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Norfolk Boreas Offshore Wind Farm

Consultation Report

Appendix 9.16 Norfolk Boreas Benthic Ecology, Fish Ecology, MPP and MSWQ outgoing documents

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Photo: Ormonde Offshore Wind Farm

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Norfolk Boreas Offshore Wind Farm

Environmental Impact Assessment

Fish and Shellfish Ecology Method Statement

January 2018

VATTENFALL

Brown & May Marine Ltd.

Project Title/Location	Norfolk Boreas EIA Fish and Shellfish Method Statement
Project Reference Number	VNB FSE MS_001
Date	11/01/2018

Norfolk Boreas Offshore Wind Farm Environmental Impact Assessment

Fish and Shellfish Ecology Method Statement

Undertaken by
Brown & May Marine Limited

Ref	Rev.	Author	Date	Checked (BMM)	Approved (Client)	Sign off
VNB-FSE-MS001	Draft	JM	11/01/2018	JK/ FB		
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This method statement has been prepared by Brown and May Marine Limited on behalf of Norfolk Boreas Limited in order to build upon the information provided within the Norfolk Boreas Environmental Impact Assessment (EIA) Scoping Report. It has been produced following a full review of the Scoping Opinion provided by the Planning Inspectorate. All content and material within this document is draft for stakeholder consultation purposes, within the Evidence Plan Process.

Many participants of the Norfolk **Boreas** Evidence Plan Process will also have participated in the Norfolk **Vanguard** Evidence Plan Process. This document is presented as a complete and standalone document, however in order to maximise resource and save duplication of effort, the main areas of deviation from what has already been presented through the Norfolk Vanguard Evidence Plan Process and PEIR or in the Norfolk Boreas Scoping Report are presented in orange text throughout this document.

List of Acronyms

ANSI – American National Standards Institute
Cefas – Centre for Environment, Fisheries and Aquaculture Science
CIEEM – Chartered Institute of Ecology and Environmental Management
COWRIE – Collaborative Offshore Wind Research into the Environment
CPA – Coast Protection Act 1949
DATRAS – Database of Trawl Surveys
DCO – Deme Consent Order
DECC – Department of Energy and Climate change
DEFRA – Department of Environment, Food and Rural Affairs
DTI – Department of Trade and industry
EEZ – Exclusive Economic Zone
EIA – Environmental Impact Assessment
EMF – Electromagnetic field
EN-1 – Overarching National Policy Statement for Energy 1
EN-3 – Overarching National Policy Statement for Energy 3
EPP – Evidence Plan Process
ES – Environmental Statement
ETG – expert Topic Group
EU – European Union
FEPA – Food and Environment Protection Act 1985
HDD – Horizontal Directional Drilling
HF – High Frequency
HVAC – High Voltage Alternating Current
HVDC – High Voltage Direct Current
IBTS – International Bottom Trawl Surveys
ICES – international Council for Exploration of the Sea
IFCA – Inshore Fisheries and Conservation Authority
kj – kilo joules
kV – kilo volts
LF – Low Frequency
MarLIN – Marine Life Information Network
MCEU – Marine Consents and Environment Unit
MCZ – Marine Conservation Zones
MIK – Midwater Ring Net
MF – Mid Frequency
MMO – Marine Management Organisation
MW – Mega watts
NPS – National Policy Statements
NV – Norfolk Vanguard
O&M – Operation and Maintenance
OWF – Offshore Wind Farm
PEIR –Preliminary Environmental Impact Report
PSA – Particle Size Analysis
PTS – Permanent Threshold Shift
REC – Regional Environmental Characterisation
SSC – Suspended sediment concentrations
TBC – To be confirmed
TLP –Tension Leg Platform
TTS – Temporary threshold shift

VWPL – Vattenfall Wind Power Limited
WGEGGS2 – Working Group 2 on North Sea Cod and Plaice Egg Survey in the North Sea
ZEA – Zonal Environmental Appraisal

Contents

Tables

1.0 Introduction

1. This method statement and the consultation around it form part of the Norfolk Boreas Evidence Plan Process (EPP). The purpose of this document is to provide background rationale for the Environmental Impact Assessment (EIA) approach to fish and shellfish ecology for the Norfolk Boreas project and seek agreement on approach from members of the Fish and Shellfish Ecology Expert Topic Group (ETG). Agreement regarding fish and shellfish ecology will then be recorded in the agreement log. The data sources which will be used to establish the current baseline environment and inform the subsequent assessment of impacts are described and key ecological receptors and potential impacts for assessment identified. The methodology which will be used to undertake the assessment and the associated guidance are also outlined. Indicative project information is provided to inform the worst case scenario. The parameters presented may be subject to change as the project design and EIA processes develop.

2. This method statement has been produced following a full review of the Scoping Opinion provided by the Planning Inspectorate, responses to Norfolk Vanguard PEIR (Royal HaskoningDHV (2017b)) and consultation undertaken through the Norfolk Vanguard EPP. Table 1.1 below sets out a summary of the scoping comments of most relevance to fish and shellfish ecology.

3. The approach outlined in this method statement takes account of previous correspondence with the Marine Management Organisation (MMO) and the Centre for Environment, Fisheries and Aquaculture Science (Cefas), including:

- Vattenfall introduction meeting with the MMO in January 2016;
- Vattenfall Vanguard EPP meetings held in February 2017; and
- Email and telephone correspondence with the MMO and Cefas in April 2016 regarding advice on fisheries survey requirements.

1.1 Background

4. A Scoping Report for the Norfolk Boreas EIA was submitted to the Planning Inspectorate on the 8th May 2017. Further background information on the project can be found in the Scoping Report which is available at:

https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010087/EN010087-000015-Scoping%20Report.pdf

5. The Scoping Opinion was received on the 16th June 2017 and can be found at:

https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010087/EN010087-000013-Scoping%20Opinion.pdf

1.2 Norfolk Boreas Programme

DCO Programme

- Scoping Request submission 08/05/2017 (complete)
- Preliminary Environmental Information submission Q4 2018
- Environmental Statement and DCO submission Q2 2019

Evidence Plan Process Programme

6. The Evidence Plan Terms of Reference (Royal Haskoning DHV, 2017) provides an overview of the Evidence Plan Process and expected logistics, below is a summary of anticipated meetings:

- Agreement of Terms of Reference with steering group Complete
- Consultation of method statements (meeting to be held if agreement cannot be reached through the Agreement log) Q1 2018
- Expert Topic Group and Steering Group meetings as required 2018
- To be determined by the relevant groups based on issues raised
- PEI Report (PEIR) Expert Topic Group and Steering Group meetings Q4 2018/ Q1 2019
- To discuss the findings of the PEIR (before or after submission)
- Pre-submission Expert Topic Group and Steering Group meetings Q1/Q2 2019
- To discuss updates to the PEIR prior to submission of the ES

7. Responses to the Norfolk Vanguard PEIR (Royal HaskoningDHV, 2017b) were received in December 2017. This method statement has been updated to incorporate any key comments made that affect the proposed methodology for the Norfolk Boreas EIA.

Scoping Opinion Responses

8. The relevant comments from the MMO provided in the Planning Inspectorate Scoping Opinion (June 2017) are provided in Table 1.1. The MMO scoping response includes advice from Cefas, thus MMO comments represent the all main comments received. The recommendations and comments will inform the Evidence Plan Process (EPP) and will be incorporated into the relevant stage of the assessment during the EIA process. PEIR feedback comments will also be included in the EIA chapter. Fisheries advice from Cefas regarding the EPP for Vanguard was provided on the 11th April 2016 and its relevance to Boreas will be confirmed with Cefas during this process. This correspondence is provided in Appendix 1.

Table 1.1 Scoping Opinion Consultation Responses

Consultee	Scoping Opinion Comment	Section where addressed in this Method Statement
Marine Management Organisation (MMO)	Overall the key species of importance and potential impacts to fish have been correctly identified.	Key species of importance are outlined in section 3.1. The potential impacts on these species are identified in section 4.2.
MMO	The data gathered points to the presence of appropriate habitat for sand eels, while the mapped spawning areas/nursery grounds for sand eels point to the presence of the species within the area. An assessment of the effects on sand eel including its habitats is therefore required within the ES. We recommend that the aggregate industry sand eel habitat assessment (Marine Space 2013) criteria be considered as an approach during the Environmental Impact Assessment (EIA) to assess habitat significance.	The spawning and nursery grounds of sand eels are outlined in section 3.1, figure 3.2.The Marine Space Criteria will be used in the EIA undertaken as part of the PEI and subsequent ES.
MMO	We recommend that any fisheries data taken from previous surveys that is used in the EIA includes all relevant information such as; dates and times of surveys, locations, gears used, mesh size, duration of tow/soak times. Any limitations of the data sources used should be presented in the ES.	Survey data from EA1, EA3, the former EA4 (now Norfolk Vanguard East) and Zonal surveys will be used to inform the EIA as outlined in section 1.2 'Survey Programme' and section 3.1. Descriptions of relevant gear specifications and details of sampling/survey programme will be provided in the technical appendix.
MMO	For the ES, we recommend a longer time series of data (e.g. up to ten years' worth of fisheries landings data) is used rather than the seven years proposed, to be consistent with applications of a similar nature. Requests for additional data can be submitted to the MMO for consideration. The ES should explain how landing weights have been calculated and we recommend showing the average landed weights broken down by International Council for Exploration of the Sea (ICES) rectangle. This will show any variation in abundance per rectangle for each species.	Fisheries landings data by ICES rectangle are outlined within sections 3.1 and 4.2.

MMO	Table 2.13 (in the scoping report) uses ICES data to establish the average catch per unit effort per hour for individuals for species recorded in International Bottom Trawl Surveys (IBTS) within the ICES. Having reviewed the table, we believe that the data for both greater sand eel and Raitt's sand eel may be incorrect. For example, we have looked at ICES' IBTS data for 2011-2016 for sand eels and the largest catch per unit effort shown in the number per hour is 6.21 for greater sand eel in rectangle 34F2 in Quarter 3 of 2015. This will need to be corrected in the ES, and the MMO will engage with the applicant through the evidence plan process and provide relevant advice as to the accuracy and appropriateness of data.	This will be addressed within the technical appendix, PEI and ES. IBTS data are outlined within sections 3.1 and 4.2.
MMO	The MMO would also recommend that the International Herring Larval Survey (IHLS) data is reviewed and considered to determine if any potential underwater noise could impact herring. The extent to which herring larvae may be impacted by sediment plumes for example, should also be considered.	IHLS data will be included within the assessment of impacts on Herring as outlined within section 3.1 and 4.2.
MMO	Impacts to herring, sand eel, cod and seabass should have their own species-specific assessment.	Species specific impact assessment are outlined in section 4.2.
MMO	Any previous survey data presented in the desk based assessment and used in the EIA should include, or provide signposting to, all relevant information such as: dates and times of surveys; locations; gear used; mesh size; and duration of tow/soak times. The limitations of any data sources used in the EIA should be presented and acknowledged. Any inconsistencies in survey techniques from past surveys should be discussed in the ES. In addition, catch data should be standardised.	Survey data from EA1, EA3, the former EA4 (now Norfolk Vanguard East) and Zonal surveys will be used to inform the EIA as outlined in section 1.2 'Survey Programme' and section 3.1. Descriptions of relevant gear specifications and details of sampling/survey programme will be provided in the technical appendix.
MMO	The impacts of dredging, piling, loss of habitat and increased suspended sediment on fish should be clearly assessed in the ES.	The impacts of dredging, piling, loss of habitat and increased suspended sediment on fish are outlined in section 2.4 'Worst Case' and section 4.2 'Species specific impacts'.
MMO	The MMO recommends that in the ES assessment of herring and Sand eels, the aggregate industry habitat assessment (Marine Space, 2013) criteria be followed during the EIA which will utilise site specific Particle Size Analysis (PSA) data to assess habitat significance in the array area and along the export cable route. For herring, it is recommended that IHLS data is also used.	Worst case suspended sediment concentration is outlined in section 2.4 and table 2.1. PSA analysis is referenced in section 3.1. IHLS data are detailed within section 3.1 and 4.2.

MMO	The proposed project site is located near to known herring spawning grounds. Herring and their eggs and larvae are considered to be sensitive to noise and vibration from anthropogenic activities such as piling and dredging. The ES should include an assessment of impacts from piling noise and cable installation on spawning grounds (including consideration of gravid adults, eggs and larvae).	The distribution of known herring spawning grounds in the context of the Norfolk Boreas project will be assessed using the data sources outlined in section 3.1 and figure 3.1 (Coull *et al*. etc.). Noise modelling and subsequent assessment on adults, eggs, and larvae will be undertaken as outlined in section 2.4 and table 2.1.
MMO	The former East Anglia Zone is located in an area considered to be a cod spawning ground. Piling noise has the potential to damage eggs and larvae and disturb spawning aggregations of adults. An assessment of potential impacts of underwater noise from piling on cod should be undertaken in the ES. The assessment should consider the state of the cod stock and importance of the surrounding spawning and nursery grounds.	The distribution of cod spawning activity in the context of the Norfolk Boreas project will be assessed using the data sources outlined in section 3.1 and figure 3.4 (Coull *et al*. etc.). Noise modelling and subsequent assessment on adults, eggs, and larvae will be undertaken as outlined in section 2.4 and table 2.1.
MMO	The current state of cod stocks is determined by the International Council on the Exploration of the Sea (ICES). The latest advice issued in November 2016 for North Sea cod shows that stocks are currently harvested sustainably, however recruitment has been poor since 1998 (ICES, 2016). Cod is widely distributed throughout the North Sea but there are indications of subpopulations inhabiting different regions of the North Sea. The Southern North Sea sub-region (where the Norfolk Boreas site is located) has suffered a general decline in biomass and there has been a lack of recovery (ICES, 2016).	The most up to date ICES data available will be used to inform the assessment of impacts on cod. The methodology for assessment will follow that outlined above.
MMO	The ICES Working Group 2 on North Sea Cod and Plaice Egg Surveys in the North Sea (WGEGGS2) carries out Midwater Ring Net (MIK net) surveys directed primarily at cod and plaice and data has been collected in the North Sea in 2004, 2009, and annually since 2012. The survey data is downloadable from ICES: http://www.ices.dk/marine-data/data-portals/Pages/Eggs-and-larvae.aspx. The MMO recommends that this data is considered in the ES assessment.	WGEGGS2 survey data will be included in the assessment and is outlined in section 3.1.

MMO	Seabass are a slow growing species that have suffered a long-term decline in population due to overfishing. As a result of declining stocks, fishing regulations have now been implemented to protect juvenile stocks of seabass. Seabass have also been placed under special protection measures as scientific advice has clearly identified the need to drastically reduce catches of this species, following an increase in the fishing pressure and a reduction in reproduction. The ES should consider seabass in the context of the current special measures in place and include consideration of whether cabling activities are likely to disturb nursery grounds or juvenile fish.	The distribution of juvenile seabass and associated nursery grounds is currently undefined by resources such as Coull et al 1998 and Ellis et al. 2012 (presented in section 3.1.) Therefore, all available literature and information sources will be reviewed and any relevant data and information will be used to inform the assessment of potential impacts on adults, juveniles and potential nursery grounds. is outlined in section 3.1.

Survey Programme

9. There are no specific surveys planned prior to the delivery of the Fish and Shellfish Ecology EIA. The ecological baseline used to inform the EIA will be established through desk based research using established and recognised sources of information, peer reviewed scientific literature and data from surveys carried out as part of the fisheries assessment for the East Anglia Zonal Environmental Appraisal (ZEA), and East Anglia Three and East Anglia Four EIAs. This approach has been agreed previously through the Norfolk Vanguard EPP in consultation with Cefas and the MMO (see Appendix 1).

2.0 Project Description

2.1 Context and Scenarios

10. Vattenfall Wind Power Limited (VWPL) is developing Norfolk Boreas and Norfolk Vanguard in tandem, and is planning to co-locate the export infrastructure for both projects to minimise overall impacts. This co-location strategy applies to the export cable route and the cable landfall.

11. The Norfolk Vanguard project is approximately 12 months ahead of Norfolk Boreas in terms of the Development Consent Order (DCO) process. As such, the Norfolk Vanguard team is leading on site selection for both projects. Although Norfolk Boreas is the subject of a separate DCO application, the project would adopt these strategic site selection decisions.

12. There is a possibility that the Norfolk Vanguard project would not be constructed. In order for Norfolk Boreas to stand up as an independent project, this scenario must be provided for within the DCO for Norfolk Boreas. Thus, two alternative scenarios are being considered in the context of this Method Statement; Scenario 1 where the offshore elements of Norfolk Vanguard has been fully constructed before any construction of Norfolk Boreas begins, and Scenario 2 where Norfolk Vanguard is not constructed.

13. For both scenarios, Norfolk Boreas would consent and construct all required offshore infrastructure so there is no difference in the approach to the assessment of fish and shellfish ecology for Norfolk Boreas alone. The only offshore difference is that under Scenario 1, Norfolk Vanguard would be considered within the Cumulative Impact Assessment (CIA), together with the parameters of Norfolk Boreas.

2.2 Site Selection Update

14. The Norfolk Boreas Scoping report presented three potential landfall locations. Data was reviewed on a broad range of environmental factors, including existing industrialised landscape, the presence of the Cromer Shoal Chalk Beds Marine Conservation Zone (MCZ), coastal erosion and archaeology alongside statutory and non-statutory consultation.

15. After publication of the scoping report, VWPL concluded, taking account of all engineering and environmental factors, as well as public feedback, that the most suitable landfall location would be Happisburgh South. The decision to go to Happisburgh south was presented to the Norfolk Vanguard Evidence Plan Expert Topic groups in June and July 2017 and in the Norfolk Vanguard PEIR (Royal HaskoningDHV, 2017b). The landfall location is shown in the inset of Figure 2.1.

16. Happisburgh South also has the benefit of being large enough to accommodate landfall works of both Norfolk Vanguard and Norfolk Boreas, therefore reducing the spatial extent of impacts associated with the two projects. Ongoing public and stakeholder consultation as well as initial EIA data collection will be used to inform any further site selection work for the EIA and DCO application.

17. The offshore site boundaries are now established and are not anticipated to change for the PEIR. Impacts that cannot be avoided through site selection will aim to be reduced through sensitive siting, alternative engineering solutions (mitigation by design) and additional mitigation measures, where possible. Mitigation options would be developed in consultation with stakeholders.

18. For the purpose of the fish and shellfish ecology EIA , the Offshore Project Area is defined as :

- Norfolk Boreas site (Figure 2.1)
- Offshore cable corridor (Figure 2.1)

19. The landfall search area was presented in the Scoping Report as Figure 1.3. Since the publication of the scoping report and the input of responses from interested parties, this has been refined to a single landfall location; Happisburgh South (shown in Figure 2.1) following studies on the engineering feasibility of horizontal directional drilling (HDD). Data on coastal erosion, including estimates of coastline movement over the life time of the wind farm, and the likelihood of archaeological finds, has been reviewed to understand the feasibility of a landfall south of Happisburgh.

2.3 Construction Programme

Construction Programme

Phasing

20. It is envisaged that Norfolk Boreas would either be built in one single 1,800MW phase; two phases of 900MW or three phases of 600MW. The location of each phase across the Norfolk Boreas site would be determined based on constraint identification throughout the EIA process as well as post consent site investigations. The EIA will therefore assess up to the capacity of 1,800MW.

21. Norfolk Boreas construction is likely to be staggered and may have temporal overlap between phases. The objective is to ensure each phase is complete and generating electricity in as short a time as possible. For each potential impact during construction, the assessment will commence with a description of the single-phase approach and then will highlight any pertinent differences associated with the two and three-phased approaches.

22. The indicative three phase programme would be the same under both Scenario 1 and Scenario 2 as follows:

- Phase 1 - Construction and commissioning 2027;
- Phase 2 - Construction and commissioning 2028; and
- Phase 3 - Construction and commissioning 2029.

2.4 Indicative Worst Case Scenarios

23. The following section sets out the indicative worst-case scenarios for fish and shellfish ecology. The PEIR/ES will provide a detailed Project Description describing the final project design (also known as Rochdale) envelope for the Norfolk Boreas DCO application. Each chapter of the PEIR/ES will define the worst-case scenario arising from the construction, operation and decommissioning phases of the Norfolk Boreas project for the relevant receptors and impacts. Additionally, each chapter will consider separately the anticipated cumulative impacts of Norfolk Boreas with other relevant projects which could have a cumulative impact on the receptors under consideration.

24. Generally, the largest number of structures, greatest spatial extents (and dimensions) and durations would be expected to result in the worst-case scenario in relation to fish and shellfish ecology. There are some potential exceptions to this generality. For example, in the case of underwater noise the worst-case scenario may result from fewer turbines with the largest monopile foundations which necessitate the highest hammer energies during installation. The worst-case assumptions will be assigned on an impact by impact basis for each phase of the development.

25. A range of foundation options; jacket, gravity base, suction caisson, monopile and floating foundation with tension legs will be included in the project design envelope. Table 2.1 provides indicative footprints for 7MW and 20MW turbines.

26. Further to the information provided in the Scoping Report, floating foundations will also be included in the Norfolk Boreas Rochdale Envelope. Ongoing review by the VWPL engineering team has identified that this is necessary in order to future proof the EIA and DCO to include the types of foundations that are likely to be available by the time of Norfolk Boreas construction (potentially starting in 2023 onshore and 2025 offshore).

27. The design parameters which constitute the high level worst case scenario for fish and shellfish ecology based on currently available information are presented by impact in Table 2.1.

Table 2.1 Worst case scenarios for the assessment of impacts on fish and shellfish ecology

Impact	Infrastructure parameter worst case	Rationale
Construction Phase		
Impact: Physical disturbance and temporary loss of sea bed habitat	Seabed preparation for installation of 257 GBS foundations Installation of two Met Masts on GBS foundations. Seabed disturbance for installation of up to 750 km of inter-array cables, with a 20m wide grapnel run, giving a total area of 15 km^2. Seabed disturbance for installation 840 km of HVAC export cables using jetting/trenching/mass flow excavation/pre-sweeping, with a 30m disturbance width for sand wave clearance, giving a total area of 25.2 km^2. Seabed disturbance for installation of up to three offshore substation platforms including two offshore converter platforms, two met masts, two wave buoys, potentially mounted on a foundation, two lidar buoys and one accommodation or helicopter platform.	Would result in greatest possible area of seabed disturbance
Impact: Increased Suspended Sediment Concentrations (SSCs) and Sediment Re-deposition	Seabed preparation for GBS foundations: 14,137m^3 for a 15MW turbine foundation. Potential to disturb 2,523,098m^3 across	Would result in the highest volumes of sediment released into the water column over the largest spatial extent and longest duration

	the Norfolk Boreas site. Trenching for installation of up to 750 km of inter-array cables, 840 km of inter-array cables and 150 km of interconnector cables would produce maximum volume of disturbed material of 14,850,000 m^3. Seabed disturbance for installation of up to three offshore substation platforms including two offshore converter platforms, two met masts, two wave buoys, potentially mounted on a foundation, two lidar buoys and one accommodation or helicopter platform.	
Impact: Underwater noise	Maximum hammer energy of 5,000 kJ for installation of 90 x 20MW monopile foundations (TBC, subject to underwater noise modelling results). 7mw = WCS for biggest temporal impact 771 hours (32.1 days) (TBC by modelling but less hammer energy required) 20MW = WCS spatial impact (require max hammer energy TBC by modelling) but with smaller duration of 270 hours (11.2 days)..	Installation of 15m diameter piles using the maximum hammer energy of 5000 kJ is expected to result in the greatest spatial extent of the impact with respect to fish and shellfish species, however this will be confirmed through modelling
Operational Phase		
Impact: Permanent loss of sea bed habitat	Permanent habitat loss through Installation of 120 15-20MW floating turbines on gravity anchors with scour protection (122,500m^2 per turbine, 14,700,000 m2 across Norfolk Boreas site) Array cables: up to 125,000m^2 rock protection for non-buried cables (assumes maximum of 10% of cable length not buried). Array cable crossings: up to 20,000 m^2 of rock berm protection for all cable crossings. Export Cables: up to 75,000m^2 rock protection for non-buried cables (assumes maximum of 10% of cable length not buried). Export Cables: Installation of up to 48,000 m^2 of rock berm protection for all cable crossings. Seabed disturbance for installation of up to three offshore substation platforms	These parameters would result in the greatest calculated area of permanent seabed habitat loss.

	including two offshore converter platforms, two met masts, two wave buoys, potentially mounted on a foundation, two lidar buoys and one accommodation or helicopter platform.	
Impact: Underwater noise during operation	257 wind operational turbines. Up to 480 visits per year by various vessels associated with O&M.	Highest number of operational turbines and associated vessel visits would result in greatest underwater noise generated during operation
Impact: Electromagnetic Fields (EMF's)	Up to 750 km of 66kV Inter-array cables Up to 840 km of 220kV HVAC cables Up to 420 km of 320 kV HVDC export cables	Would result in largest potential area impacted by EMF emissions
Decommissioning		
The worst-case scenarios for decommissioning activities and associated implications for fish and shellfish are to be considered to fall within those assessed for the construction phase		
Cumulative Impact scenarios		
Cumulative impacts would be greatest when the greatest numbers of other schemes, present or planned, are considered.		

3.0 Baseline Environment

3.1 Desk Based Review

Available Data

28. The principal sources of data and information to inform the baseline component of the PEIR/ES will include, but not be limited to the following:

- MMO Landings data (principally by weight but also value) by species 2007- 2016[1];
- Spawning and nursery grounds of selected fish species in UK waters mapped by Coull *et al.* 1998 and revised by Ellis *et al.* 2012);
- North Sea International Bottom Trawl Survey Data (IBTS);
- International Herring Larval Survey (IHLS) database;
- North Sea Cod and Plaice Egg Midwater Ring Net (MIK net) surveys (WGEGGS2);
- English 3rd quarter North Sea Groundfish Survey Data;
- IMARES monthly ichthyoplankton surveys in the Southern North Sea;
- East Coast Regional Environmental Characterisation (REC) (Limpenny, 2011);
- East Marine Plan documents, July 2013 (MMO, 2013);
- Reports, survey data and publications by organisations including Cefas, MMO, COWRIE, ICES, IFCA and Environment Agency;
- MCZ recommendations – Net Gain and Natural England;
- Site specific Particle Size Analysis (PSA) data; and
- Other relevant peer-review publications and stock assessments.

[1] This data series may be updated depending on the timing of the release of data for 2017.

29. Fisheries advice from Cefas (Appendix 1) and Scoping Opinion responses included in Table 1.1 highlighted herring (*Clupeas harengus*), sand eels (*Ammodytes* spp.), cod (*Gadus morhua*), seabass (*Dicentrarchus labrax*) and elasmobranchs as key receptors for consideration within the assessment. In addition, Cefas also recommend the assessment of potential impacts on other commercially important species including sole (*Solea solea*) and plaice (*Pluronectus platessa*) as well as species of conservation importance.

30. Spawning and nursery grounds have been adapted from Coull *et al.* (1998) and Ellis *et al*. (2010) and are shown for these key species and species groups (Figures 3.1 to 3.3) identified in scoping. Thornback ray (*Raja clavata*) is provided as an example of elasmobranch species for the purpose of this method statement due to its local commercial importance. Charts depicting spawning and nursery grounds for other elasmobranch and fish species of commercial and conservation importance will be included within the Fish and Shellfish ecology technical report and Baseline Environment section of the PEIR.

31. In addition to the data sources outlined above, the fish and shellfish ecology assessment will be informed by the outcomes of the following assessments: Marine Geology, Oceanography and Physical Processes; Marine Water and Sediment Quality; Benthic and Intertidal Ecology; Commercial Fisheries.

32. Site specific fish and shellfish assemblage characterisation data collected in relation to East Anglia THREE and East Anglia FOUR (2013) and survey data collected as part of the Zonal Environmental Appraisal (ZEA) will be accessed in order to inform the Norfolk Boreas baseline. The Norfolk Vanguard PEIR will also be used to inform the above. Survey data and details (e.g. frequency, timing, location etc.) will be summarised and included within the PEIR.

Designated Sites

33. Designated marine sites in the study area are shown in Figure 2.1 (section 2.1). The Norfolk Boreas export cable corridor transects the Haisborough, Hammond and Winterton Special Area of Conservation (SAC). These sites are designated on the basis of presence of particular habitats such as *Sabellaria spinulosa* reef (see benthic ecology Method Statement PB5640-004-013) as opposed to any fish and shellfish species of particular conservation importance. However, both support important stocks of edible crab (*Cancer pagurus*) and lobster (*Homarus gammarus*) which form the basis of commercially significant local fisheries.

3.2 Planned Data Collection

34. There is no planned data collection in relation to the Norfolk Boreas Project in respect of fish and shellfish ecology. As described in the previous section, survey data collected for the East Anglia THREE and East Anglia FOUR developments (2013), and for the ZEA, will be used to inform the Norfolk Boreas EIA. This approach has been agreed previously through consultation with the MMO and Cefas through the Norfolk Vanguard EPP.

4.0 Impact Assessment Methodology

35. The assessment of potential impacts on fish and shellfish ecology will be undertaken with specific reference to the relevant National Policy Statement (NPS):

- Overarching NPS for Energy (EN-1) (Department of Energy and Climate Change (DECC) 2011a); and
- NPS for Renewable Energy Infrastructure (EN-3), July 2011.
- In addition to the NPS guidance, the following documents will be used to inform the approach to assessment of potential impacts:
- Guidelines for ecological impact assessment in Britain and Ireland: Marine and coastal. CIEEM (2010);
- Cefas (2012) Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects; and
- Cefas, Marine Consents and Environment Unit (MCEU), Department for Environment, Food and Rural Affairs (DEFRA) and Department of Trade and Industry (DTI) (2004) Offshore Wind Farms - Guidance note for Environmental Impact Assessment In respect of FEPA and CPA requirements, Version 2;

36. It is anticipated that the potential impacts of the proposed Norfolk Boreas project on fish and shellfish will be as specified in the Cefas and MCEU (2004) guidelines for offshore wind developments. Potential impacts will be assessed on the following ecological aspects:

- Spawning grounds;
- Nursery grounds;
- Feeding grounds;
- Overwintering areas for crustaceans (e.g. lobster and crab);
- Migration routes;
- Conservation Importance;
- Importance in the food web; and
- Commercial importance.

37. The assessment of impacts on the aspects of fish and shellfish outlined above will be undertaken separately for the construction, operational and decommissioning phases.

38. Cumulative impacts relevant to fish and shellfish ecology arising from other marine developments will also be assessed.

39. Scoping opinion responses from the MMO and fisheries advice from Cefas via the MMO (Appendix 1) have highlighted herring (*Clupeas harengus*), sand eels (Ammoditidae spp.), cod (*Gadus morhua*), seabass (*Dicentrarchus labrax*) and elasmobranchs as key receptors to be considered within the assessment.

40. The final approach to assessment of potential impacts on fish and shellfish ecology will be agreed in consultation with Cefas and the MMO through the EPP and completion of the Agreement Log.

4.1 Defining Impact Significance

Sensitivity

41. Receptor sensitivity will be assigned on the basis of species specific adaptability, tolerance, and recoverability when exposed to a potential impact. The following parameters will also be taken into consideration within the assessment:

- Timing of the impact: whether impacts overlap with critical life-stages or seasons (i.e. spawning, migration; also see approach to assessment); and
- Probability of the receptor-effect interaction occurring (e.g. vulnerability)

42. Throughout the assessment, receptor sensitivities will be informed by review of the available peer-reviewed scientific literature, monitoring results from operational offshore wind farms, findings from industry-wide studies (e.g. COWRIE funded research) and assessments available on the Marine Life Information Network (MarLIN) database. It is acknowledged that the MarLIN assessments have limitations and these will be taken into account and caveated as appropriate. Other information and data will be accessed where relevant and if available. Definitions of receptor sensitivity are provided in Table 4.1.

43. With regard to noise related impacts, the criteria adopted will be based on the now established peer-reviewed evidence and criteria recently published by Popper *et al.* (2014). The findings of two associated follow up reports will also be considered (Hawkins *et al.* 2015, Hawkins and Popper 2016). The underwater noise method statement is included in Appendix 2.

Table 4.1 Definitions of Receptor Sensitivity

Sensitivity	Definition
High	Individual receptor (species or stock) has very limited or no capacity to avoid, adapt to, accommodate or recover from the anticipated impact.
Medium	Individual receptor (species or stock) has limited capacity to avoid, adapt to, accommodate or recover from the anticipated impact.
Low	Individual receptor (species or stock) has some tolerance to accommodate, adapt or recover from the anticipated impact.
Negligible	Individual receptor (species or stock) is generally tolerant to and can accommodate or recover from the anticipated impact.

Ecological Value

44. Where appropriate, the ecological value of the receptor may be taken into account within the framework of the assessment. In these instances 'value' refers to the importance of the receptor with respect to conservation status, role in the ecosystem, and geographic frame of reference. Note that for stocks of species which support significant fisheries, commercial value is also taken into consideration. Generic definitions of ecological values are provided in Table 4.2.

Table 4.2 Definition of Ecological Value

Value	Definition
High	Internationally or nationally important
Medium	Regionally important or internationally rare
Low	Locally important or nationally rare
Negligible	Not considered to be particularly important or rare

Magnitude

45. The magnitude of an effect is considered for each predicted impact on a given receptor and is defined geographically, temporally and in terms of the likelihood of occurrence. The definitions of terms relating to the magnitude of a potential impact on fish and shellfish ecology are provided in Table 4.3.

46. With respect to duration of potential impacts, those associated with construction are considered to be short term, occurring over a maximum of 2 years. Impacts associated with operation are longer term, occurring over the operational lifetime of the proposed Norfolk Boreas Project.

Table 4.3 Definitions of Magnitude of Effect

Magnitude	Definition
High	Fundamental, permanent / irreversible changes, over the whole receptor, and / or fundamental alteration to key

Magnitude	Definition
	characteristics or features of the particular receptors character or distinctiveness.
Medium	Considerable, permanent / irreversible changes, over the majority of the receptor, and / or discernible alteration to key characteristics or features of the particular receptors character or distinctiveness.
Low	Discernible, temporary (throughout project duration) change, over a minority of the receptor, and / or limited but discernible alteration to key characteristics or features of the particular receptors character or distinctiveness.
Negligible	Discernible, temporary (throughout project duration) change, over a minority of the receptor, and / or limited but discernible alteration to key characteristics or features of the particular receptors character or distinctiveness.
No Impact	No loss of extent or alteration to characteristics, features or elements.

