Dudgeon and Sheringham Shoal Offshore Wind Farm Extensions

Preliminary Environmental Information Report

Volume 3

Appendix 8.1 - Physical Processes Method Statement

April 2021

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Glossary of Acronyms

DEP	Dudgeon Extension Project
EIA	Environmental Impact Assessment
EPP	Evidence Plan Process
ES	Environmental Statement
ETG	Expert Topic Group
GBS	Gravity Base Structures
HDD	Horizontal Directional Drilling
MAREA	Marine Aggregate Regional Environmental Assessment
MCZ	Marine Conservation Zone
PEIR	Preliminary Environmental Information Report
REC	Regional Environmental Characterisation
SEP	Sheringham Shoal Extension Project

Glossary of Terms

The Applicant	Equinor New Energy Limited
Dudgeon Offshore Wind Farm Extension site	The Dudgeon Offshore Wind Farm Extension offshore wind farm boundary.
The Dudgeon Offshore Wind Farm Extension Project (DEP)	The Dudgeon Offshore Wind Farm Extension site as well as all onshore and offshore infrastructure.
DEP offshore survey area	The benthic characterisation survey area covering DEP offshore wind farm area, offshore interlink and DEP export cable.
DEP offshore area	The Dudgeon Offshore Wind Farm Extension offshore wind farm boundary, including all offshore infrastructure
Infield cables	Cables which link the wind turbine generators to the offshore substation platforms.
Interlink cables	Cables linking two separate project areas. This can be cables linking: 1. DEP South and DEP North 2. DEP South and SEP 3. DEP North and SEP 1 is relevant if DEP is constructed alone or first in a phased development. 2 and 3 are relevant in a tandem construction.
Landfall	The point at the coastline at which the offshore export cables are brought onshore, connecting to the onshore cables at the transition joint bay above mean high water.
Offshore cable corridor	An area which will contain cables outside of a wind farm site(s), either interlink cables or offshore export cables.

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.
PEIR boundary	The area subject to survey and preliminary impact assessment to inform the PEIR, including all permanent and temporary works for DEP and SEP. The PEIR boundary will be refined down to the final DCO boundary ahead of the application for development consent.
Study area	Area where potential impacts from the project could occur, as defined for each individual EIA topic.
Sheringham Shoal Offshore Wind Farm Extension site	Sheringham Shoal Offshore Wind Farm Extension offshore wind farm boundary.
SEP offshore survey area	The benthic characterisation survey area covering SEP offshore wind farm area and SEP export cable.
SEP offshore area	Sheringham Shoal Offshore Wind Farm Extension offshore wind farm boundary, including all offshore infrastructure.
The Sheringham Shoal Offshore Wind Farm Extension Project (SEP)	The Sheringham Shoal Offshore Wind Farm Extension site as well as all onshore and offshore infrastructure.

8.1 MARINE GEOLOGY, OCEANOGRAPHY AND PHYSICAL PROCESSES

8.1.1 Introduction

1. The purpose of this method statement is to build upon the information provided within the Dudgeon and Sheringham Shoal Offshore Wind Farm Extensions Environmental Impact Assessment (EIA) Scoping Report, in outlining the proposed approach to be taken and considerations to be made in the assessment of the Marine Geology, Oceanography and Physical Processes (including the intertidal areas of the landfall) effects of the proposed project.

2. This method statement and the consultation around it form part of the Dudgeon and Sheringham Shoal Offshore Wind Farm Extensions Evidence Plan Process (EPP). The aim is to gain agreement on this method statement from all members of the Seabed Expert Topic Group (ETG) which will be recorded through the agreement log.

8.1.1.1 Background

3. A Scoping Report for the proposed Dudgeon Extension Project (DEP) and Sheringham Shoal Extension Project (SEP) EIA was submitted to the Planning Inspectorate on 7th October 2019. Further background information on the project can be found in the Scoping Report which is available at:

https://infrastructure.planninginspectorate.gov.uk/document/EN010109-000007

4. The Scoping Opinion was received on 11th November 2019 and is available at:

https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010109/EN010109-000006-EQNR_Scoping%20Opinion%202017%20EIA%20Regs.pdf

5. This method statement has been produced following a full review of the Seabed ETG meeting minutes (August 2019 and June 2020), the Scoping Opinion provided by the Planning Inspectorate (November 2019), and experience of other wind farm EPPs. Key points within the EIA Scoping Opinion that relate to Marine Geology, Oceanography and Physical Processes are summarised in **Table 8.1**.

Table 8.1: Scoping opinion responses

Consultee	Comment	Response / where addressed in this document
PINS	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	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 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 1.5.1.2**. The assessment will be completed using conceptual methods and expert-based judgement.
PINS	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 can be scoped out of the ES.	Transboundary effects associated with hydrodynamic and sedimentary processes effects are scoped out of the EIA.
PINS	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 1.5.1.4** discusses the approach to coastal and landfall impacts. These impacts will be addressed in the ES and cross reference will be made, where appropriate, to other technical reports and the Shoreline Management Plan. The UKCP18 climate change projections will be applied in the assessment at the coast.
PINS	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 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 **Sections 1.4.1** and **1.4.2**. The assessment will be 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 is disproportionate to the potential effect that would occur. The S-P-R conceptual model is proportionate.

