to export cable installation would be less than those that have been assessed in relation to the disturbance of near-surface sediments during foundation installation activities (**Section 6.6.4.1** and **Section 6.6.4.2**), although the location of effect would differ as it would be focused along the offshore cable corridor.

239. Also, although suspended sediment concentrations will be elevated they are likely to be lower than concentrations that would develop in the water column during storm conditions including the December 2013 storm surge and other recent events. Storms can rapidly change sea bed sediment distribution through re-suspension and re-deposition. They are short-term natural phenomenon that are likely to drive greater changes to the sea bed than the changes that would occur due to the presence of the wind farm infrastructure. Also, once jetting is completed, tidal currents are likely to rapidly disperse the suspended sediment (i.e. over a period of a few hours) in the absence of any further sediment input.

240. It is likely that the increase in concentrations would be greatest in the shallowest sections of the offshore cable corridor, but in these locations the background concentrations are also greater than in deeper waters, with values up to 170mg/l recorded in the vicinity of the coast at Great Yarmouth (ABPmer, 2012).

241. Modelling simulations undertaken for SOW and DOW (Section **6.6.3.4.1**) confirm the evidence-based assessment and provided the following quantification of magnitude of change:

- Sand and gravel-sized sediment (which represents most of the disturbed sediment) would settle out of suspension rapidly to the bed in the immediate location of the export cable corridor. Fine sand will most likely remain in the bottom 1-2 m of the water column, and with settling velocities of around 10mm/s, this will ensure the fine sand settles within half an hour or less or become part of the ambient near bed transport (Soulsby, 1997).
- The majority of disturbed sediment will initially resettle within 20m of the export cable, with almost no sand being transported further than 100m from the cable.
- Mud-sized material (which represents only a very small proportion of the disturbed sediment) would be advected a greater distance up to 2km and persist in the water column for hours to days.

242. In areas where the cable is buried up to 1.0m, the cable would be installed in (mobile) sands only, with no disturbance of underlying chalk or other beds. The amount of fine sediment recorded from samples along the export cable corridor is less than 10% in 90% of samples. Therefore, dispersion from these areas is assumed to be very low.

243. As described in **Section 6.5**, there are similarities in water depth, sediment types and metocean conditions between the offshore export cable corridors for SOW and DOW and for SEP and DEP making the earlier modelling studies a suitable analogue for the present assessments.

244. The HDD exit point will be in the subtidal zone approximately 1000m offshore, seaward of the low water mark and at least 9-10m below LAT. The cable exit point would require excavation of a trench to bury the nearshore portion of the offshore cable on the seaward side of the landfall HDD. This excavation has the potential to increase suspended sediment concentrations close to shore.

245. During the excavation process the suspended sediment concentrations will be elevated above prevailing conditions, but are likely to remain within the range of background nearshore levels (which will be high close to the coast because of increased wave activity) and lower than those concentrations that would develop during storm conditions. Also, once jetting is completed, the high energy nearshore zone is likely to rapidly disperse the suspended sediment (i.e. over a period of a few hours) in the absence of any further sediment input.

246. Excavated sediment would be backfilled into the trench by mechanical means (within a few days of excavation) and the nearshore zone re-instated close to its original morphology. This activity would result in some localised and short-term disturbance to the beach and nearshore zone, but there would be no long-term effect on sediment transport processes.

6.6.4.5.2 Magnitude of Effect – SEP or DEP in Isolation

247. The worst-case changes in suspended sediment concentrations due to export cable installation at SEP or DEP are likely to have the following magnitudes of effect shown in **Table 6-21**.

Table 6-21: Magnitude of Effect on Suspended Sediment Concentrations Under the Worst-Case Scenario for Export Cable Installation within the Offshore Cable Corridor

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field* (nearshore)	Low	Negligible	Negligible	Negligible	Negligible
Near-field* (offshore)	Low	Negligible	Negligible	Negligible	Negligible
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

* The near-field effects are confined to a small area likely to be of the order up to a kilometre from the offshore cable corridor, and would not cover the whole offshore cable corridor.

6.6.4.5.3 Impact Significance – SEP or DEP in Isolation

248. These effects on suspended sediment concentrations due to export cable installation within the offshore cable corridor would have **no impact** upon the identified receptors groups for marine geology, oceanography and physical processes. This is because the receptors are dominated by processes that are active along the sea bed and are not affected by sediment suspended in the water

column. However, there may be impacts arising from subsequent deposition of the suspended sediment on the sea bed and these are discussed under construction Impact 4 (**Section 6.6.4.6**).

249. The effects do have the potential to impact upon other receptors and therefore the assessment of impact significance is addressed within the relevant chapters of this ES (see **Section 6.9**).

6.6.4.5.4 SEP and DEP

250. For SEP and DEP, the worst-case scenario for the export cable is a two OSP scenario (**Table 6-2**). The same volume of sand wave levelling (pre-sweeping) may be required at the northern end of the export cable corridor at the DEP North array area prior to export cable installation (**Figure 4.9** of **Chapter 4 Project Description**).

251. The potential change in suspended sediment concentrations due to export cable installation for SEP and DEP (including sand wave levelling and trenching at the HDD exit point) is similar to that of DEP in isolation (**Table 6-2**). Although suspended sediment concentrations will be elevated, they are likely to be lower than concentrations that would develop in the water column during storm conditions. Once jetting is completed, tidal currents are likely to rapidly disperse the suspended sediment (i.e. over a period of a few hours) in the absence of any further sediment input.

252. The overall impact of export cable installation under a worst-case scenario on suspended sediment concentrations for the identified morphological receptor groups is considered to be **no impact** because the receptors are dominated by processes that are active along the sea bed and are not affected by sediment suspended in the water column .

6.6.4.6 Impact 4: Change in sea bed level due to deposition from the suspended sediment plume during export cable installation within the offshore export cable corridor

253. The assessment of change in sea bed level due to offshore export cable installation has been considered separately from those for the infield and interlink cables.

6.6.4.6.1 SEP or DEP in Isolation

254. The increases in suspended sediment concentrations associated with offshore export cable installation have the potential to result in changes in sea bed level as the suspended sediment deposits.

255. The plume modelling simulations for SOW and DOW indicate that sand-sized material would settle out of suspension within less than 20m from the point of installation within the offshore export cable corridor and persist in the water column for less than half an hour. Almost no sand was predicted to be carried more than 100m from the cable. As there is already significant ambient sand transport in the vicinity, the small amounts of additional resettled sand will not change the local transport to any significant degree. Due to the coarse sediment particle sizes observed across the site (predominantly medium-grained sand), a large proportion of the disturbed sediment would behave in this manner.

256. The low amount of mud-sized material present at SEP and DEP (**Section 6.5**) would be advected a greater distance and persist in the water column for hours to days, before depositing to form a thin layer on the sea bed. However, it is anticipated that under the prevailing hydrodynamic conditions, this sediment would be readily re-mobilised, especially in the shallow inshore area where waves would regularly agitate the bed. Accordingly, outside the immediate vicinity of the offshore export cable trench, bed level changes and any changes to sea bed character are expected to be not measurable in practice. Also, as outlined in **Section 6.6.4.5.1,** although chalk plumes may extend some distance, there is no evidence that the very low levels of suspended load have any impact on marine habitats or species (DOW, 2009).

6.6.4.6.2 Magnitude of Effect – SEP or DEP in Isolation

257. The worst-case changes in sea bed levels due to export cable installation within the offshore cable corridor are likely to have the magnitudes of effect described in **Table 6-22**.

Table 6-22: Magnitude of Effects on Sea Bed Level Changes due to Export Cable Installation within the Offshore Cable Corridor Under the Worst-Case Scenario for Suspended Sediment Concentrations

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field*	Low	Negligible	Negligible	Negligible	Low
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

*The near-field effects are confined to a small area of sea bed likely to be up to a kilometre from the offshore cable corridor, and would not cover the whole export cable corridor.

258. Importantly, the offshore export cable corridor passes through the Cromer Shoal Chalk Beds MCZ and will be close to the East Anglian coast. It will also be in proximity to sand bank receptors in the north of the cable corridor close to the DEP North array area. The sensitivity and value of the receptors are presented in **Table 6-23**.

Table 6-23: Sensitivity and Value Assessment of Identified Morphological Receptors

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
East Anglian Coast	Negligible	Negligible	Negligible	High	Negligible
Cromer Shoal Chalk Beds MCZ	Negligible	Negligible	Negligible	High	Negligible
Sand banks (and associated sand waves)	Negligible	Negligible	Negligible	High	Negligible

6.6.4.6.3 Impact Significance – SEP or DEP in Isolation

259. Based on the DOW plume modelling simulations, conceptual evidence-based assessment of deposition from the plume generated from cable installation indicates that the changes in sea bed elevation are effectively immeasurable within the

accuracy of any numerical model or bathymetric survey. This means that given these very small magnitude changes in sea bed level arising from export cable installation, the impacts on the identified morphological receptors would not be significant. Hence, the overall impact of offshore cable installation activities under a worst-case scenario on bed level changes for the identified morphological receptor groups is considered to be **no impact** for the East Anglian Coast and **negligible adverse** impact for Cromer Shoal Chalk Beds MCZ and sand banks in the north of the export cable corridor close to the DEP North array area.

260. In many parts of the offshore cable corridor the export cable installation is unlikely to result in the release of the volumes of sediment considered under this worst-case scenario. In addition, the optimisation of the offshore cable route selection within the corridor, depth and installation methods during detailed design would ensure that impacts are minimised.

261. The effects on sea bed level also have the potential to impact upon other receptors and therefore the assessment of impact significance is addressed within relevant chapters of this ES.

6.6.4.6.4 SEP and DEP

262. The potential change in sea bed level due to export cable installation for SEP and DEP will be similar to that outlined for DEP in isolation (see **Section 6.6.4.6.1**). Hence, the overall impact of offshore cable installation activities under a worst-case scenario on bed level changes for the identified morphological receptor groups is considered to be **no impact** for East Anglian Coast and **negligible adverse impact** for Cromer Shoal Chalk Beds MCZ and sand banks in the north of the export cable corridor close to the DEP North array area.

6.6.4.7 Impact 5: Change in Suspended Sediment Concentrations due to Offshore Cables Installation (Infield and Interlink Cables)

263. As the interlink cables between the DEP North array area and SEP, the DEP South array area and SEP, and DEP North and DEP South array areas will only be constructed in a DEP in isolation or SEP and DEP scenario, changes in suspended sediment concentrations due to interlink cable installation are not considered within a SEP in isolation scenario.

6.6.4.7.1 SEP or DEP in Isolation

264. The details of the infield and interlink cabling are dependent upon the final project design (**Table 6-2**). There are no interlink cables for a SEP in isolation scenario. The cable burial technique for infield and interlink cables is assumed to be 50% jetting and 50% mechanical cutting. The worst-case cable laying technique is considered to be mechanical cutting due the greater width of disturbance compared to jetting, and so the assessment below considers 100% of infield and interlink cables installed by mechanical cutting.

265. Sand wave levelling (pre-sweeping) may be required in the DEP North array area, DEP South array area and adjacent sections of offshore cable corridors prior to infield and interlink cable installation (**Figure 4.9** of **Chapter 4 Project Description**).

No sand wave levelling is expected for a SEP in isolation scenario. The worst-case scenario assumes that sediment would be dredged and returned to the water column at the sea surface as overflow from a dredger vessel. This process would cause localised and short-term increases in suspended sediment concentrations both at the point of dredging at the sea bed and, more importantly, at the point of its discharge back into the water column. **Table 6-2** summarises the worst-case scenario volume of sediment disturbed for each scenario.

266. Mobilised sediment from these activities may be transported by wave and tidal action in suspension in the water column. The disturbance effects at each location are likely to last for no more than a few days. The sediment released at any one time would depend on the capacity of the dredger. Any sediment excavated during sand wave levelling would be disposed of within the DEP wind farm sites and export cable corridor, meaning there will be no net loss of sand from the sites.

267. The types and magnitudes of effects that could be caused have previously been assessed within an industry best practice document on cabling techniques (BERR, 2008). This document has been used to support the evidence-based assessment of site conditions to inform the below.

268. Conceptual evidence-based assessment indicates that the changes in suspended sediment concentration due to infield and interlink cable installation would be similar to those that have been assessed in relation to the disturbance of near-surface sediments during foundation installation activities (see Construction impact 1a).

6.6.4.7.2 Magnitude of Effect – SEP or DEP in Isolation

269. The worst-case changes in suspended sediment concentrations due to infield and interlink cable installation are likely to have the following magnitudes of effect (**Table 6-24**).

Table 6-24: Magnitude of Effect on Suspended Sediment Concentrations under the Worst-Case Scenario for Infield and Interlink Cable Installation

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field*	High	Negligible	Negligible	Negligible	Medium
Far-field	Low	Negligible	Negligible	Negligible	Low

* The near-field effects are confined to a small area likely to be up to a kilometre from the cable, and would not cover the entirety of the sea bed area within the SEP or DEP wind farm site.

6.6.4.7.3 Impact Significance – SEP or DEP in Isolation

270. The effects on suspended sediment concentrations due to infield and interlink cable installation (including that from any sea bed preparation) will have **no impact** upon the identified receptors groups for marine geology, oceanography and physical processes. This is because the receptors are dominated by processes that are active along the sea bed and are not affected by sediment suspended in the water column. However, there may be impacts arising from subsequent deposition of the

suspended sediment on the sea bed and these are discussed under construction Impact 6 (**Section 6.6.4.8**).

271. The effects do have the potential to impact upon other receptors and therefore the assessment of impact significance is addressed within the relevant chapters of this ES (see **Section 6.9)**.

6.6.4.7.4 SEP and DEP

272. The details of the infield and interlink cabling are dependent upon the final project design (**Table 6-2**).

273. The cable burial technique for infield and interlink cables is assumed to be 50% jetting and 50% mechanical cutting. The worst-case cable laying technique is considered to be mechanical cutting due the greater width of disturbance compared to jetting, therefore the assessment below considers 100% of infield cables installed by mechanical cutting.

274. Sand wave levelling is required prior to interlink and infield cable installation at the north end of the corridor between SEP and the DEP North array area, between the DEP North array area and DEP South array area, and within the DEP North and DEP South array areas (**Figure 4.9**). Any excavated sediment due to sand wave levelling preparation for the infield and interlink cables would be disposed of within the SEP and DEP wind farm sites. This means there will be no net loss of sand from the site. **Table 6-2** summarises the worst-case volume of sediment affected due to infield and interlink cable installation, including sand wave levelling.

275. It is anticipated using evidence-based assessment that the changes in suspended sediment concentration due to infield and interlink cable installation would be similar to those arising from the disturbance of near-surface sediments during foundation installation activities including sea bed preparation (see construction impact 1a).

6.6.4.7.5 Impact Significance – SEP and DEP

276. The worst-case changes in suspended sediment concentrations due to infield and interlink cable installation for SEP and DEP are likely to have the same magnitudes of effect as those outlined in **Table 6-24**. Hence, there will be **no impact** on the identified receptors groups associated with the suspended sediment generated by SEP and DEP.

6.6.4.8 Impact 6: Change in Sea Bed Level due to Offshore Cable Installation (Infield and Interlink Cables)

277. The increases in suspended sediment concentrations associated with construction Impact 5 (**Section 6.6.4.7**) have the potential to result in changes in sea bed levels as the suspended sediment deposits.

278. Given that interlink cables will only be required in a DEP in isolation or SEP and DEP scenario, changes in sea bed level due to interlink cable installation are not assessed for SEP in isolation.

6.6.4.8.1 SEP or DEP in Isolation

279. As discussed in **Section 6.6.4.7**, sand wave levelling (pre-sweeping) is only required for a DEP in isolation scenario. No sand wave levelling is expected for a SEP in isolation scenario.