Significance

Table 4.4 applies the significance criteria to the assessment of an effect, taking into account the magnitude of effect and sensitivity of the receptor. In the context of impacts on fish and shellfish receptors, a low magnitude combined with a low sensitivity results in a minor significance. Those effects which are moderate or major are considered significant with respect to Environmental Impact Assessment (EIA) assessments.

48. The matrix is seen as a framework to aid understanding of how a judgement has been reached from the narrative of each impact assessment and it is not a prescriptive formulaic method. To some extent defining impact significance will therefore be qualitative and reliant on professional experience, interpretation and judgement.

49. The significance of each impact on fish and shellfish receptors, where appropriate, will be expressed in terms of the impact at a species population level. Where it is not possible to quantify impacts, and where a qualitative or semi-qualitative assessment is made, the assessment will set out the logical and robust in support of the conclusion.

Table 4.4 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 4.5 Impact Significance Definitions

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 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.

4.2 Potential Impacts

50. Scoping opinion responses from the MMO and fisheries advice from Cefas via the MMO (Appendix 1) have highlighted herring (*Clupea harengus*), sand eels (Ammoditidae .), cod (*Gadus morhua*), seabass (*Dicentrarchus labrax*) and elasmobranchs as key receptors to be considered within the assessment. This is with particular reference to piling noise (herring), increased suspended sediments (herring and sand eels) and electromagnetic field (EMF) generation (elasmobranchs). Other fish and shellfish species taken forward for assessment will be identified using information from previous site-specific surveys, IBTS, IHLS and IMARES ichthyoplankton surveys, commercial fisheries landings data collated by the MMO for the relevant ICES rectangles and peer-reviewed scientific publications.

51. Final impacts and receptors taken forward for assessment will be finalised in consultation with the MMO and Cefas through the EPP.

Potential Impacts during Construction

Physical Disturbance and temporary loss of seabed habitat

52. There is potential for direct physical disturbance of the seabed during construction from the installation of cables, foundations (through placement of jack up barge legs, anchors/chains etc.) and seabed preparation (e.g. dredging). These construction phase activities have the potential to directly impact fish and shellfish species and their spawning or nursery grounds.

53. The installation of turbine foundations will result in the temporary loss of some areas of natural fish and shellfish habitat during the construction phase. The temporal and spatial extent of the effect will be limited.

54. It is proposed that habitat loss during construction is assessed together with the physical disturbance impact.

55. This impact is of particular relevance to both sand eels which require specific habitats for their burrowing and herring which are substrate specific demersal spawners. Both have been identified as key receptors within the Cefas EPP fisheries advice (Appendix 1) and MMO scoping opinion responses.

Approach to Assessment

56. The area of impact from physical disturbance and proportion of the population affected will be assessed using a worst-case scenario for the construction activities identified in Table 2.1.

57. Sensitivities will be assigned based on the available data and information sources including assessments available on MarLIN. Assessments of sensitive species and species with conservation status will be guided by review of available literature.

58. Assessments to spawning and nursery grounds will be guided by the known spawning and nursery habitats mapped by Coull *et al*. (1998) and updated by Ellis *et al*. (2012). This impact is of particular relevance to both sand eels (substrate specific habitat requirements) and herring (substrate specific spawning ground requirements). Both have been identified as key receptors within scoping opinion responses from the MMO and Cefas EPP advice (Appendix 1).

59. Information generated as part of the Marine Geology, Oceanography and Physical Processes assessment and calculations based on the design parameters will be used to quantify the magnitude of the impact and will be based on the maximum seabed area affected by seabed preparation for foundations, export cable and inter-array/platform/project cable installation. The sensitivity of fish and shellfish receptors will be based on the proximity of habitat, spawning and nursery grounds in combination with the available literature including the results from monitoring at operational offshore wind farms.

Increased suspended sediment concentrations and re-deposition of sediment

60. Certain construction activities (e.g. seabed preparation for gravity base installation) have the potential to mobilise sediments into the water column resulting in an increase of suspended sediment concentrations (SSC) and re-settlement rates in excess of those encountered within the range of naturally occurring variation. Potential impacts include physiological effects, short term disturbance to migration and changes to the composition of spawning substrates and smothering effects for benthic spawning species (e.g. herring, *Clupea harengus*).

Approach to Assessment

61. Magnitude of impact will be assigned on the basis of the worst-case scenario (e.g. maximum spatial and temporal impact) identified from the results of the following assessments: Marine Geology, Oceanography and Physical Processes; Marine Water and Sediment Quality; Benthic and Intertidal Ecology. Magnitude will be reviewed separately for all potential impacts. Sensitivity of receptors will be assessed in the context of life-history stage (e.g. eggs, larvae, adult) and the location of known spawning habitats and nursery grounds in addition to the relevant MarLIN assessments and peer reviewed scientific literature.

Underwater Noise

62. There are a number of potential sources of underwater noise during construction including piling, construction vessel traffic, seabed preparation, rock dumping and cable installation. Of these piling noise (specifically installation of monopiles or jacket foundations) is considered to have the greatest potential environmental impact with respect to fish and shellfish ecology, particularly with reference to fish species. Potential impacts range from lethal trauma to behavioural effects such as

disturbance to migration or spawning. The assessment of noise impacts will therefore focus on piling noise.

Approach to Assessment

63. The potential for disturbance to spawning/nursery and migration routes for fish and shellfish receptors will be assessed in relation to the available data on defined spawning locations and the timing and duration of the noise generated by piling events.

64. The qualification of the magnitude of this impact will be guided by both the results of noise assessments and the findings of the underwater noise modelling report. The under water noise modelling for fish and shellfish ecology will follow the Popper et al (2014) guidelines. This work is yet to be commissioned but is expected to follow identical methodology to that provided previously by Subacoustech for Norfolk Vanguard (see Appendix 2).

65. Assessment of sensitivities of fish and shellfish species to underwater noise will be informed by available literature including the assessments available on MarLIN and peer-review publications. The assessment will apply focus to those species considered to be particularly sensitive to noise related impacts (e.g. herring and other cluepids). Cefas have identified herring as a species to be taken forward for the assessment of noise related impacts (see Appendix 1).

Potential Impacts during Operational Phase

66. In general potential impacts during the operational phase of the development are anticipated to be lower than those potentially occurring during construction.

Permanent loss of Seabed Habitat

67. The construction of the wind farm could lead to a permanent loss of habitat in the footprint of foundations and areas where cable protection methods are employed.

Approach to assessment

68. The magnitude of the impact will be quantified by calculating the footprint of foundations, scour protection and cable protection as a percentage of potentially available habitat, nursery or spawning ground. The impact on key receptors will be considered at the local and population level.

Underwater Noise during Operation

69. Sources of operational noise would include wind turbine vibration, the contact of waves with offshore structures and maintenance vessel engines. It is likely that these would increase noise levels only marginally above existing baseline levels (i.e. pre-construction).

Approach to assessment

70. The qualification of the magnitude of this impact will be guided by the results of noise assessment and the findings of the underwater noise report. Sensitivity will be based on species sensitivity to noise, life history phase and the location of spawning and nursery grounds in addition to review of the relevant scientific literature.

Electromagnetic Fields (EMFs)

71. Certain marine organisms are known to be sensitive to electromagnetic fields or have the potential to detect them. The principal groups of relevance known to be electro-sensitive are elasmobranchs (sharks, skates and rays) and agnathans (i.e. lampreys). The evidence plan fisheries advice letter issued by Cefas (see Appendix 1) recommends the assessment of EMFs on elasmobranchs where cable burial is not possible. It is noted that Cefas also acknowledge adequate cable burial will mitigate the potential for EMF impacts on elasmobranch species (see Appendix 1).

Approach to assessment

72. The level of magnitude will be informed by the design specifications of the array and export cables and the amount of buried cable, burial depth and location and type of cable protection proposed.

73. Assessment of sensitivities of fish and shellfish species to EMF will be informed by available literature including the assessments available on MarLIN and peer-review publications. The location of potential migration routes and spawning and nursery grounds will also be considered within the assessment. The impact on key receptors will be considered at the local and population level.

Potential Impacts during Decommissioning

74. During decommissioning the potential impacts are anticipated to be similar to those described for the construction phase, although in some cases the magnitude of potential impacts will be much reduced. For example, there will be no requirement to undertake piling and therefore the noise impacts will be lower. If array and export cables are to be decommissioned '*in situ*', then there will no seabed disturbance and loss of habitat associated with this aspect of decommissioning.

Approach to assessment

75. The methods used for assessing the impacts during decommissioning will be the same as those used during the construction phase. However, for the reasons outlined above all impacts will be expected to fall within the Rochdale envelope (e.g. 'the worst case') parameters previously defined and the impacts will be assumed to be, at worst, analogous to those assessed for the construction phase.

Potential Cumulative Impact Scenarios

76. The majority of potential cumulative impacts from offshore wind farms in the North Sea will be temporary, small scale and localised. Given the recoverability of fish and

shellfish receptors in the area, in addition to the relatively small areas of seabed habitat impacted, the cumulative impact of permanent habitat loss during the operational phase of the Norfolk Boreas project in combination with other offshore wind farms is not anticipated to be significant.

77. Underwater noise could have cumulative impacts spatially (if two or more piling operations are undertaken simultaneously) or temporally (if piling operations are happening consecutively) with the potential for displacement impacts across the southern North Sea, noise 'barriers' blocking migration routes or consecutive piling programmes displacing sensitive fish from large areas for sustained periods. Noise modelling will be undertaken for the Norfolk Boreas project in isolation and cumulatively with other potential projects in the North Sea.

78. Should there be any potential overlap in construction with other developments in relatively close proximity to the Norfolk Boreas development, such as Norfolk Vanguard then there may be some potential for cumulative impacts of increased suspended sediment concentrations and re-deposition.

79. Table 4.6 below shows all of the projects considered for the cumulative impact assessment in relation to fish and shellfish ecology.

Table 4.6 Summary of the Projects considered for the Cumulative Impact Assessment in relation to Fish and Shellfish Ecology

Project	Distance from site (km)	Size (MW)	Maximum number of turbines
Norfolk Boreas	**N/A**	**1,800**	**257**
Consented			
East Anglia ONE	40	714	102
East Anglia THREE	0	1,200	172
Hornsea Project One	95	1,200	174
Application in progress			
Norfolk Vanguard	30	1,800	120-257
Hornsea Project Three	88	2,400	342
East Anglia One North	30	800	115
East Anglia TWO	45	800	115

Approach to assessment

80. Already installed infrastructure, practised licenced activities (e.g. dredging activity) and implemented measures will be assumed to constitute part of the existing environment to which receptors have adapted. Only projects with anticipated construction periods that are likely to overlap with that of the Norfolk Boreas project and which are at sufficient distance for zones of impact on fish and shellfish to overlap spatially will be taken forward for assessment.

81. The assessment will focus on key receptors and the main impacts which could have the greatest potential cumulative impacts:

- Underwater noise on sensitive species (e.g. herring); and
- Increased suspended sediments (impacts on sand eel habitat and herring spawning ground).

82. Other impacts will be assessed under a generic single assessment:

- Physical disturbance and permanent habitat loss;
- Introduction of hard substrate; and
- EMFs.

Transboundary Impacts

83. There is a high level of development in the southern North Sea in other EU Member States waters and populations of fish may be highly mobile. Therefore, there is the potential for transboundary impacts to occur particularly with respect to cumulative displacement or migration barrier impacts from noise. Following review of the underwater noise report, it will be apparent whether the piling noise from any developments outside the UK EEZ will have the potential to have a cumulative impact on fish and shellfish species.

84. As the distribution of fish and shellfish species is independent of national geographical boundaries the cumulative assessment will have been undertaken taking account of the distribution of fish stocks and populations irrespective of political limits. As a result, it is considered that a specific assessment of trans-boundary effects is unnecessary as this will have been effectively covered under the cumulative assessment.

5.0 References

Cefas, Marine Consents and Environment Unit (MCEU), Department for Environment, Food and Rural Affairs (DEFRA) and Department of Trade and Industry (DTI) (2004) Offshore Wind Farms - Guidance note for Environmental Impact Assessment In respect of FEPA and CPA requirements, Version 2.

Centre for Environment, Fisheries and Aquaculture Science (Cefas) (2012) Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects.

Chartered Institute of Ecology and Environmental Management (CIEEM) (2010) Guidelines for Ecological Impact Assessment in Britain and Ireland: Marine and Coastal Chartered Institute of Ecology and Environmental Management, Winchester.

Coull, K.A., Johnstone, R., and S.I. Rogers. 1998. Fisheries Sensitivity Maps in British Waters. Published and distributed by UKOOA Ltd.

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Hawkins, A. D., Pembroke, A., and Popper, A. (2015). Information gaps in understanding the effects of noise on fishes and invertebrates. Reviews in Fish Biology and Fisheries, 25: 39–64pp.

Hawkins, A. D., and Popper, A. N. (2016). A sound approach to assessing the impact of underwater noise on marine fishes and invertebrates. – ICES Journal of Marine Science, doi:10.1093/icesjms/fsw205.

Renewable UK (2013) Cumulative impact assessment guidelines, guiding principles for cumulative impacts assessments in offshore wind farms.

Popper A N, Hawkins A D, Fay R R, Mann D A, Bartol S, Carlson T J, Coombs S, Ellison W T, Gentry R L, Halvorsen M B, Løkkeborg S, Rogers P H, Southall B L, Zeddies D G, Tavolga W N., ASA S3/SC1.4 TR-(2014). Sound Exposure Guidelines for Fishes and Sea Turtles, Springer Briefs in Oceanography, DOI 10.1007/978-3-319-06659-2.

6.0 Appendix 1

MARINE AND COASTAL ACCESS ACT (2009). EAST ANGLIA (NORTH) TRANCHE 1 EVIDENCE PLAN PROCESS
Reference Number: DCO/2016/00002

FISHERIES ADVICE

From: Georgina Greenhalgh - Cefas, Lowestoft Laboratory
Date: 11th April 2016
Tel: 01502 524299
Email: georgina.greenhalgh@cefas.co.uk

To: Frances Edwards – MMO (by e-mail)
Cc: Fisheries Advice – Cefas, Lowestoft
SEAL Case Officer – Cefas, Lowestoft

With reference to the above application for East Anglia (North) Tranche 1 Offshore Wind Farm by Vattenfall Ltd and your request for comments dated 22nd March 2016 please find my comments below in my capacity as advisor on fisheries.

Document (s) reviewed
East Anglia Tranche 1 Offshore Wind Farm, Benthic Sampling, Proposed Methodology PB4476.003.001

East Anglia Tranche 1 Offshore Wind Farm, Evidence Plan, Terms of Reference PB4476.001.004

Description of the proposed works
The Crown Estate has awarded Vattenfall Wind Power Ltd (VWPL) the right to develop the north area of the East Anglia Zone for the construction of a round three UK Offshore Wind Farm. VWPL's development of the north area, known as Tranche 1 will have a capacity of 1800MW and will be separated into East and West zones within Tranche 1.

In order to consider the requirements for an Environmental Impact Assessment (EIA), VWPL have submitted their proposed methodology for benthic sampling and collection of fisheries data with an overview of the proposed works.

Major comments 1
We note that no additional fisheries survey will be carried out prior to delivery of the EIA. Instead, data on fisheries will be established through a desk based study using previously published research resources and past survey results.
Given the previous surveys in the vicinity (undertaken as part of the East Anglia ZEA and East Anglia Three and East Anglia Four EIA's), a desk based study is likely to identify the key species present in the area together with nursery and spawning grounds, without the need for a new fisheries survey to be carried out.

We would request that any previous survey data presented in the desk based assessment and used in the EIA, includes or signposts to documents that present all relevant information such as dates and times of surveys, locations, gear used, mesh size, duration of tow / soak times. We recommend that the limitations of any data sources used in the EIA are presented and acknowledged in the report. Any inconsistencies in survey techniques from past surveys should be discussed in the report and we recommend that catch data has been standardised.

A comprehensive review of the fish and shellfish assemblages should be completed. Species of commercial importance and conservation concern in the vicinity should be sufficiently evaluated Direct impacts, cumulative and in-combination impacts should be discussed within the document.
Major comments 2

We would recommend that the following species are considered within the EIA and that potential impacts and resulting mitigation (if required) are discussed in the report; herring, Sand eels, elasmobranchs:

Herring: The main species for concern are herring; they are known to be sensitive to noise and sedimentation in relation to spawning activities. Herring are benthic spawners and require a specific substrate on which to lay their eggs. Typical spawning sites consist of gravel, coarse sand, maerl or shell with a low proportion of fine sediment and well oxygenated water. Data from the International Herring Larvae Surveys (IHLS) will provide herring larvae details for the Southern North Sea area. IHLS data can be found via the ICES Egg and Larvae data portal website; http://www.ices.dk/marine-data/data-portals/Pages/Eggs-and-larvae.aspx

Sand eels: are ecologically important and also fished commercially. Sand eels generally spawn where they are found, therefore nursery grounds are generally located in the same area as spawning grounds. Ellis et al.., 2012 identifies that there may be Sand eel nursery and spawning grounds around the development area. Sand eels may be present in samples collected using epibenthic trawls and benthic grabs undertaken during the benthic ecology surveys. Although these survey methods are not designed to target Sand eels, if Sand eels are recorded in either gear this indicates presence in the survey area and any presence in the samples should be discussed in the EIA.

Elasmobranchs: Submarine export cables from windfarms are known to produce an electromagnetic field (EMF). Electrosensitive elasmobranchs (i.e. sharks, skates and rays) may have the potential to detect and react to the EMF produced by such export cables. The National Policy Statement for Renewable Energy Infrastructure (EN-3) (Dept. of Energy & Climate Change, 2011) recommends to minimise the potential effect of EMF that cables are laid to a depth of greater than 1.5m. The effects of EMF on sensitive species e.g. elasmobranchs may be mitigated by adopting this recommendation. However, we recognise that this may be subject to local seabed geology, and other receptors in the area.

We would also recommend that commercially important species such as cod, sole and plaice as well as species of conservation concern are sufficiently assessed in the EIA.

Observations 1
In order to characterise the fish and shellfish ecology for the EIA, a variety of desk based resources will be used e.g. Ellis et al.., 2012 & Coull et al.., 1998 and International Bottom Trawl Survey (IBTS) data. We agree that the information sources described in the report combined with the existing East Anglia FOUR data will allow characterisation of the Tranche 1 offshore project area for the EIA, without the need for further fish trawl surveys.

Cefas beam trawl surveys are conducted in the Eastern English Channel in ICES divisions VIId and IVc. Data from these trawls may provide an additional source of fisheries information. Information can be downloaded from the ICES DATRAS website http://datras.ices.dk/Home/Default.aspx

Observations 2
We note and endorse the Particle Size Analysis (PSA) to be carried out to determine sediment type as part of the benthic characterisation. PSA data can also provide information on site suitability for Sand eel habitats and herring spawning grounds
Any additional comments

We promote and encourage good relations with fishermen and those working in the industry who may be affected by the such developments. We encourage developers to consider the impacts to shipping and commercial fishing as a result of construction activity. Impacts should be identified and appropriate mitigation measures outlined in the report to ensure minimal disruption to other sea users.

Georgina Greenhalgh
Fisheries Scientist

Quality Check	***Date***
Louise Straker Cox ***Senior Fisheries Environmental Impact Advisor***	***12/04/2016***

SEAL high level QC	***Date***
Ruth Edwards	13/04/2016

References

Department of Energy & Climate Change. 2011. National Policy for Renewable Energy Infrastructure (EN-3). [Online] Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/47856/1940-nps-renewable-energy-en3.pdf. (Accessed 11th April 2016)

7.0 Appendix 2

Method Statement relating to underwater noise propagation modelling parameters for Norfolk Vanguard

Underwater noise propagation modelling is proposed as part of the Environmental Impact Assessment (EIA) for Norfolk Boreas. As part of this, a decision must be made as to certain modelling parameters in the Evidence Plan Process. This Method Statement examines the methodology used in the East Anglia Three Offshore Wind Farm (OWF) EIA as the most recent EIA to go through examination and updates it based on best available current research and guidelines.

Modelling

The underwater noise modelling will utilise a combined parabolic equation (as per RAM/RAMSGeo) and ray-tracing (for high frequency elements) solver within the dBSea package. This incorporates bathymetry and seabed and sediment data to ensure realism to the environment. During modelling, the results will be precautionary, using the worst case for:

- Hammer energies
- Ramp-up profiles
- Cumulative noise exposure
- Position of the receptor in the water column

The impact criteria to be applied are also designed to be conservative.

Thresholds and criteria

Underwater noise impacts on marine life are under investigation around the world and new research is published frequently. Two key and current papers concerning underwater noise impacts have been published: NMFS (2016)[2] and the American National Standards Institute (ANSI)-approved Popper *et al.*. (2014)[3], for marine mammals and fish, respectively. These update the recommended criteria for use in impact assessments.

[2] National Marine Fisheries Service. 2016. Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts. U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-55, 178 p.

[3] Popper A N, Hawkins A D, Fay R R, Mann D A, Bartol S, Carlson T J, Coombs S, Ellison W T, Gentry R L, Halvorsen M B, Løkkeborg S, Rogers P H, Southall B L, Zeddies D G, Tavolga W N., ASA S3/SC1.4 TR-2014 Sound Exposure Guidelines for Fishes and Sea Turtles, Springer Briefs in Oceanography, DOI 10.1007/978-3-319-06659-2

Marine Mammals

Since it was published in 2007, Southall *et al.*[4] has been the source of the most widely used criteria to assess the effects of noise on marine mammals. The Norfolk Boreas Scoping Opinion advises that NMFS (2016) impact criteria are reviewed. NMFS (2016) was co-authored by many of the same authors from Southall *et al.*. and effectively updates it. Most criteria become more restrictive.

Table 6 shows the criteria used in the underwater noise impact assessment for East Anglia THREE and the most up to date criteria provided by NMFS (2016). The criteria are divided into species 'hearing groups' which represent the sound frequencies over which the group of species are sensitive. The thresholds to be used in the Norfolk Boreas EIA will be discussed and agreed with stakeholders through the Evidence Plan Process.

PTS (Permanent Threshold Shift)	**East Anglia Three**		**NMFS (2016)**	
	SPL_{peak} Unweighted (dB re 1 µPa)	SEL_{cum} Weighted (dB re 1 $µPa^2s$)	SPL_{peak} Unweighted (dB re 1 µPa)	SEL_{cum} Weighted (dB re 1 $µPa^2s$)
High Frequency (HF) Cetaceans (e.g. Harbour porpoise)	200	179 (single strike)	202	155
Mid Frequency (MF) Cetaceans (e.g. Bottlenose dolphin)	230	198	230	185
Low Frequency (LF) Cetaceans (e.g. Baleen whales)	230	198	219	183
Phocid Pinnipeds (e.g. harbour seal)	218	186	218	185

Table 6 Criteria for assessment of injury to marine mammals

East Anglia THREE used an assumption that a fleeing response or avoidance of an area occurred concurrently with the noise exposure believed to cause a temporary reduction in hearing sensitivity (Temporary Threshold Shift or "TTS"). Table 7 represents the criteria for this effect, and therefore the concurrent fleeing response.

TTS (Temporary Threshold Shift)	**East Anglia THREE**		**NMFS (2016)**	
	SPL_{peak} Unweighted (dB re 1 µPa)	SEL_{cum} Weighted (dB re 1 $µPa^2s$)	SPL_{peak} Unweighted (dB re 1 µPa)	SEL_{cum} Weighted (dB re 1 $µPa^2s$)
High Frequency (HF) Cetaceans (e.g. Harbour porpoise)	194	164	196	140
Mid Frequency (MF) Cetaceans (e.g. Bottlenose dolphin)	224	183	224	170
Low Frequency (LF) Cetaceans (e.g. Baleen whales)	224	183	213	168
Phocid Pinnipeds (e.g. harbour seal)	212	171	212	170

[4] Southall, B. L., Bowles, A. E., Ellison, W. T., Finneran, J. J., Gentry, R. L., Greene Jr., C. R., Kastak, David, Ketten, D. R., Miller, J. H., Nachtigall, P. E., Richardson, W. J., Thomas, J. A., and Tyack, P. L. (2007) Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations, Aquatic Mammals, 33 (4), pp. 411-509

Table 7 Criteria for assessment of TTS to marine mammals

While, strictly speaking, the criteria are designed for TTS rather than fleeing, this follows the methodology agreed for use in East Anglia THREE's criteria, as there is little broadly accepted evidence currently available for setting behavioural avoidance criteria. However, the following alternative criteria applied for East Anglia THREE could be used, which are identified in Table 8 below, derived from Southall *et al.*, 2007.

Potential avoidance of area	**East Anglia THREE**	
	SPL_{peak} Unweighted (dB re 1 µPa)	SEL_{cum} Weighted (dB re 1 µPa^{2}s)
High Frequency (HF) Cetaceans (e.g. Harbour porpoise)	168	145
Mid Frequency (MF) Cetaceans (e.g. Bottlenose dolphin)	None	160-170
Low Frequency (LF) Cetaceans (e.g. Baleen whales)	None	142-152
Phocid Pinnipeds (e.g. harbour seal)	As TTS	As TTS

Table 8 Criteria for assessment of potential avoidance of an area by marine mammals

Fish

The vast variety and variation in fish species leads to a greater challenge in production of a generic noise criterion, or range of criteria, for the assessment of noise impacts. Whereas previously broad criteria were applied based on limited studies, the publication of Popper *et al.*. (2014) provides an authoritative summary of the latest sound exposure guidelines. The following Table 9 provides a summary of the most conservative of these, in respect of offshore pile driving, alongside the criteria recommended for East Anglia THREE.

Effect on fish	**East Anglia Three**		**Popper *et al.*. (2014)**	
	SPL_{peak} Unweighted (dB re 1 µPa)	SEL_{cum} Unweighted (dB re 1 µPa^{2}s)	SPL_{peak} Unweighted (dB re 1 µPa)	SEL_{cum} Unweighted (dB re 1 µPa^{2}s)
Fish injury	206	211	207	203
TTS	None	None	None	186
Startle response / C-turn reaction	200	None	Qualitative	Qualitative
General behavioural response	168 – 173	None	Qualitative	Qualitative

Table 9 Criteria for assessment of effects on fish

The Popper *et al.*. guidelines do not recommend quantitative criteria for behavioural effects on fish as the best research available is limited to very specific studies on species under artificial conditions. Therefore it is recommended that behavioural effects for fish are considered qualitatively only.

It should be noted that two follow-ups to the Popper *et al.*. (2014) report (Hawkins *et al.*. 2015[5], Hawkins and Popper 2016[6]) elaborate further on the challenge of setting criteria for the large variety

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[5] Hawkins, A. D., Pembroke, A., and Popper, A. 2015. Information gaps in understanding the effects of noise on fishes and invertebrates. Reviews in Fish Biology and Fisheries, 25: 39–64

[6] Hawkins, A. D., and Popper, A. N. 2016. A sound approach to assessing the impact of underwater noise on marine fishes and invertebrates. – ICES Journal of Marine Science, doi:10.1093/icesjms/fsw205

of sensitivities of the many species of fish and invertebrates. The reports detail the data gaps, especially in relation to many species sensitive to the particle motion rather than pressure component of sound in the water and to the potential for impacts from seabed vibration. Although clearly identifying that many species will not be sensitive to the sound pressure for which the criteria are based, there are neither recognised criteria or thresholds in terms of particle motion currently available, nor appropriate data to apply the criteria to.

The papers make a strong recommendation to undertake research to fill these data gaps. Until such research exists, however, it is recommended to continue to use the existing criteria as defined in Popper *et al..* 2014 as best practice.

Piling locations

Concurrent piling at two locations within NV East and two in NV West will be modelled for locations at the furthest extent of the boundaries, in order to provide the maximum combined sound propagation. Consideration will also be given to seabed bathymetry when selecting the worst case scenario concurrent piling locations.

The underwater noise modelling will also assess the worst case scenario for a single piling location within NV East and NV West which may be represented by one of the locations identified for concurrent piling or may be a new location, subject to the bathymetry data.

In addition, the maximum noise impact contour for harbour porpoise will be modelled at one location with NV East and NV West which provides the maximum overlap with the Southern North Sea proposed Special Area of Conservation. This may be represented by one of the locations identified above or may be a new location.

A geophysical survey at Norfolk Boreas was undertaken in 2016 and the bathymetry data from this will be assessed to identify the worst case scenario location, when available.

Norfolk Boreas Offshore Wind Farm

Environmental Impact Assessment

Marine Physical Processes Method Statement

Document Reference: PB5640-004-024

Author: Royal HaskoningDHV
Applicant: Norfolk Boreas Ltd
Date: January 2018

Date	Issue No.	Remarks / Reason for Issue	Author	Checked	Approved
26/11/2017	01D	Internal review	DB	DT	AD
8/12/2017	02D	Updates following internal review	DB	DT	AD
16/01/2018	02D	Issue for Vattenfall Review	DB	DT	JL
01/02/2018	03D	Vattenfall Comments addressed	DB	DT	
05/02/2018	01F	Issue for Consultation	DB	DT	JL

This method statement has been prepared by Royal HaskoningDHV on behalf of Norfolk Boreas Limited in order to build upon the information provided within the Norfolk Boreas Environmental Impact Assessment (EIA) Scoping Report. It has been produced following a full review of the Scoping Opinion provided by the Planning Inspectorate. All content and material within this document is draft for stakeholder consultation purposes, within the Evidence Plan Process.

Many participants of the Norfolk **Boreas** Evidence Plan Process will also have participated in the Norfolk **Vanguard** Evidence Plan Process. This document is presented as a complete and standalone document, however in order to maximise resource and save duplication of effort, the main areas of deviation from what has already been presented through the Norfolk Vanguard Evidence Plan Process and PEIR or in the Norfolk Boreas Scoping Report are presented in orange text throughout this document.

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1 INTRODUCTION

1. The purpose of this method statement is to build upon the information provided within the Norfolk Boreas 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 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 Norfolk Boreas Evidence Plan Process (EPP). The aim is to gain agreement on this Method Statement from all members of the Marine Physical Processes Expert Topic Group (ETG) which will be recorded through the agreement log.

3. This method statement has been produced following a full review of the Scoping Opinion provided by the Planning Inspectorate, responses to the Norfolk Vanguard Preliminary Environmental Information Report (PEIR) and experience of the Norfolk Vanguard EPP. Key points within the EIA Scoping Opinion that relate to marine physical processes (and coastal processes) are summarised in **Table 1.1**.

4. Information provided in this Method Statement is a draft for stakeholder consultation only and is provided in confidence. It is recognised that Norfolk Vanguard ETG meetings are being held in January 2018 and that agreements will be made during those meetings in relation to Norfolk Vanguard which may be relevant to Norfolk Boreas, but cannot be reflected here, due to the timescales of the two projects. Due to project "Mile Stones" which have been set by The Crown Estate, Norfolk Boreas must progress on a programme which requires consultation on the Norfolk Boreas Method Statements prior to the conclusion of the Norfolk Vanguard EPP. Therefore, the information provided in this document represents the best available at the time of writing. It is a commitment across both projects that, wherever possible, the approach taken to the development of the EIA and HRA for Norfolk Vanguard and Norfolk Boreas will be as consistent as possible.

Table 1.1: Scoping opinion responses

Consultee	Comment	Response / where addressed in this document
Secretary of State	The SoS welcomes the proposal for surveys to develop the understanding of the seabed conditions across the site. The SoS recommends that the scope of these surveys is agreed with the relevant consultees, including the Environment Agency (EA), the Marine Management Organisation (MMO) and Natural England (NE). The survey methodology should be set out within the ES.	Section 3.2 summarises the completed and planned data collection. Survey methodologies for the geophysical data collection were agreed with the MMO and Natural England in February 2017 and the results will be presented in the PEIR.
Secretary of State	The ES should provide details of all models used including any assumptions and limitations and how these have been factored in to the assessment.	Section 3.1.1 details modelling that will be used to support the assessment. The ES will provide additional detail to

Consultee	Comment	Response / where addressed in this document
		address this comment.
Secretary of State	Scour mitigation measures should be detailed within the ES; the EIA should outline a clear justification for the quantity and area to be covered, in addition to the total area of seabed likely to be covered by hard substrata.	Section 2.3.1 and 2.3.1.1 highlight areas to be covered. A number of scour protection options will be considered and detailed within the PEIR along with the predicted maximum quantities.
Secretary of State	The SoS considers this [The project] could result in an 'alteration to coastline', which is noted in paragraph 905. The potential impacts of landfall works on coastal processes, including erosion and deposition, should be addressed with appropriate cross reference to other technical reports including landscape and visual impacts. Consideration should be given to the interaction with the Bacton seascaping project.	Section 5.1.3 and 5.3 discuss the approach to coastal and landfall impacts. These impacts will be addressed in the ES and cross references will be made, where appropriate, to other technical reports. Section 5.1.3 refers to the Bacton sand engine, which will be considered within the CIA.
Secretary of State	"The Scoping Report states that "Modelling of sediment plumes completed as part of the East Anglia ONE EIA showed that coarser material is likely to settle out within a short distance (between a few hundred meters and 1km) of the activity and limit the overall footprint of the affected area". However, no reference has been made to the distance which finer material may settle. As such, the assertion that designated bathing waters (3.1km and 3.9km from the landfall search area) are unlikely to be affected has not been fully justified. Any such statements should be clarified within the ES, with reference to guidance or studies from which the conclusions have been drawn."	The reason this is stated is because the nature of the seabed in the working areas is coarse sand. As a result, modelling information on coarser grained material is relevant. This will be further clarified within the PEIR chapter.
Natural England	[As part of a list of key issues which will need to be considered in the EIA and HRA and discussed with Natural England and the MMO] Potential in-combination impacts with other sea defence projects at the landfall location.	Section 5 and subsections note other sea defence projects including the Bacton sand engine and Bacton coastal projection scheme. The potential in-combination impacts of Norfolk Boreas with other sea defence projects will be considered as part of the CIA.
Natural England	Natural England welcomes the commissioning of a number of detailed surveys to address gaps in the existing survey coverage, including the additional surveying of the cable corridor, to provide up-to-date data with which to inform the ES.	Section 3.2 details data collection for the impact assessments. The offshore cable corridor was surveyed in 2016 and the data collected during these surveys is deemed suitable for the purposes of Norfolk Boreas. Further studies have been commissioned to assess the possible effects on physical process within the cable corridor and at the coast, further detail is provided in section 3.3.
MMO	The proposed project area abuts an international boundary, therefore trans-boundary impacts from waves should be considered within the ES.	Transboundary impacts will be assessed through consideration of the extent of influence of changes or effects and their potential to impact upon marine physical processes receptor groups that are located within other European Union

Consultee	Comment	Response / where addressed in this document
		member states (section 2.3.10).
MMO	It is acknowledged that hydrodynamic impacts on the current regime are localised within the wind farm licence boundary, however, those associated with waves have been shown by modelling studies to extend beyond the boundary. Furthermore, the cumulative impacts from adjacent proposed wind farm project, Norfolk Vanguard, lies on the prevailing wind direction to the nearest coastline (north-east) and therefore has the potential to impact on the integrity of the coastal defences. The MMO recommends that the "Regional Environmental Assessment" (REA) approach, developed by the aggregates industry, is used to explore the scale, shape and orientation of the cumulative impact footprints from all the wind farms in a single model run (with all wind directions). This can be then tested against the "5% rule of thumb" in terms of changes in wave height and direction at coastal features (beach and offshore sandbanks) which act as flood defences along the Norfolk coastline. Further information on REA can be found at:- www.marine-aggregaterea. Info / documents	The nearest parts of Norfolk Boreas and Norfolk Vanguard (West) are situated 70km and 47km from the coast, respectively. It is considered that the coast is located remotely from the cumulative zone of influence and there would be no pathway that could link the source (the zone of influence) to the receptor (the coast). Hence, the use of numerical modelling is considered to be disproportionate to the potential effect that would occur and a Source-Pathway-Receptor (S-P-R) conceptual model is considered proportionate. A more detailed justification for this position is provided in sections 2.3.9 and 4.1.3.
MMO (late response)	Point 247 (page 60): Environment Agency data from monitoring of beach profiles is considered to be appropriate to insure the integrity of the cable at the Landfall. Please clarify whether additional profile data will be collected to assess the variability on various time scales (yearly, inter-annual or over the lifetime of the wind farm).	No new beach profiles are being collected for this assessment. Existing data would be sufficient to support assessment of historic beach changes. A study has been commissioned to assesses the potential effects of HDDs on coastal erosion (section 3.3 provides further detail).