Consultee	Comment	Response / where addressed in this document
PINS	The ES should assess any likely significant effects from changes in current and wave action resulting from introduced scour protection measures.	**Section 1.5.2.1** highlights areas to be covered. Several scour protection options will be considered and detailed within the ES and the effects on hydrodynamics and waves considered.
PINS	The Scoping Report refers to 'previous studies' however does not reference these. The ES should provide clear references to any studies used to inform the approach and support its conclusions.	Cross references to previous studies will be included in the ES.
PINS	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. 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 and will collect bathymetry, sea bed texture and near-bed geology across the array sites and cable corridor is provided in **Section 8.1.1.4**. 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.
PINS	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 should clearly identify the data sources used to inform the suspended sediment baseline.	**Sections 1.3.2** and **1.3.3** detail how data sources used to inform the suspended sediment concentration baseline will be identified.
PINS	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 will be relevant to the assessment.
PINS	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 should assess the likely significant effects of changes to hydrodynamic and sedimentary processes on these receptors.	**Section 1.5** outlines how the MCZ and SPA assessments will be completed.
PINS	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 will be included in the future baseline for physical processes.
Historic England	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	Part of assessment covers changes to sedimentary processes which in themselves are not necessarily impacts to which

Consultee	Comment	Response / where addressed in this document
	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.	significance can be ascribed. However, such changes may indirectly impact other receptors such as the historic environment and will be referenced in the ES. The significance of impacts on historic environment will be made in the historic environment chapter.
MMO	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 construction impacts on hydrodynamics are scoped out of the EIA.
Natural England	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	A separate report on sedimentary processes in the MCZ covering this issue has been completed and will be appended to the ES as supporting documentation.
Natural England	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 EIA.
Natural England	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.	**Sections 1.5.1.1** and **1.5.1.2** outline how the MCZ assessments will be completed.
Natural England	There is currently no reference to specific impacts of suspended sediment concentrations from disposal of dredged material at specific disposal grounds offshore. This needs to be considered further and scoped into the assessment.	Sea-bed levelling will be carried out in some locations in the offshore export cable corridors prior to cable installation, and at turbine locations prior to foundation installation if suction buckets or GBS foundations are used. Any excavated sediment due to sand-wave levelling would be disposed of

Consultee	Comment	Response / where addressed in this document
		close to source and therefore there will be no net loss of sand from the site. How this impact would be addressed is discussed in **Section 1.5.1.1**.
Natural England	Will wake effects from the turbines be considered further in the assessment?	**Section 1.5.2.1** describes how wakes caused by localised flow accelerations around the foundations and wave shadow effects attributable to individual foundations will be assessed in the ES.
Natural England	Increased concentrations of suspended sediments and release of contaminants due to ongoing scour during operation should be scoped in. This has been recognised by the scoping in of increased suspended sediment concentrations during operation in regard to Benthic and intertidal ecology.	**Section 1.5.2.1** highlights areas to be covered. Several scour protection options will be considered and detailed within the ES and the effects on hydrodynamics and waves considered.
Weybourne Parish Council	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 will be included in the baseline and will be assessed conceptually.

8.1.1.2 Development Programme

6. The anticipated Development Consent Order programme is outlined in **Table 8.2**.

Table 8.2: Development programme

Deliverable	Date
EIA Scoping Report submission	7th October 2019 (complete)
Preliminary Environmental Information (PEI) submission	February 2021
Environmental Statement (ES) and DCO submission	September 2021

8.1.1.3 Evidence Plan Process Programme

7. The Evidence Plan Terms of Reference provides an overview of the Evidence Plan Process and expected logistics. **Table 8.3** provides a summary of anticipated meetings for discussion of Marine Geology, Oceanography and Physical Processes.

Table 8.3: Evidence plan process programme

Meeting	Date
Seabed Expert Topic Group meeting to agree method statement	June 2020
Seabed Expert Topic Group meetings as required	2020/2021
PEI Report (PEIR) Seabed Expert Topic Group meetings to discuss the findings of the PEI	Q1 2021
Pre-submission Seabed Expert Topic Group meetings to discuss updates to the PEIR prior to submission of the ES	Q2 2021

8.1.1.4 Survey Programme

8. The baseline characterisation will be informed by a suite of geophysical surveys described in **Table 8.4**. The geophysical survey of the export cable corridor was completed between September and December 2019. The geophysical survey of the extension arrays and interconnector corridors was completed in April and May 2020. Geophysical surveys will be supported by a targeted benthic survey, planned for summer 2020, which will acquire sea bed images and grab samples of sea bed sediments.

Table 8.4: Baseline geophysical surveys

<table>
<tr><th>Survey</th><th>Dates</th><th>Survey Techniques</th></tr>
<tr><td>Export cable corridor</td><td>September to December 2019</td><td rowspan="2">• Multibeam echosounder
• Single beam echosounder
• Side-scan sonar
• Sub-bottom profiler</td></tr>
<tr><td>Extension arrays and interconnector corridors</td><td>April and May 2020</td></tr>
</table>

8.1.2 Project Description

9. This section provides an overview of DEP and SEP. It sets out the design and main components of the offshore wind farms and their infrastructure. It also describes the key activities that will be undertaken during construction, operations and maintenance (O&M phase) as well as decommissioning. At this early stage the project description is indicative for the purpose of informing the method statement.

8.1.2.1 Indicative Worst Case Scenarios

10. The following sections set out the current indicative worst case scenarios for **Chapter 8 Marine Geology, Oceanography and Physical Processes**. **Chapter 5 Project Description** for PEIR and ES will describe the final project design (also known as Rochdale Envelope) for the DCO application. Each chapter of the PEIR and ES will define the worst case scenario arising from the construction, O&M and decommissioning phases of DEP and SEP for the relevant receptors and impacts. Additionally, each chapter will consider separately the anticipated cumulative impacts of DEP and SEP with other relevant projects on the receptors under consideration.

11. The parameters discussed in this section are based on the best available information for DEP and SEP at the time of writing and are subject to change as the project progresses.

8.1.2.1.1 Wind Turbine Generator Foundations

12. The size and capacity of the wind turbines will be decided later, prior to final investment decision. Technology develops rapidly and available sizes of turbines are expected to increase over the coming years. The current wind turbine design envelope for DEP and SEP is up to 34 turbines at DEP and up to 27 turbines at SEP.

13. A range of foundation options including monopile, jackets on piles, jackets on suction buckets (four legs) and gravity base structures (GBS) are in the current project design envelope. Review of geotechnical data, metocean data, environmental considerations and the market situation for fabricating wind turbine foundations will be used to select the final wind turbine foundation type(s). The location of the wind turbines would be finalised pre-construction based on ground investigation and constraints identified in the PEIR and ES.