280. The evidence-based assessment suggests that coarser sediment disturbed during cable installation would fall rapidly to the sea bed (minutes or tens of minutes) as a highly turbid dynamic plume immediately after it is discharged. Deposition of this sediment would form a linear mound (likely to be tens of centimetres high) parallel to the cable as the point of release moves along the excavation. Due to the coarser sediment particle sizes observed across the site (predominantly medium-grained sand), a large proportion of the disturbed sediment would behave in this manner and be similar in composition to the surrounding sea bed. This would mean that there would be no significant change in sea bed sediment type.

281. A very small proportion of mud would also be released to form a passive plume and become more widely dispersed before settling on the sea bed. The conceptual evidence-based assessment suggests that due to the dispersion by tidal currents, and subsequent deposition and re-suspension, the deposits across the wider sea bed would be very thin (millimetres).

6.6.4.8.2 Magnitude of Effect – SEP or DEP in Isolation

282. Evidence-based assessment indicates that changes in sea bed level due to infield and interlink cable installation (including any deposition arising from spilled sediment from sand wave levelling) would be minor and are likely to have the magnitudes of effect shown in **Table 6-25**.

Table 6-25: Magnitude of Effect on Sea Bed Level Changes due to Deposition Under the Worst-Case Scenario for Sediment Dispersion Following Infield Cable Installation (Including Sand Wave Levelling)

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field*	Low	Negligible	Negligible	Negligible	Low
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

*The near-field effects are confined to a small area of sea bed likely to be up to a kilometre from the cable, and would not cover the whole of SEP or DEP.

6.6.4.8.3 Impact Significance – SEP or DEP in Isolation

283. These effects on sea bed level are considered highly unlikely to have the potential to impact directly upon the identified receptor groups for marine geology, oceanography and physical processes. Any impacts will be of lower magnitude than those sea bed level impacts already considered for the installation of foundations. Consequently, the overall impact of infield and interlink cable installation under a worst-case scenario on sea bed level changes for the East Anglian Coast and Cromer Shoal Chalk Beds MCZ is considered to be **negligible adverse** impact due to the separation distance between these receptors and infield and interlink cables.

The overall impact of infield and interlink cable installation under a worst-case scenario on sea bed level changes for sand banks is therefore considered to be **negligible adverse** for SEP or DEP in isolation.

284. The effects on sea bed level also have the potential to impact upon other receptors and the assessment of impact significance is addressed within the relevant chapters of this ES (see **Section 6.9**).

6.6.4.8.4 SEP and DEP

285. Although the volume of sediment disturbed for SEP and DEP will be greater than DEP in isolation (**Section 6.6.4.7.4** and **Table 6-2**), evidence-based assessment suggests that the change in sea bed level due to infield and interlink cable installation would be less than that arising from the change in sea bed level during foundation installation activities including sea bed preparation. This is because the overall sediment release volumes would be low and confined to near the sea bed (rather than higher in the water column) along the alignment of the cables, and the rate at which sediment is released from the mechanical cutting process would be relatively slow.

6.6.4.8.5 Impact Significance – SEP and DEP

286. The worst-case change in sea bed level due to infield and interlink cable installation for SEP and DEP is likely to have the same magnitude of effects as those outlined in **Table 6-25**.

287. Consequently, the overall impact of infield and interlink cable installation activities under a worst-case scenario on sea bed level changes for the East Anglian Coast and Cromer Shoal Chalk Beds MCZ is considered to be **negligible adverse** impact due to the separation distance between these receptors and infield and interlink cables. The overall impact of infield and interlink cable installation under a worst-case scenario on sea bed level changes for sand banks is therefore considered to be **negligible adverse** for SEP and DEP.

6.6.4.9 Impact 7: Interruptions to Bedload Sediment Transport due to Sand Wave Levelling for Offshore Cable Installation

288. Sand wave levelling is required prior to offshore cable installation at the north end of the cable corridor between SEP and the DEP North array area, between the DEP North and DEP South array areas, and within the DEP North and DEP South array areas (**Figure 4.9** of **Chapter 4 Project Description**). No sand wave levelling is required for a SEP in isolation scenario.

289. The removal of sand waves could potentially interfere with sediment transport pathways that supply sediment to the local sand bank systems.

6.6.4.9.1 DEP in Isolation

290. Any excavated sediment due to sand wave levelling for offshore cables would be disposed of within the SEP and DEP wind farm sites or offshore cable corridors (see the **Disposal Site Characterisation Report** (document reference 9.13) and therefore there will be no net loss of sand from the site. Tidal currents would, over

time, re-distribute the sand back over the levelled area (as re-formed sand waves). The extent of sand wave levelling required and specific disposal locations within the project sites would be determined post consent following detailed geophysical surveys. However, given the relatively low volumes of sand likely to be affected, the overall effect of changes to the sea bed would be minimal.

291. The dynamic nature of the sand waves in this area means that any direct changes to the sea bed associated with sand wave levelling are likely to recover over a short period of time due to natural sand transport pathways. This conceptual evidence-based assessment is supported by the findings of a review of the evidence base into the recovery of sand waves at the similarly dynamic areas of Race Bank and Haisborough Hammond and Winterton SAC (the Norfolk Projects).

292. To install parts of the array and export cables for Race Bank Offshore Wind Farm, the crests of sand waves were reduced in elevation. Ørsted (2018) reported the results of multibeam echosounder monitoring of pre- (2015/2016), during (2017) and post- (2018) sand wave levelling (pre-sweeping) to assess the level of disturbance and the rate of natural recovery (restoration) of sea bed morphology. Nine areas were chosen (seven array cables routes, two areas along the export cable routes) where significant sediment mobility was expected. The results showed that along most of the nine study areas, the sea bed had completely or nearly completely recovered to pre-construction levels (greater than 75% recovery of sand waves in all areas).

293. ABPmer (2018) completed a sand wave study in relation to cable installation activities in the Haisborough, Hammond and Winterton SAC which has informed the impact assessments for the Norfolk Projects. They showed that the cable corridor is in an active and highly dynamic environment governed by current flow speeds, water depth and sediment supply, all of which are conducive to the development and maintenance of sand banks. Therefore, despite the disturbance to sand waves intersecting the cable corridor, the Haisborough, Hammond and Winterton SAC sand bank system would remain undisturbed as new sand waves will continue to be formed. They concluded that the overall form and functioning of any sand wave, or the SAC sandbank system, is not disrupted by levelling of the sand waves.

6.6.4.9.2 Magnitude of Effect – DEP in Isolation

294. The worst-case changes in bedload sediment transport due to sand wave levelling within offshore cable corridors are likely to have the magnitudes of effect described in **Table 6-26**.

Table 6-26: Magnitude of Effects on Bedload Sediment Transport under the Worst-Case Scenario for Sand Wave Levelling within Offshore Cable Corridors

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field*	Medium	Negligible	Negligible	Negligible	Low
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

*The near-field effects are confined to a small area of sea bed (likely to be of the order of several hundred metres up to a kilometre from the cable corridors), and would not cover the whole cable corridors.

6.6.4.9.3 Impact Significance – DEP in Isolation

295. Keeping the dredged sand within the sand bank system enables the sand to become re-established within the local sediment transport system by natural processes and encourages the re-establishment of the bedform features. Given the local favourable conditions that enable sand wave development, the sediment would be naturally transported back into the levelled area within a short period of time. The levelled area will naturally act as a sink for sediment in transport and will be replenished in the order of a few days to a year. The overall impact of sand wave levelling activities within the offshore cable corridors on the East Anglian Coast and Cromer Shoal Chalk Beds MCZ is considered to be **no impact** due to the separation distance between these receptors and offshore cable corridors. The overall impact of sand wave levelling activities on sand banks is considered to be **negligible adverse**.

296. The effects on bedload sediment transport also have the potential to impact upon other receptors and therefore the assessment of impact significance is addressed within relevant chapters of this ES (see **Section 6.9**).

6.6.4.9.4 SEP and DEP

297. The worst-case for SEP and DEP assumes a one OSP scenario. Although the volume of sediment disturbed for SEP and DEP will be greater than DEP in isolation (**Table 6-2**), evidence-based assessment suggests that given the local favourable conditions that enable sand wave development, the sediment would be naturally transported back into the levelled area within the order of a few days to a year.

6.6.4.9.5 Impact Significance – SEP and DEP

298. The worst-case impact of interruption to bedload sediment transport due to sand wave levelling activities within offshore cable corridors for SEP and DEP are likely to have the same magnitude of effects as those outlined in **Table 6-26.**

299. Consequently, the overall impact of sand wave levelling activities under the worst-case scenario for the identified morphological receptor groups for SEP and DEP is considered to be **no impact** for the East Anglian Coast and Cromer Shoal Chalk Beds MCZ and **negligible adverse** impact for sand banks.

6.6.4.10 Impact 8: Indentations on the sea bed due to installation vessels

6.6.4.10.1 SEP or DEP in Isolation

300. There is potential for certain vessels used during installation of SEP or DEP and cable infrastructure to directly impact the sea bed. This applies for those vessels that utilise jack-up legs or several anchors to hold station and to provide stability for a working platform. Where legs or anchors (and associated chains) have been inserted into the sea bed and then removed, there is potential for an indentation to remain, proportional to the dimensions of the object. The worst-case scenario is considered to correspond to the use of jack-up vessels, since the depressions would be greater than the anchor scars.

301. As the leg is inserted, the sea bed sediments would primarily be compressed vertically downwards and displaced laterally. This may cause the sea bed around

the inserted leg to be raised in a series of concentric pressure ridges. As the leg is retracted, some of the sediment would return to the hole via mass slumping under gravity until a stable slope angle is achieved. Over the longer term, the hole would become shallower and less distinct due to infilling with mobile sea bed sediments. Indeed, post-construction monitoring of DOW indicates that natural processes are restoring local areas of sea bed affected by the construction works.

302. A six-legged jack-up barge used for the installation of turbines/OSPs would have a footprint of 1,200m^2. Each leg could penetrate 5 to 15m into the sea bed and may be cylindrical, triangular, truss leg or lattice. The worst-case scenario assumes that two jack-up deployments will be required at each turbine/OSP, with up to 12 temporary mooring lines required (**Table 6-2**). The export and interlink cable installation vessels will require seven mooring lines. Cable protection measures at the HDD exit point will require jack-up deployments with a footprint of 128m^2 (**Table 6-2**).

6.6.4.10.2 Magnitude of Effect – SEP or DEP in Isolation

303. The worst-case changes in terms of indentations on the sea bed due to installation vessels are likely to have the magnitudes of effect described in (**Table 6-27**).

Table 6-27: Magnitude of Effect on Sea Bed Level Changes under the Worst-Case Scenario for Installation Vessels

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field (immediate vicinity of leg)	High	Negligible	Negligible	Medium	Medium
Near-field (beyond immediate vicinity of leg)	No change	-	-	-	No change
Far-field	No change	-	-	-	No change

304. Installation of the export cable and cable protection measures at the HDD exit point will involve a small jack-up and anchor footprint within the Cromer Shoal Chalk Beds MCZ. These activities will not impact the East Anglian coast as they are at least 1,000m offshore. Given this, the sensitivity and value of this receptor is presented in **Table 6-28**.

Table 6-28: Sensitivity and Value Assessment for the Cromer Shoal Chalk Beds MCZ

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Cromer Shoal Chalk Beds MCZ	Negligible	Negligible	Negligible	High	Negligible

6.6.4.10.3 Impact Significance – SEP or DEP in Isolation

305. The footprint of jack-ups and mooring lines used during the installation of turbines/OSPs and interlink cables would not extend beyond the direct footprint. Therefore, there is **no impact** from these activities associated with SEP or DEP in

isolation on the Cromer Shoal Chalk Beds MCZ or East Anglian coast since these receptors are located remotely from this zone of potential effect.

306. The layout of turbines and offshore cables will be decided post consent, however, as outlined in **Table 6-3**, foundations and offshore cables will be micro-sited to minimise the requirement for sea bed preparation and therefore sand bank features within the wind farm sites and along the offshore cable corridors will largely be avoided. In the event that it is not possible for jack-up vessel legs or cable installation vessel anchors to avoid sand banks, there is potential for indentations to occur however any disturbance footprint would be limited in scale (see **Table 6-2**) and any impacts would be temporary in nature with indentations infilling through natural processes over the course of a few days to months. Therefore, a **negligible adverse impact** would occur from these activities associated with SEP or DEP in isolation on sand banks.

307. The extremely small footprints of the jack-ups and anchors (**Table 6-2**) associated with the installation of the export cable and cable protection measures at the HDD exit point would have a **negligible adverse impact** on the Cromer Shoal Chalk Beds MCZ.

308. The significance of these effects on other receptors is addressed within the relevant chapters of this ES (see **Section 6.9**).

6.6.4.10.4 SEP and DEP

309. For SEP and DEP, the overall areas of the sea bed affected by vessels would be greater (**Table 6-2**) and the construction phase would occur over 48 months if built concurrently (i.e. the same as SEP or DEP in isolation) or potentially up to four years if built sequentially. The assessment of significance for wind turbine/OSP and interlink cables previously made for SEP or DEP in isolation is the same for SEP and DEP with respect to the Cromer Shoal Chalk Beds MCZ or East Anglian coast since these receptors are located remotely from the zone of potential effect. As such, there is **no impact** under a worst-case scenario on the identified receptor groups during wind turbine/OSP and interlink cable installation Whilst, under a sequential build scenario, the potential impacts from indentations on the sea bed at the HDD exit point have potential to occur over a longer time period compared to SEP or DEP in isolation or a concurrent build scenario, upon completion of the activity, infilling through natural processes over the course of a few days to months would still occur and therefore an equivalent **negligible adverse impact** associated with export cable installation and installation of cable protection measures at the HDD exit point within the Cromer Shoal Chalk Beds MCZ (**Table 6-2**) is predicted.

6.6.5 Potential Impacts During Operation

310. During the operational phase of SEP or DEP, there is potential for the presence of foundations to cause changes to the tidal and wave regimes due to physical blockage effects. These changes could potentially affect the sediment regime and/or sea bed morphology. These potential effects are considered as operational Impacts 1 to 6. In addition, there is potential for disturbance of the sea bed during maintenance activities. These potential effects are considered as operational Impact 7.

6.6.5.1 Impact 1: Changes to the Tidal Regime due to the Presence of Structures on the Sea Bed (Wind Turbines and OSP Foundations)

6.6.5.1.1 SEP or DEP in Isolation

311. The presence of the worst-case GBS wind turbine foundation and suction bucket OSP foundation structures on the sea bed within SEP or DEP has the potential to alter the baseline tidal regime, particularly tidal currents. Any changes in the tidal regime have the potential to contribute to changes in the sea bed morphology due to alteration of sediment transport patterns (see operational Impact 3, **Section 6.6.5.3**).

312. The conceptual evidence-based assessment suggests that each foundation would present an obstacle to the passage of currents locally, causing a small modification to the height and/or phase of the water levels and a wake in the current flow. This latter process involves a deceleration of flow immediately upstream and downstream of each foundation and an acceleration of flow around the sides of each foundation. Current speeds return to baseline conditions with progression downstream of each foundation and generally do not interact with wakes from adjacent foundations due to the separation distances.

313. The assessment of tidal currents at the adjacent SOW and DOW, which have conservative designs compared to the SEP and DEP designs (**Section 6.6.3**), concluded that there would be no significant changes to the broad scale flow regime, with a reduction in the overall flow within SOW of 1-2% and an increase in flow locally around each structure (Scira, 2006). No significant impact on the tidal current regime was anticipated for both SOW and DOW, and the same conclusion (based on SOW and DOW as analogies, **Section 6.6.3**) is drawn for SEP and DEP.

314. In addition, there is a pre-existing scientific evidence base which demonstrates that changes in the tidal regime due to the presence of foundation structures are both small in magnitude and localised in spatial extent. This is confirmed by existing guidance documents (ETSU, 2000; ETSU, 2002; Lambkin *et al*., 2009) and numerous ESs for a range of existing and planned OWFs. Also, post-construction monitoring of DOW demonstrates that changes to sea bed sediment distribution due to the presence of the turbines are minimal, implying that changes to tidal currents (and waves) are local and do not have a significant effect on sediment transport further afield.