1.1 Background

5. Physical Processes Method Statements have been completed for other wind farm consent applications within the former East Anglia Zone (East Anglia THREE / East Anglia FOUR and Norfolk Vanguard) which recommended an overall strategy for assessment of marine physical processes. The East Anglia THREE / East Anglia FOUR Method Statement was submitted to Natural England and Cefas in September 2013 as part of the Evidence Plan Process for that project. In discussion with the regulators, the Method Statement was amended and mutually agreed as a proportionate means of assessing the potential effects on the baseline physical environment. It was eventually carried through to the EIA for East Anglia THREE.

6. The Norfolk Vanguard Marine Physical Processes Method Statement was submitted to Natural England and Cefas in February 2017 as part of the Evidence Plan Process. That document provided a method statement for the assessment of potential effects

on the baseline marine physical processes due to the proposed project. The Marine Physical Processes Method Statement was discussed by Vattenfall, Royal HaskoningDHV, Cefas and Natural England at a meeting on 16th February 2017 and was used to complete the Norfolk Vanguard PEIR.

7. Given that Norfolk Boreas is located between Norfolk Vanguard West and Norfolk Vanguard East, a similar strategy is proposed here. In addition, the route of the Norfolk Boreas export cable corridor to landfall at Happisburgh South follows that of Norfolk Vanguard.

8. A Scoping Report for the Norfolk Boreas EIA was submitted to the Planning Inspectorate on the 9th May 2017. Further background information on the project can be found in the Scoping Report which is available at:

https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010087/EN010087-000015-Scoping%20Report.pdf

9. The Scoping Opinion was received on the 16th June 2017 and can be found at (See **Table 1.1** for relevant comments):

https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010087/EN010087-000013-Scoping%20Opinion.pdf

1.2 Norfolk Boreas Programme

1.2.1 Development Consent Order (DCO) Programme

• EIA Scoping Request submission	09/05/17 (complete)
• Preliminary Environmental Information (PEI) submission	Q4 2018
• Environmental Statement (ES) and DCO submission	Q2 2019

1.2.2 Evidence Plan Process Programme

10. The Evidence Plan Terms of Reference (Royal HaskoningDHV, 2017a) provides an overview of the Evidence Plan Process and expected logistics. Below is a summary of anticipated meetings:

- Agreement of Terms of Reference — Q3 2017
- Agree method statements — Q1 2018
  - Meetings will only be required if method statements cannot be agreed through review process
- Expert Topic Group and Steering Group meetings as required — 2018
  - To be determined by the relevant groups

- PEI Report (PEIR) Expert Topic Group and Steering Group meetings — Q4 2018/ Q1 2019
  - To discuss the findings of the PEI (before or after submission)
- Pre-submission Expert Topic Group and Steering Group meetings — Q2 2019
  - To discuss updates to the PEIR prior to submission of the ES

1.2.3 Consultation to Date

11. Norfolk Boreas is the sister project to Norfolk Vanguard (See section 2.1 for further details). A programme of consultation has already been undertaken for Norfolk Vanguard which is of relevance to Norfolk Boreas and this is listed below:

- EIA Scoping Request submission — 03/10/16
- Receipt of Scoping Opinion — 11/11/16
- Steering Group meeting — 21/03/16
- Steering Group meeting — 20/09/16
- Post-scoping Expert Topic Group meetings
  - Discuss method statements and Project Design Statement — 31/01/2018
- Expert Topic Group and Steering Group meetings as required — 2018

2 PROJECT DESCRIPTION

2.1 Context and Scenarios

12. Vattenfall Wind Power Limited (VWPL) is developing Norfolk Boreas and Norfolk Vanguard in tandem, and is planning to co-locate the export infrastructure for both projects in order to minimise overall impacts. This co-location strategy applies to the export cable route and the cable landfall.

13. The Norfolk Vanguard project is approximately 12 months ahead of Norfolk Boreas in terms of the Development Consent Order (DCO) process. As such, the Norfolk Vanguard team is leading on site selection for both projects. Although Norfolk Boreas is the subject of a separate DCO application, the project would adopt these strategic site selection decisions.

14. There is a possibility that the Norfolk Vanguard project is not constructed. In order for Norfolk Boreas to stand up as an independent project, this scenario must be provided for within the DCO for Norfolk Boreas. Thus, two alternative scenarios are being considered in the context of this Method Statement; Scenario 1 where Norfolk Vanguard has been constructed before any offshore construction of Norfolk Boreas begin, and Scenario 2 where Norfolk Vanguard is not constructed.

15. For both scenarios, Norfolk Boreas would consent and construct all required offshore infrastructure, and so there is no difference in the assessment of marine physical processes between the scenarios for Norfolk Boreas alone. The only offshore difference is that under Scenario 1, Norfolk Vanguard would be considered within the Cumulative Impact Assessment (CIA), together with the parameters of Norfolk Boreas.

2.2 Site Selection Update

16. The Norfolk Boreas Scoping report presented three potential landfall locations. Data was reviewed on a broad range of environmental factors, including existing industrialised landscape, the presence of the Cromer Shoal Chalk Beds Marine Conservation Zone (MCZ), coastal erosion and archaeology alongside statutory and non-statutory consultation.

17. After publication of the scoping report, VWPL concluded, taking account of all engineering and environmental factors, as well as public feedback, that the most suitable landfall location would be Happisburgh South. The decision to go to Happisburgh south was presented to the Norfolk Vanguard Evidence Plan Expert Topic groups in June and July 2017 and in the Norfolk Vanguard PEIR (Royal HaskoningDHV, 2017b).

2.3 Indicative Worst Case Scenarios

18. The following sections set out the current indicative worst case scenarios for marine physical processes and provides justification for why certain parameters will be used with the EIA over others. The Norfolk Boreas ES will describe the final project design (also known as Rochdale Envelope) for the DCO application in the Project Description Chapter. Each chapter of the PEIR and ES will define the worst case scenario arising from the construction, operation and decommissioning phases of the Norfolk Boreas project for the relevant receptors and impacts. Additionally, each chapter will consider separately the anticipated cumulative impacts of Norfolk Boreas with other relevant projects on the receptors under consideration.

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

20. The indicative worst case scenario for marine physical processes is based upon the general assumption that the greatest footprint represents the greatest potential for disruption to physical processes.

2.3.1 Wind Turbine Generator Foundations

21. A range of 7MW to 20MW wind turbines are included in the Norfolk Boreas project design envelope in order to future proof the EIA and DCO to accommodate foreseeable advances in technology.

22. The foundations of 15MW and 20MW turbines are anticipated to have the same physical parameters (parameters of other aspects of the turbines may differ). As a result, if the worst case scenario for a given parameter is associated with the largest wind turbines, 120 x 15MW would be the worst case scenario, rather than 90 x 20MW, due the greater number of devices making up the maximum site capacity of 1,800MW. The maximum number of wind turbines would be achieved by 257 x 7MW.

23. A range of foundation options; monopile, jackets on pin piles (on three or four legs), jackets on suction caissons (on three or four legs), gravity base structures (GBS) and floating foundations with a tension leg mooring system are included in the current project design envelope. Ongoing review by the Norfolk Boreas engineering team has identified that this is necessary in order to future proof the EIA and DCO to include the types of foundations that are likely to be available at the time of Norfolk Boreas construction.

24. GBS foundations are currently considered to provide the worst case scenario for the majority of marine physical processes impacts for two reasons. Firstly they occupy

the greatest volume within the water column and secondly they would require the greatest volume of seabed preparation. Gravity anchors for a tension leg floating platform foundations have a larger seabed footprint than the GBS, but this is a relatively low-lying flat structure whereas a GBS structure is elevated through the water column. The gravity anchors and their associated scour protection would however have form the worst case for the operational impact of loss of seabed morphology.

25. **Table 2.1** provides indicative maximum parameters for 7MW and 15MW to 20MW GBS and base foundations and floating foundation gravity anchors. Thus providing justification for the parameters which will form the worst case scenario (highlighted with bold text).

Table 2.1: Indicative wind turbine foundation maximum parameters. The worst case parameters which will be used in the assessment are presented in bold

Foundation Type	7MW wind turbines	15MW-20MW wind turbines
Number of foundations	257	120
GBS foundation footprint	40m diameter = 1257m^2	50m diameter= 1963.5m^2
GBS area of scour protection (includes foundation footprint)	5 x diameter of GBS = 31,416m^2	5 x diameter of GBS = 49,087m^2
GBS height above seabed	In excess of **12m**	In excess of 12m
Floating foundation gravity anchor footprint	45 x 45 = 2025m^2	70 × 70 =4,900m^2
Floating foundation gravity anchor scour protection footprint (includes foundation footprint)	Approximately 5 x size of foundation. 225 x 225 = 50,625m^2	Approximately 5 x size of foundation. 350 x 350 = **122,500m^2**
Floating foundation gravity anchor height above the seabed	Currently assumed to be in the region of two to five metres	Currently assumed to be in the region of two to five metres
Monopiles and Jackets (3 and 4 leg and pin pile and suction caisson) including scour protection	Would have significantly smaller footprints and cross sectional areas than GBS and tension leg floating foundations.	

26. Based on the indicative parameters provided for GBS foundations, the greater number of 257 x 7MW wind turbines is considered to represent the worst case scenario for impacts caused by an interaction between the project and physical processes, rather than 120 x 15MW wind turbines.

27. Consideration is given to seabed preparation requirements. **Table 2.2** details the potential for sediment re-suspension during the installation of each foundation option. The worst case scenario for sediment disturbance is 257 x 7MW GBS foundations, however all foundation types are considered to provide justification for what comprises the worst case scenario.

Table 2.2: Indicative potential for sediment release for each foundation option during construction. The worst case volumes which will be used in the assessment are presented in bold

Foundation Type	Comments associated with the potential for sediment release	Potential volume of sediment that could be suspended
Monopiles	Seabed preparation Sediment could be released as a result of seabed preparation and drilling if either are required. In relation to seabed preparation, if sand waves are present, the seabed might need to be levelled first by excavation to the trough of the sand wave.	Seabed preparation may be required by removing up 5m of sediment Approximate volume of seabed preparation material disturbed across the project 7MW monopile =72,924m^3 (257 x 56.75m^2 x 5m) Approximate volume of seabed preparation material disturbed across the project 15-20MW monopile = 106,026m^3 (120 x 176.71m^2 x 5m)
	Drill arisings Drill arisings may be released at the surface (subject to a disposal licence) providing potential for sediment plumes. Alternatively spoil material may require removal and disposal Piles are generally expected to be driven but drilling may be required at up to 50% of the locations if these foundation options are chosen	Approximate volume of drill arisings across the project with 7MW monopiles = 77,100m^3 (257 x average drill arisings of 600m^3 x 50%) Approximate volume of drill arisings across the project with 15-20MW monopiles = 42,000m^3 (120 x drill average arisings of 700m^3 x 50%)
Pin piles (quadropod)	As with the monopile, drill arisings may be released at the surface providing potential for sediment plumes. Alternatively spoil material may require removal and disposal No significant seabed preparation works are anticipated for pile installation. There might be a requirement to carry out minor flattening at some locations but unlikely to be significant in relation to other options Piles are generally expected to be driven but drilling may be required at up to 50% of the locations if these foundation options are chosen	Four pin piles (quadropod) represent the worst case scenario for drill arisings due to having the greatest number of piles The maximum volume of drill arisings for 7MW quadropods = 72,705m^3 (257 x 565.5m^3 x 0.5) The maximum volume of drill arisings for 15-20MW quadropods = **117,810m^3**. (120 x 1,963.5m x 50%)
Suction caissons (quadropod)	No drilling is required for suction caissons It is possible that excavation to the trough of the sand wave would be necessary before installing the suction caisson	Seabed preparation may be required up to a sediment depth of 5m. Four suction caissons (quadropod) represent the worst case scenario for seabed preparation Approximate volume of seabed preparation sediment disturbed across the project using 15-20MW suction caisson quadropods = 227,072m^3 (120 x 176.71m^2 x 4 x 5) Approximate volume of seabed preparation sediment disturbed across the project using 7MW suction caisson quadropods =

Foundation Type	Comments associated with the potential for sediment release	Potential volume of sediment that could be suspended
		227,072m^3 (257 x 176.71m^2 x 4 x 5)
GBS	No drilling is required for GBS. Seabed preparation may require dredging works and the installation of a bedding and levelling layer with the potential for release of suspended solids at the seabed. The dredging works are likely to be carried out using a trailer suction hopper dredger	Seabed preparation may be required up to a sediment depth of 5m The preparation area per 15-20MW GBS = 2,828m^2 (based on a 60m preparation diameter) with a seabed preparation volume of up to 14,137m^3 The preparation area per 7MW GBS = 1,964m^2 (based on a 50m preparation diameter) with a seabed preparation volume of up to 9,817m^3 The 15-20MW represents the worst case scenario for seabed preparation at any one time / location however **257 x 7MW wind turbines represents the worst case scenario across the Norfolk Boreas site which would be 2,523,098m^3.**
Floating	The suction pile anchor option may require a small amount of seabed preparation however the gravity anchor would not require any.	The volume of potential re-suspended sediment will be significantly less than that of gravity base foundations.

2.3.1.1 Scour Protection

28. For all types of foundations, scour protection is likely to be installed where required during construction in order to mitigate the effects of scour and the potential release of suspended sediment and seabed level changes in the vicinity of each wind turbine.

29. A number of options will be considered (and detailed within the PEIR/ ES) to protect the foundations from scour if required, including rock dumping, frond mats and mattressing. The maximum area impacted is likely to be five times the diameter of the foundation therefore a 40m GBS may require 200m diameter scour protection. The area occupied by scour protection for the various foundation types is provided in **Table 2.1**.

30. As it is intended that scour protection is used anywhere it is needed, the impact of scour as a result of turbine presence can be scoped out of the impact assessment. This is because scour protection will reduce the sediment released to negligible quantities.

2.3.1.2 Wind Turbine Layout

31. The location of the wind turbines would be finalised pre-construction based on ground investigation and constraints identified in the EIA. However, it is anticipated that the layout of wind turbines would be regular in plan (i.e. turbines will be set out in rows). The maximum capacity that may be located in Norfolk Boreas is 1,800MW.

2.3.2 Offshore Cabling

32. Two electrical solutions are being considered for Norfolk Boreas, a High Voltage Alternating Current (HVAC) scheme and a High Voltage Direct Current (HVDC) scheme. The decision on which solution to be used would be taken post consent and would depend on availability, technical considerations and cost. Both electrical solutions would have implications on the required offshore infrastructure which are detailed in the following sections.

33. The preferred installation technique and depth of burial for the offshore electrical infrastructure will be decided pre-construction based on ground investigation. Possible installation techniques include:

- Ploughing;
- Jetting;
- Dredging;
- Mass flow excavation [1]; and
- Trenching.

34. In terms of potential impacts to marine physical processes, indicative offshore cabling parameters are as follows:

- Number of cables;
    - o Up to six subsea HVAC export cables or four subsea HVDC export cables;
    - o Up to three subsea interconnector cables in up to two trenches linking the offshore substation platforms; and
    - o Array cabling - subject to the number of wind turbines and layout.
- Export cable length per cable (from substation to landfall);
    - o 140km for both HVAC and HVDC electrical solutions.
- Maximum export cable length;
    - o 840km based on six HVAC cables;
- Interconnector cable length up to 50km per cable for both HVAC and HVDC electrical solutions (maximum of three cables under the HVDC solution;
- Array cable length up to 750km;
- Temporary footprints during installation;

[1] An example of a mass flow excavator is available at http://www.rotech.co.uk/subsea/

- Export cable – temporary trench width 10m for installation with a 20m dredging corridor for the HVDC electrical solution, and a 30m dredging corridor for the HVAC electrical solution
- Interconnector cable – temporary trench width 10m for installation with a 20m pre-sweeping (dredging) corridor; and
- Array cable jetting or ploughing – trench width 1m with a 20m pre-sweeping (dredging) corridor.

- Burial depth;
  - Maximum burial depth would be 3m for the majority of the route. In soft sediments, burial up to 5m may be necessary.

35. Increases in suspended sediment concentration may result from disturbance arising from cable installation activities. To be conservative, and regardless of technique, the physical processes 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 seabed and protected).

2.3.2.1 Cable Protection

36. In some cases, cable burial would not be possible and surface laying with cable protection would be required. In addition to this it is estimated that 50m of array cable would be surface laid on approach to each wind turbine as well as 50m of export cable and interconnector cables on approach to the substation platforms. The total volume of cable protection will be estimated as part of the worst case scenario and provided in the PEIR but the following worst case scenarios are currently expected.

Array cables

37. Cable protection for unburied cables would be up to 0.5m in height and 5m wide in a trapezoid shape. Cable protection for crossings would be up to 0.9m in height and 10m wide.

38. Each wind turbine would have up to 100m of unburied array cable (two cables x 50m per structure) that would be surface laid (257 turbines = 257 x 50 x 2 = 25,700m) with an area of 128,600m^2 and volume of 38,580m^3. The area required for up to ten crossings would be 128,500m^2 with a volume of 115,650m^3.

Interconnector cables

39. The maximum length of interconnector cables that will be protected is 15km (10% of the total length of 150km). The 15km of cable would be protected with 5m wide, 0.5m high cable protection.

Export cables

40. Cable protection would be required at crossing locations in the offshore cable corridor. A total of seven crossings (five cable crossings and two pipeline crossings) are required for each cable (up to six cables) resulting in a total footprint of 42,000m^2 (based on an area per crossing of 1000m^2 and up to six cables), of which the following may be required:

- Two crossings within the Haisborough, Hammond and Winterton SAC with a footprint of 12,000m^2; and
- Five crossings in the remaining offshore cable corridor (excluding the nearshore, within the 10m depth contour, where no crossings are required).

41. The height of cable crossings would be up to 0.9m

42. Cable protection could be required at each of the landfall HDD exit points (for the long HDD option). This would entail one mattress (6m long x 3m wide x 0.3m high) plus rock dumping (5m long x 5m wide x 0.5m high) at each exit point (up to six cables).

43. Further cable protection may be required during the operation and maintenance phase, should cables become unburied (excluding in the nearshore within the 10m depth contour where no additional cable protection would be used). Up to 10km per cable (60km in total) could require additional protection under the scenario that no pre-sweeping is used during the initial installation. The need for reburial and/or protection would be significantly less where pre-sweeping is used.

2.3.3 Ancillary Infrastructure

2.3.3.1 Offshore Electrical Platforms

44. Up to three 600MW substation platforms (HVAC) or two 900MW convertor platforms (HVDC) would be required. Foundation options include:

- Piled monopile (10m diameter per substation)
- Suction caisson monopile (20m diameter caisson per substation);
- Piled tripod (3m diameter pile per substation);
- GBS 40m diameter.
- Suction caisson tripod (3 x 3m diameter caissons per substation);
- Piled quadropod (4 x 3m diameter pile per foundation); and
- Suction caisson quadropod (4 x 3m diameter caisson per foundation).

45. For marine physical processes the current worst case scenarios for substation parameters are provided in **Table 2.3**. These may be further refined within the PEIR and ES.

Table 2.3: Indicative potential worst case scenarios for offshore electrical platforms

Parameter	Worst Case
Increased suspended sediment from seabed preparation	GBS foundation type 40m in diameter and 5m depth of seabed preparation = 18,850m^3 (across all three electrical platforms)
Increased suspended sediment from drill arisings	Piled quadropod foundations platforms = 5,891m^3(across all three electrical platforms)
Footprint with scour protection	40m diameter GBS foundation with 200m diameter of scour protection = 94,248m^2 (across all three electrical platforms)

2.3.3.2 Accommodation Platform

46. A single accommodation platform could be required and the worst case scenario is the same as for the offshore electrical platforms described in section 2.3.3.1

2.3.3.3 Meteorological Masts and Buoys

47. Up to two operational meteorological masts (met masts) may be installed within the Norfolk Boreas site. Foundation options include:

- Jacket with pin piles;
- Jacket with suction caissons;
- GBS;
- Suction caisson monopole; and
- Piled monopile.

48. In addition, equipment such as LiDARs (Light Detection and Ranging) and wave monitoring devices (installed on buoys) could also be installed within the Norfolk Boreas site. For marine physical processes the worst case scenario parameters for the met masts, LiDAR and wave monitoring equipment are provided in **Table 2.4**. These may be further refined within the PEIR and ES.

Table 2.4: Indicative potential worst case scenarios for substations

Parameter	Worst Case
Increased suspended sediment from seabed preparation for met masts	Two met masts each with a 20m diameter and 5m depth of seabed preparation = 3,142m^3
Increased suspended sediment from drill arisings for met masts	Two met masts on quadropod pin piled foundations = 3,927m^3
Footprint with scour protection	Two Jacket met mast with jacket foundations = 15,708m^2 (based on 100m diameter of scour protection)
Increased suspended sediment from drill arisings for met masts	Two LiDAR mounted on a monopile foundation = 1,200m^3
No seabed preparation is anticipated for LiDAR or wave buoy installation	

2.3.4 Construction Vessels

49. Further to the infrastructure parameters outlined in sections 2.3.1 to 2.3.3, vessel anchors and jack up vessels required for construction also have the potential to impact physical processes of the seabed. The maximum number of anchors or jack-ups representing the worst case scenario will be defined in the PEIR but the worst case scenario is likely to be that jack-up vessels with four legs per barge (up to 176.71m^2 per leg, 706.86m^2 combined leg area) would be used for wind turbine installation contributing a total maximum footprint area of 363,316m^2 (based on two jacking operations per wind turbine for 257 x 7MW turbine sites).

50. It is anticipated that several types of construction vessel could work in parallel during the construction of Norfolk Boreas. For wind turbine installation, the most likely installation vessel would be a jack-up vessel, although DP vessels are also under consideration.

2.3.5 Landfall

51. The landfall is the location where the export cables are brought ashore and jointed to the onshore cables within transition pits. Norfolk Boreas would share a landfall with Norfolk Vanguard at Happisburgh South.

52. The export cables would be required to be installed in ducts under the existing sea defences and to be jointed to the onshore cables at the transition pits located on the landward side of the landfall site. Ducts would be installed using HDD which is a trenchless installation technique. The HDD would exit at one of the following two locations:

- On the beach, above the level of mean low water spring (classified as short HDD); or
- At an offshore location, seaward the beach (up to 1,000m in drill length) (classified as long HDD).

53. In the case of a short HDD, temporary beach closures may be required during drilling exit and duct installation to maintain public safety. Beach access would be required for an excavator and 4x4 vehicles.

54. The key elements at the landfall with potential affects on marine (coastal) physical processes would be:

- A total of six ducts for the HVAC option or two ducts for the HVDC electrical solution;
- A temporary footprint of works of up to 3,000m^2; and
- Full re-instatement of the site upon completion of the landfall works.

2.3.6 Construction Programme

2.3.6.1 Phasing

55. It is envisaged that Norfolk Boreas would either be built in one single phase of 1800MW, two phases of 900MW or three phases of 600MW. The location of each phase across the Norfolk Boreas site would be determined based on constraint identification throughout the EIA process as well as post consent site investigations. The EIA will therefore assess up to the capacity of 1,800MW.

56. Norfolk Boreas construction is likely to be staggered and may have temporal overlap between phases offshore. The objective is to ensure each phase is complete and generating electricity in as short a time as possible. For each potential impact during construction, the assessment will commence with a description of the single-phase approach and then will highlight any pertinent differences associated with the two and three-phased approaches.

57. Under Scenario 1 (where Vanguard has been constructed), an indicative three-phase programme would be:

- Phase 1 - Construction and commissioning 2028;
- Phase 2 - Construction and commissioning 2029; and
- Phase 3 - Construction 2029 and commissioning 2030.

58. Under Scenario 2 (where Vanguard has not been constructed), an indicative three-phase programme would be

- Phase 1 - Construction and commissioning 2027;
- Phase 2 - Construction and commissioning 2028; and
- Phase 3 - Construction and commissioning 2029.

2.3.6.2 Foundations

59. The construction programme with the longest continuous duration has the greatest potential to disturb marine physical processes. If there are breaks in construction, recovery would start to occur and therefore this is not considered to be the worst case scenario. It is expected that installation of all foundations would take up to 12 months across three years of construction. However, if breaks in construction occur the three phases of construction could occur over a period of up to seven years. Up to four foundation installation vessels will be on site at one time to install foundations simultaneously.

2.3.6.3 Offshore Cable Laying

60. Under a single-phase approach, cable laying could take up to 14 months. Under two- or three-phase approaches the principal difference compared to the single-phase approach is that installation of the cables would occur over two or three distinct phases, each lasting up to nine months or five months, respectively, but the overall time spent installing the cables would remain similar.

2.3.6.4 Landfall

61. For an indicative HDD length of 500m, it is anticipated that site establishment, drilling of six ducts and demobilisation would take approximately 30 weeks when considering 12 hour (7am-7pm), seven-day shifts. A 24-hour operation could be employed for drilling activities, subject to planning and environmental restrictions, and could reduce the installation to approximately 20 weeks. Cable pulling would be undertaken subsequent to the duct installation.

2.3.7 Operation and Maintenance (O&M) Strategy

62. Once commissioned, the wind farm would have an indicative design life of 25 years. All offshore infrastructure including wind turbines, foundations, cables and offshore substation platforms would be monitored and maintained during this period in order to maximise efficiency.

63. As for construction, vessel anchors and jack-ups required for these maintenance activities also have the potential to affect marine physical processes with the maximum number of anchors/jack-ups representing the worst case.

2.3.8 Decommissioning

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

- All of the wind turbine components;
- Part of the foundations (those above seabed level); and
- The sections of the array cables close to the offshore structures, as well as sections of the export cables.

65. 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.

66. It is anticipated that a full EIA will be carried out ahead of any decommissioning works to be undertaken.

2.3.9 Cumulative Impact Scenarios

67. Cumulative impacts will be considered through awareness of the extent of influence of changes to marine 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 seabed activities, including marine aggregate extraction and marine disposal.

2.3.9.1 Wind farm projects

68. The CIA will draw from findings of the East Anglia ZEA (EAOW, 2012a) which considered cumulative effects arising from development of the whole former East Anglia Zone, the PEIR and ES for Norfolk Vanguard (Royal HaskoningDHV, 2017b), the ES for East Anglia THREE (EATL, 2015) and the ES for East Anglia ONE (EAOW, 2012b) all of which considered cumulative effects from those projects and other project activities in close proximity. A summary of the methods used in those assessments is provided in Appendix 1.

69. Although Norfolk Boreas will undertake a screening process to define which projects will be considered in the Marine Physical Processes CIA it is considered likely that only Norfolk Vanguard, and East Anglia THREE as close enough to the project to act cumulatively. **Table 1** in Appendix 1 provides a summary of the wind farm parameters for these projects. The Norfolk Boreas EIA will also use the latest available information for new projects including East Anglia ONE North and East Anglia TWO. However these are considered to be too distance from the project to act cumulatively with Norfolk Boreas and therefore it is proposed that these are screened out of the assessment.

2.3.9.2 Other Projects

70. Any other developments (such as cables, pipelines, dredging, oil and gas) will be considered in the CIA. CIA screening will be undertaken in consultation with stakeholders.

2.3.10 Transboundary Impact Scenarios

71. Transboundary impacts will be assessed through consideration of the extent of influence of changes or effects and their potential to impact upon marine physical processes receptor groups that are located within other European Union (EU) member states.

3 BASELINE ENVIRONMENT

3.1 Desk Based Review

3.1.1 Available Data

72. The EIA Scoping Report for Norfolk Boreas (Royal HaskoningDHV, 2017c) provides an overview of the baseline conditions in relation to Marine Physical Processes based on available information.

73. Considerable data and information exists relating to marine physical processes within the former East Anglia Zone. Much of it was collated for the East Anglia ZEA (EAOW, 2012a), including from the following sources:

- Marine Renewable Atlas;
- Wavenet;
- National Tide and Sea Level Forecasting Service;
- Environment Agency (extreme sea levels database);
- TotalTide (UKHO tidal diamonds);
- BODC;
- POL Class A tide gauges;
- baseline numerical model runs;
- UKCP09 climate projections;
- BGS 1:250,000 seabed sediment mapping;
- BGS bathymetric contours and paper maps; and
- Admiralty Charts and UKHO raw survey data.

74. Numerical modelling of waves and tidal currents was undertaken as part of a Metocean Conditions Study (GL Nobel Denton, 2011) to inform the East Anglia ZEA. Wind and wave data were obtained from the BMT ARGOSS WaveWatch III model covering a ten-year period (January 1999 – December 2008), including wave height, period, direction, wind speed and direction in three-hour time steps. These data were used in a MIKE 21 Spectral Wave (SW) model to produce wave direction extremes at seven locations, fatigue data (frequency analyses) at three locations and spells analyses at two locations across the former East Anglia Zone. The model was calibrated against measured wave data from the K13, West Gabbard and Southwold buoys available via WaveNet. In addition, a MIKE 21 Flexible Mesh (FM) hydrodynamic model was developed. These models provide a useful basis for extracting further metocean parameters from different locations or different time periods across the former East Anglia Zone.

75. Deltares (2012) assessed various sets of normal and extreme metocean parameters (wind, waves, water levels and currents) across the former East Anglia Zone, for the purpose of engineering, construction, operation and maintenance. The metocean conditions at selected locations across the former East Anglia Zone were assessed by

means of extensive data analyses and hydrodynamic wave, tide and surge modelling. The modelling was based on detailed bathymetry surveys for model setup and measured wind, waves, water levels and currents for model validation. Boundary conditions for the models (wind, waves, water levels and air pressure) were based on a number of data points from the ERA-Interim global re-analysis database as developed by the European Centre for Medium-Range Weather Forecasts (ECMWF). After validation of the ERA-Interim data, the wave (SWAN) and tide (Delft3D-FLOW) models covering the former East Anglia Zone were used to hindcast a continuous period of 12 years (2000–2011) as well as for one in one, 10, 50 and 100 year extreme conditions. Modelled data was output from 20 locations across the former East Anglia Zone.

76. Further to the ZEA for the former East Anglia Zone, baseline data collected for East Anglia ONE, East Anglia THREE and Norfolk Vanguard will be considered when characterising the baseline conditions for Norfolk Boreas. In addition, data was collected for the former East Anglia FOUR site which is now Norfolk Vanguard East. Key information derived from these previous assessments of relevance has been used to outline the baseline conditions in the Norfolk Boreas EIA Scoping Report (Royal HaskoningDHV, 2017c).

3.1.1.1 East Anglia ONE Surveys

77. Project-specific surveys were undertaken for the East Anglia ONE project and provide a useful, detailed characterisation of that area of the former East Anglia Zone (EAOW, 2012b – see Volume 2 Figures 6.3 and 6.12).

78. Metocean surveys were undertaken between January 2011 and January 2012 including water levels, current velocity, and wave heights and directions. Optical backscatter sensors were deployed to capture suspended sediment concentrations.

79. High resolution swath bathymetry and side scan providing 100% coverage and shallow sub-bottom profiles were collected between April 2010 and February 2011 across the East Anglia ONE site and between October 2011 and February 2012 along the export cable corridor. These data documented the underlying geology, sediment types and thicknesses, the geometry of bedforms and sediment transport directions.

80. Benthic survey data including 150 grab samples was collected from March to September 2010 in and adjacent to the East Anglia ONE site and between July and August 2011 along the export cable corridor. These samples were used to investigate the chemical and physical composition of surface sediments.

81. Appendix 6.2 of the East Anglia ONE ES (EAOW, 2012b) provides the baseline characterisation of physical processes specific to the East Anglia ONE site. This

information is summarised within Chapter 6 of the East Anglia ONE ES (EAOW, 2012b).

3.1.1.2 East Anglia THREE and East Anglia FOUR Surveys

82. To inform the East Anglia THREE and FOUR projects, metocean surveys were completed for one year from December 2012 to December 2013, with one Acoustic Wave and Current (AWAC) meter and one Directional Wave Rider (DWR) buoy deployed within each project area (in additional to a new DWR in the East Anglia ONE site) (EATL, 2015 – see Volume 3 Figures 7.2.3 to 7.2.5).

83. A geophysical survey of East Anglia THREE and FOUR was completed between June and September 2012 (Fugro EMU, 2013), achieving 100% coverage with in-line spacing of no more than 100m covering seabed bathymetry, seabed texture and morphological features, and shallow geology.