14. It is possible that scour protection will be installed where required during construction in order to mitigate the effects of scour and the potential release of suspended sediment and sea bed level changes in the vicinity of each wind turbine. This could include rock dumping, frond mats and mattressing. The volume and area of scour protection per turbine foundation would be included in the PEIR and ES and assessed accordingly.

8.1.2.1.2 Offshore Cabling

15. Array cables will connect the turbines to each other and to the offshore substation. Cable system design will be based on radial strings from the offshore substation(s) and connecting multiple turbines per string. The length of each array cable, and string, will depend on the distance between the turbines and the distance between the first turbine on the string and the offshore substation. A realistic maximum distance of array cables will be defined for the purposes of the PEIR and ES and used as the basis for the assessments. Two export cables are likely to connect the offshore substation(s) to a transition joint bay at the landfall.

16. The cables will be installed in separate trenches and protected in line with good industry practice. Installation of cables typically takes place by ploughing or trenching depending on the soil conditions along the cable route. However, different installation techniques along the cable corridors will be assessed to determine the most suitable in both mobile and non-mobile substrates. The purpose of cable burial is to ensure that the cables are protected from damage by external factors. Typical burial depth is between 0.5 to 1.5m, but no protection will also be considered. The appropriate level of protection will be determined based on an assessment of the risks posed to the project in specific areas.

17. A cable installation/trenching assessment (cable specification, installation and monitoring plan) will be completed to define where (and by which method) cables can be buried and the realistic worst-case length (and where) of cable protection required. This will include strategies across mobile and non-mobile substrates. The assessment will evaluate the adequacy of existing geophysical, geological and geotechnical data, consider the available cable installation tools, determine the feasibility to bury the cables to the optimum depth so they remain buried over the lifetime of the project, and how to reduce cable protection to a minimum within the MCZ. The cable installation assessment of Norfolk Vanguard Norfolk Boreas offshore wind farms will be used as examples of the approach.

18. Increases in suspended sediment concentration may result from disturbance arising from cable installation activities. To be conservative, and regardless of technique, the assessment will assume that the whole volume of sediment from the trench dimensions is released for dispersion as a worst case scenario. The worst case scenario (for this impact specifically) also assumes that the entire length of each cable is buried (i.e. there are no sections that would be laid on the sea bed and protected).

8.1.2.1.3 Offshore Substations

19. The cables from a string of turbines will be brought to an offshore substation, located appropriately to optimise the array cable and export cable lengths. There will be up to two offshore substations. In the case of two substations there will be one substation located in each extension area. The location of the offshore substation/s will be confirmed during the detailed design process but will be within the limits of each array site. The offshore substation foundation type will likely be a jacket or a GBS foundation. In case of a worst-case GBS the diameter of the foundation at sea bed will be up to 50m.

8.1.2.1.4 Construction Vessels

20. Vessel anchors and jack up vessels required for construction also have the potential to impact physical processes at the sea bed. The maximum number of anchors or jack-ups representing the worst case scenario will be defined in the PEIR and ES. Several types of construction vessel could work in parallel during the construction of DEP and SEP. For wind turbine installation, the most likely installation vessel would be a jack-up vessel, although dynamically positioned vessels (enabling installation without any direct contact with the sea bed) are also under consideration. For export cable installation, the potential to not use jack-up vessels as mitigation for sea bed disturbance will be considered for those lengths of cable that pass through the Cromer Shoal Chalk Beds MCZ.

8.1.2.1.5 Landfall

21. The landfall at Weybourne is the location where the export cables are brought ashore and jointed to the onshore cables within transition pits. Cable installation methodology at the landfall will be selected based on a comparative assessment of impacts. It is assumed that suitable technologies may include open-cut trenching or horizontal directional drilling (HDD). The offshore and onshore cables will be jointed in one or two transition bays onshore.

22. Open cut is a well-known installation methodology for underground cabling in relatively unconstrained areas. It can also be used to install cables in a landfall and would require an open trench to be dug out before cables are installed and the trench refilled. If HDD is chosen as the appropriate installation methodology at the landfall, each export cable will require one HDD i.e. up to two in total. The HDD is drilled from an onshore construction compound and will exit the sea bed in an exit pit at a suitable site with 8-10m water depth. The length of the HDD will depend upon factors such as water depth, sea bed topography, shallow geology/soil conditions and environmental constraints.

23. The exit pits offshore of the HDDs will be spaced some distance apart, typically 20-50m. However, environmental and technical constraints may guide the actual separation distance to be used. The exit pits are likely to be 3m wide at the bottom to allow collection of drilling fluids. The total length will be approximately 10m, while the depth of the exit pits will reflect the depth at which the export cable will continue further offshore. However, it is likely that depths will be less than 1m. The export cables are generally protected in the HDD exit pits and in the offshore export cable trench. However, there is a section between the HDD exit pit and the cable trench of up to 50m where the export cables are not naturally protected. This stretch may require additional permanent protection measures in the form of rock protection.

8.1.2.1.6 Construction Programme

24. It is envisaged that DEP and SEP would either be built in one single phase or two phases separated by approximately 2-3 years. Under a single-phase, offshore construction would take just under three years, whereas under two phases, it would take about four years.

8.1.3 Operation and Maintenance Strategy

25. Once commissioned, the wind farms would have an indicative design life of 30 years. All offshore infrastructure including wind turbines, foundations, cables and offshore substation platforms would be monitored and maintained during this period to maximise efficiency. As for construction, vessel anchors and jack-ups required for these maintenance activities also have the potential to affect Marine Geology, Oceanography and Physical Processes with the maximum number of anchors/jack-ups representing the worst case.

8.1.3.1 Decommissioning

26. Decommissioning would most likely involve the accessible installed components comprising:

- All the wind turbine components;
- The parts of the foundations above sea bed level; and
- Sections of the array cables close to the offshore structures, as well as sections of the export cables.