6.6.5.1.2 Magnitude of Effect – SEP or DEP in Isolation

315. The worst-case changes to tidal currents due to the presence of GBS foundations are likely to have the following magnitudes of effect (**Table 6-29**).

Table 6-29: Magnitude of Effects on Tidal Currents under the Worst-Case Scenario for the Presence of GBS Foundations

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field	Low	High	Medium	Negligible	Low

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Far-field	Negligible	High	Medium	Negligible	Negligible

316. These effects on the tidal regime have been translated into a ‘zone of potential influence’ based on an understanding of the tidal ellipses. The zone of potential influence is based on the knowledge that effects arising from wind turbine and substation foundations on the tidal regime are relatively small in magnitude, and local. It is expected that changes to the tidal regime would have returned to background levels immediately outside the excursion of one tidal ellipse, and this threshold has been used to produce the maximum ‘zone of potential influence’ on the tidal regime, as presented in **Figure 6.11**.

317. The DEP North array area zone of influence (**Figure 6.11**) overlaps with sand banks located in the north-west of DEP North array area and DEP South array area and in the north of the cable corridor between the DEP North array area and SEP. The sensitivity and value of the receptor is presented in **Table 6-30**.

Table 6-30: Sensitivity and Value Assessment of Sand Bank Receptors

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Sand banks (and associated sand waves)	Negligible	Negligible	Negligible	High	Negligible

6.6.5.1.3 Impact Significance – SEP or DEP in Isolation

318. The East Anglian coast and Cromer Shoal Chalk Beds MCZ receptor groups are remote from the zone of potential influence on the tidal regime. Due to this, no pathway exists between the source and these receptors, so in terms of impacts on these receptor groups there is **no impact** associated with SEP or DEP in isolation.

319. The predicted zone of influence for the DEP North array area encompasses the sand bank receptors present within the DEP North array area, DEP South array area and the north of the cable corridor between the DEP North array area and SEP. As outlined in **Section 6.6.5.1.1**, no significant impact on the tidal current regime is anticipated for SEP and DEP and therefore the impact on sand banks is anticipated to be **negligible adverse**.

6.6.5.1.4 SEP and DEP

320. **Figure 6.11** shows that the zones of potential influence for SEP and DEP do not overlap, and the combined effect on tidal currents would be the same as the two sites individually. Hence, the worst-case changes to tidal currents due to the presence of GBS foundations (43 18MW wind turbines) and suction bucket foundations (eight legs at two OSPs) at SEP and DEP will be similar to those outlined for SEP or DEP in isolation. No pathway exists between the source and the East Anglian coast or Cromer Shoal Chalk Beds MCZ receptors, so there is **no impact** associated with SEP and DEP. Due to the overlap of the zone of potential

influence for the DEP North array area with sand banks within DEP North array area, DEP South array area and north of the cable corridor between DEP North array area and SEP, there is potential for impact on sand banks however any impact is anticipated to be **negligible adverse**.

6.6.5.2 Impact 2: Changes to the Wave Regime due to the Presence of Structures on the Sea Bed (Wind Turbine and OSP Foundations)

6.6.5.2.1 SEP or DEP in Isolation

321. The presence of foundation structures within SEP or DEP and the OSP has the potential to alter the baseline wave regime, particularly in respect of wave heights and directions. Any changes in the wave regime may contribute to changes in the sea bed morphology due to alteration of sediment transport patterns (see operational Impact 3, **Section 6.6.5.3**).

322. The wave modelling considered a number of wave and wind directions to determine the worst-case direction, that is the direction that results in the worst-case nearshore wave conditions along the East Anglian coast (**Appendix 6.2**). Two return period events were assessed; the 1 in 1 year and 1 in 50 year events. The simulations showed that waves approaching from the 0°N directional sector resulted in the worst-case nearshore wave conditions for both return period events. This directional sector was therefore used in the assessment of effects.

323. The results were analysed to predict changes in nearshore wave climate as a result of the proposed SEP and DEP OWFs. This was completed by comparing the results of the model for a baseline scenario (using the 0°N directional sector), which included the presence of SOW and DOW, against a scenario which included SEP and DEP alongside SOW and DOW. The cumulative impacts of SOW and DOW together with SEP and DEP were also assessed (see **Section 6.7**).

324. **Plate 6.22** and **Plate 6.23** show the difference in significant wave height between the baseline condition and the SEP and DEP foundation layouts for the 1 in 1 year and 1 in 50 year return period events, respectively. They show that SEP and DEP are predicted to have only a localised impact on wave climate, where reflection from the wind turbines results in a slight reduction in wave conditions, up to 0.05m significant wave height. There is no impact on the nearshore wave conditions along the East Anglian coast.

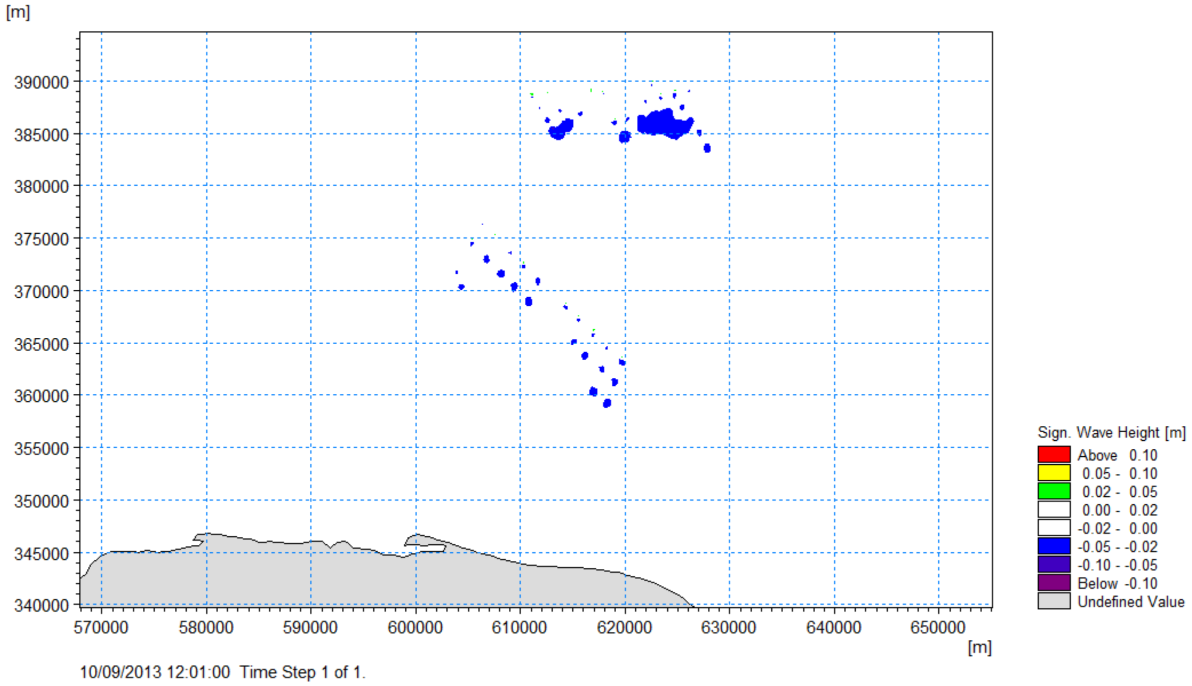

Plate 6.22: Difference in significant wave height for the 1 in 1 year return period event - 0ºN offshore wave direction

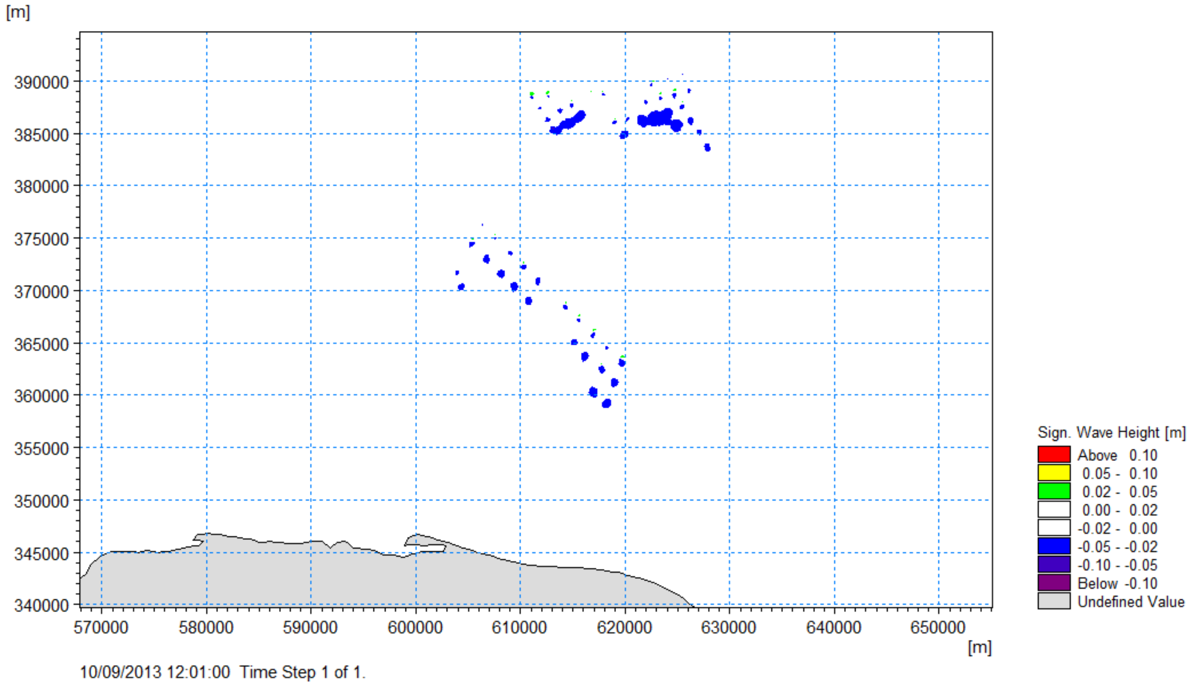

Plate 6.23: Difference in significant wave height for the 1 in 50 year return period event - 0ºN offshore wave direction

325. The results show that each foundation would present an obstacle to the passage of waves locally, causing a small modification to the height and / or direction of the waves as they pass. This causes a small wave shadow effect to be created by each foundation. Wave heights return to baseline conditions with progression

downstream of each foundation and generally do not interact with effects from adjacent foundations due to the separation distances.

326. Also, post-construction monitoring at DOW demonstrates that changes to sea bed sediment distribution due to the presence of the turbines are minimal, implying that changes to waves (and tidal currents) are local and do not have a significant effect on sediment transport further afield.

6.6.5.2.2 Magnitude of Effect – SEP or DEP in Isolation

327. The worst-case changes to the wave regime due to the presence of GBS foundations are likely to have the following magnitudes of effect (**Table 6-31**).

Table 6-31: Magnitude of Effect on the Wave Regime under the Worst-Case Scenario for the Presence of GBS Foundations

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field	Low	High	Medium	Negligible	Low
Far-field	Negligible	High	Medium	Negligible	Negligible

328. The DEP North array area zone of influence (**Figure 6.11**) overlaps with sand banks located in the north-west of DEP North array area and DEP South array area and in the north of the cable corridor between the DEP North array area and SEP. The sensitivity and value of the receptor is presented in **Table 6-32**.

Table 6-32: *Sensitivity and Value Assessment of Sand Bank Receptors*

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Sand banks (and associated sand waves)	Negligible	Negligible	Negligible	High	Negligible

6.6.5.2.3 Impact Significance – SEP or DEP in Isolation

329. The East Anglian coast and Cromer Shoal Chalk Beds receptor groups are remote from the zone of effect arising from changes in the baseline wave regime. Due to this, no pathway exists between the source and these receptors, so in terms of impacts on these receptor groups there is **no impact** associated with the proposed SEP or DEP projects in isolation.

330. The predicted zone of influence for the DEP North array area encompasses the sand bank receptors present within the DEP North array area, DEP South array area and the north of the cable corridor between DEP North array area and SEP. As outlined in **Section 6.6.5.2.1**, no significant impact on the wave regime is anticipated for SEP and DEP and therefore the impact on sand banks is anticipated to be **negligible adverse**.

6.6.5.2.4 SEP and DEP

331. The model results show that wave heights over a wide area for SEP and DEP individually would not change. Hence, the worst-case changes to waves due to the presence of GBS foundations at SEP and DEP will be similar to those outlined for SEP or DEP in isolation. No pathway exists between the source and the East Anglian Coast and Cromer Shoal Chalk Beds MCZ receptors, so there is **no impact** on these receptor groups associated with SEP and DEP. Due to the overlap of the zone of potential influence for the DEP North array area with sand banks within DEP North array area, DEP South array area and north of the cable corridor between DEP North array area and SEP, there is potential for impact on sand banks, however any impact is anticipated to be **negligible adverse**.

6.6.5.3 Impact 3: Changes to the Sediment Transport Regime due to the Presence of Structures on the Sea Bed (Wind Turbine and OSP Foundations)

6.6.5.3.1 SEP or DEP in Isolation

332. Modifications to the tidal regime and/or the wave regime due to the presence of the foundation structures during the operational phase may affect the sediment regime. This section addresses the broader patterns of suspended and bedload sediment transport across, and beyond, the SEP or DEP wind farm site and sediment transport at the coast.

333. The predicted reductions in tidal regime (operational Impact 1) and wave regime (operational Impact 2) associated with the presence of the worst-case GBS foundation structures would result in a reduction in the sediment transport potential across the areas where such changes are observed. Conversely, the areas of increased tidal flow around each wind turbine would result in increased sediment transport potential.

334. These changes to the marine geology, oceanography and physical processes would be both low in magnitude and largely confined to local wake or wave shadow effects attributable to individual wind turbine foundations and, therefore, would be small in geographical extent.

335. In addition to the evidence from theoretical studies, there is a post-construction benthic survey of the DOW array site carried out in 2018 (MMT, 2019). Grab samples were recovered from three zones. The primary impact zone during the pre-construction survey included locations within the proposed infield site, which were expected to be subjected to direct impacts. The secondary impact zones during the pre-construction survey included locations within the maximum tidal extent of the site, and thus were allocated to areas of indirect impacts. The reference areas during pre-construction survey, included locations outside the tidal excursion of the wind farm.

336. Comparison of the pre-construction and post-construction particle size data showed that there have been no significant changes in sea bed sediment composition, indicating that sediment composition has remained unaffected by the development of the wind farm. What little changes there have been are a small reduction in mud content and a small increase in gravel content. Overall, mean mud content reduced

from 4.5% to 2.6%, and gravel content increased from 24.8% to 27.0%. Both of these changes over the four-year period, are within the bounds of change expected under natural processes. Indeed, the secondary impact zones and reference areas had the greatest shift in sediment composition compared to the primary impact zone, indicating that natural variation due to natural processes is having a greater effect on sea bed character than the presence of the wind turbine foundations.

337. The results of the geophysical survey describe only minor and localised effects remaining from the wind farm construction, with evidence of natural processes acting to restore any local areas of sea bed affected by the construction works to the pre-construction condition. The overall topography of the sea bed within DOW has not greatly changed.

6.6.5.3.2 Magnitude of Effect – SEP or DEP in Isolation

338. Since it is expected that the changes in tidal flow and wave heights during the operational phase of SEP and DEP would have no significant far-field effects, then the changes in sediment transport would be similar, with the likely following magnitudes of effect (**Table 6-33**).

Table 6-33: Magnitude of Effects on the Sediment Transport Regime under the Worst-Case Scenario for the Presence of GBS foundations

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field	Low	High	Medium	Negligible	Low
Far-field	Negligible	High	Medium	Negligible	Negligible

339. The DEP North array area zone of influence (**Figure 6.11**) overlaps with sand banks located in the north-west of the DEP North array area and DEP South array area and in the north of the cable corridor between DEP North array area and SEP. The sensitivity and value of the receptor is presented in **Table 6-34**.