84. Grab samples of surface sediments were collected as part of a comprehensive benthic survey undertaken in 2010 across the whole of the former East Anglia Zone. In addition, further targeted survey has been undertaken in 2013 to cover previously un-surveyed areas within the East Anglia THREE and FOUR export cable corridors.

85. Appendices 7.1 to 7.3 of Chapter 7 of the East Anglia THREE ES (EATL, 2015) provided the following baseline characterisations specific to the East Anglia THREE site.

- Appendix 7.1: Physical Processes Evidence Plan;
- Appendix 7.2: Marine Geology, Oceanography and Physical Processes – Environmental Baseline;
- Appendix 7.3: Marine Geology, Oceanography and Physical Processes – Scour Assessments; and
- Appendix 7.5 Metocean Data Report.

3.1.1.3 Norfolk Vanguard Surveys

86. Project-specific surveys were undertaken for the Norfolk Vanguard project to supplement the data collected for the former East Anglia FOUR site (Royal HaskoningDHV, 2017b – see Figures 8.1, 8.3, 8.4, 8.9, and 8.10).

87. A geophysical survey was completed for Norfolk Vanguard West and the export cable corridor between September and November 2016 (Fugro Survey B.V., 2016). For Norfolk Vanguard East, geophysical data are available from a survey of the former East Anglia FOUR site.

88. A seabed sediment grab sampling campaign was completed between October and November 2016 to fill gaps in Norfolk Vanguard and to cover the entire length of the export cable corridor (Fugro, 2017). In total, 15 additional grab samples were collected from Norfolk Vanguard West, eight from Norfolk Vanguard East and 33 from the export cable corridor.

89. A metocean campaign is ongoing within Norfolk Vanguard west; a wave buoy was deployed in June 2017 and will remain in place for three years. An AWAC will be deployed on the seabed in May 2018, for one year.

3.1.1.4 Other Relevant Studies

90. Considerable literature exists that covers the Norfolk Boreas offshore project area. This includes some major publications, including:

- 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); and
- Industry guidance.

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

3.1.2 Designated Sites

92. Consideration of offshore physical processes is also important because of the proximity of two sand bank complexes designated as the Haisborough, Hammond and Winterton SAC and the North Norfolk Sandbanks and Saturn Reef SAC. Norfolk Boreas is located east of both designated sites. The export cable corridor passes through the Haisborough, Hammond and Winterton SAC.

93. The principal receptors with respect to marine physical processes are those features with an inherent geological or geomorphological value or function which may potentially be affected by the proposed Norfolk Boreas project. For individual projects, the East Anglia ZEA recommended that the potential impacts on marine physical processes should be considered for four receptor groupings, two of which are relevant to Norfolk Boreas. These are the sensitive East Anglia coastline and the Norfolk Natura 2000 site. These receptor groups have been retained for Norfolk Boreas to allow comparability with previous work and CIA. The other two receptors (Suffolk Natura 2000 site and ‘non-designated sand banks’) are considered to be too distant from the Norfolk Boreas project to be influenced. The specific features defined within these two receptor groupings as requiring further assessment at the EIA stage for individual projects are listed in **Table 3.1**.

Table 3.1 Marine physical processes receptors relevant to Norfolk Boreas

Receptor group	Extent of coverage	Description of features	Distance from Norfolk Boreas
East Anglian coast (waves and sediment transport)	King's Lynn to Felixstowe	Gravel and sand beaches, dunes and cliffs	72km from the nearest point of Norfolk Boreas with the export cable making landfall on the East Anglian coast (at Happisburgh South)
Norfolk designated sites (waves, currents and sediment transport)	Haisborough, Hammond and Winterton SAC	Offshore sand banks	Export cable corridor passes through the SAC. The Norfolk Boreas site is 33km from the SAC at the closest point.
	Cromer Shoal Chalk Beds MCZ	Chalk reef	The export cable corridor is adjacent to the southern point of the MCZ.
	North Norfolk Sandbanks and Saturn Reef SAC / SCI	Offshore sand banks and reef	The SAC is 23km to the west of Norfolk Boreas

3.1.2.1 Haisborough, Hammond and Winterton SAC

94. The Haisborough, Hammond and Winterton SAC is highly dependent upon the prevailing marine physical processes. This SAC is located off the north-east coast of Norfolk and presents marine features which meet the descriptions for the two Annex I habitats 'Sand banks slightly covered by sea water all the time' and 'Reefs' formed by *Sabellaria spinulosa*. The Conservation Objectives for this SAC are:

- Maintain the Annex I Sand banks in Favourable Condition, implying that existing evidence suggests the feature to be in favourable condition; and
- Maintain or restore the Annex I reefs in Favourable Condition, implying that the feature is degraded to some degree.

3.1.2.2 North Norfolk Sand Banks and Saturn Reef SAC

95. North Norfolk Sand Banks and Saturn Reef SAC is located off the north-east coast of Norfolk approximately 23km west of Norfolk Boreas. The marine features and conservation objectives are the same as those for Haisborough, Hammond and Winterton SAC above.

3.1.2.3 Cromer Shoal Chalk Beds MCZ

96. Closer to the coast is the Cromer Shoal Chalk Beds MCZ. The site was designated as a MCZ in January 2016. It is located 200m off the north Norfolk coast, covering an area of 321km^2, with maximum depth of 20m.

97. The Conservation Objectives for this MCZ is to "*maintain favourable conditions for 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).*"

98. The export cable corridor is routed to the south of this MCZ to make landfall at Happisburgh South.

3.2 Data Collection

99. The data requirements for a baseline understanding of the marine physical processes at Norfolk Boreas that will underpin our understanding and provide input to the assessments can be classified into two areas: material and process. The material data includes knowledge of the geology of the seabed and sub-seabed, bathymetry, and the lithology and distribution of mobile and non-mobile sediments. The material information has been obtained through the 2017 survey data specifically collected for the Norfolk Boreas site and described below.

100. 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 previous East Anglia projects (East Anglia ONE, East Anglia Three, Norfolk Vanguard and the ZEA).

101. A metocean campaign is also planned for the Norfolk Boreas site. This will commence in May 2018 and will include the deployment for one year of a wavebuoy and AWAC near to the existing East Anglia Offshore Windfarm met mast. All available data at the time of writing will be used to inform the PEIR and ES.

102. The Norfolk Boreas baseline characterisation will also be informed by a suite of geophysical, Environmental and geotechnical surveys which were undertaken in May to October 2017, which will be reported in early 2018. The data collection included:

- A geophysical (sub-bottom profiler data, sidescan sonar, and multibeam echosounder) survey of the Norfolk Boreas site (the export cable corridor has full coverage from the previous 2016 Norfolk Vanguard survey).
- A seabed drop-down video and photographic stills supported by 35 grab samples of surface sediments within Norfolk Boreas. Each sample has been analysed for particle size.
- Collection of 50 vibrocores within the Norfolk Boreas site.

3.3 Commissioned studies

103. VWPL have commissioned three studies which will inform the Norfolk Vanguard and Norfolk Boreas EIAs, these are:

- A study completed by CWind (part of the Global Marine Group)) to predict the likely locations and maximum volumes of material which would be pre-swept prior to export cable installation (should this approach be undertaken (GMSL, Unpublished);
- A study completed by ABPmer to assess the potential rate of recovery of seabed morphology following the pre-sweep activity within the Haisborough, Hammond and Winterton SAC; and
- A study (currently being undertaken by Riggall) to assess the possible effects on erosion rates of horizontally drilling at landfall to install ducts and cables under the cliffs.

104. Further details of the above studies are provided where relevant in section 5. The CWind study has not been published as it contains confidential information, however the ABPmer study has been provided along with this Method Statement. The Riggall study has not been completed yet, but the results will be presented within the PEIR.

4 IMPACT ASSESSMENT METHODOLOGY

4.1 Defining Impact Significance

105. The assessment of effects on the marine 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.

106. An example of the S-P-R conceptual model is provided by cable installation which disturbs sediment on the seabed (source). This sediment is then transported by tidal currents until it settles back to the seabed (pathway). The deposited sediment could change the composition and elevation of the seabed (receptor).

107. Consideration of the potential effects of Norfolk Boreas on the marine 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 wind farm 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).

108. 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;
- Operation and maintenance phase; and
- Decommissioning phase.

109. For the effects on marine physical processes, the assessment will follow two approaches. The first type of assessment will be impacts on marine physical processes whereby a number of discrete direct receptors can be identified. These include certain morphological features with ascribed inherent values, such as:

- Offshore sandbanks – these morphological features play an important role in influencing the baseline tidal, wave and sediment transport regimes; and
- Beaches and sea cliffs - these morphological features play an important natural coastal defence role at the shoreline.

110. 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.

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

sediment concentrations) represent effects which may manifest themselves as an impact upon other receptors, most notably marine water and sediment quality, benthic ecology, and fish and shellfish ecology (e.g. in terms of increased suspended sediment concentrations, or erosion or smothering of habitats on the seabed).

112. Hence, the two approaches to the assessment of marine 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 (see section 4.1.1) and magnitude of effect (see section 4.1.2) by means of an impact significance matrix (see section 4.1.3).
- Situations where effects (or changes) in the baseline marine physical processes may occur which could manifest as impacts upon receptors other than marine physical processes. In this case, the magnitude of effect is determined in a similar manner to the first assessment method (see section 4.1.2) but the significance of impacts on other receptors is made within the relevant chapters of the ER pertaining to those receptors.

4.1.1 Sensitivity, Value and Magnitude

113. 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 a particular effect);
- *Adaptability* (i.e. the ability of the receptor to avoid adverse impacts that would otherwise arise from a particular 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).

114. In addition, a *value* component may also be considered when assessing a receptor. This ascribes whether the receptor is rare, protected or threatened.

115. 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).

116. The sensitivity and value of discrete morphological receptors and the magnitude of effect will be assessed using expert judgement and described with a standard semantic scale. Definitions for each term are provided in **Table 4.1**, **Table 4.2** and **Table 4.3**. These expert judgements of receptor sensitivity, value and magnitude of effect will be closely guided by the conceptual understanding of baseline conditions.

Table 4.1 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 (>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 4.2 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 4.3 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 5 to 10 years.

Magnitude	Definition
	Frequency: The effect would occur regularly but not all the time. Reversibility: The effect is very slowly reversible (5 to 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 to 5 years. Frequency: The effect would occur occasionally but not all the time. Reversibility: The effect is slowly reversible (1 to 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 <1 year. Frequency: The effect would occur highly infrequently. Reversibility: The effect is quickly reversible (<1 year).

4.1.2 Impact Significance

117. 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 4.4** as a framework to guide how a judgement of the significance will be determined.

Table 4.4 Indicative 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*

118. Through use of this matrix, an assessment of the significance of an impact will be made using expert judgement in accordance with the definitions in **Table 4.5**.

Table 4.5 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

Impact Significance	Definition
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

119. 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 in their own right, it is important to distinguish these from other non-significant (negligible) impacts as they may contribute to significant impacts cumulatively.

4.1.3 Justification for why a conceptual approach is appropriate for Norfolk Boreas

120. Considerable amounts of previous numerical modelling work has been undertaken specifically for the East Anglia ONE project located about 60km to the south of Norfolk Boreas to assess the potential effects of the offshore wind farm on the marine physical environment. The results of the modelling from East Anglia ONE (within the former East Anglia Zone) will be used as part of the expert-based assessment and judgement of potential construction and operation and maintenance effects or impacts of Norfolk Boreas. The physical basis for using the modelling results is that the East Anglia ONE wind farm design and marine physical processes operating at the site are similar to Norfolk Boreas and therefore provide suitable evidence (and is a suitable analogue) to support the assessment of effects or impacts at Norfolk Boreas.

121. Justification for using the modelling results from East Anglia ONE as the principal evidence of potential effects or impacts at Norfolk Boreas is provided in **Table 4.6**, which describes the designs and the existing physical and sedimentary conditions (water depths, tidal currents, waves, seabed sediments, sediment transport, bedforms and suspended sediment concentrations) at each of the sites.

122. The similarities (and dissimilarities) between the characteristics of each site are:

- Water depths at East Anglia ONE (30-53m CD) are slightly deeper than those at Norfolk Boreas, but are predominantly comparable;
- Tidal currents demonstrate similar directions on the flood tide (to the south or south-south-west) and ebb tide (to the north or north-north-east);
- Tidal currents have similar asymmetries with stronger ebb flows than flood flows;
- Peak spring tidal current velocities are about 1.2m/s at East Anglia ONE, and 1m/s at Norfolk Boreas;

- Predominant waves approach both sites from similar directions (from the south-south-west in East Anglia ONE and from the south-south-west and north-north-west in Norfolk Boreas);
- Maximum significant wave heights of about 4.8m and 5.2m are experienced at East Anglia ONE and Norfolk Boreas, respectively; and
- Seabed sediments at both sites are predominantly medium-grained sand with mud comprising less than 5%.

123. As a result of the above characteristics, the following marine physical processes are similar at each site:

- Tidal currents are the main driver of sediment transport and water depths are large enough to limit the effect of wave action on seabed sediments;
- Net sediment transport is towards the north as a result of the asymmetry in tidal currents;
- Sand waves of similar dimensions (6-8m high and wavelengths of 200-500m) occur across all three sites with crests oriented perpendicular to the predominant current direction;
- The majority of the sand waves are asymmetric with their steeper sides predominantly facing north, indicating migration towards the north; and
- Baseline suspended sediment concentrations are typically in the range 0 to 40mg/l.

124. Whilst it is recognised that there are small differences in conditions and project parameters between the East Anglia ONE and Norfolk Boreas project sites, the highly conservative nature of the numerical modelling conducted for East Anglia ONE (discussed further throughout the impact assessments) allow for these differences in the effect that may arise due to these factors.

125. In addition, East Anglia ONE is more likely to have an impact at the coast compared to Norfolk Boreas because it is much closer. However, the modelling of East Anglia ONE predicts no marine physical processes impacts at the coast, because the zones of influence for waves, tidal currents and sediment transport do not impinge on the coast. Hence, given the similarities between the two wind farms, their respective distances from the coast and the smaller number of turbines in Norfolk Boreas, means that marine physical processes impacts at the coast from Norfolk Boreas are extremely unlikely. Numerical modelling of marine physical processes effects of Norfolk Boreas would be disproportionate to the potential impact and an expert-based assessment is preferable.

Table 4.6 Comparison of design and marine physical processes parameters at East Anglia ONE and Norfolk Boreas

Parameter	East Anglia ONE	Norfolk Boreas
Area	300km^2	297km^2
Distance from shore	43.4km at closest point	70.0km at closest point
Indicative capacity	Up to 1,200MW	Up to 1,800MW
Number of largest wind turbines	150 (8MW)	90 (20MW)
Number of smallest wind turbines	325 (3MW)	257 (7MW)
Export cable corridor length	73km	89km
Cable landfall	Bawdsey	Happisburgh South
Minimum water depth	30.5m CD	20m CD
Maximum water depth	53.4m CD	43m CD
Current regime	The flood tide is to the south to south-south-west and the ebb tide is to the north to north-north-east. Peak spring depth-averaged tidal current speeds within the East Anglia ONE site are around 1.15 to 1.25m/s, with the fastest velocities recorded in the north of the site. Mean neap values are approximately half of that recorded during spring tides.	The flood tide is to the south and the ebb tide is to the north. Peak spring tidal current velocities are about 1m/s at Norfolk Boreas.
Wave regime	Waves propagate in general through the East Anglia ONE site from the north to north-north-east and from the south-south-west. Maximum significant wave heights of approximately 4.8m have been recorded over a years' survey period. The mean significant wave height was 1.21m.	Waves propagate in general through the Norfolk Boreas site from the north to north-north-east and from the south-south-west. Maximum 1 in 1 year significant wave heights of approximately 5.2m have been estimated.
Seabed sediment	Seabed sediments across the East Anglia ONE site generally consist of slightly gravelly sand with some sand and sandy gravel. Fine (silt and clay sized) particles	Seabed sediments across the Norfolk Boreas site generally consist of sand and slightly gravelly sand with some gravelly sand. Fine (silt and clay sized) particles

Parameter	East Anglia ONE	Norfolk Boreas
	are largely absent (less than 2%). On average all grab samples comprise approximately 75% medium grained sand (in the range 0.25 to 0.5mm).	are absent in 55% of the samples, with 10% less than 2% mud, and the remainder (35%) containing between 2 and 20%. On average grab samples comprise approximately 60% medium grained sand (in the range 0.25 to 0.5mm).
Bedload sediment transport	Within the East Anglia ONE site, sediment transport is predominantly under the control of tidal forcing and because water depths are generally between 30 and 50m CD, only large, infrequently occurring storm waves are likely to have any significant influence on sediment transport at the bed. Across most of the East Anglia ONE site, net sediment transport is towards the north as a result of the asymmetry in tidal currents.	Within the Norfolk Boreas site, sediment transport is predominantly under the control of tidal forcing and because water depths are generally between 20 and 43m CD, only large, infrequently occurring storm waves are likely to have any significant influence on sediment transport at the bed. Across most of the Norfolk Boreas site, net sediment transport is towards the north as a result of the asymmetry in tidal currents.
Bedforms	Dense fields of active migrating sand waves are extensive in the southern third of the East Anglia ONE site, as well as in the east and the northern corner of the site. These sand waves can have heights of over 8m and wavelengths of up to 500m, whilst many of the sand waves show some degree of asymmetry.	Dense fields of active migrating sand waves are present across the Norfolk Boreas site related to a series of five north-south oriented sand banks. These sand waves can have heights of up to 6m and wavelengths up to 700m. All the large sand waves have a steeper slope facing to the north.

5 POTENTIAL EFFECTS

5.1 Potential Effects during Construction

5.1.1 Effect: Changes in Offshore Suspended Sediment Concentrations, Seabed Levels and Sediment Type

5.1.1.1 Foundation Installation

126. 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 seabed.

127. 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 seabed. Drilling has the potential to disturb seabed and sub-seabed sediments, which are raised to the sea surface from where they may be dispersed into the water column. For suction caisson and GBS foundations, an area of seabed may need to be ploughed or dredged (seabed preparation) in order to provide a level surface upon which they are installed. Installation of scour protection or anchors for floating turbines would also disturb seabed sediments.

5.1.1.2 Cable Installation

128. 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 sand bank complex designated as the Haisborough, Hammond and Winterton SAC, which meets the Annex 1 habitat description 'Sandbanks slightly covered by sea water all the time'.

129. A variety of techniques could be used to excavate a trench for each export cable (and array and interconnector cables). These include jetting, ploughing, trenching, cutting, mass flow excavation and pre-sweeping (dredging). During excavation (by whichever method), 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 corridor and, depending on the extent of sediment transport, in more remote environments.

130. An important component of the potential release of suspended sediment is pre-sweeping sand waves along the proposed cable route corridor that passes through the Haisborough, Hammond and Winterton SAC (GMSL, unpublished). Pre-sweeping

is essentially the removal of the top of the sand waves where the sediment is considered to be mobile and migrating. The gap created by removal of the pre-swept sediment creates a path through the sand waves that allows the cable to be buried. GMSL (unpublished) calculated a pre-sweep sediment volume to be approximately 1,400,000m^3 for the Norfolk Boreas cables under the worst case scenario (6 HVAC export cables)

5.1.1.2.1 Approach to Assessment

131. 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 Norfolk Boreas where available:

- Previous Zonal CIA (in the ZEA);
- Expert based assessment of potential effects previously undertaken for East Anglia THREE (in its ES) and Norfolk Vanguard (in its PEIR), both of which were verified and tested against the numerical modelling for East Anglia ONE;
- Detailed modelling previously undertaken for the East Anglia ONE project (EAOW, 2012b); and
- GMSL (Unpublished) completed a study which predicts the likely locations and volumes of material which will need to be pre-swept prior to export cable installation

132. The results from these previous developments indicate that the effects on suspended sediment concentrations of their construction activities were minimal. These studies will be used as analogies for Norfolk Boreas:

- Modelling for East Anglia ONE and the expert-based assessments for East Anglia THREE and Norfolk Vanguard show no significant effect from construction activities for those projects.
- Tidal ellipses across the former East Anglia Zone show no significant potential for interaction, even within several consecutive tidal cycles, between Norfolk Boreas and sensitive seabed and shoreline receptors.
- Sediment characteristics indicate only a very small proportion of fine sediment content and therefore sediment plumes are expected to be limited and sediment will fall to the seabed in relatively close proximity to its point of release into the water column.

133. The proposed approach is considered proportionate to the likely risk of significant impact on the habitat. This is because the planned export cables will pass through a predominantly sandy environment 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 seabed in relatively close proximity to its point of release into the water column.

5.1.2 Effect: Indentations on the Seabed due to Installation Vessels

134. There is potential for certain vessels used during the installation of the wind farm and offshore cable infrastructure to directly impact the seabed. This applies for those vessels that utilise jack-up legs or a number of anchors to hold station and to provide stability for a working platform. Where legs or anchors (and associated chains) have been inserted into the seabed and then removed, there is potential for an indentation 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.

5.1.2.1 Approach to Assessment

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

5.1.3 Effect: Changes in Coastal Sediment Transport and Suspended Sediment Concentrations at the Landfall

136. The proposed export cable corridor for Norfolk Boreas will make landfall at Happisburgh South where it must transit through the intertidal zone. It is presently envisaged that cable ducts and a HDD technique would be used. Installation of the ducts and the HDD process 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.

137. The HDD for Norfolk Boreas will exit either on the beach, above the level of mean low water spring (short HDD) or at an offshore location, away from the beach (up to 1000m in drill length from the onshore HDD location) (long HDD). Cable burial will be undertaken from the HDD exit point in the intertidal or subtidal zone. Short HDD is considered to be the worst case for this particular impact.

5.1.3.1 Approach to Assessment

138. The north-east Norfolk coast has been subject to numerous detailed investigations of coastal geomorphology and processes, including the Shoreline Management Plan 2, Southern North Sea Sediment Transport Study, peer-reviewed publications, and ongoing studies to develop a strategy for coastal protection at Bacton Gas Terminal.

139. The existing studies in the landfall areas discussed above, 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 Happisburgh South and its adjacent areas. Therefore, the proposed approach to assess the cable landfall for

Norfolk Boreas is to review existing data and apply expertise-based interpretation within the context of the construction programmes for the project.

140. The landfall is south of Bacton Gas Terminal where there is an ongoing EIA in relation to undertaking large-scale beach nourishment (sand engine) as a coastal protection technique. The CIA of coastal processes will consider how the landfall construction and operation at Happisburgh South will interact with proposed coastal protection and the Norfolk Vanguard landfall.

5.2 Potential Effects during Operation and Maintenance

5.2.1 Effect: Changes to Tidal and Wave Regimes due to the Presence of Foundation Structures

5.2.1.1 Tidal Regime

141. Over the operational lifetime of the proposed project, the tidal regime effects are likely to be evident through persistent and direct changes, resulting from tidal current interactions with the foundation structures. The potential effects on the tidal regime associated with the presence of the foundations may include changes to the naturally occurring patterns of tidal water levels, current speeds and directions. 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 particular layout pattern.

5.2.1.2 Wave Regime

142. When waves coincide with a wind turbine foundation, 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.

5.2.1.2.1 Approach to Assessment

143. 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 previous wind farm assessments (including post-construction monitoring), East Anglia ZEA, East Anglia ONE EIA, East Anglia THREE EIA and Norfolk Vanguard PEIR will be used to identify potential tidal current and wave changes local to each foundation.

144. 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, 2002; COWRIE, 2009) and numerous Environmental Statements for offshore wind farms (e.g. Dogger Bank Creyke Beck, Royal Haskoning 2013). Numerical modelling of changes in hydrodynamics associated with the East Anglia ONE project also describe small magnitude and localised changes in tidal currents.

145. There is also a strong scientific evidence base which demonstrates that the changes in the wave regime due to the presence of foundation structures, even under a worst case of the largest diameter GBS, are both relatively small in magnitude and relatively localised 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 in close proximity to each wind turbine, reducing with greater distance from each wind turbine. Effects are relatively localised 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). This evidence base is supported by the more conservative wave modelling completed on East Anglia ONE.

146. For waves, the assessment will also consider the relative effects of different foundation types in different water depths experienced across Norfolk Boreas.

5.2.2 Effect: Changes to Seabed Morphology due to the Presence of Foundation Structures

147. Seabed morphology directly impacted by the footprint of each foundation structure on the seabed within the site, constitutes a loss in natural seabed area during the operational life of the proposed project.

5.2.2.1 Approach to Assessment

148. The assessment will quantify the construction footprint and the total loss of seabed habitat due to the foundations and compare that area to the total seabed area within the site. These data will then be used to assess the likely scale and area of effect.

5.2.3 Effect: Sediment Transport due to Cable Protection Measures

149. Parts of the array cables and offshore and nearshore export cables may require some form of protection on the seabed (rock dumping, frond mats or grout bags). The cables may be surface laid for up to 50m on approach to the wind turbines or platforms and if there is an absence of sufficient surface sand to allow burial. There

is also a possibility that up to 10km per export cable (60km in total) could require additional protection under the scenario that no pre-sweeping is used during the initial installation, which could potentially create a partial barrier to sediment transport. This potential effect is particularly prevalent within the designated sand bank complex where a continuous flux of bedload sediment transport through the Norfolk Boreas export cable corridor is likely to occur. This sediment transport regime supports the morphological integrity of the banks.

5.2.3.1 Approach to Assessment

150. The key factors in determining the magnitude of the potential effect on bedload sediment transport of remedial protection are the type and aerial extent of transport on the bed. The two main drivers of transport in the nearshore zone are waves and tidal currents further offshore. The aerial 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.

151. 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 seabed as a result of wave-driven processes.
- Active nearshore cross-shore sediment transport: this transport mechanism also occurs along the nearshore seabed 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. Cables, or cable protection works, would be unlikely to significantly affect cross-shore sediment transport since they would be laid broadly in alignment with the cross-shore transport direction, providing little obstruction to sediment movement.

5.2.4 Effect: Impact to Morphology and Sediment Transport of Designated Sites

152. Any morphological or sediment transport impacts to the designated sites during either construction or operation will be related to the effects on marine physical processes described above. The export cables will pass through the Haisborough, Hammond and Winterton SAC.

153. An important element of the cable installation would be the potential need to pre-sweep sand waves in the cable corridor. Up to 1,400,000m^3 would need to be

dredged from sand waves within Haisborough, Hammond and Winterton SAC and disposed of within the SAC boundary. The seabed remaining after dredging will initially have a different morphology to the existing bed and there is the potential to alter the form and function of this area. Two key potential impacts would be:

- The potential for the sand waves within the SAC not to reform following dredging of their crests; and
- The transport and final destination of the sediment that is disposed of within the SAC (is their potential for it to be transported outside the SAC).

5.2.4.1 Approach to Assessment

154. Establishing the extent to which the seabed is mobile in the area of interest is fundamental to understanding the rate/ timescales over which the seabed may recover from dredging. Accordingly, the commissioned study (ABPmer, 2017) has furthered the understanding of seabed mobility in the area and assessed potential impacts on their form and function using three complementary approaches:

- Desk based literature review to develop an initial conceptual understanding of the system;
- Investigation of bedform migration rates through interrogation of available detailed bathymetric survey data; and
- Desk based empirical analyses considering potential sediment transport rates.

155. The findings of this study were that although the sandwaves may not recover to the precise shape of that exhibited before the pre-sweep, their overall form will recover and therefore their function will also recover.

156. Given the large amounts of existing information and assessment (both local to the banks and from analogous examples close to or within other sand banks in the southern North Sea), an assessment of effects based on a conceptual understanding and the use of expert judgement to predict changes is proposed, without the need for numerical modelling. There is also a large existing evidence base from industry best practice guidance (BERR, 2008) and modelling of other wind farms (e.g. Nysted, Kentish Flats, Cromer, Dogger Bank) that shows that the marine physical processes impacts of cable installation are insignificant to the form and function of the surrounding environment.

157. 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 Norfolk Boreas:

- ABPmer (2017) Norfolk Vanguard Export Cable Route Sandwave bed levelling;
- Burningham and French (2016) Study of morphological change of the Haisborough banks and their interconnecting seabed through analysis of historical charts; and

- GMSL (Unpublished) completed a study which predicts the likely locations and volumes of material which will need to be pre-swept prior to export cable installation; and

5.3 Potential Effects during Decommissioning

158. The types of effect would be comparable to those identified for the construction phase, namely:

- Changes in suspended sediment concentrations and seabed levels due to foundation removal;
- Changes in suspended sediment concentrations and seabed levels due to removal of parts of the array, platform link and interconnector cables;
- Changes in suspended sediment concentrations and seabed levels due to removal of parts of the export cables;
- Indentations on the seabed due to decommissioning vessels; and
- Changes in coastal sediment transport and suspended sediment concentrations due to removal of the landfall infrastructure.

5.3.1 Approach to Assessment

159. The approach to assessment will be as for construction outlined above.

5.4 Potential Cumulative Impacts

160. The Norfolk Boreas CIA will consider the staged nature of offshore wind development within the former East Anglia Zone (further detail provided in Appendix 1, 2 and 3) as well as the relative proximity of Norfolk Boreas to other offshore activities, including the North Sea oil and gas fields, shipping routes and marine aggregate dredging sites. The CIA will also consider cumulative impacts with Norfolk Vanguard, but only under Scenario 1. The export cables of Norfolk Boreas will be installed along the same cable corridor as Norfolk Vanguard (with separate spurs to each wind farm site). The current proposed list of projects for consideration in the CIA are:

- Norfolk Vanguard offshore wind farm (Under Scenario 1)
- East Anglia THREE Offshore windfarm;
- Marine aggregate dredging; located approximately 27km south of the export cable corridor; and
- Decommissioning of oil and gas infrastructure within and in close proximity to the Norfolk Boreas site.

161. Other projects such as the Hornsea and Dogger Bank Wind Farms, and East Anglia ONE East Anglia ONE North and TWO are considered too distant to have a cumulatively effect with Norfolk Boreas.

162. As presented in the Norfolk Vanguard PEIR, due to the fact that the Norfolk Boreas HDD at landfall is unlikely to have an impact on coastal erosion and the nearshore cable protection would have negligible impact on sediment transport processes at the coast, there will be no cumulative impacts between Norfolk Vanguard and Bacton sand engine or the Bacton coastal protection scheme.

5.4.1 Construction Changes to the Suspended Sediment Concentrations

163. Cumulative construction effects will be restricted to interaction of sediment plumes and their deposition on the seabed. Cumulative effects may arise if the construction of foundations and cables at Norfolk Boreas 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 seabed.

5.4.1.1 Approach to Assessment

164. 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.

5.4.2 Operational Changes to the Tidal Current and Wave Regimes

165. The cumulative effect of the operation of Norfolk Boreas with other offshore projects could occur for waves and tidal currents.

166. On the basis of modelling analyses for previous offshore wind farm developments, post-construction monitoring and published guidance documents, changes to tidal current velocities are expected to be greatest in the immediate vicinity of the foundation structures and reduce with increased distance away. Outside of the array, it was considered that changes in flow speed would be confined to within one peak spring tidal excursion of the array boundary.

167. A number of simple empirical relationships were used to determine the interactions between waves and foundation structures within the former East Anglia Zone and then expert judgement was used alongside an analysis of the predominant wind and wave directions to determine the effect of wave blocking caused by different foundation types on the identified receptor groups. It was considered that the

largest changes to individual wave heights would occur within the former East Anglia Zone, with wave shadowing in a down-wave direction of each foundation.

5.4.2.1 Approach to Assessment

168. The results of the East Anglia ZEA (see Appendix 1) numerical modelling will be used as a basis for the CIA for Norfolk Boreas. This assessment concluded that the potential cumulative impacts to identified receptor groups arising from changes to the tidal current regime were not significant, but it recommended that the effect should be considered further at the EIA stage in respect of the Haisborough, Hammond and Winterton SCI (now SAC) and the North Norfolk Sandbanks and Saturn Reef SCI (now SAC). Potential cumulative impacts arising from changes to the wave regime were also concluded to be not significant, but require further consideration at the EIA stage in respect of the East Anglia coastline, as well as the Haisborough, Hammond and Winterton SAC and the North Norfolk Sandbanks and Saturn Reef SAC.

5.4.3 Operational Changes to the Sediment Transport Regime

169. The cumulative effect on waves and tidal currents could potentially have a cumulative effect on the bedload sediment transport regime.

170. Following analyses of residual tidal current vectors, residual bedload transport vectors and other regional bedload transport indicators, it was identified that across almost the entire former East Anglia Zone, sediment transport is in a northerly direction across the seabed. Along the coastline of Norfolk, sediment transport is generally to the south.

5.4.3.1 Approach to Assessment

171. The results of the sediment transport analysis for the ZEA will be used as a basis for the CIA for Norfolk Boreas. The assessment concluded that the potential cumulative impacts to identified receptor groups arising from changes to the sediment transport regime were not significant for all but one receptor group. The potential cumulative impacts to the sediment transport regime at the East Anglian coast were considered to be of moderate significance since at its closest point this coastline is only 15km from the boundary of the former East Anglia Zone. The assessment recommended that the effect should be considered further at the EIA stage in respect of the Haisborough, Hammond and Winterton SAC and the North Norfolk Sandbanks and Saturn Reef SAC.

5.5 Supplementary documentation

172. The PEIR and ES will contain as appendices:

- The ABPmer (2018) study on recoverability of sand waves within the SAC described above;
- The Geophysical, Geotechnical, and Benthic survey reports provided by Fugro; and
- Burningham and French (2016).

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APPENDIX 1 - CIA WITH OTHER PROJECTS WITHIN THE FORMER EAST ANGLIA ZONE

173. Previous work has been undertaken within the former East Anglia Zone and for the East Anglia ONE, East Anglia THREE and Norfolk Vanguard projects to assess the potential effects of the offshore wind farms on the marine physical environment. This Appendix 1 provides an overview of the East Anglia ONE, East Anglia THREE and Norfolk Vanguard (Norfolk Vanguard West and Norfolk Vanguard East) Marine Physical Processes assessments.

174. The findings from the Zonal CIA, the ES's of East Anglia Project ONE, East Anglia Project THREE and Norfolk Vanguard and other studies collected independently of the previous East Anglia wind farms, are important in defining a suitably robust, yet proportionate assessment methodology for the assessment of marine physical process effects arising from the proposed Norfolk Boreas project.