27. The process for removal of foundations is generally the reverse of the installation process. Possible impacts associated with the decommissioning stage(s) will be further considered as part of the EIA. It is anticipated that a full EIA will be carried out ahead of any decommissioning works to be undertaken. The decommissioning sequence will take approximately three years and will be undertaken in reverse of the construction sequence, involving similar types and numbers of vessels and equipment. The decommissioning plan and programme will be developed prior to construction and be updated during the DEP and SEP' lifespan to take account of changing best-practice and new technologies.

8.1.3.2 Cumulative Impact Scenarios

28. Cumulative impacts will be considered through awareness of the extent of influence of changes to Marine Geology, Oceanography and Physical Processes arising from the proposed DEP and SEP alone and those arising from DEP and SEP cumulatively or in combination with other offshore wind farm developments and other nearby sea bed activities, including marine aggregate extraction and marine disposal. The full list of ongoing plans or projects to be included in the PEIR and ES will be developed as part of on-going consultation with technical consultees.

8.1.3.3 Transboundary Impact Scenarios

29. Given that the likely physical and sedimentary impacts of DEP and SEP will be restricted to near-field change only, transboundary impacts are unlikely to occur, or are unlikely to be significant. Therefore, transboundary impacts to Marine Geology, Oceanography and Physical Processes have been scoped out of the EIA.

8.1.4 Baseline Environment

8.1.4.1 Designated Sites

30. 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 DEP and SEP. These are the Cromer Shoal Chalk Beds MCZ and the East Anglia coast (gravel and sand beaches, dunes and cliffs). The extension arrays and interconnector corridors 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.

31. 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 'be 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'.

32. The specific features defined within these two receptors as requiring further assessment at the EIA stage for DEP and SEP are listed in **Table 8.5**.

Table 8.5: Marine Geology, Oceanography and Physical Processes receptors relevant to DEP and SEP

Receptor Group	Extent of Coverage	Description of Features	Distance from DEP and SEP
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
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 the SEP with the export cable making landfall at Weybourne

8.1.4.2 Desk Based Review

33. The EIA Scoping Report for DEP and SEP (Royal HaskoningDHV, 2019) provides an overview of the baseline conditions in relation to Marine Geology, Oceanography and Physical Processes based on available information. Considerable data and information exist relating to Marine Geology, Oceanography and Physical Processes of the existing Dudgeon and Sheringham Shoal offshore wind farms.

8.1.4.2.1 Main Existing Data Sources

34. **Table 8.6** identifies the main desk-based sources from the adjacent Dudgeon and Sheringham Shoal offshore wind farms that will be accessed to inform the characterisation of the existing environments and support the EIA for DEP and SEP.

Table 8.6: Existing data sources that will be used in the EIA

Data source	Date	Data contents
Sheringham Shoal Offshore Wind Farm Environmental Statement and associated technical supporting documents	2006	All marine geology, oceanography and physical processes information and data related to the existing offshore wind farm
Sheringham Shoal Offshore Wind Farm coastal and sea bed processes	2006	Numerical modelling and theoretical assessments of the existing offshore wind farm
Sheringham Shoal Offshore Wind Farm metocean		Wind, waves, water levels and currents
Dudgeon Offshore Wind Farm Environmental Statement and associated technical supporting documents	2009	All marine geology, oceanography and physical processes information and data, including numerical modelling, related to the existing wind farm
Dudgeon Offshore Wind Farm coastal and sea bed processes	2009	Numerical modelling and theoretical assessments of the existing offshore wind farm
Dudgeon Offshore Wind Farm metocean		Wind, waves, water levels and currents
Sheringham Shoal Offshore Wind Farm post construction geophysical monitoring	2013-18	Bathymetry and sea bed character
Sheringham Shoal Offshore Wind Farm post construction environmental monitoring	2012-20	Sea bed sediment and particle size
Dudgeon Offshore Wind Farm post construction geophysical monitoring	2018	Bathymetry and sea bed character

Data source	Date	Data contents
Dudgeon Offshore Wind Farm post construction environmental monitoring	2018	Sea bed sediment and particle size
Sheringham Shoal Offshore Wind Farm export cables post-construction environmental monitoring	2013-20	Sea-bed sediment

35. All the data collected for the adjacent offshore wind farms will be utilised for the assessment of DEP and SEP. These data include tidal current and sediment plume dispersion modelling, metocean, and post-construction geophysical and environmental data. These will be incorporated into the baseline characterisation, and reviewed and interpeted in the context of the impact assessment.

36. Numerical modelling of baseline tidal currents was undertaken to inform the Sheringham Shoal Offshore Wind Farm EIA (HR Wallingford, 2006) and Dudgeon Offshore Wind Farm (HR Wallingford, 2009). Sediment plume dispersion (particularly the release of chalk fines) during cable installation was also modelled using the baseline tidal current model outputs as the driver of the sediment plume, as well as a theoretical assessment of foundation scour potential for different areas of the wind farm. Sediment plume dispersion during foundation installation was not modelled. The assessment of the effects on waves and tidal currents of the wind turbine foundations and generators was completed using theoretical methods coupled with expert-based judgement; numerical modelling of waves and tidal currents with the arrays in place was not carried out.

37. The assessment of DEP and SEP will consider the most recent metocean data available that was collected for the adjacent offshore wind farms or any nearby metocean data collected for other purposes. The metocean data will be incorporated into the baseline characterisation and used to support the conceptual assessment of effects.

8.1.4.2.2 Other Relevant Studies

38. Literature exists that covers DEP and SEP, includes some major publications:

- Southern North Sea Sediment Transport Study;
- Futurecoast;
- Shoreline Management Plans;
- Thames Regional Environmental Characterisation (REC);
- East Coast REC;
- East Anglia Marine Aggregate Regional Environmental Assessment (MAREA);
- British Geological Survey geology and sea bed sediment maps and regional reports; and
- Industry guidance.