Table 6-34 Sensitivity and Value Assessment of Sand Bank Receptors

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Sand banks (and associated sand waves)	Negligible	Negligible	Negligible	High	Negligible

6.6.5.3.3 Impact Significance – SEP or DEP in Isolation

340. The impacts on the sediment transport regime would not extend beyond the zones of influence previously illustrated for the changes to the tidal (**Figure 6.11**) and wave regimes and therefore, there is **no impact** on the East Anglian coast and Cromer Shoal Chalk Beds MCZ .

341. As outlined in **Section 6.6.5.3.1**, natural variation due to natural processes is having a greater effect on sea bed character than the presence of the wind turbine foundations following the construction of DOW. Geophysical surveys show only minor and localised effects remaining from the wind farm construction, with evidence of natural processes acting to restore any local areas of sea bed affected by the

construction works to the pre-construction condition. Therefore, the impact on sand banks is anticipated to be **negligible adverse**.

6.6.5.3.4 SEP and DEP

342. **Figure 6.11** shows that the tidal current zones of potential influence for SEP and DEP do not overlap, and the numerical modelling assessment indicates the combined influence of waves would be similar to SEP or DEP in isolation. Hence, the combined effect on sediment transport would be the same as the two sites individually. Hence, the worst-case changes to sediment transport due to the presence of GBS foundations at SEP and DEP will be similar to those outlined for SEP or DEP in isolation. No pathway exists between the source and the East Anglian coast and Cromer Shoal Chalk Beds receptors, so there is **no impact** on these receptors for SEP and DEP. Due to the overlap of the zone of potential influence for the DEP North array area with sand banks within DEP North array area, DEP South array area and north of the cable corridor between DEP North array area and SEP, there is potential for impact on sand banks however any impact is anticipated to be **negligible adverse**.

6.6.5.4 Impact 4: Loss of Sea Bed Area due to the Footprint of Wind Turbine and OSP Foundation Structures

6.6.5.4.1 SEP or DEP in Isolation

343. The sea bed would be directly impacted by the footprint of each foundation structure on the sea bed within the SEP or DEP wind farm sites. This would constitute a loss in natural sea bed area during the operational life of the Projects.

344. This direct footprint due to the presence of foundation structures could occur in one of two ways; without and with scour protection. Scour protection will be installed at locations where required, as determined by pre-construction surveys. A worst-case scenario of all foundations having scour protection is considered to provide a conservative assessment.

345. Under the worst-case scenario of scour protection being provided for all foundations, the sea bed would be further occupied by material that is 'alien' to the baseline environment, such as concrete mattresses, fronded concrete mattresses, rock dumping, bridging or positioning of gravel bags.

346. The worst-case is associated with the maximum number of 18MW GBS turbine foundations, with scour protection and an OSP with suction bucket foundations and scour protection (**Table 6-2**).

6.6.5.4.2 Magnitude of Effect – SEP or DEP in Isolation

347. The worst-case loss of sea bed due to the presence of foundation structures with scour protection is likely to have the following magnitudes of effect (**Table 6-35**). It is likely that any secondary scour effects associated scour protection would be confined to within a few meters of the direct footprint of that scour protection material.

Table 6-35: Magnitude of Effects on Sea Bed Morphology under the Worst-Case Scenario for the Footprint of Foundations and Scour Protection

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field*	High	High	High	Negligible	High
Far-field	No change	-	-	-	No change

*The near-field effects are confined to within the footprint of each foundation structure

6.6.5.4.3 Impact Significance – SEP or DEP in Isolation

348. The near-field effects are confined to the footprint of each foundation structure, and therefore have no pathway to the East Anglian coast and Cromer Shoal Chalk Beds MCZ receptors. There is therefore **no impact** for SEP or DEP in isolation. A loss of sea bed will have **no impact** on sand banks (and associated sand waves) as sand will continue to be transported around the turbine foundation and over any scour protection due to the dynamic nature of the area.

349. The significance of these effects on other receptors is addressed within the relevant chapters of this ES (see **Section 6.9**).

6.6.5.4.4 SEP and DEP

350. The maximum footprint on the sea bed from GBS foundations and scour protection for each wind turbine and suction bucket OSP foundations with scour protection is larger than that of SEP or DEP in isolation (**Table 6-2**), however any near-field effects are confined to the footprint of each foundation structure. The impacts associated with SEP and DEP would be the same as those outlined for SEP or DEP in isolation (**Section 6.6.4.5.1**).

351. The worst-case changes to the sea bed morphology due to the presence of foundation structures at SEP and DEP would have the same magnitudes of effect as those outlined for SEP or DEP in isolation.

6.6.5.5 Impact 5: Morphological and Sediment Transport Effects due to Cable Protection Measures within the SEP and DEP Wind Farm Sites and Interlink Cable Corridors

352. Given that interlink cables will only be required in a DEP in isolation or SEP and DEP scenario, morphological and sediment transport effects due to cable protection for interlink cables are not assessed for SEP in isolation.

6.6.5.5.1 SEP or DEP in Isolation

353. As a worst-case scenario, if infield or interlink cables cannot be buried, they would be surface-laid and protected in some manner, and cable protection would also be required at any cable crossings. Cable protection will take the form of rock placement.

354. The effects that such works may have on marine geology, oceanography and physical processes primarily relate to the potential for interruption of sediment transport processes and the footprint they present on the sea bed.

355. In areas of active sediment transport, any linear protrusion on the sea bed may interrupt bedload sediment transport processes during the operational phase of the proposed project. There is unlikely to be any significant effect on suspended sediment processes since armoured cables or cable protection works (including where the cable crosses other sub-marine infrastructure such as pipelines and other cables) are relatively low above the sea bed (a maximum of 0.5m).

356. The worst-case scenario of cable protection for the infield and interlink cables, and crossings is rock berm protection (**Table 6-2**).

357. The presence of sand waves across both SEP and DEP indicates that some bedload sediment transport exists, with a net direction towards the southeast (see **Section 6.5.8**). There are also megaripples present across the sites. Protrusions from the sea bed are unlikely to significantly affect the migration of sand waves, since sand wave heights (up to 4m) in most areas would exceed the height of cable protection works, and would pass over them. There may be localised interruptions to bedload transport in other areas, but the gross patterns of bedload transport across the SEP and DEP array sites would not be affected significantly.

358. The presence of cable and crossing protection works on the sea bed would represent the worst-case in terms of a direct loss of sea bed area, but this footprint is likely to be lower than that of the foundations (and associated scour protection works) within SEP or DEP.

6.6.5.5.2 Magnitude of Effect – SEP or DEP in Isolation

359. The worst-case changes to the sea bed morphology and sediment transport due to cable and crossing protection measures for infield and interlink cables are likely to have the following magnitudes of effect (**Table 6-36**).

Table 6-36: Magnitude of Effects on Sea Bed Morphology and Sediment Transport under the Worst-Case Scenario for Cable and Crossing Protection Measures for Infield and Interlink Cables

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field*	High	High	High	Negligible	High
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

* The near-field effects are confined to a small area (likely to be within the footprint of cable protection works), and would not cover the whole SEP or DEP wind farm sites

6.6.5.5.3 Impact Significance – SEP or DEP in Isolation

360. The effects on sea bed morphology and sediment transport arising from the presence of infield and interlink cable and crossing protection measures would not extend far beyond the direct footprint. Therefore, there is **no impact** associated with the proposed project on the East Anglian coast or Cromer Shoal Chalk Beds MCZ since these are located remotely from this zone of potential effect. As outlined above in **Section 6.6.5.5.1**, if cable protection does present an obstruction to bedload transport, then it is likely that sand waves would pass over them. Gross patterns of bedload transport would therefore not be affected significantly, and

therefore there would be a **negligible adverse** impact on sand banks (and associated sand waves).

361. The significance of these effects on other receptors is addressed within the relevant chapters of this ES (see **Section 6.9**).

6.6.5.5.4 SEP and DEP

362. The footprint of sea bed impacted by cable and crossing protection measures would be the same as DEP in isolation scenario. Gross patterns of bedload transport would not be affected significantly since sand wave heights (up to 4m) in most areas would exceed the height of cable protection works and would pass over them. Therefore, impacts associated with SEP and DEP would be the same as those outlined for SEP or DEP in isolation (**Table 6-2** and **Section 6.6.5.5.1**).

363. The worst-case changes to the sea bed morphology and sediment transport due to protection measures for infield and interlink cables, and crossings for SEP and DEP would have the same magnitudes of effect as SEP or DEP in isolation, as the effects would not extend far beyond the direct footprint. Therefore, there is **no impact** associated with SEP and DEP on the East Anglian coast or Cromer Shoal Chalk Beds MCZ since these are located remotely from this zone of potential effect. Due to the insignificant impact on gross patterns of bedload transport across cable protection for infield and interlink cables, and crossings for SEP and DEP export cables, an impact of **negligible adverse** significant is anticipated on sand banks (and associated sand waves).

6.6.5.6 Impact 6: Morphological and Sediment Transport Effects due to Cable Protection Measures within the Offshore Cable Corridor (Export Cables)

6.6.5.6.1 SEP or DEP in Isolation

364. As a worst-case scenario it has been assumed that burial of the export cables would not practicably be achievable within some areas of the offshore cable corridor and, instead, cable protection measures would need to be provided to surface-laid cables in these areas. The locations where cable protection measures are most likely to be required are areas of cable crossings and in areas of sea bed characterised by exposed bedrock (**Table 6-2**).

365. Cable protection may take the form of concrete mattresses, fronded concrete mattresses, or uraduct shell. The Applicant has committed to not using loose rock placement within the MCZ.

366. The effects that export cable protection may have on marine geology, oceanography and physical processes primarily relate to the potential for interruption of sediment transport processes and the footprint they present on the sea bed.

367. In areas of active sediment transport, any linear protrusion on the sea bed may interrupt bedload sediment transport processes during the operational phase. There is likely to be a difference in effect depending on whether the cable protection works are in ‘nearshore’ or ‘offshore’ areas within the offshore cable corridor. Any works in areas closest to the coast have the potential to affect alongshore sediment transport processes and circulatory pathways across any nearshore banks.

368. The seaward limit which marks the effective boundary of wave-driven sediment transport is called the 'closure depth' and can be calculated using the methods of Hallermeier (1978). For the sea bed offshore from the landfall, this would typically be located in around 5m of water.

369. Any protrusions from the sea bed associated with cable protection measures could potentially have an effect on sediment transport in the nearshore and along the coast. Any interruptions to sediment transport locally within this zone could, in turn, affect the morphological response of wider areas (e.g. frontages along the sediment transport pathway etc.) due to reductions in sediment supply to those areas.

370. The potential magnitude of the effect will depend on the local sediment transport rates; a lower rate would reduce the potential effect on sediment supply to wider areas. There would be a range of sediment transport potentials across the export cables. If chalk or Pleistocene geological units are exposed at the sea bed or covered by a thin lag, then they are static and have zero transport potential (i.e. no mobile sediment). If the cable protection is laid in these areas, then sediment transport is not an issue as no sediment is being transported.

371. Where the sea bed is composed of mobile sand, it can be transported under existing tidal conditions. If the protection does present an obstruction to this bedload transport the sediment would first accumulate one side or both sides of the obstacle (depending on the gross and net transport at that location) to the height of the protrusion (up to 0.5m in most cases). With continued build-up, it would then form a 'ramp' over which sediment transport would eventually occur by bedload processes, thereby bypassing the protection. The gross patterns of bedload transport across the export cables would therefore not be affected significantly.

372. The presence of cable protection works on the sea bed would represent the worst-case in terms of a direct loss of sea bed area, but this footprint would be lower than that of the wind turbine foundations (and associated scour protection works) within the SEP and DEP wind farm sites (**Table 6-2**).

373. In recognition of these potential effects, considerable effort has been given to selecting an appropriate landfall location and export cable corridor to minimise sediment transport effects as far as practicably achievable. The most important marine geological and geomorphological features present in the nearshore and at the landfall are those associated with the Cromer Shoal Chalk Beds MCZ. Royal HaskoningDHV (2020) showed that potential bedload sediment transport rates are low to non-existent in areas where cable protection is most likely to be required within the MCZ (**Appendix 6.3**). These areas consist of chalk overlain by a thin static lag of sand and gravel.

374. A commitment has also been made to install the export cable at the landfall using HDD techniques, thus minimising disturbance and avoiding the need for cable protection in the intertidal and shallowest nearshore zones. It is likely that the HDD pop-out location would be in water depths of approximately 9-10m below LAT, which is seaward of the 5m closure depth. Hence, there would be no interruption to sediment transport pathways close to the coast because the export cables would be buried.

375. Also, a commitment has been made to only use cable protection at the HDD exit point and up to a maximum of 100m for each of the two export cables inside the MCZ (totalling 1,800m^2).

376. As a consequence of this embedded mitigation, the proposed HDD method and HDD exit point location would:

- Minimise direct physical disruption to the Cromer Shoal Chalk Beds MCZ;
- Avoid disturbance to the alongshore sediment transport processes; and
- Reduce the risk of suspended sediment (during construction) affecting the MCZ.

6.6.5.6.2 Magnitude of Effect – SEP or DEP in Isolation

377. The worst-case changes to the sea bed morphology and sediment transport due to cable protection measures for export cables are likely to have the following magnitudes of effect (**Table 6-37**).

Table 6-37: Magnitude of Effect on Sea Bed Morphology and Sediment Transport under the Worst-Case Scenario for Cable Protection Measures for Export Cables

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Landfall	Negligible	High	High	Negligible	Negligible
Shallower than 9m water depth (excluding landfall)	No change	-	-	-	No change
Deeper than 9m water depth	Low	High	High	Negligible	Low

378. Inshore of the closure depth, these effects could potentially affect the Cromer Shoal Chalk Beds MCZ or indirectly affect parts of the East Anglian coast. Given this, the sensitivity and value of these receptors are presented in **Table 6-38**.

Table 6-38: Sensitivity and Value Assessment for the Cromer Shoal Chalk Beds MCZ and East Anglian coast

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Cromer Shoal Chalk Beds MCZ	Medium	Low	Negligible	High	Medium
East Anglian coast	Medium	Low	Negligible	High	Medium

6.6.5.6.3 Impact Significance – SEP or DEP in Isolation

379. Offshore of the closure depth, the effects on sea bed morphology and sediment transport arising from the presence of export cable protection measures would not extend far beyond the direct footprint. Therefore, there is **no impact** in these locations associated with the proposed project on the East Anglian coast since this receptor is located remotely from this zone of potential effect.

380. As outlined above in **Section 6.6.5.6.1**, if cable protection does present an obstruction to bedload transport, then a continued build up would form a 'ramp' over which sediment transport would occur by bedload processes, thereby bypassing the protection. The gross patterns of bedload transport across the export cables would therefore not be affected significantly. Therefore, there would be a **negligible adverse** impact on sand banks (and associated sand waves).

381. It is considered that the extremely small areas associated with cable protection (**Table 6-2**) would have no significant effect on the sediment transport processes in the MCZ. Therefore, there would be **negligible adverse** impact on the Cromer Shoal Chalk Beds MCZ.

382. As no cable protection will be used landward of the HDD exit point in the nearshore area (about 1,000m from the coast) of the offshore cable corridor, no morphological effects would take place and so there would be **no impact** on coastal morphology at the cable landfall during the operational phase of SEP or DEP.

383. The significance of these effects on other receptors is addressed within the relevant chapters of this ES (see **Section 6.9**).

6.6.5.6.4 SEP and DEP

384. As outlined above in **Section 6.6.5.6.1**, the detail of the export cabling is dependent upon the final project design (**Table 6-2**).