Former East Anglia Zone Environmental Appraisal

175. Chapter 5 of the former East Anglia Zone Environmental Appraisal (ZEA) (EAOW, 2012a) presents the Zonal CIA for physical processes, based on a 'Source-Pathway-Receptor' conceptual model. It considered the potential for anthropogenic changes to occur both within the former East Anglia Zone and across the wider physical processes area which covers the seabed of large areas of the southern North Sea and the adjacent shores of the United Kingdom and mainland Europe.

176. The assessment was undertaken using expert judgment, based upon an understanding of tidal excursion, sediment mobility and sediment transport pathways established through detailed baseline studies. It was also informed using an evidence-base established from Environmental Statement (ES) chapters and post-construction modelling associated with operational offshore wind farm developments. The assessment process considered issues such as the magnitude of effect, the sensitivity of the receptor, the value of the receptor and the degree of interaction to determine a regional significance level. The foundation types considered included jackets and GBS.

177. The principal receptors considered in the Zonal CIA included:

- The sensitive coasts within the area;
- Morphological features contained within the offshore European Union (EU) designated conservation sites;
- Morphological features contained within the coastal EU designated conservation sites; and

- Non-designated sediment banks located in close proximity to the former East Anglia Zone, and which may afford protection to the coast by dissipating wave energy.

178. These receptors have the potential to be directly affected by anthropogenic changes to the tidal currents and/or changes to the wave regime, or consequent changes to the sediment regime in terms of transport at the seabed, transport at the coast and transport within the water column. It is principally the physical disturbance during foundation or cable installation and the physical presence of the foundations that have the greatest potential to interact with physical processes, causing the changes which may affect the receptors.

179. The findings from this Zonal CIA concluded that cumulative impacts on the Norfolk Natura 2000, Suffolk Natura 2000 sites and on the sensitive East Anglia coast should be considered further at the EIA stage for changes to the tidal current, wave and sediment regimes. These issues were further investigated specifically for East Anglia ONE and reported in the accompanying ES for that project.

180. The Zonal CIA continues to be relevant because it assessed similar geographical project areas and assumed a larger number of foundations than the proposed CIA for Norfolk Boreas. It is likely, therefore, to over-estimate the cumulative impact, but still concluded that the offshore impacts would not be significant.

East Anglia ONE EIA

181. The Norfolk Boreas EIA will draw on the approach and findings of East Anglia ONE but due to the distance between the projects, will not include this project in the CIA.

182. Chapter 6 of the East Anglia ONE ES (EAOW, 2012b) presents an assessment of the potential impacts on the marine physical processes arising from East Anglia ONE. This assessment is based on a combination of analysis of site data (including former East Anglia Zone-specific and East Anglia ONE project-specific geophysical, geotechnical, benthic and metocean surveys), consideration of the existing evidence base from the construction and operational phases of other offshore wind farms, empirical evaluation using industry standard formulae, and detailed numerical modelling using the Delft3D suite hydrodynamic (FLOW), wave (SWAN) and sediment plume (PART) models.

183. The East Anglia ONE EIA included initial former East Anglia Zone-wide modelling and then additional modelling specific to East Anglia ONE. The latter wave and tidal current models covered the whole East Anglia ONE project area and cable route and adjacent seabed areas. However, for suspended sediment transport, the model was restricted to determine the effects of the consecutive construction of 15 GBS. The cable route was included in the model domain and used to assess the effects of

offshore cable installation and the cumulative effects of offshore cable installation and aggregate dredging.

184. Where modelling was undertaken, it was used to quantify the impacts in terms of geographical extent and magnitude of change when compared against the baseline conditions. Further details regarding the set-up, calibration and application of the numerical modelling tools is provided in Appendix 6.1 of the East Anglia ONE ES Volume 2 (EAOW, 2012b).

185. The assessment of potential effects of East Anglia ONE upon the physical processes was undertaken in three stages:

1. Determination of the baseline physical environment (including climate change effects over the 25-year operational lifetime of the project;
2. Determination of the worst case scenario; and
3. Assessment of near-field and far-field effects arising from the worst case scenario during its construction, operation and maintenance, and decommissioning phases using a 'Source-Pathway-Receptor' conceptual model.

186. The assessment process considered the magnitude of an effect in terms of its scale, duration, frequency and reversibility alongside receptor attributes such as the value of the receptor, its tolerance to an effect, its ability to adapt to or avoid an adverse effect, and its recoverability to evaluate a significance level of the effect. Significance was then evaluated ranging from 'not significant', through 'moderate significance' to 'major significance'.

187. The findings from this project-specific EIA that are relevant to Norfolk Boreas are presented in further detail in Appendix 2 of this Method Statement and will be used to inform the assessment of Norfolk Boreas.

East Anglia THREE EIA

188. Chapter 7 of the East Anglia THREE ES (EATL, 2015) presents an assessment of the potential impacts on marine geology, oceanography and physical processes arising from East Anglia THREE. The assessment was based upon the Method Statement agreed by the regulators to adopt an approach to assessment based on interpretation of the evidence base using expert judgement. The assessment of effects of East Anglia THREE was therefore informed by the following:

- Interpretation of field data specifically collected for the proposed East Anglia THREE project;
- Consideration of the existing evidence base regarding the effects of offshore wind farm developments on the physical environment;

- Empirical assessments (assessments using empirical formulae cited in published, peer-reviewed literature) of scour formation around the wind turbine foundations;
- Cross-reference to previous detailed numerical modelling studies undertaken for both the East Anglia ZEA (EAOW, 2012a) and the ES of the East Anglia ONE project (EAOW, 2012b);
- Discussion and agreement with key stakeholders; and
- Application of expert-based judgement.

189. No new modelling was considered necessary with justification provided in the East Anglia THREE Evidence Plan.

190. The potential effects upon marine geology, oceanography and physical processes were assessed conservatively using realistic worst case scenarios for the proposed East Anglia THREE project.

191. The findings from the East Anglia THREE ES relevant to Norfolk Boreas are presented in Appendix 3 of this Method Statement and will be used in the CIA for Norfolk Boreas.

Norfolk Vanguard Preliminary Environmental Information

192. In addition to Norfolk Boreas, VWPL is also developing the Norfolk Vanguard offshore wind farm to the south (Norfolk Vanguard East) and west (Norfolk Vanguard West), with the EIA following approximately a year after the Norfolk Vanguard EIA. The development of Norfolk Boreas would use the same export cable corridor as Norfolk Vanguard with the addition of a spur to the Norfolk Boreas site.

193. If Norfolk Boreas uses the same landfall as Norfolk Vanguard, a total of 12 ducts would be required at the landfall (six for each project under the worst case HVAC electrical solution).

194. The full implications of Norfolk Boreas and Norfolk Vanguard cumulative impact scenarios, as well as cumulative impacts with respect to other existing and planned projects (including, but not limited to, East Anglia THREE, East Anglia ONE, East Anglia One North and East Anglia Two) will be fully considered as part of the EIA process.

195. The assessment process for Norfolk Vanguard was informed by the following:

- Interpretation of survey data specifically collected for the proposed project including bathymetry, geology and metocean;
- Interpretation of survey data collected for the previous East Anglia FOUR project (located in a similar position to Norfolk Vanguard East);

- Consideration of the existing evidence base regarding the effects of offshore wind farm developments on the physical environment;
- Cross-reference to previous detailed numerical modelling studies undertaken for both the former East Anglia Zone Environmental Appraisal (ZEA) and the ES of East Anglia ONE and desk-based assessments undertaken for the ES of East Anglia THREE;
- Discussion and agreement with key stakeholders; and
- Application of expert-based assessment and judgement by Royal HaskoningDHV.

196. No new modelling was considered necessary with justification provided in the Norfolk Vanguard Evidence Plan.

197. The findings from this detailed project-specific Preliminary Environmental Information relevant to Norfolk Boreas are presented in detail in Appendix 4 of this Method Statement and will be used in the CIA for Norfolk Boreas. The Norfolk Vanguard ES will also be used to inform the Norfolk Boreas PEIR.

Projects to be screened into the assessment

198. **Table 1** below provides a summary of the wind farm parameters for the projects that will be screened into the CIA assessment .

Table 1. Worst case scenarios for marine physical processes for East Anglia THREE, Norfolk Vanguard and Norfolk Boreas within the former East Anglia Zone

Parameter	EA THREE	Norfolk Vanguard East	Norfolk Vanguard West	Indicative Norfolk Boreas parameters
Area	305km^2	297km^2	295km^2	725 km^2
Distance from shore	69km from the closest point to Lowestoft	89km	73km	70km at closest point
Min water depth	25m LAT	21m CD	25m CD	20m CD
Max water depth	49m LAT	45m CD	47m CD	43m CD
Indicative capacity	Up to 1200MW	Up to 1,200MW	Up to 1,800MW	Up to 1,800MW
		Combined maximum capacity of 1800MW		
Number of largest wind turbine	100 (12MW)	120 (15MW)		90 (20MW)
Number of smallest wind turbine	172 (7MW)	257 (7MW)		257 (7MW)
Indicative spacing	675m in row and 900m between row	4 to 15 x rotor diameter (rotor diameter 154m to 303m)		4 to 20 x rotor diameter (616 to 6,060m)
Cable corridor	166km	~89km	~73km	89km
Cable landfall	Bawdsey	Happisburgh South	Happisburgh South	Happisburgh South
Foundation options considered	• 40 – 60m diameter GBS • 25 – 30m diameter suction caisson • 10 – 12m diameter monopile • 33.5x33.5 – 43.5x43.5 jacket with pin piles • 38x38 – 50x50 jacket with suction caisson	• 40 – 50m diameter GBS • 8.5 – 10m diameter suction caisson monopile • 8.5 – 10m diameter monopile • 30x30 – 40x40 jacket (tripod or quadropod) with pin piles • 30x30 – 40x40 jacket (tripod or quadropod) with suction caisson • Floating wind turbines with tension mooring (parameters to be confirmed)		• GBS • Monopile • Jackets on pin piles (on three of four legs) • Jackets on suction caissons (on three of four legs • Floating wind turbines with tension mooring
Worst Case Scenario	GBS (seabed preparation,	GBS (seabed preparation, sediment released at		GBS (seabed preparation, sediment

Parameter	EA THREE	Norfolk Vanguard East	Norfolk Vanguard West	Indicative Norfolk Boreas parameters
(WCS) surface / shallow depth sediment displacement for foundations during construction	sediment released at surface of water column)	surface of water column)		released at surface of water column)
WCS surface / shallow depth sediment displacement for cables during installation	Jetting or vertical injector (using jetting) in shallower areas. All cables buried up to 5m in depth	Jetting, ploughing, dredging, mass flow excavation or trenching. Target depth of burial is 1 to 3m with up to 5m potentially necessary in soft sediments		Jetting, ploughing, dredging, mass flow excavation or trenching. Target depth of burial is 1 to 3m with up to 5m potentially necessary in soft sediments
WCS sub-surface sediment displacement	Jacket (drilling)	Jacket (drilling).	Jacket (drilling).	Jacket (drilling)
WCS physical blockage during operation	GBS with minimum wind turbine spacing	GBS with minimum wind turbine spacing.	GBS with minimum wind turbine spacing.	GBS with minimum wind turbine spacing.
WCS Piled Monopile	Maximum 172 12m diameter piles to a seabed depth of 40m. 4,524m^3 of sediment disturbance per wind turbine. Total volume of 778,128m^3	Piles drilled up to a penetration of 30m into seabed before piling up to 50m penetration. Drilling estimated to be required at up to 50% of wind turbine locations. Scour protection (if required) of 5x monopile diameter, so 10m diameter monopile = 50m diameter scour protection		Piles drilled up to a penetration of 30m into seabed before piling up to 50m penetration. Drilling estimated to be required at up to 50% of wind turbine locations. Scour protection (if required) of 5x monopile diameter, so 10m diameter monopile = 50m diameter scour protection
WCS Suction Caisson Monopile	Bucket diameter up to 25m for 7MW wind turbine and 30m for 12MW wind turbines	Bucket diameter up to 25m for 7MW wind turbines and 35m for 15-20MW wind turbines. Maximum penetration depth of 10 to 30m, respectively		Bucket diameter up to 25m for 7MW wind turbines and 35m for 20MW turbines. Maximum penetration depth of 15m and 30m respectively.
WCS Jacket with Suction Caisson (tripod or quadropod)	Bucket diameter up to 10m for 7MW wind turbine and 10m for 12MW wind turbine	Bucket diameter up to 12m for 7MW wind turbine and 15m for 15-20MW wind turbines. Maximum penetration depth of 12 to 15m, respectively. Bucket spacing to centre - 30m		Bucket diameter up to 12m for 7MW wind turbines and 15m for 20MW wind turbines. Maximum penetration depth of 12 and 15m, respectively. Bucket

Parameter	EA THREE	Norfolk Vanguard East Norfolk Vanguard West	Indicative Norfolk Boreas parameters
			spacing centre to centre 35m and 50m respectively.
WCS Jackets with Pin Piles (tripod or quadropod)	Maximum 172. Each jacket has four legs, each up to 3.5m in diameter. Penetration 50m into seabed. Spill volume 481m^3 per pile, 1,924m^3 per jacket. Assumed 100% disaggregation into component particle sizes.	Spacing between legs is a maximum of 40m. Piles drilled up to 25m into seabed before piling up to 50m penetration. Drilling estimated to be required at up to 50% of wind turbine locations. Scour protection if required	Spacing between legs at seabed is max. 35m (7MW) or 50m (20MW). Piles drilled up to 20 or 25m into seabed before piling up to 40m or 50m penetration depth (respectively). Drilling estimated to be required for up to 50% of wind turbine locations, with scour protection if required.
WCS GBS	Maximum 172 with base diameter of 40m. 17,500m^3 seabed preparation per wind turbine. Total seabed preparation volume of 3,010,000m^3	Base slab diameter up to 50m. Seabed preparation up to 60m diameter as necessary. Scour protection if required up to five times foundation diameter	Base slab diameter up to 50m. Seabed preparation up to 60m diameter as necessary. Scour protection if required up to five times foundation diameter and up to 5m depth.
WCS Floating	N/A	Anchor options include suction caisson, piles, or drag anchor. Mooring lines will either be catenary (with slack to allow the wind turbine to rise and fall with the tide) or under tension. Parameters TBC	Maximum diameter of floating structure 70m with max. 12 anchor lines. Water penetration depth of maximum 35m. Anchor options include suction caisson (max diameter 30m), piled anchor or gravity anchor.
WCS Collector, Converter and Rectifier Substation Platforms	Up to six offshore platforms, 103x155m foundation dimensions. 73,225m^3 seabed preparation per wind turbine. Total seabed preparation volume of 439,350m^3	HVAC electrical solution – three 600MW substations. HVDC electrical solution – two 900MW converter stations.	HVAC electrical solution – three 600MW substations. HVDC electrical solution – two 900MW converter stations.
WCS Met Masts	Maximum of two on either jacket or GBS, 20m diameter	Maximum of two on jackets with pin piles, jacket with suction caissons, GBS, suction caisson monopole or	Maximum of two on jackets with monopile.

Parameter	EA THREE	Norfolk Vanguard East Norfolk Vanguard West	Indicative Norfolk Boreas parameters
		piled monopile	
WCS Installation Vessels	Jack-up barges with maximum six legs per barge (50-300m^2 per leg). Maximum seabed depression up to 20m diameter per leg and penetrating up to 2m.	Likely to include jack-up vessels, footprints TBC	Likely to include jack-up vessels. Jack-up leg footprint area 176.71m^2 per leg.
WCS Cabling	550km array cables, up to 15x15km platform links, 4x95km interconnector cables (to East Anglia ONE), 664km (4x166km) export cables. Significant proportion of export cable route shared with EA ONE. 100% assumed buried	Approximately 515km array cables. Up to six HVAC export cables or up to two HVDC export cables. Two HVAC interconnector cables linking the three offshore substations or one subsea interconnector cable linking the two offshore converter stations. Burial is first choice cable protection method. Rock placement, concrete mattresses, frond mattresses or uraducts may be used when ground conditions result in the cable being laid on the seabed and on the approach to the wind turbines / offshore platforms.	Approximately 750km array cables. Up to six HVAC export cables or up to four HVDC export cables. Two HVAC interconnector cables linking the three offshore substations or one subsea interconnector cable linking the two offshore converter stations. Burial is first choice cable protection method. Rock placement, concrete mattresses, steel bridging and concrete bridging may be used when ground conditions result in the cable being laid on the seabed and on the approach to the wind turbines / offshore platforms.
WCS Landfall	HDD installed through ducts at depths of 3 to 10m below seabed, long ducts 1,100m long or short ducts.	Long and short HDD options with the exit points subtidal (up to 1km from the onshore HDD pit) or intertidal, respectively.	Minimum HDD length 150m, maximum 1000m. Total space required 0.003km^2 (3000m^2).
WCS Construction Programme	Built in either one or two phases. Up to 45 months for two phases.	Built in either two or three phases. Construction staggered or overlapping. Minimum construction period for 1800MW is three years with the maximum being ten years	Built in either two or three phases. Minimum construction period for 1800MW is three years with the maximum being seven years.

Parameter	EA THREE	Norfolk Vanguard East	Norfolk Vanguard West	Indicative Norfolk Boreas parameters
WCS Operational Lifetime	Up to 25 years.	25 years		Expected design life of 25 years.
WCS Decommissioning	Up to 24 months.	Approximately 12 months		Approximately 12 months

APPENDIX 2 – SUMMARY OF EAST ANGLIA ONE ENVIRONMENTAL STATEMENT

Phase	Potential Impact	WCS Details	Assessment Method	Assessment of Effect
Construction and Decommissioning	Changes in suspended sediment concentrations as a result of GBS seabed preparation activities and drilling for jacket installation.	**GBS**: one foundation installed per day. Dredging (in areas of sand waves) of up to 22,500m^3 of *surface* sediment (characterised by grab samples, with 75% being medium sand and only 2% being mud) per foundation and disposal by barge (surface release) in close proximity to each foundation. **Jacket**: one jacket installed per 48hrs. 50% of the 325 wind turbine jackets would be drilled, releasing 982m^3 of *sub-surface* sediments (characterised by boreholes, clays, silts and sands) per jacket. 100% disaggregation into component particle sizes assumed (not considering cohesion and clastic properties).	• Numerical modelling using Delft3D-PART (15 plume releases over a 15 day spring-neap cycle run) • Standard empirical equations (mobilisation and settling of sediment particles) • Existing evidence base from marine aggregate dredging industry • Conceptual understanding of potential impact • Interpretation against baseline SSC values (summer and winter) and storm effects	Short term and localised increases in SSC may affect other receptors (e.g. marine water quality, fish, benthic ecology and marine mammals). Given the sediment types and tidal currents considered, the majority of sediment from GBS installation will rapidly (seconds to minutes) descend to the seabed as a high concentration dynamic phase plume. It will form a mound on the bed, spreading radially under gravity. The remainder of the sediment will form a passive phase plume and become dispersed by tidal action before subsequently falling to the bed. Sands within this plume will settle within around 20 minutes of release, extending over an area of up to 1km. Finer sediments may persist for longer (hours to days) and travel over a wider area, with net movement to the north. For jackets, due to the finer nature of the sub-surface sediments, material may be transported over tens of kilometres from the release points. Significance of impact on receptors = **Not significant**
Construction and Decommissioning	Changes in bed levels and sediment type at the seabed as a result of GBS seabed preparation activities and drilling for jacket installation.	As above.	• As above.	For GBS, up to 2m thickness of deposition due to dynamic phase plume over a likely worst case area of 100m x 100m (10,000m^2) near to each foundation. Less than 0.2mm thickness of deposition of finer material over a wider area during the passive phase plume. For jackets, up to a few centimetres of deposition of sand within a few hundred metres of release, with less than 0.025mm thickness of deposition of finer material over a considerably wider area during the passive phase plume. Significance of impact on receptors = **Not significant**
Construction and Decommissioning	Potential release of contaminants from the Warren Springs Environmental Disposal Site.	Potentially affected by GBS seabed preparation activities, as described above.	• As above.	Fate of contaminants dependent on release and deposition of bed sediments, as assessed above. Significance of impact on receptors = **Not significant**
Construction and Decommissioning	Changes in suspended sediment concentrations, bed levels and sediment type as a result of array cable installation activities.	Up to 550km of array cable. Dredging in areas of large ripples and sand waves.	• Conceptual understanding of potential impact	Subordinate scale of potential impact compared against foundation installation, assessed above. Significance of impact on receptors = **Not significant**
Construction and Decommissioning	Changes in suspended sediment concentrations, bed levels and sediment type as a result of export cable installation activities.	Jetting to bury cable to a depth of 5m along the entire export cable route.	• Numerical modelling using Delft3D-PART • Existing evidence base from industry best practice guidance (BERR, 2008) and other wind farms (e.g. Nysted, Kentish Flats, Cromer) • Conceptual understanding of potential impact • Interpretation against baseline SSC values (summer and winter) and storm effects	Short term and localised increases in SSC due to installation, but baseline SSC values in shallower waters nearer to shore are greater than those further offshore across the wind farm site. Localised (<1km of release) concentrations up to 400mg/l in very shallow water, typically <100mg/l in deeper water (>20m water depth). Dispersion of fine-grained material within 180 hours of release. Bed level changes of up to 2mm observed within a few hundred metres and up to 0.2mm observed 20km from cable. Significance of impact on receptors = **Not significant**
Construction and Decommissioning	Interaction between bed preparation and foundation installation within the East Anglia ONE wind farm and sediment plumes created by installation of the East Anglia ONE export cable.	Construction programmes overlap such that plumes coalesce.	• Conceptual understanding of potential impact (based on tidal excursion ellipses)	There is only limited opportunity for plume combination due to the arrangement of the layout and cable route with respect to the tidal excursion ellipses. The combined plume may cover a slightly larger geographical area and, for a very short period of time, locally exhibit higher concentrations than assessed for foundation and export cable plumes individually. However, this higher concentration plume would not be expected to persist for much longer than a few hours. Significance of impact on receptors = **Not significant**
Construction and Decommissioning	Indentations on seabed left by vessels (vessel jack-up and anchoring operations).	Up to six legs of a jack-up barge. Each leg will have a maximum diameter of 16m and form footprint between 50 to 200m^2. Penetration will be between 0.5 to 3m into the bed.	• Conceptual understanding of potential impact	As each leg is inserted it will cause the already partially consolidated sediments to be compressed downwards and displaced laterally. This may cause the seabed around the inserted leg to be raised in a series of concentric pressure ridges. As the leg is retracted, some material that has previously been displaced will avalanche back into the depression until a maximum stable slope

Phase	Potential Impact	WCS Details	Assessment Method	Assessment of Effect
		Anchor arrays (of four to six anchors) will typically be smaller than jack-up barge legs		angle is achieved. The pits will infill under tidally-driven sediment transport, probably over a timescale of months to years. For anchors, anchor scars will be created in the seabed. These will become reworked and flattened to a baseline conditions by the action of tidal currents over a few tidal cycles. Significance of impact on receptors = **Not significant**
Construction and Decommissioning	Disruption to coastal morphology at cable landfall.	HDD at landfall at Bawdsey.	• Conceptual understanding of potential impact	Minimal direct disturbance is caused by HDD and the construction programme for this activity is relatively short in duration (up to a few months). Significance of impact on receptors = **Not significant**
Operational	Changes to the tidal regime due to the presence of the foundation structures.	Array of wind turbines founded on GBS	• Numerical modelling using Delft3D-FLOW • Existing evidence base from other wind farms • Conceptual understanding of potential impact • Interpretation against baseline tidal current values (typically 1.15 to 1.25m/s on peak spring tides) •	No measureable change in water levels (maximum modelled change is 0.007m). Localised flow accelerations around the foundations and wake effects downstream of the foundations (within up to a few hundred metres downstream). Maximum reductions modelled in the range 0.05 to 0.1m/s within the array. Maximum increases modelled to be 0.05m/s within the array. Only very minor changes in flow direction (<5°). Significance of impact on receptors = **Not significant**
Operational	Changes to the wave regime due to the presence of the foundation structures.	Array of wind turbines founded on GBS	• Numerical modelling using Delft3D-SWAN • Existing evidence base from other wind farms • Conceptual understanding of potential impact • Interpretation against baseline wave climate values (typically H_s = 0.5 to 1.0m and T_m = 3.5 to 4.0s) •	Maximum reductions in wave height appear within, or along the boundary of, the array. These may reach up to 20% during large storm events within the array, but under typical conditions reductions are less than 2% at a distance of 40km from the array. There is no measureable effect on wave conditions at the shore. Significance of impact on receptors = **Not significant**
Operational	Changes to the sediment transport regime due to the presence of the foundation structures.	Array of wind turbines founded on GBS	• Outputs from numerical modelling using Delft3D FLOW and SWAN • Standard empirical equations (mobilisation and settling of sediment particles) • Existing evidence base from other wind farms and industry guidance • Conceptual understanding of potential impact • Interpretation against baseline sediment transport regimes	Local changes in tidal current and wave regimes may induce scour. The broader bedload and suspended sediment transport regimes will be largely unaffected as changes in tidal and wave regimes are so minor. Similarly, there will be no change in the sediment transport regime at the shore. Significance of impact on receptors = **Not significant**
Operational	Scour effects due to the presence of the foundation structures, resulting in erosion, re-suspension and settling of sediments.	Jackets (no scour protection planned) and GBS (scour protection provided) both considered.	• Outputs from numerical modelling using Delft3D FLOW and SWAN • Standard empirical equations (empirical scour formulae) • Existing evidence base from other wind farms • Conceptual understanding of potential impact • Interpretation against baseline variations in seabed levels	Scour hole development will occur around individual legs of a jacket, and group scour under the jacket may also occur. With scour protection provided, no scour will occur around the GBS. Significance of impact on receptors = **Not significant**

Phase	Potential Impact	WCS Details	Assessment Method	Assessment of Effect
Operational	Scour effects due to the exposure of array and export cables and cable protection measures.	Cables buried along entire length.	• Standard empirical equations (empirical scour formulae) • Existing evidence base from other wind farms and industry guidance (BERR, 2008) • Conceptual understanding of potential impact • Interpretation against baseline variations in seabed and shore levels	Scour of any exposed cable lengths to a depth of one to three times the cable diameter (i.e. 0.1 – 0.7m) and across an area of seabed 50 times the cable diameter (i.e. 4.5 – 12m). Significance of impact on receptors = **Not significant**
Cumulative Effects	Interaction of sediment plumes as a result of the combined activities of East Anglia ONE construction (including export cable installation) and construction of other wind farms.	Consideration of any other wind farms located within one spring tidal excursion ellipse from East Anglia ONE	• Agreement reached with regulators during scoping and consultation phases. • Conceptual understanding of potential impact • Interpretation against baseline tidal excursion ellipses.	No other wind farms are located within a distance of one spring tidal excursion ellipse from East Anglia ONE. Significance of impact on receptors = **Not significant**
Cumulative Effects	Interaction of sediment plumes as a result of the combined activities of East Anglia ONE construction (including export cable installation) and installation of other offshore wind farm export cables.	Consideration of any other wind farms' export cables being installed at the same time and located within one spring tidal excursion ellipse from East Anglia ONE	• Agreement reached with regulators during scoping and consultation phases. • Conceptual understanding of potential impact • Interpretation against baseline tidal excursion ellipses.	No other wind farms' export cables are being installed at the same time and are located within a distance of one spring tidal excursion ellipse from East Anglia ONE. Significance of impact on receptors = **Not significant**
Cumulative Effects	Interaction of sediment plumes as a result of the combined activities of East Anglia ONE construction and marine aggregate dredging.	Consideration of any marine aggregate dredging located within one spring tidal excursion ellipse from East Anglia ONE	• Agreement reached with regulators during scoping and consultation phases. • Conceptual understanding of potential impact • Interpretation against baseline tidal excursion ellipses.	No marine aggregate dredging sites are located within a distance of one spring tidal excursion ellipse from East Anglia ONE. Significance of impact on receptors = **Not significant**
Cumulative Effects	Changes to the current regime as a result of the combined activities of East Anglia ONE operation and bed level changes from marine aggregate dredging.	Changes in current speed arising from an array of wind turbines founded on GBS	• Outputs from numerical modelling using Delft3D FLOW • Conceptual understanding of potential impact	Changes in current flow speeds do not extend to marine aggregate dredging areas. Significance of impact on receptors = **Not significant**
Cumulative Effects	Changes to the wave regime as a result of the combined activities of East Anglia ONE operation and bed level changes from marine aggregate dredging.	Changes in wave regime arising from an array of wind turbines founded on GBS	• Outputs from numerical modelling using Delft3D SWAN • Conceptual understanding of potential impact	Changes in wave regime essentially oppose potential changes from marine aggregate dredging. Significance of impact on receptors = **Not significant**
Cumulative Effects	Interaction of sediment plumes as a result of the combined activities of East Anglia ONE export cable installation and marine aggregate dredging.	Consideration of any marine aggregate dredging located within one spring tidal excursion ellipse from East Anglia ONE and export cable	• Outputs from numerical modelling using Delft3D FLOW and SWAN • Existing evidence base from marine aggregate dredging industry (including East Anglia MAREA) • Conceptual understanding of potential impact • Interpretation against baseline variations in seabed levels	Cumulative plumes may potentially cover a slightly larger geographical area and, for a very short period of time, locally exhibit higher concentrations than assessed for each operation individually. However, this higher concentration plume would be expected to persist for a short duration only. Significance of impact on receptors = **Not significant**
Cumulative Effects	Interaction of sediment plumes as a	Consideration of any dredge disposal	• Agreement reached with regulators	No dredge disposal sites are located within a distance of one spring tidal excursion ellipse from

Phase	Potential Impact	WCS Details	Assessment Method	Assessment of Effect
	result of the combined activities of East Anglia ONE construction (including export cable installation) and disposal of dredged material.	activities located within one spring tidal excursion ellipse from East Anglia ONE and export cable	during scoping and consultation phases. • Conceptual understanding of potential impact • Interpretation against baseline tidal excursion ellipses.	East Anglia ONE. Significance of impact on receptors = **Not significant**
Cumulative Effects	Interaction between East Anglia ONE wind farm and other wind farms in the region, causing a change to the hydrodynamic regime and associated changes in sediment transport.	Array of wind turbines founded on GBS	• Outputs from numerical modelling using Delft3D FLOW and SWAN • Existing evidence base from other wind farms • Conceptual understanding of potential impact • Interpretation against baseline tidal current and wave regimes	Magnitude of change in hydrodynamic regime from East Anglia ONE is negligible and therefore there is no potential for interaction with other wind farms in the region. Significance of impact on receptors = **Not significant**

APPENDIX 3 – SUMMARY OF EAST ANGLIA THREE ENVIRONMENTAL STATEMENT

Phase	Potential Impact	WCS Details	Assessment Method	Assessment of Effect
Construction and Decommissioning	Changes in suspended sediment concentrations as a result of GBS seabed preparation activities.	Installation of 40m basal diameter GBS for 7MW wind turbines or 60m basal diameter GBS for 12MW wind turbines. Worst case for each individual 12MW GBS is a dredged sediment volume of 26,000m^3. For the 7MW GBS the conservative dredged sediment volume is 17,500m^3. Worst case for total sediment volume released is 3,010,000m^3 associated with 172 7MW GBS compared with 2,600,000m^3 for 100 12MW GBS. A further worst case sediment volume of 533,325m^3 would be yielded by met masts and jacket foundations for offshore platforms. So, total worst case sediment volume would be 3,543,325m^3 of dredged sediment. Overall foundation installation programme for GBS would last up to 12 months (single phase) or 14 months (two periods each lasting up to seven months for two phases).	Expert based assessment of potential effects predicated on a source-pathway-receptor (S-P-R) conceptual model, and verified and tested against previous numerical modelling for East Anglia ONE and the conceptual assessment for East Anglia THREE.	Effects are mainly expected to arise only locally around the source and persist for short time scales (hours to days). Due to the relatively large sediment particle sizes present across the wind farm site, the sediment disturbed by the drag head of the dredger would remain close to the seabed and rapidly settle, whilst the majority of sediment released at the water surface from the dredger vessel would rapidly (minutes or tens of minutes) fall to the seabed as a highly turbid dynamic plume immediately upon its discharge. Some of the finer sand fraction from this release and the very small proportion of muds that are 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 measureable but modest concentration plume (tens of mg/l) for around half a tidal cycle and sediment would fall to the seabed in relatively close proximity to its release (within a few hundred metres up to around a kilometre, along the axis of the tidal flow) within hours. Significance of impact on receptors = **Not significant**
Construction and Decommissioning	Changes in seabed levels as a result of GBS seabed preparation activities.	As above	As above	Relatively coarse sediment would fall rapidly (minutes or tens of minutes) to the seabed as a highly turbid dynamic plume immediately upon its discharge, forming a deposit ('mound') local to the point of release. Due to the predominantly medium sand or coarser sediment across the site (with very little fine sand or mud), a large proportion of the disturbed sediment would behave in this manner. The resulting mound would be a measureable protrusion from the seabed (likely tens of centimetres to a few metres high) but would remain local to the release point. The geometry of each mound would vary across the wind farm site, depending on the prevailing conditions, but in all cases the sediment within the mound would be similar to that on the existing seabed and there would be no significant change in sediment type. In addition to the localised mounds, some of the sediment from this release (mainly the fine sand fraction and the very small proportion of muds) is likely to form a passive plume and become more widely dispersed before settling on the seabed. Due to the dispersion by tidal currents, the thickness of deposits across the wider seabed area would be up to a few millimetres. Significance of impact on receptors = **Not significant**
Construction and Decommissioning	Changes in suspended sediment concentrations as a result of drilling for monopile installation.	Drilled monopiles of up to 12m diameter to a depth of 40m below the seabed. Worst case for each individual 12m diameter monopile is a sediment release of 4,524m^3. For the 10m diameter monopile drilled to the same depth the sediment volume is 3,142m^3. Worst case for total sediment volume released is 540,353m^3 associated with 172 7MW monopiles compared with 452,389m^3 for the 100 12MW monopiles. A further worst case sediment volume of 17,490m^3 would be yielded for two met masts and jacket foundations for offshore platforms. So, total worst case sediment volume would be 557,843m^3 of released sediment. Overall construction programme would last up to seven months (single phase) or ten months (two periods each lasting	As above	Effects at each monopile are likely to last for no more than a few days of construction activity. Although the sub-surface sediment release quantities under a worst case scenario for monopiles are considerably lower than those involved in the worst case scenario for the surface and near-bed sediments, the sediment types would differ, with a larger proportion of finer materials. The coarser sediment fractions (medium and coarse sands and gravels) and aggregated 'clasts' of finer sediment would settle out of suspension in relatively close proximity to the foundation location, whilst disaggregated finer sediments (fine sands and muds) would be more prone to dispersion across a wider area. Due to the small quantities of released sediment involved, these disaggregated finer sediments are likely to be widely and rapidly dispersed, resulting in only low elevations in suspended sediment concentration and very small changes in seabed level when they are ultimately deposited. Significance of impact on receptors = **Not significant**