39. In addition, the Environment Agency has collected a time series of beach profiles (on-the-ground surveys and Lidar) for the potential landfall site and adjacent areas. Profiles are typically completed every six months.

8.1.4.3 Completed and Planned Data Collection

40. The data requirements for a baseline understanding of the Marine Geology, Oceanography and Physical Processes at DEP and SEP that will underpin the assessment can be classified into two areas: material and process.

41. The material data includes knowledge of the geology of the sea bed and sub-sea bed, bathymetry, and the lithology and distribution of mobile and non-mobile sediments. The material information for DEP and SEP has been obtained through geophysical surveys completed in December 2019 and May 2020. Data collected included multibeam echosounder, side-scan sonar, and sub-bottom profiler data. Further material data (sea bed sediments, particle size and sea bed imagery) will be collected during the benthic survey planned for summer 2020.

42. The process data includes knowledge of the forcing factors such as waves, tide-generated currents, their strengths, directions and variability with time, and sediment transport regime. The process data will be obtained from the results of existing metocean and numerical modelling campaigns carried out for the Dudgeon and Sheringham Shoal offshore wind farms and any nearby metocean data collected for other purposes.

8.1.5 Impact Assessment Methodology

8.1.5.1 Defining Impact Significance

43. The assessment of effects on the Marine Geology, Oceanography and Physical Processes will be predicated on a Source-Pathway-Receptor (S-P-R) conceptual model, whereby the source is the initiator event, the pathway is the link between the source and the receptor impacted by the effect, and the receptor is the receiving entity. An example of the S-P-R conceptual model is provided by cable installation which disturbs sediment on the 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 Marine Geology, Oceanography and Physical Processes effects of DEP and SEP would be disproportionate to the potential impact and an expert-based assessment is preferred.

44. Consideration of the potential effects of DEP and SEP on the Marine Geology, Oceanography and Physical Processes will be carried out over the following spatial scales:

- Near-field: the area within the immediate vicinity (tens or hundreds of metres) of the array site and along the 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).

45. There are three main phases of development that will be considered, in conjunction with the present-day baseline, over the life cycle of the proposed project. These are:

- Construction phase;
- O&M phase; and
- Decommissioning phase.

46. For the effects on Marine Geology, Oceanography and Physical Processes, the assessment will follow two approaches. The first type of assessment will be impacts on Marine Geology, Oceanography and Physical Processes whereby several discrete direct receptors can be identified. These include certain morphological features with ascribed inherent values, such as chalk reef and other MCZ features, and beaches and sea cliffs at the coast.

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

48. In addition to identifiable receptors, the second type of assessment would cover 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 will be:

- 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 PEIR and ES pertaining to those receptors.

49. Assessment of direct impacts on receptors with morphological value will be completed for the parts of DEP and SEP inside and immediately adjacent to the Cromer Shoal Chalk Beds MCZ. The main features of conservation interest are outcropping chalk at the sea bed and subcropping chalk covered by a thin veneer of coarse non-mobile (not subject to transport) sediment (lag). In other areas of the MCZ, the chalk (and its coarse lag where present) can be covered by a layer of mobile sand. Although outcropping and subcropping chalk will be distinguished in the EIA, a similarly precautionary approach will be adopted to the impacts on both types of feature. This will include assessment of the recoverability of the sea bed after potential disturbance (e.g. trenching for cables in mobile and non-mobile areas), including seabed morphology and benthic communities.

50. Parts of the mobile sand in the export cable corridor within the MCZ are up to 3m thick, thinning towards the edges of the sand. It is expected that the sand lies directly on top of non-mobile coarse lag which is underlain by chalk. However, this buried geological sequence is difficult to prove and it is possible that in some areas the mobile sand buries chalk without an overlying coarse lag. Therefore, there is a risk that in some areas movement of the sand units at their edges could expose previously outcropping chalk and this will be considered appropriately in the assessment (a precautionary approach will be adopted).

8.1.5.1.1 Sensitivity, Value and Magnitude

51. 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).

52. 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).

53. The sensitivity and value of discrete morphological receptors and the magnitude of effect will be assessed using expert-based judgement and described with a standard semantic scale. Definitions for each term are provided in **Table 8.7**, **Table 8.8** and **Table 8.9**. These expert-based judgements of receptor sensitivity, value and magnitude of effect will be closely guided by the conceptual understanding of baseline conditions.

Table 8.7: Definitions of the different sensitivity levels 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 (greater than ten 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 (five to ten 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 (one to five 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 (less than one year).

Table 8.8: Definitions of the different value levels 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 8.9: Indicative criteria for assessing magnitude of effect

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 five to ten years. Frequency: The effect would occur regularly but not all the time. Reversibility: The effect is very slowly reversible (five to ten 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 one to five years. Frequency: The effect would occur occasionally but not all the time. Reversibility: The effect is slowly reversible (one to five years).
Negligible	Scale: A change which would not be noticeable from monitoring and is extremely small compared to natural variations in background conditions. Duration: Change persists for less than one year. Frequency: The effect would occur highly infrequently. Reversibility: The effect is quickly reversible (less than one year).

8.1.5.2 Impact Significance

54. Following the identification of receptor sensitivity and value, and magnitude of the effect, it is possible to determine the significance of the impact. A matrix is presented in **Table 8.10** as a framework to guide how a judgement of the significance will be determined.

Table 8.10: 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*

55. Through use of this matrix, an assessment of the significance of an impact will be made using expert-based judgement in accordance with the definitions in **Table 8.11**.

Table 8.11: Indicative Impact Significance Categories

Impact 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 is likely to be an important consideration at a local level
Minor	Small change in receptor condition, which may be raised as a local issue but is unlikely to be important in the decision-making process
Negligible	No discernible change in receptor condition

56. Note that for the purposes of the EIA, 'major' and 'moderate' impacts are deemed to be significant (in EIA terms). In addition, whilst minor impacts are not significant, it is important to distinguish these from other non-significant (negligible) impacts as they may contribute to significant impacts cumulatively.