385. The morphological and sediment transport effects due to cable protection measures along the export cable for SEP and DEP will be the same as those outlined in **Section 6.6.5.6.1**. Given the extremely small areas of cable protection, **no impact** is anticipated on the East Anglian coast. Due to the insignificant impact on gross patterns of bedload transport across cable protection along export cables, an impact of **negligible adverse** significance is anticipated on sand banks (and associated sand waves). Due to the small area of rock berm present within Cromer Shoal Chalk Beds MCZ (0.0006%) associated with the SEP and DEP scenario, an impact of **negligible adverse** significance is anticipated on the Cromer Shoal Chalk Beds MCZ.

6.6.5.7 Impact 7: Cable Repairs and Reburial

6.6.5.7.1 SEP or DEP in Isolation

386. Cable repairs and reburial could be needed over the operational lifetime of SEP or DEP. Turbine repairs may also need to be carried out as required. The disturbance areas for reburial and repairs of cables are extremely small in comparison to construction. The **Outline CSCB MCZ CSIMP** (document reference 9.7) provides further information on the potential repair and reburial of cables during the operational period.

387. There is potential for temporary physical disturbance to the Cromer Shoal Chalk Beds MCZ in the offshore export cable corridor due to cable maintenance and repair operations. The maximum disturbance area for cable repair and reburial inside the MCZ is estimated as 1,500m^2 (for SEP or DEP) every ten years. This equates to 0.0005% of the total area of the MCZ (321km^2). This is estimated from 400m per

cable pair within the MCZ, with a disturbance width of 3m. If reburial is required, this would be for up to 100m per cable pair with a disturbance width of 3m (300m^2 for SEP or DEP in isolation) within the Cromer Shoal Chalk Beds MCZ.

388. There is potential for certain vessels used during the maintenance of the wind turbines to directly impact the sea bed during the operational phase. This applies for those vessels that utilise jack-up legs or several anchors to hold station and to provide stability for a working platform. Where legs or anchors are temporarily placed on the sea bed, there is potential for an indentation to remain proportional in size to the dimensions of the object. There is also potential for local effects on waves, tides and sediment transport and for local scour-hole formation around the legs or anchors while they remain in place for the duration of the maintenance works.

389. The worst-case scenario is considered to correspond to the use of jack-up vessels for wind turbine repairs since the depressions and potential for effects on marine geology, oceanography and physical processes and scour-hole formation would be greater than the anchor scars. The worst-case scenario is presented in **Table 6-2**.

390. The sediment volumes arising from repair and reburial would be small in magnitude and cause an insignificant effect in terms of enhanced suspended sediment concentrations and deposition elsewhere.

6.6.5.7.2 Magnitude of Effect – SEP or DEP in Isolation

391. The worst-case changes in terms of indentations on the sea bed due to maintenance vessels and cable repair and reburial footprints are likely to have the magnitudes of effect shown in **Table 6-39**.

Table 6-39: Magnitude of effect on the sea bed under the worst-case scenario for maintenance vessels

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field (immediate vicinity of leg)	High	Negligible	Negligible	Medium	Medium
Near-field (beyond immediate vicinity of leg)	No change	-	-	-	No change
Far-field	No change	-	-	-	No change

6.6.5.7.3 Impact Significance – SEP or DEP in Isolation

392. There is **no impact** under a worst-case scenario on the East Anglian coast receptor since it is remote from the immediate vicinity of each leg.

393. The sensitivity and value of the Cromer Shoal Chalk Beds MCZ and sand banks to disturbance is shown in **Table 6-40**.

Table 6-40: Sensitivity and value assessment of Cromer Shoal Chalk Beds MCZ and sand banks

Receptor	Tolerance	Adaptability	Recoverability	Value	Sensitivity
Cromer Shoal Chalk Beds MCZ	Negligible	Negligible	Negligible	High	Negligible
Sand banks (and associated sand waves)	Negligible	Negligible	Negligible	High	Negligible

394. The assessment indicates that temporary physical disturbance may occur within the Cromer Shoal Chalk Beds MCZ (**Table 6-2**). Although temporary physical disturbance may occur, this area is a very small part of the MCZ, and the need for cable repairs is likely to be intermittent in nature. In addition, no sediment would be removed from the MCZ during maintenance activities. Due to the short duration and small scale of any maintenance works (if required) there will be no effect on the form or function of the site. Therefore, it is assessed as **negligible adverse** impact.

395. Due to the dynamic nature of sand banks and sand waves in this area, it is not known whether cable repair and reburial will directly impact on this receptor during the operation phase. However, due to the short duration and small scale nature of any maintenance works (if required) it is anticipated that if they are present within the area at the time of cable repairs and reburial there will be a **negligible adverse** impact.

396. The significance of these effects on other receptors is addressed within relevant chapters of this ES.

6.6.5.7.4 SEP and DEP

397. The maximum disturbance area for a SEP and DEP scenario would be larger than SEP or DEP in isolation (**Table 6-2**), however, the disturbance areas for reburial and repairs of cables, and associated jack-up footprint are still small in comparison to construction.

398. It is possible that different areas would be affected in each year of the operational phase. There is **no impact** under a worst-case scenario of SEP and DEP on the East Anglian coast receptor since it is remote from the immediate vicinity of each leg.

399. Given the short duration and small scale nature of any maintenance works (if required) there will be **negligible adverse** impact on the form or function of the MCZ site and **negligible adverse** impact on sand banks (and associated sand waves) if present within the area at the time of cable repairs and reburial. The magnitude of effects are expected to be the same as those outlined above in **Table 6-39** and **Table 6-40**.

6.6.6 Potential Impacts During Decommissioning

400. The scope of the decommissioning works would most likely involve removal of the accessible installed components. This is outlined in **Section 4.4.12** of **Chapter 4 Project Description** and the detail would be agreed with the relevant authorities at the time of decommissioning. Offshore, this is likely to include removal of all the

wind turbine components, part of the foundations (those above sea bed level), removal of some or all of the infield cables, interlink cables, and export cables. Scour and cable protection would likely be left *in situ,* other than in the MCZ where it may be removed.

401. During the decommissioning phase, there is potential for wind turbine foundation and cable removal activities to cause changes in suspended sediment concentrations and/or sea bed or shoreline levels because of sediment disturbance effects. The types of effect would be comparable to those identified for the construction phase:

- Impact 1 Changes in suspended sediment concentrations due to foundation removal;
- Impact 2 Changes in sea bed level due to foundation removal;
- Impact 3 Changes in suspended sediment concentrations due to removal of parts of the export cable;
- Impact 4 Changes in sea bed level due to removal of parts of the export cable;
- Impact 5 Changes in suspended sediment concentrations due to removal of parts of the infield and interlink cables;
- Impact 6 Changes in sea bed level due to removal due to removal of parts of the infield and interlink cables; and
- Impact 7 Interruptions to bedload sediment transport due to sand wave levelling for offshore cable installation
- Impact 8 Indentations on the sea bed due to decommissioning vessels.

402. The magnitude of effects would be comparable to or less than those identified for the construction phase. Accordingly, given the construction phase assessments concluded "**no impact**" or "**negligible adverse** impacts" for marine geology, oceanography and physical processes receptors, it is anticipated that the same would be valid for the decommissioning phase regardless of the final decommissioning methodologies. The magnitude of effects will be the same for SEP or DEP in isolation and for SEP and DEP.

403. The significance of effects on other receptors is addressed within relevant chapters of this ES (**Chapter 7 Marine Water and Sediment Quality**, **Chapter 8 Benthic Ecology**, **Chapter 9 Fish and Shellfish Ecology**, **Chapter 10 Marine Mammal Ecology** and **Chapter 11 Offshore Ornithology**).

6.7 Cumulative Impacts

6.7.1 Identification of Potential Cumulative Impacts

404. The receptors that have been identified in relation to marine geology, oceanography and physical processes are the East Anglian coast, Cromer Shoal Chalk Beds MCZ and sand banks (and associated sand waves). The marine geology, oceanography and physical processes effects that have been assessed for SEP and DEP alone are all anticipated to result in either **no impact** or **negligible adverse** impact to the above-mentioned receptors. This is primarily because these receptors are located remotely from the zones of influence arising from most of the effects and no pathway

has been identified that can link the source to the receptor in most cases. This assessment remains valid for both SEP or DEP in isolation and for SEP and DEP.

405. The first step in the cumulative assessment is the identification of which residual impacts assessed for SEP and/or DEP on their own have the potential for a cumulative impact with other plans, projects and activities (described as 'impact screening'). This information is set out in **Table 6-41** below, together with a consideration of the confidence in the data that is available to inform a detailed assessment and the associated rationale. Only potential impacts assessed in **Section 6.6** as negligible or above are included in the CIA (i.e. those assessed as 'no impact' are not taken forward as there is no potential for them to contribute to a cumulative impact).

Table 6-41: Potential Cumulative Impacts (Impact Screening)

Impact	Potential for Cumulative Impact	Rationale
Construction		
Construction Impact 2a: Changes in sea bed level due to sea bed preparation for foundation installation	No	Impacts occur at discrete locations for a time-limited duration and are negligible adverse in magnitude. This applies to SEP or DEP in isolation, and SEP and DEP.
Construction Impact 2b: Changes in sea bed level due to drill arisings for installation of piled foundations for wind turbines and OSPs [negligible adverse impact applies to Cromer Shoal Chalk Beds MCZ only]	No	Impacts occur at discrete locations for a time-limited duration and are negligible adverse in magnitude. This applies to SEP or DEP in isolation, and SEP and DEP.
Construction Impact 4: Change in sea bed level due to deposition from the suspended sediment plume during export cable installation within the offshore cable corridor [negligible adverse impact applies to Cromer Shoal Chalk Beds MCZ only]	Yes	Based on a Hornsea Project Three construction start in 2023 and offshore export cable corridor construction in years 3 and 4 (2026-2027), and possibly also years 8 and 9 in a two-phase development (2030-2031), there is potential for temporal overlap of export cable construction (also see **Table 6-42**).
Construction Impact 6: Change in sea bed level due to offshore cable installation (infield and interlink)	No	Impacts occur at discrete locations for a time-limited duration and are local in nature with a low impact magnitude. This applies to SEP or DEP in isolation, and SEP and DEP.
Construction Impact 7: Interruptions to bedload sediment transport due to sand wave levelling for offshore cable installation (infield and interlink cables) [negligible adverse impact applies to sandbanks (and associated sand waves) receptor only]		
Construction Impact 8: Indentations on the sea bed due to installation vessels		
Operation		

Impact	Potential for Cumulative Impact	Rationale
Operational Impact 1: Changes to the Tidal Regime due to the Presence of Structures on the Sea Bed (Wind Turbines and OSP Foundations)	Yes	Impacts could occur due to the combined effect of SEP/DEP with SOW/DOW
Operational Impact 2: Changes to the Wave Regime due to the Presence of Structures on the Sea Bed (Wind Turbine and OSP Foundations)		
Operational Impact 3: Changes to the Sediment Transport Regime due to the Presence of Structures on the Sea Bed (Wind Turbine and OSP Foundations)		
Operational Impact 6: Morphological and sediment transport effects due to cable protection measures within the offshore cable corridor (export cables) [negligible adverse impact applies to Cromer Shoal Chalk Beds MCZ only]	Yes	Impacts could potentially coalesce with those arising from other windfarm projects (e.g. Hornsea Project Three) and disturb sediment transport pathways, particularly if protection measures are near to shore
Operational Impact 7: Cable repairs and reburial [negligible adverse impact applies to Cromer Shoal Chalk Beds MCZ only]	No	Impacts will be highly localised around the foundations and cables and therefore there will be no cumulative impact.
Decommissioning		
Decommissioning Impact 4: Change in sea bed level due to removal of parts of the export cable	No	Impacts occur at discrete locations for a time-limited duration and negligible adverse in magnitude. This applies to SEP or DEP in isolation, and SEP and DEP.
Decommissioning Impact 6: Changes in sea bed level due to removal due to removal of parts of the infield and interlink cables		

6.7.2 Other Plans, Projects and Activities

406. The second step in the cumulative assessment is the identification of the other plans, projects and activities that may result in cumulative impacts for inclusion in the CIA (described as 'project screening'). This information is set out in **Table 6-42** below, together with a consideration of the relevant details of each, including current status (e.g. under construction), planned construction period, closest distance to SEP and DEP, status of available data and rationale for including or excluding from the assessment.

407. The project screening has been informed by the development of a CIA Project List which forms an exhaustive list of plans, projects and activities in a very large study area relevant to SEP and DEP. The list has been appraised, based on the confidence in being able to undertake an assessment from the information and data available, enabling individual plans, projects and activities to be screened in or out.

Table 6-42: Summary of Projects Considered for the CIA in Relation to Marine Geology, Oceanography and Physical Processes

Project	Status	Construction Period	Closest Distance from the Project (km)	Confidence in Data	Included in the CIA (Y/N)	Rationale
DOW	Operational	N/A	0 (cable corridor) 0 (array area)	High	Y	SOW and DOW are operational. Impacts from operation and maintenance activities are considered to be non-significant for both projects, as shown in the environmental assessments accompanying the marine licence applications for operational and maintenance (O&M) activities: Sheringham O&M generation (MLA/2020/00095) • Sheringham O&M Transmission (MLA/2020/00096) • Dudgeon O&M generation (MLA/2018/00511 • Dudgeon O&M Transmission (MLA/2019/00049) Indirect impacts to SEP and DEP are considered to be small scale and localised, meaning there is no pathway for interaction with SOW and DOW.
SOW	Operational	N/A	0 (cable corridor) 0 (array area)	High	Y	
Hornsea Project Three	Consented	2023-2031 (offshore export cable construction 2026-2027, possibly also 2030-2031)	0 (cable corridor) 83 (array area)	High	Y	As shown on **Figure 6.12** the Hornsea Project Three export cable corridor bisects the SEP and DEP export cable corridor and there is potential for temporal overlap of export cable installation activities.
Viking Link interconnector project	Planned	2020-2023	43 (to SEP array)	High	N	The project is over 40km away from SEP and DEP and there is therefore no potential for cumulative impact on the identified receptors.
Aggregate resource areas (AGG3)	N/A	N/A	0	N/A	N	The AGG3 area is identified as having a high potential aggregate resource. There are no specific plans that the Applicant is aware of to undertake aggregate dredging in the

Project	Status	Construction Period	Closest Distance from the Project (km)	Confidence in Data	Included in the CIA (Y/N)	Rationale
						vicinity of SEP and DEP on which to base an assessment and this plan is therefore screened out of the CIA.
Blythe Hub Development	Under construction	Approved in 2020 (subject to subsequent permit applications) and first gas is expected in 2022.	1 (array area), (4 cable corridor)	High	N	First gas is expected in 2022 therefore the project will be operational before SEP and DEP construction begins in 2024 at the earliest. Given all impacts were considered not significant (except for permanent habitat loss in the MCA/SPA) and are local in nature it is considered there is no impact pathway for interaction between the two projects.

6.7.3 Cumulative Construction Effects with Hornsea Project Three

408. Based on a Hornsea Project Three construction start in 2023 and an assumption that offshore export cable corridor construction would take place in years 3 and 4 (2026-2027), and possibly also years 7 and 8 in a two-phase development (2030-2031), there is potential for temporal overlap of offshore export cable construction. However, given that export cable installation is anticipated to be completed in 50 days for a SEP in isolation scenario, 60 days for a DEP in isolation scenario or 100 days for a SEP and DEP scenario, a temporal overlap in export cable construction activities is considered to be unlikely. Similarly, it is unlikely that cable maintenance activities would take place at the same time during operation of the wind farm export cables, and concurrent decommissioning is not expected.

409. As shown on **Figure 6.12**, the Hornsea Project Three export cable route transits through only a very small portion of the MCZ at its western extremity and therefore any cumulative change in sea bed level on this receptor would be confined to within the vicinity of where the cable corridors overlap. In the unlikely event that there was a temporal overlap in offshore export cable installation activities between SEP and DEP and Hornsea Project Three, cumulative changes in sea bed level due to deposition of the suspended sediment plume could occur. However, given the overall short term and temporary nature of the proposed activities combined with the anticipated negligible magnitude of effect for each project's export cable installation campaign, a significant cumulative impact on the CSCB MCZ receptor is not predicted.