Phase	Potential Impact	WCS Details	Assessment Method	Assessment of Effect
		up to five months for two phases).		
Construction and Decommissioning	Changes in seabed levels as a result of drilling for monopile installation.	As above Worst case assumes that the sediment that is released from drilling is wholly in the form of aggregated 'clasts' of finer sediment that remain on the seabed (at least initially), rather than being disaggregated into individual fine sediment components immediately upon release. Footprint of an individual mound arising from the 10m diameter monopiles used for 7MW wind turbines would be 1,396m^2 (or 240,188m^2 for the whole site) and the footprint of an individual mound arising from the 12m diameter monopiles used for 12MW wind turbines would be 2,011m^2 (or 201,067m^2 for the whole site).	As above	Under this scenario, the 'mound' would reside on the seabed near the site of its release. It would be composed of sediment with a different particle size and behaviour character (cohesive) to the surrounding sandy seabed. When compared against the site as a whole (304.8km^2), the worst case cumulative area affected by mounds is only 0.08% of the seabed. Significance of impact on receptors = **Not significant**
Construction and Decommissioning	Changes in suspended sediment concentrations as a result of array, platform links, and interconnector cable installation activities.	Up to 550km of array cable and up to 240km (16 x 15km) of platform links cable. Jetting to bury the cables to a depth of between 0.5 and 5m. Seabed levelling of up 136,000m^3 of sediment in areas where large megaripples and sand waves occur. Up to 380km (4 x 95km) of interconnector cable installed in two phases. Jetting to bury cable to a depth of between 0.5 and 5m. Seabed levelling of up to 147,493m^3 of sediment in areas where large megaripples and sand waves occur. Under a Single-Phase approach the installation of array, platform links and interconnector cables are likely to have some overlaps and take up to 21 months to complete. There could also be a one month overlap with the installation of the export cables. For two phases, the worst case installation period would be for one 18 month phase followed concurrently by one 17 month phase (with no overlap in installation of cable types between phases). There could be up to six months overlap in construction of these cable types with the export cables installed during each phase.	As above	Changes in suspended sediment concentration would be lower than those arising from the disturbance of seabed and near-bed sediments during foundation installation activities including seabed preparation. Sediment release (apart from that released as a result of sand wave levelling) would be low and confined to near the seabed (rather than higher in the water column) along the alignment of the cables and persist for short time scales (order of hours to days). The additional volume of sediment that may be released due to sand wave levelling prior to cable installation works is very low within the context of both the sediment spill during foundation installation and the changes that occur naturally to the seabed. Significance of impact on receptors = **Not significant**
Construction and Decommissioning	Changes in seabed levels as a result of array, platform links, and interconnector cable installation activities.	As above	As above	Given that the changes in suspended sediment concentration due to array, platform links, and interconnector cable installation (including any deposition arising from spilled sediment from sand wave levelling) would be less than those arising from the disturbance of seabed and near-bed sediments during foundation installation activities, so the seabed level changes would also be lower. The direct changes to the seabed associated with sand wave levelling would be small and localised and are likely to recover over time due to natural sand transport pathways. Significance of impact on receptors = **Not significant**
Construction and Decommissioning	Changes in suspended sediment concentrations as a result of export cable installation activities.	Up to 664km (4 x 166km) of export cable installed in two phases. Seabed levelling in areas where large megaripples and sand waves occur. Jetting to bury cable to a depth of between 0.5 and 5m. Seabed levelling of up to 324,484m^3 of sediment in areas where large megaripples and sand waves occur. Considered separately from the array, platform links cables and interconnector cables because parts of the export cable	As above	Majority of sand waves are in the most seaward sections of the export cable corridor (away from the coast). Only 22,360m^3 of sand wave clearance would be needed inshore. The seabed levelling volume is very small in relation to the sediment released as a result of seabed preparation for foundations and therefore would have a comparatively minimal effect. Changes in suspended sediment concentration due to export cable installation (including any sand wave levelling) would be less than those arising from the disturbance of seabed and near-bed

Phase	Potential Impact	WCS Details	Assessment Method	Assessment of Effect
		corridor are in shallower more coastal water and in closer proximity to identified morphological receptor groups. The installation of export cables would take up to 22 months, but there would be no overlap with the installation of array cables, platform links cables or interconnector cables (single-phase approach). The worst case installation period for the two-phased approach would be for two separate 11 month phases. There could be up to six months overlap in construction of the export cables within each phase with the other cable types installed during that phase.		sediments during foundation installation activities, although the location of effect would differ as it would be focused along the export cable corridor. Overall sediment release volumes would be low and confined to near the seabed (rather than higher in the water column) along the alignment of the export cable corridor, and the rate at which the sediment is released into the water column from the jetting process would be relatively slow. Suspended sediment concentrations would be enhanced in shallower water, but in these locations the background concentrations are also greater than in deeper waters, typically up to 170mg/l. There would be relatively little sand wave levelling prior to cable laying in these inshore areas, with most occurring further offshore. Significance of impact on receptors = **Not significant**
Construction and Decommissioning	Changes in seabed levels as a result of export cable installation activities.	As above	As above	Given that the changes in suspended sediment concentration due to export cable installation would be lower than those arising from the disturbance of seabed and near-bed sediments during foundation installation activities, so the magnitude of bed level changes would also be lower, although the location of effect would differ as the majority would be focused along the export cable corridor. Small magnitude and relatively localised changes in seabed level of up to 2mm along the inshore sections of the export cable corridor. Significance of impact on receptors = **Not significant**
Construction and Decommissioning	Indentations on the seabed due to installation vessels	Use of jack-up vessels with six legs creating seabed depressions up to 50-300m^2. Each leg could penetrate 0.5 to 2m into the seabed. Assumes that legs could be deployed on up to three different occasions around a single foundation as the jack-up barge manoeuvres into different positions.	As above	As each leg is inserted it will cause the already partially consolidated sediments to be compressed downwards and displaced laterally. This may cause the seabed around the inserted leg to be raised in a series of concentric pressure ridges. As the leg is retracted, some material that has previously been displaced will avalanche back into the depression until a maximum stable slope angle is achieved. The pits will infill under tidally-driven sediment transport, probably over a timescale of months to years. Significance of impact on receptors = **Not significant**
Construction and Decommissioning	Changes to suspended sediment concentrations and coastal morphology at the export cable landfall.	At the landfall location at Bawdsey the worst case includes installation of four cables into ducts (in the subtidal zone for a long duct or intertidal zone for a short duct) that have been pre-installed by the consented East Anglia ONE project. The ends of the ducts would need to be excavated, cables installed and sediment backfilled.	As above	For a short duct, trenching into London Clay would likely result in clumps of mud to be displaced and back-filled, rather than the material breaking down into its constituent silt and clay particles. It is therefore unlikely that significant changes in suspended sediment concentration would occur during these works. The back-filling of the trench would result in no noticeable change in coastal morphology after completion of the export cable installation into the ducts. For a long duct, cable installation would occur at a distance of 1,100m from the base of the cliff and would cause minimal direct or indirect disturbance to the shoreline or nearshore. Significance of impact on receptors = **Not significant**
Operational	Changes to the wave regime due to the presence of foundation structures.	Array of 172 7MW wind turbine founded on 40m basal diameter GBS or array of 100 12MW wind turbine founded on 60m basal diameter GBS	As above	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. There is a strong scientific evidence base which demonstrates that the changes in the wave regime due to the presence of foundation structures, even under a worst case of the largest diameter GBS, are both relatively small in magnitude and relatively localised in spatial extent. This evidence base is supported by the more conservative modelling of East Anglia ONE. Significance of impact on receptors = **Not significant**
Operational	Changes to the tidal regime due to the presence of foundation structures.	As above	As above	Potential effects on the tidal regime associated with the presence of the foundations may include changes to the naturally occurring patterns of tidal water levels, current speeds and directions.

Phase	Potential Impact	WCS Details	Assessment Method	Assessment of Effect
				There is a strong scientific evidence base which demonstrates that the changes in the tidal regime due to the presence of foundation structures are both small in magnitude and localised in spatial extent. This evidence base is supported by modelling of East Anglia ONE. Significance of impact on receptors = **Not significant**
Operational	Changes to the sediment transport regime due to the presence of foundation structures.	As above	As above	Potential effects on the sediment regime (broad patterns of suspended and / or bedload sediment transport) associated with the presence of the foundations may occur as a result of the changes to the tidal and wave climate. The reductions in tidal flow and wave height that are anticipated would result in a reduction in the sediment transport potential across the areas where such changes are observed, whereas the areas of increased tidal flow around each wind turbine would result in increased sediment transport potential. These changes to the physical processes would be both low in magnitude and largely confined to local wake or wave shadow effects attributable to individual foundations and, would be small in geographical extent. In the case of wave effects, there would also be reductions due to a shadow effect across a greater seabed area. The changes in wave heights across this wider area would be notably lower (a few %) than the changes local to each foundation (tens of %). Since it is expected that the changes in tidal flow and wave heights would have no significant far-field effects, then the changes in sediment transport would be similar. Significance of impact on receptors = **Not significant**
Operational	Changes in suspended sediment concentrations due to scour around foundation structures.	60m basal diameter GBS for a 12MW turbine installed in relatively shallow water depths (30.8m). Worst case with no scour protection. The worst case scour volume for an individual 12MW wind turbines would be 5,573m^3. Worst case scour volume for the site as a whole would be 673,415m^3 associated with 172 7MW wind turbines, two met masts and seven substation foundations.	As above	The worst case volumes are considerably less than the worst case volumes of sediment potentially released following seabed preparation activities (greater than three million m^3) and therefore the magnitude of effect would be much lower than assessed for that impact. Given the relatively coarse seabed and near-bed sediment types, most of the relatively small quantities of sediment released at each wind turbine foundation due to scour processes would rapidly settle within a few hundred metres of each structure. Significance of impact on receptors = **Not significant**
Operational	Changes to seabed morphology due to the presence of foundation structures.	Seabed morphology directly impacted by the footprint of each foundation structure on the seabed within the site, constituting a loss in natural seabed area during the operational life. Worst case seabed footprint without scour protection is for 100 12MW GBS each with a footprint area of 2,828m^2, two met masts each of 315m^2, and seven offshore platforms each of 8,011m^2. This arrangement would result in a total worst case direct foundation footprint area of 339,507m^2. Worst case scour footprint for an individual wind turbine is 5,336m^2 for a 12MW GBS. For the whole site the worst case is 172 7MW GBS plus nine further foundations for offshore platforms and met masts, resulting in a total footprint area of 551,632m^2. Worst case for 109 foundations all with scour protection is 2,673,260m^2.	As above	The total loss of seabed habitat due to foundations alone represents 0.11% of the total seabed area within the site (304.8km^2). Due to scour alone the loss is 0.18% of the total seabed area within the site. With scour protection at all 109 foundations, the loss represents 0.88% of the total seabed area. Significance of impact on receptors = **Not significant**
Operational	Morphological and sediment transport effects due to cable protection measures for array, platform links and interconnector cables.	Worst case scenario is that up to 10% of the array, platform links and interconnector cables cannot be buried and must instead be surface-laid and protected in some manner.	As above	Effects are primarily related to the potential for interruption of sediment transport processes and the footprint they present on the seabed. Protrusions from the seabed are unlikely to significantly affect the migration of sand waves, since

Phase	Potential Impact	WCS Details	Assessment Method	Assessment of Effect
		Up to 117km of cable protected with 3m wide, 1 to 3m high cable protection. At cable crossings the height of cable protection could reach up to 0.9m above seabed apart from at one location where the cable would cross a pipeline. At this single location the protection could reach up to 4m in height. The presence of cable protection works on the seabed would represent the worst case in terms of a direct 'loss' of seabed area.		sand wave heights in most areas would exceed the height of cable protection works. Where sand waves exceed the height of the protrusions they would simply pass over them. If bedload transport is obstructed then sand would accumulate one side or both sides of the obstacle (depending on the gross and net transport at that particular location) to the height of the protrusion and then form a 'ramp' over which sand transport would occur by bedload processes, thereby bypassing the obstruction. There may be localised interruptions to bedload transport in other areas, but the gross patterns of bedload transport across the site would not be affected significantly. The cable protection footprint is likely to be lower than that of the foundations (and associated scour hole or scour protection works) within the site. Significance of impact on receptors = **Not significant**
Operational	Morphological and sediment transport effects due to cable protection measures for export cables.	Worst case scenario is that burial of the export cables would not practicably be achievable within some areas and, instead, cable protection measures would need to be provided to surface-laid cables in these areas.	As above	Effects are primarily related to the potential for interruption of sediment transport processes and the footprint they present on the seabed. There is likely to be a difference in effect depending on whether the cable protection works are in nearshore or offshore areas within the export cable corridor. Works in areas closest to shore (inland of the closure depth) could potentially affect sediment transport processes along the shoreline. Any interruptions to sediment transport could, in turn, affect the morphological response of wider areas (e.g. adjacent shore frontages along the sediment transport pathway) due to reductions in sediment supply to those areas. Works in areas further offshore could potentially affect sediment transport processes across the seabed and effects would be the same as those for array, platform links and interconnector cables. Significance of impact on receptors = **Not significant**
Operational	Morphological effects due to cable protection measures at the export cable landfall.	Export cable buried at the landfall.	As above	As the export cable would remain buried at the landfall throughout the operational life, no cable protection would be required and no morphological effects would take place. Significance of impact on receptors = **Not significant**
Operational	Indentations on the seabed due to maintenance vessels.	Jack-up barges or anchored vessels placed temporarily on site to maintain the wind turbines. Worst case corresponds to the use of up to two jack-up vessels per wind turbine for a duration of one day to undertake maintenance. Total area of seabed that may be affected by these activities is 1.31km^2 per year (based on up to 730 visits by jack-up vessels each with a footprint of 1,800m^2).	As above	Equipment is only likely to be positioned at one site at a time for a relatively short duration (hours to days), and the effects upon the physical process regime would be low in magnitude, being localised in both temporal and spatial extent. Once the maintenance activities are complete the jack-up vessels would be moved on and no permanent effects on physical processes would remain. With respect to scour, the legs of the jack-up vessel are small in diameter and this would place a physical limit on the depth and plan area of any scour hole formation, and hence the volume of scoured sediment that would be released into the water column. The scour volumes arising would be small in magnitude and cause an insignificant effect in terms of enhanced suspended sediment concentrations and deposition elsewhere. Significance of impact on receptors = **Not significant**
Cumulative Effects	Effects as a result of combining East Anglia THREE and East Anglia ONE export cable installation and decommissioning.	Consideration of any construction activities of East Anglia ONE located within one spring tidal excursion ellipse from East Anglia THREE.	As above	Given the phased construction of export cable installation (including landfall works) for each of these projects, it is unlikely that there would be overlap in export cable installation between the proposed East Anglia THREE and consented East Anglia ONE. Significance of impact on receptors = **Not significant**
Cumulative Effects	Effects as a result of combining the East Anglia THREE export cable installation and decommissioning and aggregate dredging activities.	Consideration of any marine aggregate dredging located within one spring tidal excursion ellipse from the East Anglia THREE export cable.	As above	No marine aggregate dredging sites are located within a distance of one spring tidal excursion ellipse from East Anglia THREE. Significance of impact on receptors = **Not significant**

Potential Impact	Receptor	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Construction						
Impact 1A: Changes in Suspended Sediment Concentrations due to Seabed Preparation for Wind Turbine GBS Foundation Installation	Haisborough, Hammond and Winterton cSAC/SCI			**No impact**		**No impact**
	North Norfolk Sandbanks and Saturn Reef cSAC/SCI			**No impact**		**No impact**
	Cromer Shoal Chalk Beds MCZ			**No impact**		**No impact**
	East Anglian coast			**No impact**		**No impact**
Impact 1B: Changes in Suspended Sediment Concentrations due to Drill Arisings for Installation of Piled Foundations for Wind Turbines	Haisborough, Hammond and Winterton cSAC/SCI			**No impact**		**No impact**
	North Norfolk Sandbanks and Saturn Reef cSAC/SCI			**No impact**		**No impact**
	Cromer Shoal Chalk Beds MCZ			**No impact**		**No impact**
	East Anglian coast			**No impact**		**No impact**
Impact 2A: Changes in Seabed Level due to Seabed Preparation for Wind Turbine Foundation Installation	Haisborough, Hammond and Winterton cSAC/SCI	Negligible	Low (near-field), negligible (far-field)	**Negligible**	None proposed	**Negligible**
	North Norfolk Sandbanks and Saturn Reef cSAC/SCI	Negligible	Low (near-field), negligible (far-field)	**Negligible**	None proposed	**Negligible**
	Cromer Shoal Chalk Beds MCZ			**No impact**		**No impact**
	East Anglian coast			**No impact**		**No impact**
Impact 2B: Changes in Seabed Level due to Drill Arisings for Installation of Piled Foundations for Wind Turbines	Haisborough, Hammond and Winterton cSAC/SCI			**No impact**		**No impact**
	North Norfolk Sandbanks and Saturn Reef cSAC/SCI			**No impact**		**No impact**
	Cromer Shoal Chalk Beds MCZ			**No impact**		**No impact**
	East Anglian coast			**No impact**		**No impact**
Impact 3: Changes in Suspended Sediment Concentrations during Offshore Export Cable Installation	Haisborough, Hammond and Winterton cSAC/SCI			**No impact**		**No impact**
	North Norfolk Sandbanks and Saturn Reef cSAC/SCI			**No impact**		**No impact**
	Cromer Shoal Chalk Beds MCZ			**No impact**		**No impact**
	East Anglian coast			**No impact**		**No impact**
Impact 4A: Changes in Seabed Level due to Offshore Export Cable Installation	Haisborough, Hammond and Winterton cSAC/SCI	Negligible	Low (near-field), negligible (far-field)	**Negligible**	None proposed	**Negligible**
	North Norfolk Sandbanks and Saturn Reef cSAC/SCI			**No impact**		**No impact**
	Cromer Shoal Chalk Beds MCZ	Negligible	Low (near-field), negligible (far-field)	**Negligible**	None proposed	**Negligible**
	East Anglian coast			**No impact**		**No impact**

Potential Impact	Receptor	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Impact 4B: Interruptions to Bedload Sediment Transport due to Sand Wave Levelling	Haisborough, Hammond and Winterton cSAC/SCI	Negligible	Low (near-field), negligible (far-field)	**Negligible**	None proposed	**Negligible**
	North Norfolk Sandbanks and Saturn Reef cSAC/SCI			**No impact**		**No impact**
	Cromer Shoal Chalk Beds MCZ			**No impact**		**No impact**
	East Anglian coast			**No impact**		**No impact**
Impact 5: Changes in Suspended Sediment Concentrations during Array and Interconnector Cable Installation	Haisborough, Hammond and Winterton cSAC/SCI			**No impact**		**No impact**
	North Norfolk Sandbanks and Saturn Reef cSAC/SCI			**No impact**		**No impact**
	Cromer Shoal Chalk Beds MCZ			**No impact**		**No impact**
	East Anglian coast			**No impact**		**No impact**
Impact 6: Changes in Seabed Level due to Array and Interconnector Cable Installation	Haisborough, Hammond and Winterton cSAC/SCI	Negligible	Low (near-field), negligible (far-field)	**Negligible**	None proposed	**Negligible**
	North Norfolk Sandbanks and Saturn Reef cSAC/SCI	Negligible	Low (near-field), negligible (far-field)	**Negligible**	None proposed	**Negligible**
	Cromer Shoal Chalk Beds MCZ			**No impact**		**No impact**
	East Anglian coast			**No impact**		**No impact**
Impact 7: Indentations on the Seabed due to Installation Vessels	Haisborough, Hammond and Winterton cSAC/SCI			**No impact**		**No impact**
	North Norfolk Sandbanks and Saturn Reef cSAC/SCI			**No impact**		**No impact**
	Cromer Shoal Chalk Beds MCZ			**No impact**		**No impact**
	East Anglian coast			**No impact**		**No impact**
Operation						
Impact 1: Changes to the Tidal Regime due to the Presence of Wind Turbine Structures	Haisborough, Hammond and Winterton cSAC/SCI			**No impact**		**No impact**
	North Norfolk Sandbanks and Saturn Reef cSAC/SCI	Negligible	Low (near-field), negligible (far-field)	**Negligible (southern part of cSAC/SCI)**	None proposed	**Negligible**
	Cromer Shoal Chalk Beds MCZ			**No impact**		**No impact**
	East Anglian coast			**No impact**		**No impact**
Impact 2: Changes to the Wave Regime due to the Presence of Wind Turbine Structures	Haisborough, Hammond and Winterton cSAC/SCI	Negligible	Low (near-field), negligible (far-field)	**Negligible (south-east extreme of cSAC/SCI)**	None proposed	**Negligible**
	North Norfolk Sandbanks and Saturn Reef cSAC/SCI	Negligible	Low (near-field), negligible (far-field)	**Negligible (south-east extreme of cSAC/SCI)**	None proposed	**Negligible**
	Cromer Shoal Chalk Beds MCZ			**No impact**		**No impact**
	East Anglian coast			**No impact**		**No impact**
Impact 3: Changes to the Sediment	Haisborough, Hammond and Winterton cSAC/SCI	Negligible	Low (near-field), negligible (far-field)	**Negligible (south-east extreme of cSAC/SCI)**	None proposed	**Negligible**

Potential Impact	Receptor	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Transport Regime due to the Presence of Wind Turbine Foundation Structures	North Norfolk Sandbanks and Saturn Reef cSAC/SCI	Negligible	Low (near-field), negligible (far-field)	**Negligible (south and south-east extreme of cSAC/SCI)**	None proposed	**Negligible**
	Cromer Shoal Chalk Beds MCZ			**No impact**		**No impact**
	East Anglian coast			**No impact**		**No impact**
Impact 4: Loss of Seabed Morphology due to the Footprint of Wind Turbine Foundation Structures	Haisborough, Hammond and Winterton cSAC/SCI			**No impact**		**No impact**
	North Norfolk Sandbanks and Saturn Reef cSAC/SCI			**No impact**		**No impact**
	Cromer Shoal Chalk Beds MCZ			**No impact**		**No impact**
	East Anglian coast			**No impact**		**No impact**
Impact 5: Morphological and Sediment Transport Effects due to Cable Protection Measures for Array and Interconnector Cables	Haisborough, Hammond and Winterton cSAC/SCI			**No impact**		**No impact**
	North Norfolk Sandbanks and Saturn Reef cSAC/SCI			**No impact**		**No impact**
	Cromer Shoal Chalk Beds MCZ			**No impact**		**No impact**
	East Anglian coast			**No impact**		**No impact**
Impact 6: Morphological and Sediment Transport Effects due to Cable Protection Measures for Offshore Cables	Haisborough, Hammond and Winterton cSAC/SCI			**No impact**		**No impact**
	North Norfolk Sandbanks and Saturn Reef cSAC/SCI			**No impact**		**No impact**
	Cromer Shoal Chalk Beds MCZ			**No impact**		**No impact**
	East Anglian coast			**No impact**		**No impact**
Impact 7: Indentations on the Seabed due to Maintenance Vessels	Haisborough, Hammond and Winterton cSAC/SCI			**No impact**		**No impact**
	North Norfolk Sandbanks and Saturn Reef cSAC/SCI			**No impact**		**No impact**
	Cromer Shoal Chalk Beds MCZ			**No impact**		**No impact**
	East Anglian coast			**No impact**		**No impact**
Decommissioning						
Impact 1: Changes in Suspended Sediment Concentrations due to Wind Turbine Foundation Removal	Haisborough, Hammond and Winterton cSAC/SCI			**No impact**		**No impact**
	North Norfolk Sandbanks and Saturn Reef cSAC/SCI			**No impact**		**No impact**
	Cromer Shoal Chalk Beds MCZ			**No impact**		**No impact**
	East Anglian coast			**No impact**		**No impact**
Impact 2: Changes in seabed level (morphology) due to wind turbine	Haisborough, Hammond and Winterton cSAC/SCI	Negligible	Low (near-field), negligible (far-field)	**Negligible**	None proposed	**Negligible**
	North Norfolk Sandbanks and Saturn Reef cSAC/SCI	Negligible	Low (near-field), negligible (far-field)	**Negligible**	None proposed	**Negligible**

Potential Impact	Receptor	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
foundation removal	Cromer Shoal Chalk Beds MCZ			**No impact**		**No impact**
	East Anglian coast			**No impact**		**No impact**
Impact 3: Changes in Suspended Sediment Concentrations due to Removal of parts of the Array and Interconnector Cables	Haisborough, Hammond and Winterton cSAC/SCI			**No impact**		**No impact**
	North Norfolk Sandbanks and Saturn Reef cSAC/SCI			**No impact**		**No impact**
	Cromer Shoal Chalk Beds MCZ			**No impact**		**No impact**
	East Anglian coast			**No impact**		**No impact**
Impact 4: Changes in seabed level due to removal of parts of the array and interconnector cables	Haisborough, Hammond and Winterton cSAC/SCI	Negligible	Low (near-field), negligible (far-field)	**Negligible**	None proposed	**Negligible**
	North Norfolk Sandbanks and Saturn Reef cSAC/SCI	Negligible	Low (near-field), negligible (far-field)	**Negligible**	None proposed	**Negligible**
	Cromer Shoal Chalk Beds MCZ			**No impact**		**No impact**
	East Anglian coast			**No impact**		**No impact**
Impact 5: Changes in suspended sediment concentrations due to removal of parts of the offshore cable (including nearshore and at the coastal landfall)	Haisborough, Hammond and Winterton cSAC/SCI	Negligible	Low (near-field), negligible (far-field)	**Negligible**	None proposed	**Negligible**
	North Norfolk Sandbanks and Saturn Reef cSAC/SCI			**No impact**		**No impact**
	Cromer Shoal Chalk Beds MCZ	Negligible	Low (near-field), negligible (far-field)	**Negligible**	None proposed	**Negligible**
	East Anglian coast			**No impact**		**No impact**
Impact 6: Indentations on the Seabed due to Decommissioning Activities	Haisborough, Hammond and Winterton cSAC/SCI			**No impact**		**No impact**
	North Norfolk Sandbanks and Saturn Reef cSAC/SCI			**No impact**		**No impact**
	Cromer Shoal Chalk Beds MCZ			**No impact**		**No impact**
	East Anglian coast			**No impact**		**No impact**
	Cromer Shoal Chalk Beds MCZ	Negligible	Low (near-field), negligible (far-field)	**Negligible**	None proposed	**Negligible**
	East Anglian coast	Negligible	Low (near-field), negligible (far-field)	**Negligible**	None proposed	**Negligible**

Norfolk Boreas Offshore Wind Farm

Environmental Impact Assessment

Benthic and Intertidal Ecology Method Statement

Document Reference: PB5640-004-013

Author: Royal HaskoningDHV
Applicant: Norfolk Boreas Ltd
Date: February 2018

Date	Issue No.	Remarks / Reason for Issue	Author	Checked	Approved
15/11/2017	D01	Issue for internal review	ES	DT	AD
18/01/2018	02D	Issue for second internal review	DT	AD	AD
24/01/2018	03D	Second review comments addressed	DT	AD	AD
24/01/2018	03D	Issue to Vattenfall for review	DT	JL	
05/01/2018	F01	Issue to Expert Topic Group	DT		JL

This method statement has been prepared by Royal HaskoningDHV on behalf of Norfolk Boreas Limited in order to build upon the information provided within the Norfolk Boreas Environmental Impact Assessment (EIA) Scoping Report. It has been produced following a full review of the Scoping Opinion provided by the Planning Inspectorate. All content and material within this document is draft for stakeholder consultation purposes, within the Evidence Plan Process.

Many participants of the Norfolk **Boreas** Evidence Plan Process will also have participated in the Norfolk **Vanguard** Evidence Plan Process. This document is presented as a complete and standalone document, however in order to maximise resource and save duplication of effort, the main areas of deviation from what has already been presented through the Norfolk Vanguard Evidence Plan Process and PEIR or in the Norfolk Boreas Scoping Report are presented in orange text throughout this document.

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1 INTRODUCTION

1. The purpose of this method statement is to build upon the information provided within the Norfolk Boreas Environmental Impact Assessment (EIA) Scoping Report, that collated for the Norfolk Vanguard PEIR and survey data collected in summer 2017, in outlining the proposed approach to be taken and considerations to be made in the assessment of the benthic ecology effects of the proposed development.

2. This method statement and the consultation around it form part of the Norfolk Boreas Evidence Plan Process (EPP). The aim is to gain agreement on this Method Statement from all members of the benthic ecology Expert Topic Group (ETG) Which will be recorded in the agreement log.

3. This method statement has been produced following a full review of the Scoping Opinion provided by the Planning Inspectorate; initial analysis of the data collected from the site specific surveys and responses to the Norfolk Vanguard PEIR. The EIA Scoping Opinion comments received that relate to benthic ecology are summarised in **Table 1.1** along with information as to how these will be addressed in the EIA. Further consultation with Natural England and the MMO has also been undertaken regarding the site specific surveys which is also summarised in section 3.2.1**.**

4. Information provided in this Method Statement is a draft for stakeholder consultation only and is provided in confidence. It is recognised that Norfolk Vanguard ETG meetings are being held in January 2018 and that agreements will be made during those meetings which are not necessarily reflected here. Due to certain project "Mile Stones" which have been set by the Crown Estate, Norfolk Boreas must progress on a programme which requires consultation on the Norfolk Boreas Method Statements prior to the conclusion of the Norfolk Vanguard EPP. Therefore, the material provided in this document represents the best available information at the time of writing.

5. Provided with this Method Statement are the following technical studies and survey reports data sets which, taken together, are considered to present a comprehensive and suitable data set to characterise the site and undertake robust impact assessment:

- The Norfolk Boreas benthic Characterisation report (Fugro, 2018);
- The Norfolk Vanguard Intertidal survey report (Royal HaskoningDHV, 2017a);
- A study completed by Envision Mapping Limited to map potential *Sabellaria spinulosa* reef in the offshore cable corridor (Envision Mapping Limited, 2018); and
- A study completed by ABPmer of the recoverability of sandwaves within the offshore cable corridor following seabed levelling for cable installation (ABPmer, 2018). This Report will be updated following feedback from Norfolk Vanguard Expert Topic Group meetings in January 2018.

Table 1.1 Scoping opinion responses.