8.1.5.3 Using the Previous Modelling and Theoretical Results to Support the Conceptual Approach

57. Previous numerical modelling and theoretical work has been undertaken specifically for the Dudgeon and Sheringham Shoal offshore wind farms located in close proximity to DEP and SEP to assess the potential effects of the extensions on the Marine Geology, Oceanography and Physical Processes. The results of the modelling and theoretical approaches from the existing offshore wind farms will be used as part of the expert-based assessment and judgement of potential construction and O&M effects or impacts of DEP and SEP. The physical basis for using the modelling and theoretical results is that the Dudgeon and Sheringham Shoal offshore wind farm designs and marine physical processes operating at the sites are like DEP and SEP and therefore provide suitable evidence (and are suitable analogues) to support the assessment of effects or impacts at DEP and SEP.

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

59. Water depths at Sheringham Shoal Offshore Wind Farm (15-22m below CD) and Dudgeon Offshore Wind Farm (17-24m below CD) are comparable to those at SEP (14-25m below CD) and DEP (11-23m below CD).

60. 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 corridor and directions are approximately shore parallel.

61. Predominant waves approach all sites from similar directions. The whole area within which Dudgeon and Sheringham Shoal offshore wind farms, DEP and SEP are located is exposed to wave conditions generated within the North Sea, with the most severe conditions arriving from the north and northeast due to long fetch lengths. However, the most frequent waves across all sites are from the southwest to northwest sector, but their fetch lengths are relatively short, and significant wave heights are small (generally between 0.5m and 1m). Nearshore wave conditions are less severe due to the protection afforded by Sheringham Shoal sand bank.

62. Sea bed sediments at all sites are similar. The sea beds at Dudgeon and Sheringham Shoal offshore wind farms comprise mainly superficial gravelly sands or sandy gravels derived from the reworking of the underlying glacial till. The sea bed sediment across DEP and SEP also comprises a thin veneer of gravelly sand resting on till. Chalk is exposed at the sea bed closer to the coast along the export cable routes.

63. Regional suspended sediment concentrations vary from typical mean summer values of less than10 mg/l to typical mean winter values of 30 mg/l. Concentrations may increase significantly during storm events.

64. Sheringham Shoal Offshore Wind Farm comprises 88 turbines and Dudgeon Offshore Wind Farm comprises 67 turbines, whereas DEP and SEP will have up to 34 and 27 turbines, respectively. Hence, the results of the modelling and theoretical assessments of the Dudgeon and Sheringham Shoal offshore wind farm designs are conservative compared to the DEP and SEP 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 Dudgeon and Sheringham Shoal offshore wind farms allows for these differences in the effect that may arise due to these factors.

65. The post-construction geophysical and environmental survey data will be used (as far as is possible to do so) 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 DEP and SEP. It should be noted that the post-construction monitoring campaign collected sea bed data whereas the numerical model and theoretical outputs are processes active in the water column (tidal currents, waves and suspended sediment). Hence, it may be difficult to establish a link between the pre-construction modelled data and post-construction survey data. However, the data will be used to define changes in sea bed composition that may have been due to changes in physical and sedimentary processes induced by operation of DOW or SOW. These could provide analogies for potential changes to the sea bed during operation of DEP and SEP.

66. The assessments for the existing offshore wind farms were completed when the area occupied by the export cable corridors was not designated. Although the export cable corridor of DEP and SEP now passes through the Cromer Shoal Chalk Beds MCZ (designated in January 2016), the use of expert-based judgement 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 DEP and SEP through the MCZ, and are therefore a suitable analogies.

8.1.6 Potential Impacts

8.1.6.1 Potential impacts during construction

67. Impacts of construction on tidal currents and waves are scoped out of the EIA because the worst-case impacts relate to operation.

8.1.6.1.1 Changes in Suspended Sediment Concentrations and Sea Bed Levels

8.1.6.1.1.1 Foundation Installation

68. Increases in suspended sediment concentration may result from disturbance arising from foundation construction activities. Deposition of this sediment may then lead to changes in bed levels and sediment type at the sea bed.

69. The greatest effect on suspended sediment concentrations and subsequent deposition during the construction phase of the foundations will depend on the installation method used; different installation methods are required for different foundation types. Monopiles and pin piles are likely to be driven, drilled or drilled-driven into the sea bed. Drilling has the potential to disturb sea bed and sub-sea bed sediments, which are raised to the sea surface from where they may be dispersed into the water column. For suction buckets and GBS foundations, an area of sea bed may need to be ploughed or dredged (sea bed preparation) in order to provide a level surface upon which they are installed. Installation of scour protection would also disturb sea bed sediments.

8.1.6.1.1.2 Cable Installation

70. Consideration of changes to suspended sediment concentrations due to construction of the offshore cables is particularly important because the export cable corridor passes through the Cromer Shoal Chalk Beds MCZ.

71. A variety of techniques could be used to excavate a trench for each export cable (and array cables). These include jetting, ploughing, and trenching. Sand wave levelling may be required for some sections of the offshore cable corridors prior to cable installation. During excavation or pre-sweeping (by whichever methods), sediment plumes will be formed by the release of sediment into the water column. The released sediment will become dispersed in the water column both vertically and laterally, resulting in increased suspended sediment concentration and sediment deposition in the environment at and surrounding the cable and, depending on the extent of sediment transport, in more remote environments.

8.1.6.1.1.3 Approach to assessment

72. An expert-based assessment will draw from the results of the detailed sediment plume dispersion modelling previously undertaken for the existing Dudgeon and Sheringham Shoal offshore wind farms, along with the project-specific survey data for DEP and SEP. The proposed approach is considered proportionate to the likely risk of significant impact on sea bed habitat. This is because the planned foundations and export cables will be in predominantly sandy or coarser environments with very little fine sediment, and so the effects during construction on the surrounding environment are anticipated to be small. Any sediment plumes are expected to be limited and sediment will fall to the sea bed in relatively close proximity to its point of release into the water column.