6.7.4 Cumulative Operational Effects with Hornsea Project Three

410. Potential impacts could arise with Hornsea Project Three if any cable protection measures combine to enhance the disturbance to sediment transport pathways, particularly if the protection measures are within the Cromer Shoal Chalk Beds MCZ.

411. For SEP and DEP, up to 1,800m^2 of cable protection could be required in the MCZ. The maximum area of cable protection for Hornsea Project Three within the MCZ would be 2,940m^2. Hence, the cumulative area of cable protection within the MCZ would be up to 4,740m^2.

412. It is considered that this relatively small area of cable protection would have no significant effect on the sediment transport processes in the MCZ. This is because, even though the sediment would initially build-up against the protection, it would, over a short period of time, form a 'ramp' over which sediment transport would occur by bedload processes. This would then allow bypassing of the protection and the gross patterns of bedload transport across the export cables would not be affected.

6.7.5 Cumulative Operational Effects with SOW and DOW

413. There is the potential for cumulative impacts on waves, tidal currents and sediment transport due to the combined effect of the presence of SEP/DEP foundations with SOW/DOW foundations.

414. The potential cumulative impact on waves was assessed using the results of the wave model (**Appendix 6.4**), whereby a baseline scenario with no wind farms was compared to a scenario with all the wind farms (SOW, DOW, SEP and DEP) present. Plate 6.24 and **Plate 6.25** present the predicted differences in significant wave height for the 1 in 1 year and 1 in 50 year return period events, respectively.

They show that cumulatively, SOW, DOW, SEP and DEP are predicted to have only a localised impact on wave climate, where reflection from the wind turbines results in a slight reduction in wave conditions, up to 0.05m significant wave height. There is no impact on the wave conditions in the Cromer Shoal Chalk Beds MCZ or on the nearshore wave conditions along the East Anglian coast.

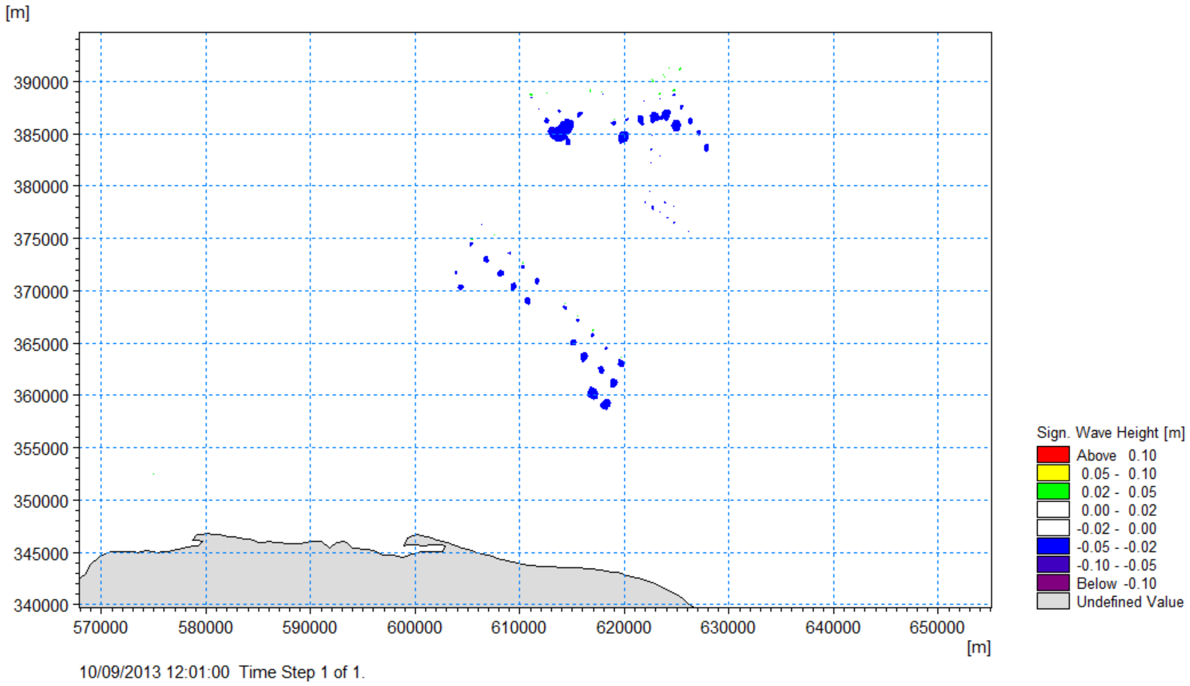

Plate 6.24: Difference in significant wave height for the 1 in 1 year return period event - 0ºN offshore wave direction with all the wind farms (SOW, DOW, SEP, and DEP) present

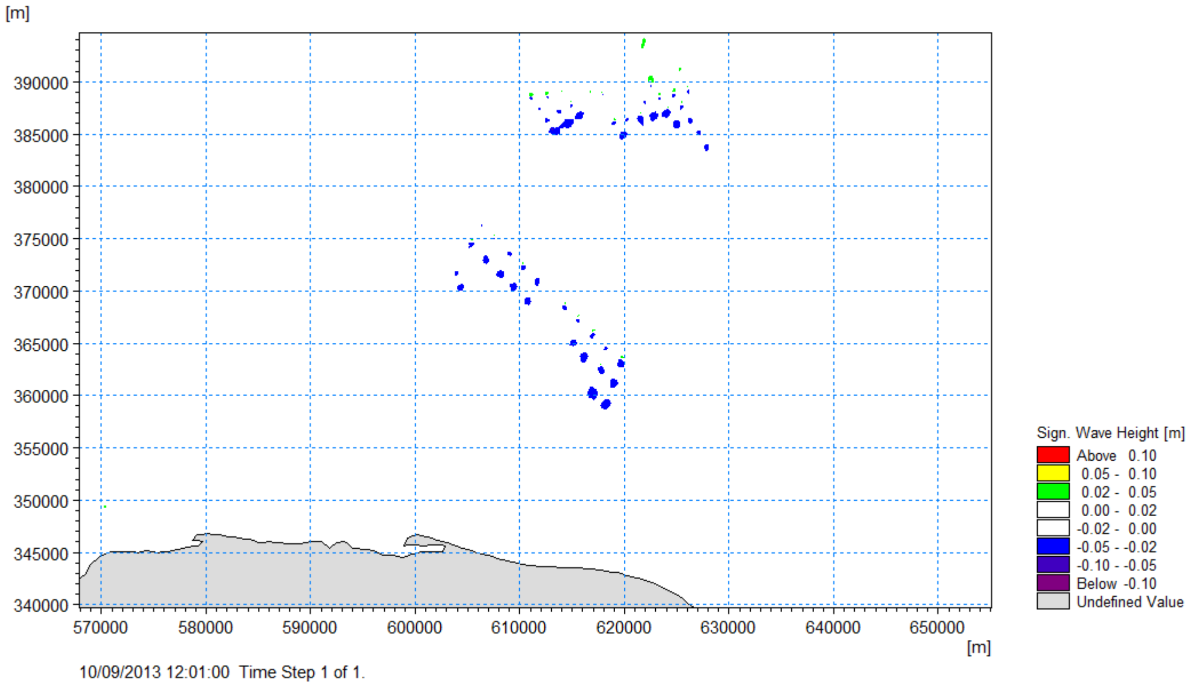

Plate 6.25: Difference in significant wave height for the 1 in 50 year return period event - 0ºN offshore wave direction with all the wind farms (SOW, DOW, SEP, and DEP) present

415. For tidal currents, the cumulative 'zone of potential influence' is the same as 'zone of potential influence' presented in **Figure 6.11** for each of SEP and DEP. This is because the zone incorporates tidal ellipses that also cover SOW and DOW. The East Anglian coast and Cromer Shoal Chalk Beds MCZ are remote from this cumulative zone of potential influence on the tidal regime and so there would be no impact.

416. Given the absence of effect on waves and tidal currents, there would be no cumulative effect on sediment transport processes at the East Anglian coast or across the Cromer Shoal Chalk Beds MCZ.

6.8 Transboundary Impacts

417. Given that there will be no impact to the hydrodynamic and sedimentary regime as a result of SEP and DEP (in isolation and where both Projects are built), transboundary impacts are unlikely to occur, or are unlikely to be significant (PINS, 2019), and therefore transboundary impacts are scoped out of further assessment.

6.9 Inter-relationships

418. There are clear inter-relationships between the marine geology, oceanography and physical processes topic and several other topics that have been considered within this ES. **Table** 6-43 provides a summary of the principal inter-relationships and sign-posts to where those issues have been addressed in the relevant chapters.

Table 6-43: Marine Geology, Oceanography and Physical Processes Inter-Relationships

Topic and description	Related chapter	Where addressed in this chapter	Rationale
Construction			
Effects on water column (suspended sediment concentrations)	**Chapter 7 Marine Water and Sediment Quality** **Chapter 9 Fish and Shellfish Ecology** **Chapter 12 Commercial Fisheries** **Chapter 8 Benthic Ecology**	**Section 6.6.4.1** and **Section 6.6.4.2** (foundation installation) **Section 6.6.4.7** (infield cables installation) **Section 6.6.4.5** (export cables installation)	Suspended sediment could be contaminated and could cause disturbance to fish and benthic species through smothering.
Effects on sea bed (morphology / sediment composition)	**Chapter 8 Benthic Ecology** **Chapter 9 Fish and Shellfish Ecology** **Chapter 12 Commercial Fisheries** **Chapter 13 Shipping and Navigation** **Chapter 14 Offshore Archaeology and Cultural Heritage** **Chapter 16 Petroleum and Other Marine Users**	**Section 6.6.4.3** and **Section 6.6.4.4** (foundation installation) **Section 6.6.4.8** (infield cables installation) **Section 6.6.4.6** (export cables) **Section 6.6.4.10** (installation vessels)	Disruption to sea bed morphology and sediment composition could affect these receptors by altering the existing sedimentary environment, however this is unlikely to be to levels which are significant.
Operation			
Effects on shoreline (morphology / sediment transport / sediment composition)	**Chapter 8 Benthic Ecology** **Chapter 18 Water Resources and Flood Risk** **Chapter 25 Seascape and Visual Impact Assessment** **Chapter 26 Landscape and Visual Amenity**	**Section 6.6** (export cable protection in nearshore and intertidal zone)	Disruption to shoreline morphology could potentially impact on these chapters through a change to the existing shoreline environment which could have implications for the receptors associated with these chapters.
Effects on sea bed (sediment transport processes / morphology)	**Chapter 8 Benthic Ecology** **Chapter 9 Fish and Shellfish Ecology**	**Section 6.6.5.3** (sediment transport regime) **Section 6.6.5.4** (loss of sea bed area)	Disruption to sediment transport processes or loss of sea bed area could affect these receptors by altering the existing sedimentary environment, however

Topic and description	Related chapter	Where addressed in this chapter	Rationale
	Chapter 12 Commercial Fisheries **Chapter 13 Shipping and Navigation** **Chapter 14 Offshore Archaeology and Cultural Heritage**	**Section 6.6.5.5** (infield and interlink cable protection) **Section 6.6.5.6** (export cable protection in offshore zone)	this is unlikely to be to levels which are significant.
Decommissioning			
Inter-relationships for impacts during the decommissioning phase will be the same as those outlined above for the construction phase.			

6.10 Interactions

419. The impacts identified and assessed in this chapter have the potential to interact with each other. The areas of potential interaction between impacts are presented in **Table 6-44**. This provides a screening tool for which impacts have the potential to interact. **Table 6-44** provides an assessment for each receptor (or receptor group) as related to these impacts.

420. Within **Table 6-44** the impacts are assessed relative to each development phase (Phase assessment, i.e. construction, operation or decommissioning) to see if (for example) multiple construction impacts affecting the same receptor could increase the level of impact upon that receptor. Following this, a lifetime assessment is undertaken which considers the potential for impacts to affect receptors across all development phases (**Table 6-45**).

421. The impacts listed in **Table 6-44** are only expressed on the following two receptors in **Table 6-45**:

- East Anglian Coast;
- MCZ; and
- Sandbanks and associated receptors.

Table 6-44: Interaction between impacts - screening

	Potential Interaction between Impacts									
	Construction									
	Impact 1a: Changes in suspended sediment concentrations due to sea bed preparation for foundation installation (wind farm site)	Impact 1b: Changes in suspended sediment concentrations due to drill arisings for installation of piled foundations for wind turbines (wind farm site)	Impact 2a: Changes in sea bed level due to sea bed preparation for foundation installation	Impact 2b: Changes in sea bed level due to drill arisings for installation of piled foundations	Impact 3: Change in suspended sediment concentrations due to export cable installation	Impact 4: Change in sea bed level due to deposition from the suspended sediment plume during export cable installation within the offshore cable corridor	Impact 5: Change in suspended sediment concentrations due to offshore cables installation (infield and interlink cables)	Impact 6: Change in sea bed level due to offshore cable installation (infield and interlink cables)	Impact 7: Interruptions to bedload sediment transport due to sand wave levelling for offshore cable installation (infield and interlink cables)	Impact 8: Indentations on the sea bed due to installation vessels
Impact 1a: Changes in suspended sediment concentrations due to sea bed preparation for foundation installation (wind farm site)	-	No	Yes	No	Yes	Yes	Yes	Yes	No	No

	Potential Interaction between Impacts									
	Construction									
	Impact 1a: Changes in suspended sediment concentrations due to sea bed preparation for foundation installation (wind farm site)	Impact 1b: Changes in suspended sediment concentrations due to drill arisings for installation of piled foundations for wind turbines (wind farm site)	Impact 2a: Changes in sea bed level due to sea bed preparation for foundation installation	Impact 2b: Changes in sea bed level due to drill arisings for installation of piled foundations	Impact 3: Change in suspended sediment concentrations due to export cable installation	Impact 4: Change in sea bed level due to deposition from the suspended sediment plume during export cable installation within the offshore cable corridor	Impact 5: Change in suspended sediment concentrations due to offshore cables installation (infield and interlink cables)	Impact 6: Change in sea bed level due to offshore cable installation (infield and interlink cables)	Impact 7: Interruptions to bedload sediment transport due to sand wave levelling for offshore cable installation (infield and interlink cables)	Impact 8: Indentations on the sea bed due to installation vessels
Impact 1b: Changes in suspended sediment concentrations due to drill arisings for installation of piled foundations for wind turbines (wind farm site)	No	-	No	Yes	Yes	Yes	Yes	Yes	No	No
Impact 2a: Changes in sea bed level due to sea bed preparation for foundation installation	Yes	No	-	No	Yes	Yes	Yes	Yes	No	Yes

	Potential Interaction between Impacts									
	Construction									
	Impact 1a: Changes in suspended sediment concentrations due to sea bed preparation for foundation installation (wind farm site)	Impact 1b: Changes in suspended sediment concentrations due to drill arisings for installation of piled foundations for wind turbines (wind farm site)	Impact 2a: Changes in sea bed level due to sea bed preparation for foundation installation	Impact 2b: Changes in sea bed level due to drill arisings for installation of piled foundations	Impact 3: Change in suspended sediment concentrations due to export cable installation	Impact 4: Change in sea bed level due to deposition from the suspended sediment plume during export cable installation within the offshore cable corridor	Impact 5: Change in suspended sediment concentrations due to offshore cables installation (infield and interlink cables)	Impact 6: Change in sea bed level due to offshore cable installation (infield and interlink cables)	Impact 7: Interruptions to bedload sediment transport due to sand wave levelling for offshore cable installation (infield and interlink cables)	Impact 8: Indentations on the sea bed due to installation vessels
Impact 2b: Changes in sea bed level due to drill arisings for installation of piled foundations	No	Yes	No	-	Yes	Yes	Yes	Yes	No	Yes
Impact 3: Change in suspended sediment concentrations due to export cable installation	Yes	Yes	Yes	Yes	-	Yes	Yes	Yes	No	No