Consultee	Comment (some of which have been summarised to reduce the size of the table)	**Response / where addressed in this document**
Secretary of State	The SoS welcomes the proposal for surveys to develop the understanding of the seabed conditions across the site. The SoS recommends that the scope of these surveys is agreed with the relevant consultees, including the EA, the MMO and NE. The survey methodology should be set out within the ES.	The scope of the surveys were agreed with the MMO and Natural England at a meeting held on the 16th February 2017 and through further correspondence. As the site is approximately 70km from the coast it was not necessary to agree the scope with the Environment agency. The Full methodology undertaken during the survey is provided in Benthic Characterisation report (Fugro,2018).
Secretary of State	The Scoping Report notes there is no epibenthic trawl data available for the offshore cable corridor, although grab surveys indicate it is broadly comparable with the benthic ecology in the array area. The Applicant should agree with relevant consultees whether or not there is a need for epibenthic trawls within the cable corridor and document any agreement within the ES.	It has been agreed through the Norfolk Vanguard EPP process that no epibenthic trawl data is required from within the export cable corridor. It has been assumed that due to the fact that the two projects share an export cable corridor no epibenthic trawl data is required for the Norfolk Boreas EIA. As stated above the scope of the Norfolk Boreas surveys were agreed with Natural England and the MMO.
MMO	Site characterisation should be informed by newly published satellite Suspended Particulate Material (SPM) data covering, which is available on the Cefas data Hub.	The applicant will use this data to inform the Baseline Environment (Section 3.1)
Secretary of State	An assessment of the potential impacts on Annex I sandbanks and biogenic reefs should be presented within the ES.	A full assessment of the potential impacts on Annex 1 sandbanks and biogenic reefs will be presented within the ES. The methodology proposed for this assessment is provided in sections 5.1.5 and 4.
Secretary of State	The Scoping Report identifies the presence of *Sabellaria spinulosa* reef within the array area and the offshore cable corridor. The ES should consider potential direct impacts from construction, and also the potential impacts from maintenance activities on reef that may colonise the cables during the operational phase.	The scoping report Identifies the potential for the presence of *Sabellaria spinulosa* reef. Section 3.2.3 establishes the likely current extent of reef within the offshore project area and section 5.2.1 outlines the proposed approach to assessing the impacts on the potential *Sabellaria* reef within the Norfolk Boreas site.
Natural England	Our key concerns are as follows and we consider that these issues will need thorough consideration through the EIA and HRA and close discussion between the Applicant, Natural England and where possible the regulators and Marine Management Organisation (MMO).....Potential effects on Annex I *S. spinulosa* reef from the installation and maintenance of the export cables - both at a project level and in-combination with Vanguard OWF	Section 5.2.1 and 6 provide the proposed methodology to assess these impacts under EIA and HRA respectively.
Natural England	Our key concerns are as follows and we consider that these issues will need thorough consideration through the EIA and HRA and close discussion between the Applicant, Natural England and where possible the regulators and Marine Management Organisation (MMO).......Potential impacts on the interest features of Cromer Shoal Chalk	The Norfolk Boreas offshore cable corridor now avoids direct overlap with the Cromer Shoal Chalk Beds Marine Conservation Zone (MCZ). The EIA will consider indirect impacts from the project alone (section 5.1.5) and cumulative impacts from both Norfolk

Consultee	Comment (some of which have been summarised to reduce the size of the table)	Response / where addressed in this document
	Beds Marine Conservation Zone (MCZ) – both at a project level and in-combination	Boreas and Norfolk Vanguard (section 5.4)
Secretary of State	When assessing the potential impacts from habitat loss, the ES should give consideration not only to habitat loss resulting from scour that occurs around foundations, but also to habitat loss resulting from the introduction of required scour protection.	The current worst case area for Impacts from scour protection is provided in section 2.3 and the methodology for assessing impacts associated with scour protection are considered in section 5.2.1
Natural England	It is our view that non-native species are, on their own right, a distinct impact on the marine ecological environment. Therefore, it should be identified under a separate [from colinisation of hard substrate] heading, providing a range of pathways how the spread of non-native species may result from the proposed development (ballast water, biofouling of boat hulls, as well as the hard structures acting as "stepping stones" for geographic spreading of these species).	As the impacts are closely linked they will be considered under the same impact heading the proposed methodology assessing these impacts is provided in section 5.2.4
Secretary of State	The SoS notes that paragraph 201 of the Scoping Report suggests the cable would be buried between 1-3m deep. The applicant should be aware of the statements within NPS EN-3 that if it is proposed to install offshore cables to a depth of at least 1.5m below the sea bed, the applicant should not have to assess the effect of the cables on subtidal or intertidal habitat	During this stage of the project it will not be possible to predict with any degree of certainty that cable burial across the entire project will achieve a depth of more than 1.5m therefore impacts from operational cables will be assessed within the EIA.
Secretary of State	The SoS notes construction of the offshore elements of the Proposed Development would be between 2025-2028 and that the Norfolk Vanguard Scoping Report identified construction between 2023-2027. The SoS therefore considers that there is a high likelihood of overlapping construction periods. The Applicant should take this into account in the cumulative assessment.	The cumulative impact assessment will assess overlapping construction programmes of Norfolk Vanguard and Norfolk Boreas further detail is provided in section 4.1.5.
Secretary of State	The ES should provide evidence to support the assertion that the recoverability of the species found, mean that cumulative impacts are unlikely to be significant.	Evidence of recoverability at other operational wind farms will form the main body of evidence for recoverability. Studies from other activities impacts affecting the seabed, such as those from the dredging industry, will also be used.
Secretary of State	Paragraph 428 of the Scoping Report proposes to scope out electromagnetic fields (EMF) on benthic species as effects are likely to be highly localised, and as EMFs are strongly attenuated and decrease as an inverse square of distance from the cable. The Scoping Report references studies which show EMFs do not impact benthic species and habitats. The SoS accepts the evidence presented by the Applicant and is content with the proposed approach.	In line with the Secretary of States opinion, effects of EMF on benthic species are not considered within this Method Statement as they have been scoped out of the EIA.
Secretary of State	The SoS welcomes the consideration of mitigation measures at this stage and recommends these are discussed and agreed during the EPP	Mitigation measures will be discussed through the Norfolk Boreas EPP as well as being informed by the Norfolk Vanguard EPP.
Natural England	We advise that the ES considers alternative cable routing (avoidance is NE preference) and mitigation options in order to minimise impacts to reefs. Where it may not be possible to avoid Annex I habitat or adopt appropriate mitigation measures to reduce the	VWPL have commissioned a study to map *Sabellaria spinulosa* reef within the offshore cable corridor (Envision, 2018). The Benthic characterisation report for Norfolk Boreas (Fugro, 2018)

Consultee	Comment (some of which have been summarised to reduce the size of the table)	Response / where addressed in this document
	impacts down to an acceptable level, evidence on the recoverability of disturbed *S. spinulosa* reef should be provided. Consideration should also be given to the implications on recovery of any phased build and/or in-combination impacts.	completed an assessment of the presence of *Sabellaria spinulosa* reef within the Norfolk Boreas site the results of which are summarised in section 3.2.3. Where possible cable routing will be designed to avoid these areas. The methodology for assessing impacts to Annex I *S. spinulosa* reef is provided in section 84.
Natural England	Due to the features of the MCZ and the scale of the proposed works, there is a possibility that Natural England will consider the impacts on the MCZ are such that the conservation targets for the site cannot be met. This is particularly relevant when in-combination impacts are considered with other projects. Therefore, should the Applicant choose to go through the MCZ, all alternative options should be considered and decision-making thoroughly validated; and a Stage 1 (and possible stage 2) assessment will be required.	Due to concerns raised by Natural England and The Wildlife Trusts the Norfolk Boreas offshore cable corridor has been refined to avoid overlap with the Cromer Shoal Chalk Beds Marine Conservation Zone (MCZ). The EIA will consider indirect impacts from the project alone (section 5.1.5) and cumulative impacts from both Norfolk Boreas and Norfolk Vanguard (section 5.4)
Natural England	UK Government's Marine Policy Statement includes on p. 20 "There may also be an increased risk of spills and leaks of pollutants into the water environment and the likelihood of transmission of invasive non-native species, for example through construction equipment, and their impacts on ecological water quality need to be considered". The full statement document can be accessed online: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69322/pb3654- marine-policy-statement-110316.pdf	Norfolk Boreas Limited are committed to the use of best practice techniques and due diligence regarding the potential for pollution throughout all construction, operation and maintenance, and decommissioning activities. An Environmental Management Plan (EMP will be produced which will include measures to ensure that all possible pollution are contained or minimised. Further detail is provided in section 5.1 of the Marine water and sediment quality method statement. The spread of non-native species will be considered in within the EIA. section 5.2.4)
MMO	Operation and maintenance (O and M) activities should be assessed within the Environmental Statement (ES). This may include use of jack-up barges for repair, cable repair, part replacements, repainting of structures and removal of fauna/flora from monopiles. The MMO is content to liaise with the applicant on this matter through the Evidence Plan process.	The current anticipated worst case scenario for operation and maintenance of the project is provided in section 2.3.9. Section 5.2 describes how operational impacts will be assessed in the ES
MMO	The potential impacts to benthos during the maintenance of the built project have not been considered and should be fully assessed within the ES.	Section 5.2 describes how operational impacts will be assessed in the ES.
MMO	It is proposed that potential effects of noise and vibration on benthic species during the operational phase have been scoped out of EIA on the basis that there is no evidence to suggest this low level of noise and vibration has a significant impact on benthic ecology. The MMO is aware of some existing research that indicates some negative effects from noise on benthic ecology. In light of this evidence, the MMO recommends that there is further discussion regarding this issue during the evidence plan process.	Section 5.2.5 includes the proposed approach to underwater noise during operation. The issue of operational noise and vibration effects on benthic species will be briefly addressed in the PEIR, however it is anticipated that impacts will be negligible.

1.1 Background

6. A Scoping Report for the Norfolk Boreas EIA was submitted to the Planning Inspectorate on the 9th May 2017. Further background information on the project can be found in the Scoping Report which is available at:

https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010087/EN010087-000015-Scoping%20Report.pdf

7. The Scoping Opinion was received on the 16th June 2017 and can be found at:

https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010087/EN010087-000013-Scoping%20Opinion.pdf

1.2 Norfolk Boreas Programme

8. This section provides an overview of the planned key milestone dates for Norfolk Boreas.

1.2.1 Development Consent Order (DCO) Programme

- EIA Scoping Request submission - 09/05/17
- Preliminary Environmental Information (PEI) submission - Q4 2018
- Environmental Statement (ES) and DCO submission - Q2 2019

1.2.2 Evidence Plan Process Programme

9. The Evidence Plan Terms of Reference (Royal HaskoningDHV, 2017b) provides an overview of the Evidence Plan Process and expected logistics, below is a summary of anticipated meetings:

- Agreement of Terms of Reference Q3 2017
- Post-scoping Expert Topic Group consultation Q1 2018
  - Discuss method statements
- Expert Topic Group and Steering Group meetings as required - 2018
  - To be determined by the relevant groups based on issues raised
- PEI Report (PEIR) Expert Topic Group and Steering Group meetings - Q4 2018/ - Q1 2019
  - To discuss the findings of the PEI (after submission)
- Pre-submission Expert Topic Group and Steering Group meetings - Q1/Q2 2019

- To discuss updates to the PEIR prior to submission of ES

1.2.3 Consultation to Date

10. Norfolk Boreas is the sister project to Norfolk Vanguard (See Section 2 for further details). A programme of consultation has already been undertaken for Norfolk Vanguard which is of relevance to Norfolk Boreas and this is listed below.

- EIA Scoping Request submission - 09/05/16
- Receipt of Scoping Opinion - 16/10/17
- Steering Group consultation - Q2 2017
- Post-scoping Expert Topic Group meetings
  - Discuss method statements and Project Design Statement - 31/01/2018
- Expert Topic Group and Steering Group meetings as required - 2018
  - To be determined by the relevant groups based on issues raised

1.2.4 Survey Programme

11. An offshore Environmental survey campaign covering the Norfolk Boreas site (shown in Figure 1) was completed in summer and autumn 2017. The details of the specific data collection and analysis undertaken during these surveys are included under section 3.2.

2 PROJECT DESCRIPTION

2.1 Context and Scenarios

12. Vattenfall (VWPL) is developing Norfolk Boreas and Norfolk Vanguard in tandem, and is planning to co-locate the export infrastructure for both projects in order to minimise overall impacts. This co-location strategy applies to the offshore cable corridor (shown in Figure 1) and the cable landfall.

13. The Norfolk Boreas project programme is approximately 12 months behind Norfolk Vanguard in terms of the DCO process. As such, the Norfolk Vanguard team is leading on site selection for both projects. There is a possibility that the Norfolk Vanguard project would not be constructed. In order for Norfolk Boreas to stand up as an independent project, this scenario must be provided for within the DCO for Norfolk Boreas. Thus, two alternative scenarios are being considered in the context of this Method Statement; Scenario 1 where Norfolk Vanguard has been fully constructed before any construction of Norfolk Boreas begins, and Scenario 2 where Norfolk Vanguard is not constructed.

14. For both scenarios, Norfolk Boreas would consent and construct all required offshore infrastructure, and so there is no difference in the assessment of benthic and intertidal ecology between the scenarios for Norfolk Boreas alone. The only offshore difference is that under Scenario 1, Norfolk Vanguard would be considered within the Cumulative Impact Assessment (CIA), together with the parameters of Norfolk Boreas.

2.2 Site Selection Update

15. The Norfolk Boreas Scoping report presented three potential landfall locations. Data was reviewed on a broad range of environmental factors, including existing industrialised landscape, the presence of the Cromer Shoal Chalk Beds Marine Conservation Zone (MCZ), coastal erosion and archaeology alongside statutory and non-statutory consultation.

16. After publication of the scoping report, VWPL concluded, taking account of all engineering and environmental factors, as well as public feedback, that the most suitable landfall location would be Happisburgh South. The decision to go to Happisburgh south was presented to the Norfolk Vanguard Evidence Plan Expert Topic groups in June and July 2017 and in the Norfolk Vanguard PEIR (Royal HaskoningDHV, 2017c).

17. The Happisburgh South landfall site also has the benefit of being large enough to accommodate landfall works of both Norfolk Vanguard and Norfolk Boreas, therefore reducing the spatial extent of impacts associated with the two projects.

18. Ongoing public and stakeholder consultation as well as initial EIA data collection will be used to inform any further site selection work for the EIA and DCO application, however the offshore site boundaries are now established and are not anticipated to change for the PEIR. Impacts that cannot be avoided through site selection will be reduced through micro siting, alternative engineering solutions (mitigation by design) and additional mitigation measures, where possible. Mitigation options will be developed in consultation with stakeholders.

2.3 Indicative Worst Case Scenarios

19. The following sections set out the indicative worst case scenarios for benthic ecology. The Norfolk Boreas EIA will provide further detail on the Project Description describing the final project design (also known as Rochdale) Envelope for the DCO application. Each chapter of the Environmental Statement (ES) will define the worst case scenario arising from the construction, operation and decommissioning phases of the Norfolk Boreas project for the relevant receptors and impacts. Additionally, each chapter will consider separately the anticipated cumulative impacts of Norfolk Boreas with other relevant projects on the receptors under consideration.

20. The indicative worst case scenario for benthic and intertidal ecology is primarily based on the greatest direct and indirect seabed footprint of the project. Scenarios associated with the greatest potential to cause suspended sediments are also considered and are closely linked to the scenarios outlined in the Marine Physical Processes Method Statement (Doc Ref: PB5640-004-024).

21. Two electrical solutions are being considered for Norfolk Boreas, a High Voltage Alternating Current (HVAC) scheme and a High Voltage Direct Current (HVDC) scheme. The decision as to which option will be used for the project will be agreed post consent and will depend on availability, technical considerations and cost. Both electrical solutions will have implications on the required offshore infrastructure which are detailed in the following sections.

2.3.1 Wind Turbine Generator Foundations

22. A range of 7MW to 20MW wind turbine is included in the Norfolk Boreas project design envelope in order to future proof the EIA and DCO to accommodate foreseeable advances in technology.

23. The foundations of 15MW to 20MW turbines are estimated to have the same physical parameters. As a result, if the worst case scenario is associated with the largest wind turbines, 120 x 15MW would be the worst case scenario, rather than 90

x 20MW, due the greater number of devices making up the maximum site capacity of 1,800MW. The maximum number of WTGs would be 257 x 7MW.

24. A range of foundation options; monopile, jackets on pin piles (on three or four legs), jackets on suction caissons (on three or four legs), gravity base structures (GBS) and floating foundations with tension leg mooring system are included in the current project design Envelope. Floating foundations with anchors would also be included in the Norfolk Boreas Rochdale Envelope. Ongoing review by the Norfolk Boreas engineering design team has identified that this is necessary in order to future proof the EIA and DCO to include the types of foundations that are likely to be available at the time of Norfolk Boreas construction. **Table 2.1** provides indicative maximum parameters for 7MW and 15MW to 20MW GBS and base foundations and floating foundation gravity anchors. Thus providing justification for the parameters which will form the worst case scenario (highlighted with bold text).

Table 2.1: Indicative wind turbine foundation maximum parameters. The worst case parameters which will be used in the assessment are presented in bold

Foundation Type	7MW wind turbines	15MW-20MW wind turbines
Number of foundations	257	120
GBS foundation footprint	40m diameter = 1257m^2	50m diameter= 1963.5m^2
GBS area of scour protection (includes foundation footprint)	5 x diameter of GBS = 31,416m^2	5 x diameter of GBS = 49,087m^2
GBS height above seabed	In excess of **12m**	In excess of 12m
Floating foundation gravity anchor footprint	45 x 45 = 2025m^2	70 × 70 =4,900m^2
Floating foundation gravity anchor scour protection footprint (includes foundation footprint)	Approximately 5 x size of foundation. 225 x 225 = 50,625m^2	Approximately 5 x size of foundation. 350 x 350 = **122,500m^2**
Monopiles and Jackets (3 and 4 leg and pin pile and suction caisson) including scour protection	Would have significantly smaller footprints than GBS and tension leg floating foundations.	

25. **Table 2.1** shows that the maximum permanent footprint is associated with floating foundations which have a gravity anchors and associated scour protection. Based on the indicative parameters provided for gravity anchors, 257 x 7MW turbine foundations represents the worst case scenario footprint rather than 90 x 20MW turbine foundations. This provides the scenario with the worst case potential for habitat loss of 13,010,625m^2 across the Norfolk Boreas site. In practice, fewer floating foundations may be used (due to larger capacity WTGs (16-20MW) installed and / or alternative foundation types used), less scour protection could be required and the effect would be less than that considered as the worst case. The current project design envelope assumes a worst case footprint which accounts for the foundation and associated scour protection and is described in section 2.3.2.

26. The worst case scenario in terms of the effects on benthic ecology due to increased suspended sediments, smothering effects upon resettlement and contaminated

sediment are directly related to the total amount of suspended sediment caused by the project. This greatest amount of sediment disturbance is currently predicted to occur as a result of seabed preparation for GBS foundations. This is predicted to be 9,817m^3 for a 7MW turbine foundation and 14,137m^3 for a 15MW turbine foundation. Thus the greatest impact at anyone location and point in time would result from the installation of a 15 -20MW turbine foundation with the potential to disturb 2,523,098m^3 of sediment across the entire Norfolk Boreas site.

27. Monopile or jackets with pin pile foundations may require drilling. Following analysis of geophysical and geotechnical data acquired from the Norfolk Boreas site drilling will only be required in a limited number of locations. As a precaution the worst case scenario is currently that drilling would be required at 50% of foundation locations. The worst case volume of drill arisings from foundation construction is currently predicted to occur as a result of drilling quadropod pinpiles for 15MW foundations. This would result in up to 1,963.5m^3 of drill arising for one foundation and up to 117,810m^3 across the entire Norfolk Boreas site (drill arising for 257 × 7MW turbine foundations would be less). Volume of material disturbed through seabed preparation for cables installation is described in section 2.3.3.

2.3.2 Scour Protection

28. A number of options will be considered (and detailed within the PEIR) to protect the foundations from scour if required, including rock dumping, frond mats and concrete mattressing. If monopile foundations are selected, the worst case area required for scour protection is likely to be five times the diameter of the foundation (i.e. a 10m monopile may require 50m diameter scour protection). Calculations for the area occupied by scour protection is provided in **Table 2.1.** Alternative foundation options are likely to require smaller areas of scour protection.

29. Maximum permanent footprints within the Norfolk Boreas site for foundations and scour protection associated with other structures within include:

- Three offshore electrical platforms with scour protection, (200m diameter) 94,248m^2
- One accommodation platform with scour protection 31,416m^2
- Two met masts (100m diameter) 15,708m^2
- Two LiDAR (Light Detection and Ranging) buoys (42.5m diameter) 2,838m^2
- One wave buoy with anchors 150m^2

2.3.3 Offshore Cabling

30. Of the two electrical solutions being considered the HVAC represents the worst case scenario in terms of the area of impact as a greater length of cabling will be required.

However, both electrical solutions will have implications on the required offshore infrastructure which are detailed in the following sections:

31. In terms of potential impacts to benthic ecology, the key indicative offshore cabling parameters are as follows:

- For HVDC export scheme:
  - Two separate HVDC links (max 900MW of power)
  - 2 offshore converter stations,
  - 2 export cable systems (each system comprised of a pair of DC power cables and a fibre-optic signal cable), with a max length of 140km and 1 trench per export cable.
  - 1 subsea interconnector cable system (comprised of a pair of DC power cables, an AC power cable and a fibre-optic signal cable), with a max length 50km and 2 trench per interconnector cable system with max trench length of 100km.
  - Maximum array cable length 750km
- For HVAC export scheme:
  - Up to 3 offshore substations
  - Up to 6 subsea HVAC export cables (containing 3 conductor cores and 1 integral fibre-optic signal cable), with two cables for each offshore substation either to the landfall location or collector platform. Max length 140km per cable
  - Subsea interconnector cable systems linking the up to 3 offshore substations (containing 3 core AC power cables and an integral fibre-optic signal cable). Max length of 50km per cable and a trench per interconnector cable, max length 50km.
  - Maximum array cable length 750km

32. Prior to cable installation pre-sweeping may be required to ensure that cables can be buried to a depth where they are unlikely to become exposed. This is most likely to be required for the export cables. VWPL commissioned GMSL to undertake a detailed study of the likely quantities of material which could be required to be dredged from the seabed during the pre-sweep. These quantities are included in the calculations below.

33. The preferred construction technique and depth of burial for the offshore electrical infrastructure will be decided pre-construction based on ground investigation. Possible installation techniques include:

- Ploughing;
- Jetting;
- Dredging; and
- Trenching.

34. The worst case scenario for temporary disturbance from cable installation is based on a 20m width of disturbance for array and interconnector cables and a 30m width for export cables. This encompasses all seabed preparation works (including pre-sweeping and pre-grapnel run) and installation of the cables themselves. The following maximum worst case areas of disturbance are predicted:

- Maximum length of array cables - 750km × 20m = 15km^2
- Maximum length of Interconnector cables - 150km × 20m = 3km^2
- Total export cable installation – length 840km × 30m = 25.2km^2.
- Disturbance within Haisborough Hammond and Winteron SAC = 7.2km^2 (included within the 25.2km^2 total disturbance area above)
- Cable trenching in the intertidal zone = 3,000m^2.

35. The worst case volumes of potential sediment release will be described in detail within the Marine Geology, Oceanography and Physical Processes Chapter of the PEIR but are anticipated to be as follows:

- The sediment released due to pre-sweeping for the offshore export cables would equate to approximately 1,600,000m^3 of sediment. Approximately 1,400,000m^3 would be within the Haisborough, Hammond and Winterton SAC; 200,000m^3 would be within the rest of the offshore cable corridor (excluding the nearshore (10m water depth contour) where no pre-sweeping is proposed).
- Following pre-sweeping, the sediment disturbed due to trenching for the offshore export cables would equate to approximately 12,600,000m^3 of sediment, based on a V shaped trench with a maximum width of 10m and average depth of 3m. Approximately 3,600,000m^3 would be within the Haisborough, Hammond and Winterton SAC; 270,000m^3 would be within the nearshore (10m water depth contour); and 8,730,000m^3 from the rest of the offshore cable corridor.

2.3.4 Cable Protection

2.3.4.1 Within the Norfolk Boreas site

36. In some cases, cable burial cannot be undertaken and surface laying with cable protection would be required. In addition to these as yet unknown areas it is estimated that 50m of array cable would be surface laid on approach to each WTG as well as 50m of export cable and interconnector cables on approach to the substation platforms. The total area occupied by cable protection will be estimated as part of the worst case scenario and provided in the PEIR but is likely to be approximately 110,600m^2 based on calculations completed for the Norfolk Vanguard PEIR (Royal HaskoningDHV, 2017c).

2.3.4.2 Within the offshore cable corridor

37. A detailed export cable installation study (CWind, unpublished) which was commissioned by VWPL Ltd. confirmed that cable burial is expected to be possible throughout the offshore cable corridor with the exception of at cable crossing locations.

38. A conservative approach has however been taken when establishing the worst case scenario and it has been assumed that cable burial will not be possible for 10km of each export cable (60km in total). Therefore, cable protection would be required at these locations, where the export cables cross other cables or pipelines, at the landfall HDD exit points, and/or during the operation and maintenance phase should cables become unburied.

39. Worst case scenario for cable protection footprint:

- Seven crossings per cable (up to six cables) = 42,000m^2 (12,000m^2 within the SAC)
- Unburied cables during operational phase using conservative estimate of 10km per cable = 300,000m^2 (120,00m^2 within the SAC).
- Total cable protection within the offshore cable corridor = 0.34km^2 (0.13km^2 within SAC)
- Landfall HDD exit point = one mattress (6m length x 3m width x 0.3m height) plus rock dumping (5m length x 5m width x 0.5m height) at each exit point (up to six cables).

2.3.5 Ancillary Infrastructure

40. In addition to the wind turbine generators a number of other structures will make up the windfarm site these are described below. The footprints of these structures are provided in the calculations above.

2.3.5.1 Offshore Substation / Convertor Station Platforms

41. Up to three 600MW substation platforms (HVAC) or two 900MW convertor platforms (HVDC) would be required. Foundation options include:

- Piled monopile (10m diameter x 3 foundations);
- Suction caisson monopile (20m diameter x 3 foundations);
- Piled tripod (3m diameter pile x 3 foundations);
- Suction caisson tripod (3m diameter caisson x 3 foundations);
- Piled quadropod (3m diameter pile x 4 foundations); and
- Suction caisson quadropod (3m diameter caisson x 4 foundations).

2.3.5.2 Accommodation platforms

42. A single accommodation platform may be required to house construction and operation and maintenance personnel and equipment. This would require a foundation structure likely to be similar to that of the collector and converter stations

2.3.5.3 Monitoring equipment

43. It is anticipated that Norfolk Boreas site will host two wave monitoring stations and two LiDAR buoys. The wave monitoring equipment may be founded to the seabed or attached to a floating buoy. The LiDARs will be attached to a floating buoy.

44. Up to two operational meteorological masts (Met masts) may be installed within the Norfolk Boreas site, neither of which would exceed the hub height of a wind turbine generator. The foundations used may be jacket, gravity base, suction caisson or monopile.

2.3.6 Construction Vessels

45. Vessel anchors and jack ups required for construction also have the potential to impact benthic ecology. The maximum number of anchors or jack-ups representing the worst case scenario will be defined in the PEIR but the worst case scenario is likely to be that jack-up barges with four legs per barge (176.71m^2 per leg, 706.86m^2 combined leg area) would be used for wind turbine installation contributing a total footprint area of 363,316m^2 (based on two jacking operations per wind turbine for 257 x 7MW turbine sites).

46. It is anticipated that several types of construction vessel could work in parallel during the construction of Norfolk Boreas. For wind turbine installation, the most likely installation vessel would be a jack-up vessel, although DP vessels are also under consideration.

47. The current construction programme estimates that up to 113 different vessels could be used to construct Norfolk Boreas with up to 57 on site at any one time. The origin of these vessels would not be determined until post consent.

2.3.7 Landfall

48. At the landfall up to six Norfolk Boreas offshore export cables would be brought ashore (Royal HaskoningDHV, 2017a). These would be jointed to the onshore cables in transition pits located within the eastern most “trenchless crossing technique” (Figure 3.1 in Royal HaskoningDHV, 2017a). Under Scenario 1 Norfolk Boreas would share the landfall area with Norfolk Vanguard at Happisburgh South.

49. Works associated at landfall would be the same under both scenarios. Under Scenario 1, if Norfolk Boreas cable ducts are installed concurrently with the Norfolk Vanguard ducts, the Norfolk Boreas ducts would be installed only on the landward side of the transition pits.

50. Ducts on the seaward side of the transition pits would be installed using Horizontal Directional Drilling (HDD) which is a trenchless installation technique. The HDD would exit at one of the following two locations (impacts of the HDD exit point will be considered in the offshore assessments including the Marine Geology, Oceanography and Physical Processes and the Benthic and Intertidal Ecology impact assessment):

- On the beach, above the level of mean low water spring (classified as “short HDD”).
- At an offshore location, seaward the beach (up to 1000m in drill length) (classified as “long HDD”).

51. As with the offshore cable, a total of six ducts for the HVAC option or two ducts for the HVDC option would be required at the landfall for Norfolk Vanguard. Therefore the landfall HVAC option represents the worst case scenario for benthic and intertidal ecology.

52. The ducts are typically floated into position at the offshore/intertidal exit point via barges, the ducts are then flooded with water and pulled into the reamed drill hole from the entry pit. Once the duct has been installed, the offshore cables can be installed when convenient by positioning the cables at the offshore exit point and pulling through the ducts to the transition pit.

2.3.8 Construction Programme

2.3.8.1 Phasing

53. It is envisaged that Norfolk Boreas would either be built in two phases of 900MW (HVDC electrical solution – Option 1) or three phases of 600MW (HVAC electrical solution – Option 2). The location of each phase across the wind farm site would be determined based on constraint identification throughout the EIA process as well as post consent site investigations. The EIA will therefore assess up to the capacity of 1,800MW.

54. Norfolk Boreas construction is likely to be staggered and may have temporal overlap between phases. The objective is to ensure each phase is complete and generating electricity in as short a time as possible. The worst case scenario for marine and benthic ecology would be the three phase option. Under Scenario 1, an indicative three phase programme would be:

- Phase 1 - Construction 2025, commissioning 2028;
- Phase 2 - Construction 2026, commissioning 2029; and
- Phase 3 - Construction 2027, commissioning 2030.

55. Under Scenario 2, an indicative three phase programme would be

- Phase 1 - Construction 2026, commissioning 2027;
- Phase 2 - Construction 2027, commissioning 2028; and
- Phase 3 - Construction 2028, commissioning 2029.

2.3.8.2 Foundations

56. The construction programme with the longest duration has the greatest potential to impact upon benthic ecology. It is expected that installation of all foundations would take up to 15 months for a single phase approach, nine months per phase for a two phased approach and six months per phase for a three phased approach over a 3-year period. Up to four foundation installation vessels used to install foundations simultaneously.

2.3.8.3 Offshore Cable Laying

57. Under a single phased approach cable laying could take up to 14 months. Under two- or three-phase approaches the principal difference compared to the single phase assessment is that installation of the cables would occur over two or three distinct phases, each lasting up to nine months or five months, respectively.

2.3.8.4 Landfall

58. For an indicative HDD length of 500m, it is anticipated that site establishment, the drilling of six ducts and demobilisation would take approximately 30 weeks when considering 12 hour (7am-7pm), seven-day shifts. A 24-hour operation could be employed for drilling activities, subject to planning and environmental restrictions, and could reduce the installation to approximately 20 weeks. Cable pulling would be undertaken subsequent to the duct installation.

2.3.9 Operations and Maintenance (O&M) Strategy

59. Once commissioned, the wind farm would operate for up to 25 years. All offshore infrastructure including wind turbines, foundations, cables and offshore substations would be monitored and maintained during this period in order to maximise efficiency.

60. A full estimate of the amount of potential maintenance work required will be provided in the PEIR. However, the following unplanned repairs and reburial are conservatively estimated:

- Reburial of all sections of array cable is estimated once every 5 years – 3m disturbance width x 750km = 2,25km^2;
- Two array cable repairs per year are estimated. An array cable may be up to 4.5km (based on turbine spacing) – 3m disturbance width x 4,500m x 2 = 27,000m^2.
- One interconnector repair per year is estimated – 10m disturbance width x 50km = 500,000m^2;
- Two export cable repairs per year with 300m sections removed and replaced. Disturbance width of 10m = 3,000m^2 per year; and
- Reburial of up to 20km length per export cable (10km in the Haisborough, Hammond and Winterton SAC and 10km outside the SAC) = 200,000m^2 per cable based on a disturbance width of 10m = 1.2km^2.

61. Maintenance of wind turbine generators will be required during O&M. An estimate of up to two locations visited per day during O&M using a jack up vessel with a footprint of 706.86m^2 which would lead to a total area of disturbance of up to 0.516km^2 per year (assuming large jack up with four legs each of 76.71m^2). Anchored vessels could also be placed temporarily on site to maintain the wind turbines. Worst case scenario is six anchors each with a footprint of 25m^2 equating to a total footprint of 150m^2 per installation.

2.3.10 Decommissioning

62. Decommissioning would most probably involve the accessible installed components comprising: all of the wind turbine components; part of the foundations (those above sea bed level); and the sections of the inter-array cables close to the offshore structures, as well as sections of the export cables. The process for removal of foundations is generally the reverse of the installation process. Possible impacts to benthic ecology associated with the decommissioning stage(s) will be further considered as part of the EIA.

63. It is anticipated that a separate consent and an associated EIA will be required ahead of any decommissioning works to be undertaken.

2.3.11 Cumulative Impact Scenarios

64. Under Scenario 1, Norfolk Vanguard and Norfolk Boreas could install a total of up to 12 offshore cables within the export cable corridor and 12 ducts at the landfall (six for each project under the worst case HVAC electrical solution).

65. The full implications of the Norfolk Vanguard and Norfolk Boreas cumulative impact scenarios, as well as cumulative impacts with respect to other existing and planned projects (including, but not limited to, East Anglia One, East Anglia Three, East Anglia One North and East Anglia Two), will be considered as part of the EIA process.

66. Other project types (e.g. aggregate dredging, oil and gas projects, cable and pipelines) will be considered in the CIA where applicable.

67. A full list of projects for consideration in the CIA are provided in section 5.4.

2.3.12 Transboundary Impact Scenarios

The localised nature of the potential impacts on the benthos means that significant transboundary impacts are unlikely. In accordance with the Scoping Report (Royal HaskoningDHV, 2017d), transboundary impacts have been scoped out of the EIA.

3 BASELINE ENVIRONMENT

68. The Scoping Report (Royal HaskoningDHV, 2017d) provides an overview of the baseline environment based on available information. This section outlines the approach to further characterising the baseline environment for the EIA.

69. Site characterisation will be undertaken using existing data for the former East Anglia Zone (Section 3.1) as well as the site-specific data for Norfolk Boreas (Section 3.2) and other available information for the region.

3.1 Available Data

70. Benthic sampling of the former East Anglia Zone was conducted in 2010 and 2011 (MESL, 2011) to inform the Zonal Environmental Appraisal (ZEA) for the former East Anglia Round 3 zone; this covered what is now the Norfolk Boreas site and part of the offshore cable corridor. These surveys included a combination of benthic grabs, trawls and seabed imagery. In total 98 grab and video sample stations were located in what is now the Norfolk Boreas site as well as 13 epibenthic trawls (Figure 1).

East Anglia Offshore Wind (EAOW) Ltd commissioned a power analysis in 2012 to assess whether further benthic sampling was required to inform the ecological baseline for the development of East Anglia FOUR, or whether information from the 2011 ZEA characterisation survey was sufficient. The power analysis determined high power values in the benthic data which suggested that the number of samples collected during the ZEA surveys was more than adequate to provide a robust baseline from which to detect spatial changes to the marine benthic fauna, and therefore the benthic ecological condition of the area (APEM, 2012). Therefore, it is expected ZEA surveys provide enough data to characterise the Norfolk Boreas site. However further data collection was undertaken to improve the robustness of the characterisation and to verify that the ZEA samples are still valid for characterisation.

71. During the Norfolk Boreas survey campaign, conducted in August 2017, video and grab (mini Hammond grab for benthic species composition analysis and mini Day grab samples for contaminant analysis) were collected from 35 locations across the Norfolk Boreas site. Video analysis was completed at all sample locations and grab samples (both benthic and contaminant) were analysed from 10 sample locations (Figure 2).

72. It was agreed with the MMO and Natural England in February 2017 that no further epibenthic trawls would be required to inform the site characterisation for the Norfolk Boreas EIA.

73. During the Norfolk Vanguard survey campaign the Norfolk Vanguard OWF sites and the provisional offshore cable corridor were subject to grab and video sampling.

Samples were taken at 15 locations within NV West, eight within NV East and 43 along the provisional offshore cable corridor. Although the sample locations within the Norfolk Vanguard OWF sites are not directly relevant to the Norfolk Boreas site, they are useful for characterisation of the general area. The samples within the shared offshore cable corridor are however directly relevant to Norfolk Boreas as the majority of the cable corridor is shared. There were 30 sample locations collected during the Norfolk Vanguard survey campaign which are located within the Norfolk Boreas offshore cable corridor (See Figure 1).