8.1.6.1.2 Impact on Sea Bed Features due to Cable Installation

73. Sea bed features along the export and array cable corridors may be impacted by the excavation of trenches (and their potential backfill) for cable laying and the potential use of cable protection. This is particularly important with respect to the designated features associated with the Cromer Shoal Chalk Beds MCZ. This could constitute a disturbance to (or loss) of features with inherent geological or geomorphological value or function, which may persist throughout the operational life of DEP and SEP.

8.1.6.1.2.1 Approach to assessment

74. Given the large amounts of existing information and assessment in and around the cable corridors, and particularly in the MCZ, an assessment of effects based on a conceptual understanding and the use of expert-based judgement to predict potential effects is proposed. An expert-based assessment will draw from the results of the following studies, as well as being informed by the project-specific survey data for DEP and SEP collected in the MCZ:

- geophysical survey of the potential DEP and SEP cable corridors;
- interpretive report on sedimentary processes in the MCZ describing in detail the baseline geological and sedimentary environments (this report will be appended to the ES as supporting documentation;
- geophysical and benthic sampling survey data collected along the existing cable corridors for Dudgeon and Sheringham Shoal offshore wind farms; and
- results of numerical modelling completed along the existing Dudgeon and Sheringham Shoal offshore wind farms cable corridors.

8.1.6.1.3 Indentations on the Sea Bed due to Installation Vessels

75. There is potential for certain vessels used during the installation of the wind farm and offshore 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 proportional to the dimensions of the object to remain. The worst case is considered to correspond to the use of jack-up vessels since the depressions would be greater than the anchor scars.

8.1.6.1.4 Approach to assessment

76. An expert-based assessment of potential effects will be undertaken. This is because the effects will be minor and local, and the depressions are likely to re-fill with mobile sediment soon after the vessel is demobilised.

8.1.6.1.5 Changes in Sediment Transport at the Landfall

77. The proposed export cable corridor for DEP and SEP will make landfall at Weybourne where export cables must transit through the intertidal zone. It is presently envisaged that either open-cut trenching or a HDD technique would be used. Open-cut trenching has the potential to interrupt bedload sediment transport along and across the coast. Also, the construction activities may release small amounts of suspended sediment into the coastal water.

8.1.6.1.5.1 Approach to assessment

78. The north Norfolk coast has been the subject of numerous detailed investigations of coastal geomorphology and processes, including the Shoreline Management Plans, Southern North Sea Sediment Transport Study, and peer-reviewed publications.

79. The existing studies in the landfall area, and others identified through the course of the impact assessment, as well as stakeholder consultation through the Evidence Plan Process, will provide enough information to develop a detailed conceptual understanding of the coastal system at Weybourne and its adjacent areas. Therefore, the proposed approach to assess the cable landfall for DEP and SEP is to review existing data and apply expert-based interpretation within the context of the construction programmes for the project.

8.1.6.2 Potential impacts during O&M

8.1.6.2.1 Changes to Tidal and Wave Regimes due to the Presence of Foundation Structures

8.1.6.2.1.1 Tidal Currents

80. Over the operational lifetime of DEP and SEP (35 years), the tidal regime effects are likely to be evident through persistent and direct changes, resulting from tidal current interactions with the foundation structures (and any scour protection). The effects on tidal currents of the foundations can be divided into two types:

- Local changes in the vicinity of each foundation created by interaction with the currents; and
- Regional changes, which are the overall changes created by the group of foundations in a layout pattern.

8.1.6.2.1.2 Waves

81. When waves coincide with a wind turbine foundation (and any scour protection), part of the energy is reflected and part of it is diffracted around the structure. This effect changes the wave climate in the vicinity of the structure and is referred to as the wave shadow effect. Potential effects on the wave regime associated with the presence of the foundations may include changes to the naturally occurring wave heights, periods and directions.

8.1.6.2.1.3 Approach to assessment

82. The approach that will be adopted for both tidal currents and waves is an expert-based assessment. This will involve delineation of indicative zones beyond which the effects on tidal currents and waves are likely to be diminished. Evidence from the previous Dudgeon and Sheringham Shoal wind farm assessments will be used to identify potential tidal current and wave changes local to each foundation.

83. There is also a pre-existing scientific evidence base which demonstrates that changes in tidal currents 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, 2002; COWRIE, 2009) and numerous Environmental Statements for offshore wind farms.

84. There is also a strong scientific evidence base which demonstrates that changes in waves due to the presence of foundation structures, even under a worst case scenario of the largest diameter GBS, are both relatively small in magnitude and relatively local in spatial extent (ETSU, 2000, 2002; Ohl *et al*., 2001; Cefas, 2005; COWRIE, 2009; Seagreen, 2012). Changes are typically less than 10% of baseline wave heights near each wind turbine, reducing with greater distance from each one. Effects are relatively local in spatial extent, extending as a shadow zone typically up to kilometres from the site along the axis of wave approach, but with low magnitudes (only a few percent change across this wider area).

8.1.6.2.2 Changes to Sea Bed Morphology due to the Presence of Foundation Structures and Cable Protection

85. Sea bed morphology directly impacted by the footprint of each foundation structure on the sea bed within the arrays, constitutes a loss in natural sea bed area during the operational life of DEP and SEP. Parts of the array cables and export cables may require some form of protection on the sea bed (rock dumping, frond mats or grout bags) which would also constitute a loss in sea bed.

8.1.6.2.2.1 Approach to assessment

86. The assessment will quantify the construction footprint and the total loss of sea bed habitat due to the foundations and compare that area to the total sea bed area within the arrays. A similar assessment will be completed for the footprint of the cable protection and any pressure exerted on the designated features within the MCZ. These data will then be used to assess the likely scale and area of effect.