	Potential Interaction between Impacts									
	Construction									
	Impact 1a: Changes in suspended sediment concentrations due to sea bed preparation for foundation installation (wind farm site)	Impact 1b: Changes in suspended sediment concentrations due to drill arisings for installation of piled foundations for wind turbines (wind farm site)	Impact 2a: Changes in sea bed level due to sea bed preparation for foundation installation	Impact 2b: Changes in sea bed level due to drill arisings for installation of piled foundations	Impact 3: Change in suspended sediment concentrations due to export cable installation	Impact 4: Change in sea bed level due to deposition from the suspended sediment plume during export cable installation within the offshore cable corridor	Impact 5: Change in suspended sediment concentrations due to offshore cables installation (infield and interlink cables)	Impact 6: Change in sea bed level due to offshore cable installation (infield and interlink cables)	Impact 7: Interruptions to bedload sediment transport due to sand wave levelling for offshore cable installation (infield and interlink cables)	Impact 8: Indentations on the sea bed due to installation vessels
Impact 4: Change in sea bed level due to deposition from the suspended sediment plume during export cable installation within the offshore cable corridor	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes	No	Yes

	Potential Interaction between Impacts									
	Construction									
	Impact 1a: Changes in suspended sediment concentrations due to sea bed preparation for foundation installation (wind farm site)	Impact 1b: Changes in suspended sediment concentrations due to drill arisings for installation of piled foundations for wind turbines (wind farm site)	Impact 2a: Changes in sea bed level due to sea bed preparation for foundation installation	Impact 2b: Changes in sea bed level due to drill arisings for installation of piled foundations	Impact 3: Change in suspended sediment concentrations due to export cable installation	Impact 4: Change in sea bed level due to deposition from the suspended sediment plume during export cable installation within the offshore cable corridor	Impact 5: Change in suspended sediment concentrations due to offshore cables installation (infield and interlink cables)	Impact 6: Change in sea bed level due to offshore cable installation (infield and interlink cables)	Impact 7: Interruptions to bedload sediment transport due to sand wave levelling for offshore cable installation (infield and interlink cables)	Impact 8: Indentations on the sea bed due to installation vessels
Impact 5: Change in suspended sediment concentrations due to offshore cables installation (infield and interlink cables)	Yes	Yes	Yes	Yes	Yes	Yes	-	Yes	No	No
Impact 6: Change in sea bed level due to offshore cable installation (infield and interlink cables)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes

	Potential Interaction between Impacts									
	Construction									
	Impact 1a: Changes in suspended sediment concentrations due to sea bed preparation for foundation installation (wind farm site)	Impact 1b: Changes in suspended sediment concentrations due to drill arisings for installation of piled foundations for wind turbines (wind farm site)	Impact 2a: Changes in sea bed level due to sea bed preparation for foundation installation	Impact 2b: Changes in sea bed level due to drill arisings for installation of piled foundations	Impact 3: Change in suspended sediment concentrations due to export cable installation	Impact 4: Change in sea bed level due to deposition from the suspended sediment plume during export cable installation within the offshore cable corridor	Impact 5: Change in suspended sediment concentrations due to offshore cables installation (infield and interlink cables)	Impact 6: Change in sea bed level due to offshore cable installation (infield and interlink cables)	Impact 7: Interruptions to bedload sediment transport due to sand wave levelling for offshore cable installation (infield and interlink cables)	Impact 8: Indentations on the sea bed due to installation vessels
Impact 7: Interruptions to bedload sediment transport due to sand wave levelling for offshore cable installation (infield and interlink cables)	No	No	No	No	No	No	No	Yes	-	No
Impact 8: Indentations on the sea bed due to installation vessels	No	No	Yes	Yes	No	Yes	No	Yes	No	-
	Operation									

	Potential Interaction between Impacts									
	Construction									
	Impact 1a: Changes in suspended sediment concentrations due to sea bed preparation for foundation installation (wind farm site)	Impact 1b: Changes in suspended sediment concentrations due to drill arisings for installation of piled foundations for wind turbines (wind farm site)	Impact 2a: Changes in sea bed level due to sea bed preparation for foundation installation	Impact 2b: Changes in sea bed level due to drill arisings for installation of piled foundations	Impact 3: Change in suspended sediment concentrations due to export cable installation	Impact 4: Change in sea bed level due to deposition from the suspended sediment plume during export cable installation within the offshore cable corridor	Impact 5: Change in suspended sediment concentrations due to offshore cables installation (infield and interlink cables)	Impact 6: Change in sea bed level due to offshore cable installation (infield and interlink cables)	Impact 7: Interruptions to bedload sediment transport due to sand wave levelling for offshore cable installation (infield and interlink cables)	Impact 8: Indentations on the sea bed due to installation vessels
	Impact 1: Changes to the tidal regime due to the presence of structures on the sea bed (wind turbines and OSP foundations)	Impact 2: Changes to the wave regime due to the presence of structures on the sea bed (wind turbines and OSP foundations)	Impact 3: Changes to the sediment transport regime due to the presence of structures on the sea bed (wind turbines and OSP foundations)	Impact 4: Loss of sea bed area due to the footprint of wind turbine and OSP foundation structures	Impact 5: Morphological and sediment transport effects due to cable protection measures within the SEP and DEP wind farm sites and interlink cable corridor	Impact 6: Morphological and sediment transport effects due to cable protection measures within the offshore cable corridor (export cables)	Impact 7: Cable repairs and reburial			
Impact 1: Changes to the tidal regime due to the presence of structures on the sea bed (wind turbines and OSP foundations)	-	Yes	No	No	No	No	No			

	Potential Interaction between Impacts									
	Construction									
	Impact 1a: Changes in suspended sediment concentrations due to sea bed preparation for foundation installation (wind farm site)	Impact 1b: Changes in suspended sediment concentrations due to drill arisings for installation of piled foundations for wind turbines (wind farm site)	Impact 2a: Changes in sea bed level due to sea bed preparation for foundation installation	Impact 2b: Changes in sea bed level due to drill arisings for installation of piled foundations	Impact 3: Change in suspended sediment concentrations due to export cable installation	Impact 4: Change in sea bed level due to deposition from the suspended sediment plume during export cable installation within the offshore cable corridor	Impact 5: Change in suspended sediment concentrations due to offshore cables installation (infield and interlink cables)	Impact 6: Change in sea bed level due to offshore cable installation (infield and interlink cables)	Impact 7: Interruptions to bedload sediment transport due to sand wave levelling for offshore cable installation (infield and interlink cables)	Impact 8: Indentations on the sea bed due to installation vessels
Impact 2: Changes to the wave regime due to the presence of structures on the sea bed (wind turbines and OSP foundations)	Yes	-	No	No	No	No	No			
Impact 3: Changes to the sediment transport regime due to the presence of structures on the sea bed (wind turbines and OSP foundations)	No	No	-	No	Yes	Yes	No			

	Potential Interaction between Impacts									
	Construction									
	Impact 1a: Changes in suspended sediment concentrations due to sea bed preparation for foundation installation (wind farm site)	Impact 1b: Changes in suspended sediment concentrations due to drill arisings for installation of piled foundations for wind turbines (wind farm site)	Impact 2a: Changes in sea bed level due to sea bed preparation for foundation installation	Impact 2b: Changes in sea bed level due to drill arisings for installation of piled foundations	Impact 3: Change in suspended sediment concentrations due to export cable installation	Impact 4: Change in sea bed level due to deposition from the suspended sediment plume during export cable installation within the offshore cable corridor	Impact 5: Change in suspended sediment concentrations due to offshore cables installation (infield and interlink cables)	Impact 6: Change in sea bed level due to offshore cable installation (infield and interlink cables)	Impact 7: Interruptions to bedload sediment transport due to sand wave levelling for offshore cable installation (infield and interlink cables)	Impact 8: Indentations on the sea bed due to installation vessels
Impact 4: Loss of sea bed area due to the footprint of wind turbine and OSP foundation structures	No	No	No	-	No	No	No			
Impact 5: Morphological and sediment transport effects due to cable protection measures within the SEP and DEP wind farm sites and interlink cable corridor	No	No	Yes	No	-	Yes	No			

	Potential Interaction between Impacts									
	Construction									
	Impact 1a: Changes in suspended sediment concentrations due to sea bed preparation for foundation installation (wind farm site)	Impact 1b: Changes in suspended sediment concentrations due to drill arisings for installation of piled foundations for wind turbines (wind farm site)	Impact 2a: Changes in sea bed level due to sea bed preparation for foundation installation	Impact 2b: Changes in sea bed level due to drill arisings for installation of piled foundations	Impact 3: Change in suspended sediment concentrations due to export cable installation	Impact 4: Change in sea bed level due to deposition from the suspended sediment plume during export cable installation within the offshore cable corridor	Impact 5: Change in suspended sediment concentrations due to offshore cables installation (infield and interlink cables)	Impact 6: Change in sea bed level due to offshore cable installation (infield and interlink cables)	Impact 7: Interruptions to bedload sediment transport due to sand wave levelling for offshore cable installation (infield and interlink cables)	Impact 8: Indentations on the sea bed due to installation vessels
Impact 6: Morphological and sediment transport effects due to cable protection measures within the offshore cable corridor (export cables)	No	No	Yes	No	Yes	-	No			
Impact 7: Cable repairs and reburial	No	No	No	No	No	No	-			
	Decommissioning									
	The magnitude of effects would be comparable to those identified for the construction phase. Accordingly, given that no significant impacts were assessed for the identified marine geology, oceanography and physical processes receptors during the construction phase, it is anticipated that the same would be valid for the decommissioning phase.									

Table 6-45: Interaction between impacts – phase and lifetime assessment

Receptor	Highest significance level				
	Construction	Operation	Decommissioning	Phase assessment	Lifetime assessment
East Anglian coast	Negligible	No impact	Negligible	No greater than individually assessed impact The impacts are considered to have no impact to negligible adverse impact on the receptor. Given that each impact will be managed with standard and best practice methodologies it is considered that there would either be no interactions or that these would not result in greater impact than assessed individually.	No greater than individually assessed impact
Cromer Shoal Chalk Beds MCZ	Negligible	Negligible	Negligible	No greater than individually assessed impact The impacts are considered to have a negligible adverse impact on the receptor. Given that the magnitudes are negligible adverse and that impact will be managed with standard and best practice methodologies it is considered that there would either be no interactions or that these would not result in greater impact than assessed individually.	No greater than individually assessed impact
Sand banks (and associated sand waves)	Negligible	Negligible	Negligible	No greater than individually assessed impact The impacts are considered to have negligible adverse magnitude of effect on the receptor. Given that that each impact will be managed with standard and best practice methodologies it is considered that there would either be no interactions or that these would not result in greater impact than assessed individually.	No greater than individually assessed impact

6.11 Potential Monitoring Requirements

422. Monitoring requirements are described in the **Offshore IPMP** (document reference 9.5) submitted alongside the DCO application and will be further developed and agreed with stakeholders prior to construction based on the IPMP and taking account of the final detailed design of the Projects. The following monitoring which has overlaps with general asset integrity monitoring that is specific to marine geology, oceanography and physical processes is proposed:

- Pre- and post-construction monitoring of sand waves to assess for example recovery rates and re-exposure of buried cables.
- Recovery of the physical form of the sea bed, including from export cable installation in the MCZ

423. Monitoring of scour protection measures and secondary scour to identify the extent, volume and integrity of any scour protection used. No other monitoring is currently proposed in relation to marine geology, oceanography and physical processes. This is on account of the outcomes of the assessment, which has concluded that all of the potential impacts considered will result in either no or, at worse, negligible adverse impacts. The conclusions can be made with a high degree of certainty on account of an accumulation of evidence from a range of studies and other existing wind farms (details in **Section 6.6**). However, as is typical for development projects of this nature, a range of geophysical surveys will be carried out both before and after construction both for engineering / asset integrity purposes and to feed into the requirements for other environmental topics such as benthic ecology and archaeology.

6.12 Assessment Summary

424. This chapter has provided a characterisation of the existing environment for marine geology, oceanography and physical processes based on both existing and site specific survey data, which has established that the impacts on the identified receptors during construction, operation and decommissioning phases of SEP and DEP (in isolation and where both Projects are built) are considered 'negligible adverse' or 'no impact'.

425. The specific receptors that have been identified in relation to this topic are the sensitive 'East Anglian' coast, Cromer Shoal Chalk Beds MCZ and sandbanks.

426. The effects that have been assessed are mostly anticipated to result in no impact to the above-mentioned receptors because they are located remotely from the zones of influence and no pathway has been identified that can link the source to the receptor. Where there is a pathway for impact, the assessment has concluded that impacts would be of no greater than negligible adverse significance. Project-specific wave modelling has been undertaken to measure potential impacts on the wave climate from SEP, DEP, SOW and DOW. The results show that SEP and DEP are predicted to have only a localised impact on wave climate, where reflection from the wind turbines results in a slight reduction in wave conditions, up to 0.05m significant wave height. There is no impact on the nearshore wave conditions along the East Anglian coast (see **Section 6.6.5.2** and **Appendix 6.4**). A summary of impacts to these receptors are listed in **Table 6-46**.

Table 6-46: Summary of Potential Impacts on Marine Geology, Oceanography and Physical Processes

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact	Cumulative residual impact
Construction							
Impact 1a: Changes in suspended sediment concentrations due to sea bed preparation for foundation installation (wind farm site)	East Anglian coast	N/A	Medium (near-field) Low (far-field)	No impact	N/A	No impact	N/A since no impacts or sites screened in for cumulative assessment
	Cromer Shoal Chalk Beds MCZ	N/A	Medium (near-field) Low (far-field)	No impact	N/A	No impact	
	Sand banks (and associated sand waves)	N/A	Medium (near-field) Low (far-field)	No impact	N/A	No impact	
Impact 1b: Changes in suspended sediment concentrations due to drill arisings for installation of piled foundations for wind turbines and OSPs	East Anglian coast	N/A	Negligible (near-field) Negligible (far-field)	No impact	N/A	No impact	
	Cromer Shoal Chalk Beds MCZ	N/A	Negligible (near-field) Negligible (far-field)	No impact	N/A	No impact	
	Sand banks (and associated sand waves)	N/A	Negligible (near-field) Negligible (far-field)	No impact	N/A	No impact	
Impact 2a: Changes in sea bed level due to sea bed preparation for foundation installation	East Anglian coast	N/A	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible	
	Cromer Shoal Chalk Beds MCZ	N/A	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible	

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact	Cumulative residual impact
	Sand banks (and associated sand waves)	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible	
Impact 2b: Changes in sea bed level due to drill arisings for installation of piled foundations for wind turbines and OSPs	East Anglian coast	N/A	Low (near-field) Negligible (far-field)	No impact	N/A	No impact	
	Cromer Shoal Chalk Beds MCZ	N/A	Low (near-field) Negligible (far-field)	No impact	N/A	No impact	
	Sand banks (and associated sand waves)	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible	
Impact 3: Change in suspended sediment concentrations due to export cable installation	East Anglian coast	N/A	Negligible (near-field (nearshore)) Negligible (near-field (offshore)) Negligible (far-field)	No impact	N/A	No impact	
	Cromer Shoal Chalk Beds MCZ	N/A	Negligible (near-field (nearshore)) Negligible (near-field (offshore)) Negligible (far-field)	No impact	N/A	No impact	
	Sand banks (and associated sand waves)	N/A	Negligible (near-field (nearshore)) Negligible (near-field (offshore)) Negligible (far-field)	No impact	N/A	No impact	