87. Also, since the start of operation of Dudgeon and Sheringham Shoal offshore wind farms, there may have been changes in the sea bed sediments within the arrays, along the cable routes and within the Greater Wash, which now include more clay content. This potential change in sea bed sediment particle size and its implications for DEP and SEP and potential cumulative impacts will be investigated in the EIA.

8.1.6.2.3 Changes to Sediment Transport due to Cable Protection Measures

88. Any cable protection on the sea bed could potentially create a partial barrier to sediment transport. The key factors in determining the magnitude of the potential effect on bedload sediment transport of cable protection are the type and spatial extent of transport on the sea bed. The two main drivers of transport in the nearshore zone are waves, and tidal currents further offshore. The spatial extent of transport will depend on the size of the zone in which sediment is actively mobile and the magnitude of transport within this zone.

8.1.6.2.3.1 Approach to assessment

89. In order to understand these factors and assess the potential for significant interruption of bedload sediment transport, expert-based assessment will be used. The assessment will define the following transport processes as a baseline to assess the potential modes of change caused by the cable protection:

- Active offshore sediment transport: this transport mechanism occurs offshore and is primarily driven by tidal currents, although shallower offshore areas may have a wave-driven component.

- Active nearshore longshore sediment transport: this transport mechanism occurs along the nearshore sea bed as a result of wave-driven processes.
- Active nearshore cross-shore sediment transport: this transport mechanism also occurs along the nearshore sea bed as a result of wave-driven processes. However, the sediment is generally transported offshore from the beach to the nearshore during storm events and returned to the beach during more constructive wave conditions. Cable protection would be unlikely to significantly affect cross-shore sediment transport since it would be laid broadly in alignment with the cross-shore transport direction, providing little obstruction to sediment movement.

8.1.7 Potential impacts during decommissioning

90. The types of effect would be comparable to those identified for the construction phase, namely:
    - Changes in suspended sediment concentrations and sea bed levels due to foundation removal;
    - Changes in suspended sediment concentrations and sea bed levels due to removal of parts of the array and export cables;
    - Indentations on the sea bed due to decommissioning vessels; and
    - Changes in coastal sediment transport and suspended sediment concentrations due to removal of the landfall infrastructure.
91. The approach to assessment will be as for construction and precautionary due to the potential for residual impacts, particularly on the conservation objectives of the MCZ, following removal of the structures.

8.1.7.1 Potential cumulative impacts

92. DEP and SEP CIA will consider the staged nature of offshore wind development as well as the relative proximity of the existing Dudgeon and Sheringham Shoal offshore wind farms and other offshore activities, including the North Sea oil and gas fields, shipping routes and marine aggregate dredging sites. The current proposed list of projects for consideration in the CIA are:
    - Combined construction and O&M activities at DEP and SEP;
    - Sheringham Shoal Offshore Wind Farm O&M activities;
    - Dudgeon Offshore Wind Farm O&M activities;
    - Hornsea Project Three construction and O&M activities;
    - Proposed sustainable seaweed farm to be located about 1.6km south of SEP;
    - Potential Race Bank offshore wind farm extension to be located about 5km west of SEP; and
    - Construction and O&M of the Blythe oil and gas platforms and Elgood well, to be tied back to Blythe, adjacent to DEP.

8.1.7.1.1 Construction Changes to the Suspended Sediment Concentrations

93. Cumulative construction effects will be restricted to interaction of sediment plumes and their deposition on the sea bed. Cumulative effects may arise if the construction of foundations and cables at DEP and SEP is synchronous with other offshore activities and the plumes that are created by the construction overlap spatially. There is the potential for the respective plumes to interact, to create a larger overall plume, with higher suspended sediment concentration and, potentially, a greater depositional footprint on the sea bed.

8.1.7.1.1.1 Approach to assessment

94. The potential interaction between plumes from different construction activities will be assessed using expert-based assessment. An initial screening exercise will identify where cumulative impacts are not anticipated with respect to overlapping plumes, thereby screening them out from further assessment. Where there is the potential for overlap of plumes, an expert view will be taken on the respective contributions from each and how they might combine to form enhanced suspended sediment concentrations.

8.1.7.1.2 O&M Changes to the Tidal Current, Wave Regimes and Sediment Transport

95. The cumulative effect of the O&M of DEP and SEP with other offshore projects could occur for tidal currents, waves, and sediment transport. Based on modelling analyses for previous offshore wind farm developments, post-construction monitoring and published guidance documents, changes to tidal current velocities, wave heights and sediment transport rates are expected to be greatest in the immediate vicinity of the foundation structures and reduce with increased distance away. Outside the array, it was considered that changes in flow speed would be confined to within one peak spring tidal excursion of the array boundary. The largest changes to individual wave heights would occur within DEP and SEP sites, with wave shadowing in a down-wave direction of each foundation. The changes to tidal currents and waves could potentially have a cumulative effect on the bedload sediment transport regime.

8.1.7.1.2.1 Approach to assessment

96. The potential interaction between tidal currents, waves and sediment transport from different construction activities will be assessed using expert-based assessment. An initial screening exercise will identify where cumulative impacts are not anticipated with respect to overlapping effects, thereby screening them out from further assessment. Where there is the potential for overlap of effects, an expert view will be taken on the respective contributions from each and how they might combine to change tidal currents velocities, wave heights and/or sediment transport within a ‘zone of potential cumulative influence’.

97. The zone of potential cumulative influence for tidal currents will be defined based on an understanding of the tidal ellipses, previous numerical modelling and knowledge that effects arising from wind turbine foundations are relatively small in magnitude and local. It is expected that changes to the tidal regime would have returned to background levels well within the excursion of one tidal ellipse, and this threshold will be used to produce the maximum ‘zone of potential influence’ on the tidal regime.

98. For the wave regime the zone of potential cumulative influence will be based on an understanding of the wave roses in the area, the use of expert-based assessment and an understanding that effects arising from wind turbine foundations on the wave regime would be local and relatively small in scale.

8.1.8 References

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