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact	Cumulative residual impact
Impact 4: Change in sea bed level due to deposition from the suspended sediment plume during export cable installation within the offshore cable corridor	East Anglian coast	Negligible	Low (near-field) Negligible (far-field)	No impact	N/A	No impact	
	Cromer Shoal Chalk Beds MCZ	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible	
	Sand banks (and associated sand waves)	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible	
Impact 5: Change in suspended sediment concentrations due to offshore cables installation (infield and interlink cables)	East Anglian coast	N/A	Medium (near-field) Low (far-field)	No impact	N/A	No impact	
	Cromer Shoal Chalk Beds MCZ	N/A	Medium (near-field) Low (far-field)	No impact	N/A	No impact	
	Sand banks (and associated sand waves)	N/A	Medium (near-field) Low (far-field)	No impact	N/A	No impact	
Impact 6: Change in sea bed level due to offshore cable installation (infield and interlink cables)	East Anglian coast	N/A	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible	
	Cromer Shoal Chalk Beds MCZ	N/A	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible	
	Sand banks (and associated sand waves)	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible	
Impact 7: Interruptions to bedload sediment	East Anglian coast	N/A	Low (near-field) Negligible (far-field)	No impact	N/A	No impact	

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact	Cumulative residual impact
transport due to sand wave levelling for offshore cable installation (infield and interlink cables)	Cromer Shoal Chalk Beds MCZ	N/A	Low (near-field) Negligible (far-field)	No impact	N/A	No impact	
	Sand banks (and associated sand waves)	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible	
Impact 8: Indentations on the sea bed due to installation vessels	East Anglian coast	N/A	Medium (near field (immediate vicinity of leg) No change (near field (beyond immediate vicinity of leg) No change (far field)	No impact	N/A	No impact	
	Cromer Shoal Chalk Beds MCZ	Negligible	Medium (near field (immediate vicinity of leg) No change (near field (beyond immediate vicinity of leg) No change (far field)	Negligible	N/A	Negligible	
	Sand banks (and associated sand waves)	Negligible	Medium (near field (immediate vicinity of leg) No change (near field (beyond immediate vicinity of leg)	Negligible	N/A	Negligible	

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact	Cumulative residual impact
			No change (far field)				
Operation							
Impact 1: Changes to the tidal regime due to the presence of structures on the sea bed (wind turbines and OSP foundations)	East Anglian coast	N/A	Low (near-field) Negligible (far-field)	No impact	N/A	No impact	N/A since no impacts or sites screened in for cumulative assessment
	Cromer Shoal Chalk Beds MCZ	N/A	Low (near-field) Negligible (far-field)	No impact	N/A	No impact	
	Sand banks (and associated sand waves)	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible	
Impact 2: Changes to the wave regime due to the presence of structures on the sea bed (wind turbines and OSP foundations)	East Anglian coast	N/A	Low (near-field) Negligible (far-field)	No impact	N/A	No impact	
	Cromer Shoal Chalk Beds MCZ	N/A	Low (near-field) Negligible (far-field)	No impact	N/A	No impact	
	Sand banks (and associated sand waves)	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible	
Impact 3: Changes to the sediment transport regime due to the presence of structures on the sea bed (wind turbines	East Anglian coast	N/A	Low (near-field) Negligible (far-field)	No impact	N/A	No impact	
	Cromer Shoal Chalk Beds MCZ	N/A	Low (near-field) Negligible (far-field)	No impact	N/A	No impact	

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact	Cumulative residual impact
and OSP foundations)	Sand banks (and associated sand waves)	Negligible	Low (near-field) Negligible (far-field)	Negligible	N/A	Negligible	
Impact 4: Loss of sea bed area due to the footprint of wind turbine and OSP foundation structures	East Anglian coast	N/A	High (near-field) No change (far-field)	No impact	N/A	No impact	
	Cromer Shoal Chalk Beds MCZ	N/A	High (near-field) No change (far-field)	No impact	N/A	No impact	
	Sand banks (and associated sand waves)	N/A	High (near-field) No change (far-field)	No impact	N/A	No impact	
Impact 5: Morphological and sediment transport effects due to cable protection measures within the SEP and DEP wind farm sites and interlink cable corridor	East Anglian coast	N/A	High (near-field) Negligible (far-field)	No impact	N/A	No impact	
	Cromer Shoal Chalk Beds MCZ	N/A	High (near-field) Negligible (far-field)	No impact	N/A	No impact	
	Sand banks (and associated sand waves)	Negligible	High (near-field) Negligible (far-field)	Negligible	N/A	Negligible	
Impact 6: Morphological and sediment transport effects due to cable protection measures within the offshore cable corridor (export cables)	East Anglian coast	Medium	Negligible (landfall) No change (Shallower than 9m) Low (deeper than 9m)	No impact	N/A	No impact	
	Cromer Shoal Chalk Beds MCZ	Medium	Negligible (landfall)	Negligible	N/A	Negligible	

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact	Cumulative residual impact
			No change (Shallower than 9m) Low (deeper than 9m)				
	Sand banks (and associated sand waves)	Negligible	Negligible (landfall) No change (Shallower than 9m) Low (deeper than 9m)	Negligible	N/A	Negligible	
Impact 7: Cable repairs and reburial	East Anglian coast	N/A	Medium (near-field (immediate vicinity of leg)) No Change (near-field (beyond immediate vicinity of leg)) No change (far-field)	No impact	N/A	No impact	
	Cromer Shoal Chalk Beds MCZ	Negligible	Medium (near-field (immediate vicinity of leg)) No Change (near-field (beyond immediate vicinity of leg)) No change (far-field)	Negligible	N/A	Negligible	

Potential impact	Receptor	Sensitivity	Magnitude	Pre-mitigation impact	Mitigation measures proposed	Residual impact	Cumulative residual impact
	Sand banks (and associated sand waves)	Negligible	Medium (near-field (immediate vicinity of leg)) No Change (near-field (beyond immediate vicinity of leg)) No change (far-field)	Negligible	N/A	Negligible	
Decommissioning							
The impacts during the decommissioning phase would be comparable to those identified for the construction phase. Accordingly, given that no significant impact was assessed for the identified marine geology, oceanography and physical processes receptors during the construction phase, it is anticipated that the same would be valid for the decommissioning phase.							

References

ABPmer (2012). East Anglia Offshore Wind Zonal Environmental Appraisal Report. Appendix G – Physical Processes Baseline and References.

AECOM (2013). Kelling to Lowestoft Ness Shoreline Management Plan.

BEIS (2021a) Draft Overarching National Policy Statement for Energy (EN-1). Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1015233/en-1-draft-for-consultation.pdf. Accessed 08/10/2021.

BEIS (2021b) Draft National Policy Statement for Renewable Energy Infrastructure (EN-3) Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1015236/en-3-draft-for-consultation.pdf.

BERR (2008). Review of Cabling Techniques and Environmental Effects applicable to the Offshore Windfarm Industry.

British Geological Survey. (2020). Shallow seismostratigraphic ground model of the Dudgeon and Sheringham Shoal wind farm extension areas. Marine Geoscience Programme Commissioned Report CR/20/078.

Cameron, T.D.J., Crosby, A., Balson, P.S., Jeffery, D.H., Lott, G.K., Bulat, J. and Harrison, D.J., (1992). United Kingdom offshore regional report: the geology of the southern North Sea. HMSO: London

Cefas (2004). Offshore wind farms: guidance note for Environmental Impact Assessment in respect of FEPA and Coast Protection Act requirements.

Cefas (2005). Assessment of the significance of changes to the inshore wave regime as a consequence of an offshore wind array. Defra R&D report.

Cefas (2011). Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects.

Cefas (2014). Cromer Shoal Chalk Beds Marine Conservation Zone (MCZ) Survey Infauna Data – 2014.

Cefas (2016). Suspended Sediment Climatologies around the UK. Report for the UK Department for Business, Energy and Industrial Strategy offshore energy Strategic Environmental Assessment Programme.

Chroston, P.N., Jones, R. and Makin, B. (1999). Geometry of Quaternary sediments along the north Norfolk coast: a shallow seismic study. Geol. Mag., 136, 465-474.

Church, J. A., Clark, P. U., Cazenave, A., Gregory, J. M., Jevrejeva, S., Levermann, A., Merrifield, M. A., Milne, G. A., Nerem, R. S., Nunn, P. D., Payne, A. J., Pfeffer, W. T., Stammer, D., and Unnikrishnan, A. S. (2013). Sea Level Change. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group 1 to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

Cooper, N.J. and Brew, D.S. (2013). Impacts on the physical environment. In: R.C. Newell and T.A. Woodcock (Eds.). *Aggregate dredging and the marine environment: an overview of recent research and current industry practice*. The Crown Estate.
Department of Energy and Climate Change (2011a). Overarching NPS for Energy (EN-1).
Department of Energy and Climate Change (2011b). NPS for Renewable Energy Infrastructure (EN-3).
Department of Energy and Climate Change (2011c). NPS for Electricity Networks Infrastructure (EN-5).
Dove, D. and Carter, G. (2021). Sheringham Shoal Nearshore Cable Route – BGS Shallow Geological Assessment. British Geological Survey Commissioned Report CR/21/039, 49pp.
Dudgeon Offshore Wind Farm (DOW) (2009). Environmental Statement – Section 7: Physical Processes.
EATL. (East Anglia Three Limited). (2015). East Anglia THREE Environmental Statement. Report to East Anglia Offshore Wind, November 2015.
EMU (2008). Sheringham Shoal Offshore Windfarm Project NH0779 Seabed and Sub-seabed Mapping Survey. Report to Scira Offshore Energy, June 2008.
Environment Agency (2018). Coastal flood boundary conditions for the UK: update 2018. Technical summary report.
ETSU (Energy Technology Support Unit) (2002). *Potential effects of offshore wind farms on coastal processes*. Report No. ETSU W/35/00596/REP.
ETSU. (Energy Technology Support Unit). (2000). *An assessment of the environmental effects of offshore wind farms.* Report No. ETSU W/35/00543/REP.
Fugro (2014a). ST13504 Dudgeon Offshore Windfarm Seabed and Sub-Seabed Mapping. Report to Statoil, January 2014.
Fugro (2014b). ST14916 Dudgeon Offshore Windfarm Development: Pre-construction baseline ecology study.
Fugro EMU (2014). Sheringham Shoal Windfarm Marine Survey 2013 Monitoring Report. Report to Scira Offshore Energy, September 2014.
Fugro EMU (2016). Sheringham Shoal Wind Farm Marine Survey Winter 2015 Results. Report to Scira Offshore Energy, August 2016.
Fugro (2019). Sheringham Shoal Wind Farm Seabed Monitoring Survey. Report to Equinor, March 2019.
Gardline (2007). Dudgeon Offshore Wind Farm Geophysical and Hydrographic Survey. September-October 2007. Amended Results Report.
Gardline (2019). UK Wind Extension of Sheringham Shoal and Dudgeon Surveys. Geophysical Survey (September to December 2019).
Gardline (2020a). UK Extension Seabed and UHRS Survey: Dudgeon and Sheringham Shoal Wind Farm Survey (March to May 2020).

Gardline (2020b). UK Extension Seabed and UHRS Survey: Sheringham Shoal and Cable Routes Wind Farm Survey: Geophysical Survey (March to May 2020).
Hiscock, D.R. and Bell, S. (2004). Physical impacts of aggregate dredging on sea bed resources in coastal deposits. *Journal of Coastal Research*, 20 (10), 101-114.
HM Government (2011). UK Marine Policy Statement. London: The Stationery Office
HR Wallingford (1988). Coastal Defence Management Study for the Anglian Region: Offshore Wave Climate. HRW Report EX 1665.
HR Wallingford (1990). Mablethorpe to Skegness Sea Defence Study: Joint probability of high waves and high water levels. HRW Report EX2161
HR Wallingford (2002a). Southern North Sea Sediment Transport Study – Phase 2. HR Wallingford report EX4526.
HR Wallingford (2002b). Cromer Coastal Defence Strategy Study: Final Report. HRW Report EX4363.
HR Wallingford (2004). Kelling to Cromer Strategy Study. HRW Report EX4985.
John, S.A., Challinor, S.L., Simpson, M., Burt, T.N. and Spearman, J. (2000). *Scoping the assessment of sediment plumes from dredging*. CIRIA Publication.
JNCC (Joint Nature Conservancy Committee) and Natural England (2011). General advice on assessing potential impacts of and mitigation for human activities on Marine Conservation Zone (MCZ) features, using existing regulation and legislation.
Kenyon, N.H. and Cooper, W. (2005). Sandbanks, sand transport and offshore wind farms. Report for the Department of Trade and Industry. Kenyon MarineGeo and ABP Marine Environmental Research Ltd, UK.
Lambkin, D.O., Harris, J.M., Cooper, W.S. and Coates, T. (2009). Coastal Process Modelling for Offshore Wind Farm Environmental Impact Assessment: Best Practice Guide. Report to COWRIE, September 2009.
Lowe, J. A., Howard, T. P., Pardaens, A., Tinker, J., Holt, J., Wakelin, S., Milne, G., Leake, J., Wolf, J., Horsburgh, K., Reeder, T., Jenkins, G., Ridley, J., Dye, S., and Bradley, S. (2009). UK Climate Projections science report: Marine and coastal projections. Met Office Hadley Centre, Exeter, UK.
MMO (Marine Management Organisation) (2012). East Inshore and East Offshore Marine Plan Areas: Evidence and Issues.
MMT (2018a). Dudgeon OWF – ST18692. Seabed Features North Sea, August-September 2018. Report to Equinor, November 2018.
MMT (2018b). Dudgeon OWF – ST18692. Export and Infield Array Cables Survey North Sea, September-October 2018. Report to Equinor, November 2018.
MMT (2019). Dudgeon OWF – ST18692. Environmental post construction survey report North Sea, August-September 2018. Report to Equinor, March 2019.
Ohl, C.O.G., Taylor, P.H., Eatock Taylor, R. and Borthwick, A.G.L. (2001). Water wave diffraction by a cylinder array part II: irregular waves. *Journal of Fluid Mechanics*, 442, 33 – 66.

Newell, R.C., Seiderer, L.J., Robinson, J.E., Simpson, N.M., Pearce, B and Reeds, K.A. (2004). Impacts of overboard screening on sea bed and associated benthic biology community structure in relation to marine aggregate extraction. Technical Report to the Office of the Deputy Prime Minister and Minerals Industry Research Organisation. Project No. SAMP 1.022, Marine Ecological Surveys Ltd, St. Ives, Cornwall.
PINS (2018). Planning Inspectorate Advice Note Nine: Rochdale Envelope.
PINS (2019). Scoping Opinion: Proposed Dudgeon and Sheringham Shoal Offshore Wind Farm Extensions. Available at: https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010109/EN010109-000006-EQNR_Scoping%20Opinion%202017%20EIA%20Regs.pdf
Royal HaskoningDHV (2017). Norfolk Vanguard Preliminary Environmental Information Report.
Royal HaskoningDHV (2018). Norfolk Boreas Preliminary Environmental Information Report.
Royal HaskoningDHV (2020). Sedimentary Processes in the Cromer Shoal Chalk Beds MCZ.
Seagreen (2012). The Seagreen Project Environmental Statement. September 2012.
Scira (2006). Sheringham Shoal Offshore Wind Farm Environmental Statement.
Soulsby, R.L. (1997). Dynamics of Marine Sands. Thomas Telford
Spray, R. and Watson, D. (2011). North Norfolk's Chalk Reef, A report on marine surveys conducted by Seasearch East.
Tillin, H.M., Houghton, A.J., Saunders, J.E. Drabble, R. and Hull, S.C. (2011). Direct and indirect impacts of aggregate dredging. *Science Monograph Series No. 1*. MEPF 10/P144
The Crown Estate, 2019, Plan-Level Habitats Regulations Assessment for the 2017 Offshore Wind Farm Extensions, Cable Route Protocol (TCE, 2019).
The Crown Estate / RPS (2019). Review of Cable Installation, Protection, Mitigation and Habitat Recoverability. Available at: [redacted]
Whiteside, P.G.D., Ooms, K. and Postma, G.M. (1995). Generation and decay of sediment plumes from sand dredging overflow. *Proceedings of the 14th World Dredging Congress*. Amsterdam, The Netherlands. World Dredging Association, 877 – 892.