74. Table 3.1 summarises existing and the new site specific data from the Boreas site which will be used to inform the benthic ecology EIA. The benthic characterisation report has been provided along with this Method Statement (Fugro, 2018)

Table 3.1 Available benthic datasets

Data	Coverage	Date
Benthic survey (grabs, trawls and video) by Marine Ecological Surveys Ltd reported in the ZEA (EAOW, 2012a)	The former East Anglia Zone	2010 - 2011
Geophysical survey by Gardline Geophysical Ltd reported in the ZEA (EAOW, 2012a)	The former East Anglia Zone	2010
Benthic survey (grabs and video) by Fugro EMU Ltd (Fugro Group, unpublished)	NV East, NV West and the offshore cable corridor	2016
Geophysical survey by Fugro (reporting will be provided in the ES for Norfolk Vanguard)	Offshore cable corridor	2016
Benthic survey (grabs and video) by Fugro (Characterisation report provided with Method Statement	Norfolk Boreas site	2017
Geophysical survey by Fugro (reporting will be provided in the ES for Norfolk Vanguard)	Norfolk Boreas site	2017
Regional Environmental Characterisation (REC) studies (Limpenny *et al.* 2011)	East Coast	2011
National Biodiversity Network (NBN) gateway	East Anglia coast	various data sources
Marine Life Information Network (MarLIN)	UK species information	various data sources
UKSeamap 2010 Interactive Map	UK	various data sources up to 2010
European Marine Observation and Data Network (EMODnet) Seabed Habitats	Europe	2004-2014
Satellite Suspended Particulate Material (SPM)	UK waters Continental shelf	1998-2015

3.1.1 Existing Geophysical Data

75. Geophysical data (sidescan sonar, multibeam echosounder and sub-bottom profiler) were collected by Gardline Geosurvey in 2010 to inform the Zone Environmental Appraisal (ZEA) corridors were spaced approximately 1 km apart resulting in approximately 28% of what is now the Norfolk Boreas site.

76. This data is largely superseded by the full coverage of geophysical data which has been collected from the site as part of the Norfolk Boreas surveys which also included scan sonar, multibeam echosounder and sub-bottom profiler.

77. As part of the Norfolk Vanguard survey campaign geophysical data (sidescan sonar, multibeam echosounder and sub-bottom profiler) were collected along the shared offshore cable corridor.

3.1.2 Existing Trawl Survey

3.1.2.1 Epibenthos

78. A total of 78 scientific beam trawls were undertaken to inform the ZEA, of which 13 are located within the Norfolk Boreas site and cable corridor.

3.2 Project Specific Data Collection and Analysis

79. The site specific survey methodology is detailed in the attached benthic characterisation report (Fugro, 2018). The data collected during the benthic surveys has been subject to some high level initial analysis and will be subjected to more detailed analysis to be presented in the PEIR.

3.2.1 Benthic Survey Methodology and Sample Processing

80. The benthic ecology characterisation survey was conducted in accordance with a sampling approach agreed by the MMO and Natural England in February 2017. The location of the 35 sample stations were originally chosen to provide good coverage of the area whilst also focusing on areas of interest, determined by the ZEA zonal data (MESL, 2011). The 2017 geophysical survey data were then used to refine these locations to ensure that all habitats within the site were sampled.

81. The objectives of the survey were to:

- Complete drop-down video and grab sampling within the footprint of the Norfolk Boreas site to provide good coverage of the site and to allow a strategic approach to the sample analysis with the aim of demonstrating that the overall habitat is comparable with the original survey.

- Provide an indication of the habitat type across the site and identify the potential presence and extent of *S. spinulosa* reef or aggregations.
- Collect samples for contaminant analysis using a Day grab and to collect samples for Particle Size Distribution (PSD) and benthic infaunal analysis using a mini Hamon grab.

82. An initial subset of ten of the 35 grab samples were analysed for taxonomic identification and enumeration, and biomass. Further information on the sample processing methodology is provided in the benthic characterisation report (Fugro, 2018).

3.2.2 Initial Analysis

83. A key element of the infaunal data analysis was to establish if the ZEA data was still valid and therefore whether it could be used in conjunction with the Norfolk Boreas data to accurately characterise the Norfolk Boreas site. For the benthic infanual data this focused around demonstrating that the infaunal communities identified within Norfolk Boreas grab samples were similar to those found during the ZEA surveys. A separate report was summited to the MMO and Natural England in October 2017 (updated and re submitted November 2017) which provided evidence that they were. Both the MMO and Natural England agreed with the findings of the report and that no further data collection was required for site characterisation.

3.2.2.1 Infaunal Multivariate Analysis

84. Once it had been established that the ZEA and Norfolk Boreas data sets could be used together Multivariate statistical analyses were conducted on the combined data set using the Plymouth Marine Laboratories (PRIMER) v6 suite of programs (Clarke and Warwick, 2001; Clarke and Gorley, 2006).

85. The full data set was subjected to hierarchical clustering to identify sample groupings based on the same Bray Curtis index of similarity. This process combines samples into groups starting with the highest mutual similarities and then gradually lowering the similarity level at which groups are formed. The process ends with a single cluster containing all stations and is best expressed as a dendrogram showing the sequential clustering of stations against relative similarity.

86. To best describe the ecological differences between sites, the groups were identified on the basis of a slice at 20% similarity for the infaunal communities. This was informed by a SIMPROF test which confirmed that a 20% slice was a reasonable cut off. Similarity slices at around 20% are commonly used for a data set of this size and the multivariate analysis for the original ZEA data used a 20% cut off point, as did the East Anglia THREE multivariate assessment (EATL, 2015).

87. An MDS (Multi-dimensional Scaling) procedure which uses the same similarity matrix as that used by the cluster analysis was used to produce an ordination of samples which is multidimensional. This was carried out to provide a visual representation of the between-samples relationships indicated by the similarity matrix. The results are displayed in **Plate 3.1** which shows the samples identified by survey and **Plate 3.2** which shows the samples identified by group as defined by the cluster analysis described above.

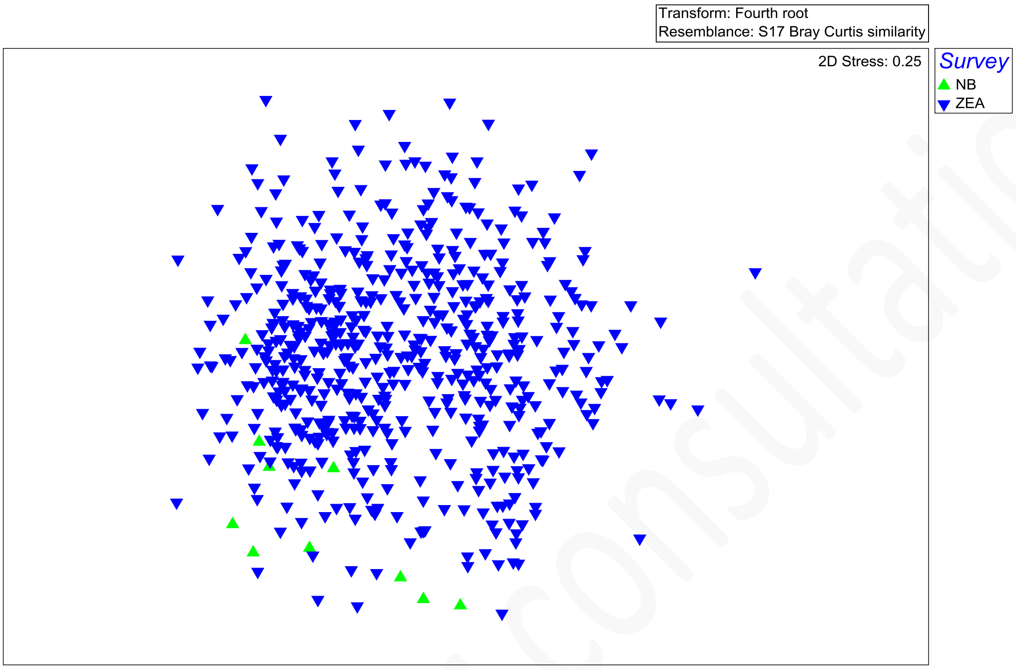

Plate 3.1 MDS 2-Dimensional plot showing the relationship of communities sampled during the Norfolk Boreas and ZEA surveys. NB= Norfolk Boreas Survey and ZEA = 2011 ZEA surveys.

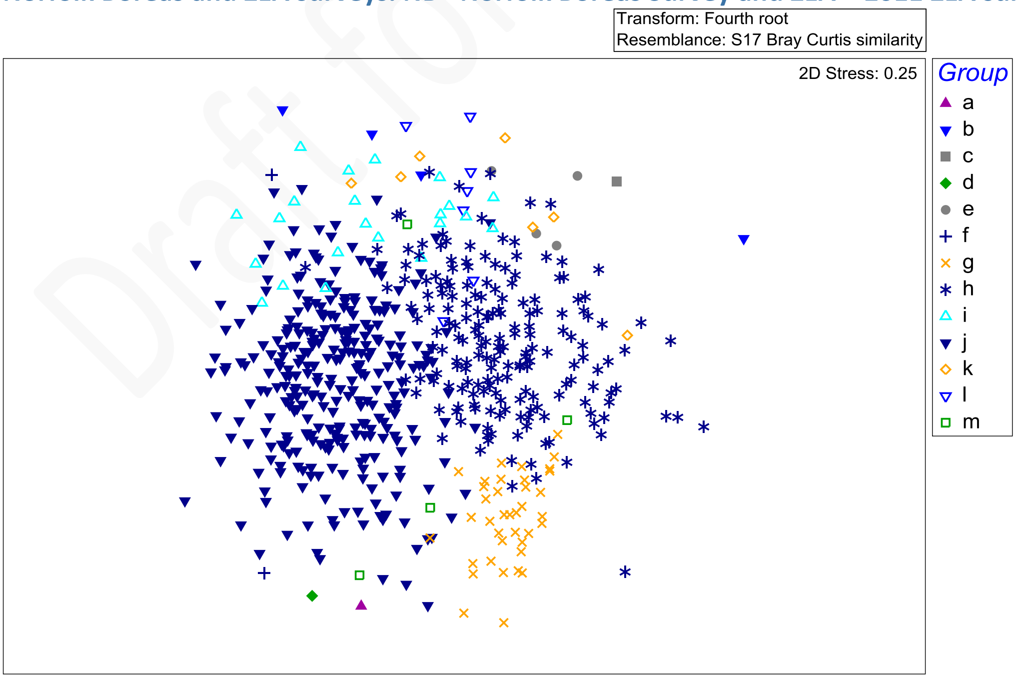

Plate 3.2 MDS 2-Dimensional plot showing groupings based on 20% similarity slice of ZEA and Norfolk Boreas faunal communities.

88. **Plate 3.1** illustrates that the data from the two surveys align relatively well. If the communities had been significantly different the Norfolk Boreas and ZEA samples would be defined in two isolated groups.

89. **Plate 3.2** shows that 13 different community groups were identified across the combined data set. Nine of the samples collected in the Norfolk Boreas surveys fell within group j with the other falling within group within group g. 300 samples across the combined data set were identified as group j and 38 were in group g.

3.2.3 *Sabellaria spinulosa* Reef Assessment and Mapping

90. As part of the benthic characterisation report (Fugro, 2018) a *Sabellaria spinulosa* reef potential assessment was undertaken for the Norfolk Boreas site. Assessment of potential reef structure followed the standard methodology for classification of reef structure and population density (Gubbay, 2007). The guidelines for the assessment of *S. spinulosa* reef, as outlined in Hendrick and Foster-Smith (2006) and Limpenny et al. (2010), were also followed. Further detail on the methods used in the assessment can be found within the report.

91. Of the 35 sample locations surveyed (see section 79) two (station 5 and 14) were identified as supporting potential *S. spinulosa* reef. Additional video transects were deployed at these sample stations to identify the extent of any potential reef structures. Following the analysis of four transects at station 5 and 1 transect at station 14 it was concluded the overall assessment for these two stations was of low (on a scale of low, medium and high) resemblance to *S. spinulosa* reef, based on patchiness (up to 83 %) and consolidation (low to medium).

92. As part of the Norfolk Vanguard site characterisation report (Fugro, 2017) a reef assessment was also completed which included the full offshore cable corridor. This assessment identified potential medium reef and low reef at one sample station each within the offshore cable corridor for Norfolk Boreas (see Figure 5.1 of that report)

93. Due to the fact that the offshore cable corridor crosses the Haisborough Hammond and Winterton SAC (see section 6 for further detail), which has 'reefs' as primary designated feature, further work has been commissioned by VWPL to use all available data to define the extent of possible reef structures. The report, which has been submitted with this Method Statement (Envision Mapping Ltd, 2018), confirmed that there are areas of medium reef within the section of offshore cable corridor which overlaps with the SAC. However the mapping process illustrates that these areas of reef are likely to be isolated patches contained within one small area of the cable corridor (see Figure 20 of that report).

3.2.4 Biotope Classification and Mapping

94. As part of benthic characterisation report (Fugro, 2018) a biotope classification process was completed at all sample stations (section 5.7 of the report). Three different biotopes were identified. SS.SSa (Sublittoral sands and muddy sands) at 25 locations; SS.SBR.PoR.SspiMx (*Sabellaria spinulosa* on stable circalittoral mixed sediment) at three locations and SS.SSA.IMuSa.FfabMag (*Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand sediment) at seven stations.

95. A biotope interpretation was then completed (see report for more details on methodology used) to provide a biotope map for the entire site. The resulting map shows the site to be very uniform in character and characterised entirely as the biotope SS.SSa (Sublittoral sands and muddy sands) (see Figure 5.29 of the report).

96. A biotope interpretation was also completed as part of the Norfolk Vanguard benthic characterisation report (Fugro, 2016) which included the shared offshore cable corridor. The resultant maps showed four confirmed and three potential biotopes within the offshore cable corridor (see section 5.5.3 of Fugro, 2016 for details).

97. As part of the *S. spinulosa* reef mapping exercise (described in section 3.2.3) Envision mapping limited also used all available data to map the predicted biotopes within the offshore cable corridor (Figure 15 of that report). This mapping exercise showed that the biotope SS.SBR.PoR.SspiMx (*Sabellaria spinulosa* on stable circalittoral mixed sediment) habitat is predicted to occur only within one section of the offshore cable corridor and that is also where the *S. spinulosa* reef is predicted.

3.2.5 Sediment Contaminant Analysis

98. The results of the sediment contamination sample analysis, which are presented in the Norfolk Boreas Marine Water and Sediment Quality Method Statement, were compared to Cefas Action Levels. Two samples marginally exceeded Cefas Action level 1 (which the MMO state are not considered to be of concern) for arsenic but no other contaminants were found to exceed action level 1. Further information is provided in the Norfolk Boreas benthic characterisation report (Fugro, 2018)

99. The Norfolk Vanguard sediment contamination sample analysis (Fugro, 2017) found that within the seven samples analysed from the offshore cable corridor one sample exceeded Cefas Action level 1 for arsenic with no other contaminants exceeding Level 1. Further detail is provided in the Norfolk Vanguard benthic characterisation report (Fugro, 2016)

3.2.6 Intertidal Survey at Landfall

100. An intertidal survey of the landfall location at Happisburgh south was undertaken on the 27th June 2017. The survey report is provided with this method statement (Royal HaskoningDHV, 2017a). The Aim of the survey was to:

- Identify the habitats and communities present within the survey area (which covered approximately 1.5km stretch of coastline);
- Identify and locate the presence of any rare or protected species within the survey area boundaries,
- Provide target notes of each biotope, including characterising, rare, protected and non-native species encountered,
- Produce maps showing the location of identified biotopes.

101. The full methodology is described in (Royal HaskoningDHV, 2017a); but consisted of sampling at five transects, spaced evenly along the shore, approximately 300m apart. Sample stations on each transect were set in the upper, mid and low shore at each station where the sub sediment was investigated by dig over and the following were recorded:

- Sediment type;
- Surface features;
- Reduction–oxidation (redox) layer depth; and
- Presence/ absence of species identified on site.

102. The survey found no ecological surface features within the intertidal zone throughout the entire survey area. The intertidal zone within the survey area was found to be almost completely uniform being composed of clean mobile fine sand in the upper shore, leading to a sand, cobble and pebble mix in the mid shore. Often the mid shore was coarse sediments covered by a shallow veneer of clean fine sands, and pebbles were often present on the surface. The lower shore was characterised by clean fine sand and gravel throughout. Therefore the entire survey area was classed as mobile barren littoral sands, with some barnacle and *U.intestinalis* communities on the limited anthropogenic hard substrata (wooden groynes). No habitats of ecological conservation importance or non-native species were identified within the survey area.

3.2.7 Further analysis for the PEIR

3.2.7.1 Species composition.

103. Within the PEIR the data from the Norfolk Boreas site (both from ZEA and Norfolk Boreas surveys) will subject to the following:

- A breakdown of taxonomic groups and comparison with the ZEA; and
- A calculation of abundance and species richness and biomass and comparisons with the ZEA.

3.2.7.2 Statistical Analysis

104. In order characterise the wider area and contextualise the communities within the Norfolk Boreas site and offshore cable corridor further more detailed analyses (to that presented section 83) will be undertaken using the combined data set (which will also include the Norfolk Vanguard data). Using PRIMER V6 the infaunal community structure will be investigated by employing the following univariate diversity indices:

- Shannon Wiener diversity index;
    - The Shannon Wiener diversity index is a measure of biodiversity based on the number of species present and the number of individuals of each species. If a few species dominate, the index value is low. A greater number and more even distribution of species both result in an increase in Shannon's diversity.
- Simpson’s dominance index.
    - Simpson’s dominance index is a measure of the probability that two individuals randomly selected from a sample will belong to the same species. Simpson's dominance index ranges from 0 (all taxa are equally present) to 1.0 (one taxon dominates the community completely).

105. In addition to the MDS analysis presented above the taxonomic groups will be further investigated. Similarity Percentage (SIMPER) analysis will be applied to the data to rank species in terms of their contribution to both the internal group similarity and “between” group dissimilarity and thereby assist the assessment of the distinctiveness of each community identified and the identification of the characterising taxa.

106. Analysis of similarity (ANOSIM) will also be performed on the data to assess how significantly different the groups are.

107. The combined particle size sediment data will also be imported into PRIMER and subjected to hierarchical clustering using Euclidean distance as the similarity measure. This will then be used to compare the sediment composition across the two survey periods.

3.3 Designated Sites

108. The offshore cable corridor is located outside of but immediately to the south of the Cromer Shoal Chalk Beds MCZ. The features of conservation importance within the

MCZ are subtidal chalk as well as peat and clay exposures. Mapping of these features (Defra, 2016) indicates that the southern part of the MCZ which is located close to the offshore cable corridor could include subtidal chalk as well as subtidal coarse sediment.

109. The Norfolk Vanguard benthic survey which overlapped with the MCZ (Section 3.1) did not observe chalk reef features in the survey area but concluded that the presence of chalk reef cannot be discounted as it may not be visible at the surveyed sediment surface. The proposed approach to the assessment of impacts to the MCZ is provided in section 5.1.5.

110. As discussed above the Norfolk Boreas offshore cable corridor overlaps with the Haisborough Hammond and Winterton SAC which is designated for:

- Sandbanks which are slightly covered by sea water all the time; and
- *Sabellaria spinulosa* reefs

111. This site will therefore be considered within the EIA (see sections 5.1.5 and 158) and the HRA (see sections 5.1.5, 158 and section 6 where proposed methodologies for respective assessments are provided).

112. Sections of the offshore cable corridor overlap with the Greater Wash pSPA which is proposed to be designated for:

- tern species during the breeding season (Sandwich tern, little tern and common tern); and
- A range of seabird species during the non-breeding season (red-throated diver, common scoter and little gull).

113. Red-throated divers are benthic feeders which include polychaete worms and bivalves within their diet. Therefore impacts on benthic habitats and species could have an indirect effect on Red-throated diver. These potential indirect impacts will be considered within the EIA (see sections 5.1.5 and 158) and the HRA (see section 6).

4 IMPACT ASSESSMENT METHODOLOGY

4.1 Defining Impact Significance

4.1.1 Sensitivity

114. The sensitivity of species and biotopes will be reviewed based on expert judgement and informed by available sensitivity information. The Marine Life Information Network (MarLIN) as well as other online resources and published research (Tyler-Walters et al, 2014 for example) will be used to assign a sensitivity using the criteria presented in Table 4.1. It is recognised that the MarLIN assessments have limitations, in particular the nature of the impact described by MarLIN when compared with the nature of the impact for Norfolk Boreas. Where information is unavailable for the key species present at Norfolk Boreas, consideration will be given to potential proxies that are closely related and have similar habitat preferences.

115. The sensitivity of a receptor is determined through its ability to accommodate change and reflects on its ability to recover if it is affected. The sensitivity level of benthic receptors to each type of impact is justified within the impact assessment and is dependent on the following factors:

- Adaptability – The degree to which a receptor can avoid or adapt to an effect;
- Tolerance – The ability of a receptor to accommodate temporary or permanent change without a significant adverse effect; and
- Recoverability – The temporal scale and extent to which a receptor will recover following an effect.

Table 4.1 Definitions of sensitivity levels for benthic ecology

Sensitivity	Definition
High	Individual receptor (species or habitat) has very limited or no capacity to accommodate, adapt or recover from the anticipated impact e.g. receptor is killed/destroyed or damaged with recovery greater than 10 years.
Medium	Individual receptor (species or habitat) has limited capacity to accommodate, adapt or recover from the anticipated impact e.g. killed/destroyed with recovery in 1 to 10 years or damaged with recovery in 5 to 10 years.
Low	Individual receptor (species or habitat) has some tolerance to accommodate, adapt or recover from the anticipated impact. e.g. killed/destroyed with recovery with 1 year or damaged with recovery in 1 to 5 years.
Negligible	Individual receptor (species or habitat) is generally tolerant to and can accommodate or recover from the anticipated impact.

4.1.2 Value

116. In addition, the 'value' of the receptor forms an important element within the assessment for instance if the receptor is a protected species or habitat. It is important to understand that high value and high sensitivity are not necessarily linked within a particular impact. A receptor could be of high value (e.g. Annex I habitat) but have a low or negligible physical/ecological sensitivity to an effect. Similarly, low value does not equate to low sensitivity and is judged on a receptor by receptor basis. The value will be considered, where relevant, as a modifier for the sensitivity assigned to the receptor, based on expert judgement. Definitions of the value levels for benthic ecology are described in **Table 4.2.**

Table 4.2 Definitions of the value levels for benthic ecology

Value	Definition
High	Internationally or nationally important
Medium	Regionally important or internationally rare
Low	Locally important or nationally rare
Negligible	Not considered to be particularly important or rare

4.1.3 Magnitude

117. The magnitude of effect will be considered in terms of the spatial extent, duration and timing (seasonality and / or frequency of occurrence) of the effect in question. Expert judgment will be employed to consider and evaluate the likely effect on the species, population or habitat identified. Definitions for the magnitude levels for benthic ecology are described in **Table 4.3**.

Table 4.3 Definitions of the magnitude levels for benthic ecology

Magnitude	Definition
High	Fundamental, permanent / irreversible changes, over the whole receptor, and / or fundamental alteration to key characteristics or features of the particular receptors character or distinctiveness.
Medium	Considerable, permanent / irreversible changes, over the majority of the receptor, and / or discernible alteration to key characteristics or features of the particular receptors character or distinctiveness.
Low	Discernible, temporary (throughout project duration) change, over a minority of the receptor, and / or limited but discernible alteration to key characteristics or features of the particular receptors character or distinctiveness.
Negligible	Discernible, temporary (for part of the project duration) change, or barely discernible change for any length of time, over a small area of the receptor, and / or slight alteration to key characteristics or features of the particular receptors character or distinctiveness.

4.1.4 Impact Significance

118. Following the identification of receptor sensitivity and the magnitude of the effect, the impact significance will be determined using expert judgement. The matrix (provided in **Table 4.4**) will be used as a framework to aid determination of the impact assessment. Definitions of impact significance are provided in Table 4.5**.**

Table 4.4 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 4.5 Impact Significance Definitions

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, likely to be considered at a local level because they contribute to achieving regional or local objectives.
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.

119. For the purposes of this EIA and specifically the benthic and intertidal ecology assessment, it is suggested that 'major' and 'moderate' impacts would normally be deemed to be significant. However, whilst 'minor' impacts would not normally be deemed significant in their own right, they may contribute to significant impacts cumulatively or through inter-relationships.

4.1.5 Cumulative Impact Assessment

120. The potential for projects to act cumulatively on benthic ecology is considered in the context of the likely spatial and temporal extent of impacts as well as the combined impact on a sensitive or important habitat or species in the wider region.

121. East Anglia THREE and Norfolk Vanguard offshore wind farms will be considered in the assessment due to their proximity to Norfolk Boreas and their potential for overlapping construction programmes. All other offshore wind farms are screened out of the assessment due to being beyond the range of potential impacts associated with Norfolk Boreas and therefore having no potential to act cumulatively.

122. Consideration will also given to any other nearby seabed activities, including marine aggregate extraction and marine disposal.

123. Each potential impact described for the construction and operation and maintenance (O&M) phases of Norfolk Boreas will be considered in the CIA (see section 5.4 for the projects for inclusion in the CIA).

4.1.6 Transboundary Impact Assessment

124. The localised nature of the potential impacts on the benthos means that significant transboundary impacts are unlikely. In accordance with the Scoping Report (Royal HaskoningDHV, 2017d), transboundary impacts have been screened out of the EIA for this topic.

5 POTENTIAL IMPACTS

5.1 Potential Impacts during Construction

5.1.1 Impact: Temporary physical disturbance

125. There is potential for temporary physical disturbance associated with construction works to impact benthic and intertidal ecology. The impact of the permanent infrastructure is considered in section 5.2, in accordance with the Scoping Report (Royal HaskoningDHV, 2017d).

126. Temporary disturbance on benthic ecology may arise from the following construction activities (see section 2.3):

- Seabed preparation (e.g. dredging)
- Construction vessel footprints (e.g. anchors and jack-up legs)
- Cable trenching

127. Temporary disturbance on intertidal ecology may arise from the HDD exit point (but only if the short HDD option is selected) and trenching from the exit point.

5.1.1.1 Approach to Assessment

128. The assessment will be separated into impacts associated with construction within the Norfolk Boreas site (wind turbine generator, offshore platforms, met masts, array cables, and interconnector cables etc.) and impacts associated with construction within the offshore cable corridor (export cables, cable crossings and landfall). An overall summary will also be presented which combines the two assessments.

129. Calculations have been made of the area of temporary disturbance using the worst case scenarios presented in section 2.3. These will be further refined for the PEIR as the project description is developed.

130. The magnitude of the impact will be quantified by calculating the maximum area of disturbance as a percentage of the Norfolk Boreas site as well as the offshore cable corridor. Consideration will be given to the nature and diversity of habitats across the offshore project area and the former East Anglia Zone (for context).

131. The layout of turbines and their associated scour protection will be determined post-consent; micro-siting could be employed to avoid sensitive features such as *S. spinulosa* reef where this is classed as Annex I habitat. Such embedded mitigation will be taken into account when determining the impact magnitude.

132. Consideration will be given to the potential for recovery and the associated timescales, based on available information.

5.1.2 Impact: Increased suspended sediment concentrations and smothering

133. Sediment disturbance and deposition from construction activities, such as cable and foundation installation could have an adverse and indirect impact on the benthic communities, through increased turbidity or as a result of smothering by sediment released during the construction process.

5.1.2.1 Approach to Assessment

134. The information generated by the Marine Physical Processes assessment will be used to determine the magnitude of potential smothering both in terms of the area impacted and the thickness of deposited material. As with 5.1.1 the impacts will be assessed separately within the context of the Norfolk Boreas site and then the offshore cable corridor and an overall summary will also be presented which combines the two assessments.

135. Assessment of the sensitivities will be guided by the assessments available on MarLIN and other available literature.

5.1.3 Impact: Potential re-mobilisation of contaminated sediments

136. Depending on the presence of contaminants in the substrate within the Norfolk Boreas offshore project areas, sediment disturbance associated with construction works could lead to the mobilisation of contaminants that could be harmful to the benthos.

5.1.3.1 Approach to Assessment

137. Sediment contaminant sampling was undertaken for Norfolk Boreas in September 2017 (section 3.2.5) and within the cable corridor in 2016 (Fugro, 2016) the results showed that of the 17 samples taken across the Norfolk Boreas site and offshore cable corridor only three samples contained levels of Arsenic above Cefas Action Level 1 (see the Marine Water and Sediment Quality Method Statement) but these were below Cefas Action Level 2. Levels of all other contaminants analysed were below Cefas Action Level 1.

138. The magnitude of the impact will be assessed based on the low levels of contamination within the offshore wind farm sites and offshore cable corridor and the maximum amount of sediment disturbance that will occur during construction.

139. Assessment of the sensitivities will be guided by the assessments available on MarLIN as well as any other relevant available literature.

5.1.4 Impact: Underwater noise and vibration

140. Research into the effects of underwater noise upon benthos is on-going. However, it is likely that there is habituation to noise created by the existing shipping which occurs in the area. There may be reactions from some benthic species to episodic anthropogenic noise (Martin et al, 2016) such as that from pile driving (Lovell et al, 2005, Heinisch and Weise, 1987) and increased vessel noise (Wale et al, 2013a and 2013b). Any impact is likely to be localised and temporary (i.e. occurring only during piling).

5.1.4.1 Approach to Assessment

141. Underwater noise modelling will estimate noise source levels and propagation which will be reviewed during the qualification of the magnitude of noise impacts on benthic ecology. It is not currently possible to model potential impacts of noise and vibration on benthos due to the fact that audiograms do not yet exist for the relevant species.

142. The sensitivity of relevant species and thus impact significance will be guided by available literature (such as the papers listed above) and by the assessments of sensitivity to noise available on MarLIN, where applicable.

5.1.5 Impact: Potential impacts on sites of marine conservation interest

143. The construction of Norfolk Boreas site has potential to impact on the designated sites discussed in section 3.3.

5.1.5.1 Approach to Assessment

144. A sub section of each of the four impacts above (section 5.1.1 to 5.1.4) will be included in the EIA to consider the three designated sites listed in section 3.3. This will consider the context of relevant features within the designated sites and will be presented in terms of an EIA context within the benthic and intertidal ecology chapter of the PEIR. Each feature will be treated in the context of its wider receptor and therefore the methodology presented in section 4 can be applied.

145. A conclusion of the significance of impact will not be provided for the Natura 2000 sites as Natural England advise in their response to the Norfolk Vanguard PEIR that "is not appropriate to use the EIA matrices which are for wider environmental receptors rather than a protected feature" for assessing impacts to designated sites; rather cross reference will be made to the HRA. For the Cromer Shoal Chalk Beds MCZ the impacts considered above (section 5.1.1 to 5.1.4) will be screened to assess their potential to impact on the features of the MCZ. However since the project no longer overlaps with the MCZ it is likely that increased suspended sediment and

smothering is the only impact where a pathway exists to affect the MCZ. Therefore impact 5.1.2 is likely to be the only impact assessment which is relevant for and will include the MCZ.

146. The HRA will assess the impact of the project in respect to the achievement of the conservation objectives of the each of the Natura 2000 sites screened into the assessment. This will be provided as a HRA Report also known as a Report to Inform Appropriate Assessment (RIAA); a draft of which will be presented to the ETG along with the PEIR with the final version forming part of the DCO application. The approach to HRA assessment is provided in section 6. Cross reference will be made between the two reports where relevant, but it is recognised that the two assessments have different methodologies and purposes.

5.2 Potential Impacts during Operation and Maintenance

5.2.1 Impact: Habitat loss through placement of infrastructure on the seabed

147. The permanent or long term presence of infrastructure (described in section 2.3) on the seabed will result in a loss of habitat. This includes foundations for turbines, offshore platforms and met masts, anchoring or foundations of wave buoys and LiDAR as well as their associated scour protection. Habitat loss associated with scour protection will also be considered. Habitat loss associated with scour will not be considered as it will be assumed that scour protection will be placed wherever scour is likely to occur.

148. The potential area of cable crossings, surface laid cables and their associated cable protection will also be quantified (see section 2.3.4). The disturbance associated with cable trenching and pre-sweeping are considered in section 5.1.1 as a temporary disturbance on the basis that the infilling of the trench or reforming of sand waves (either by mechanical process or through naturally occurring processes) will be with comparable substrate, allowing potential for recovery.

5.2.1.1 Approach to Assessment

149. As with temporary physical disturbance during construction, the worst case scenario permanent footprints (outlined in section 2.3) will be considered as a percentage of the Norfolk Boreas site. The assessment will be separated into impacts associated with the Norfolk Boreas site and impacts associated with the offshore cable corridor with an overall summary presented which combines the two assessments.

150. Consideration will be given to the nature and diversity of habitats across the Norfolk Boreas offshore project area and put in context of the former East Anglia Zone, taking into account embedded mitigation to avoid key sensitive features such as *S.*

spinulosa reef as identified in benthic characterisation report and the Norfolk Vanguard and Norfolk Boreas Sabellaria Review (see section 84).

5.2.2 Impact: Physical disturbance during O&M

151. There is potential for physical disturbance of the seabed from jack-up vessel legs during planned maintenance or, in the case or a cable failure, excavation of cables (including in the intertidal zone, depending on the location of the required repairs), and during unplanned repairs.

5.2.2.1 Approach to assessment

152. As per construction, see section 5.1.1, this impact will be assessed separately in the context of the Norfolk Boreas site and in the context of the offshore cable corridor with an overall summary which combines the two assessments. Section 2.3.9 provides an estimation of the possible levels of disturbance during operation and maintenance and these, these will be refined for the PEIR but are likely to be remain broadly similar to those presented in this document.

5.2.3 Impact: Increased suspended sediment concentrations and smothering

153. Potential changes in marine physical processes in the area caused by the deployment of the wind farm may alter suspended sediment concentrations and deposition. In addition, small volumes of sediment could be re-suspended during maintenance activities as a result of the physical disturbance discussed in section 5.1.2.

5.2.3.1 Approach to assessment

154. The information generated by the marine physical processes assessment will be used to determine the magnitude of potential suspended sediment and smothering both in terms of the area impacted and the thickness of deposited material.

5.2.4 Impact: Colonisation of introduced substrate

155. The sub-sea structures (foundations, scour protection, sections of surface laid cables and cable protection) are expected to be colonised by a range of species leading to a localised increase in biodiversity. The presence of the structures will also provide habitat for mobile species and for example serve as a refuge for fish. Although potentially viewed as a positive effect enabling greater diversity of habitats and biodiversity, this represents a change from the baseline ecology. The creation of artificial hard substrate in an area of sea dominated by sediment habitats has been suggested as a mechanism for potential colonisation by non-native species.

5.2.4.1 Approach to assessment

156. The magnitude of the impact will be assessed by calculating total available area for colonisation and reviewing available literature from monitoring studies to determine which species are likely to colonise the structures. The assessment will also include the potential for non-native species to be imported on vessels and to establish themselves within the offshore project area. A part of this assessment will consider the risk of the project introducing non-native species i.e. through ballast water.

157. The sensitivity will be assessed by using existing studies to qualify how the surrounding habitats and species may be affected by the induction of new habitat types and subsequent colonisation by foreign species.

5.2.5 Impact: Underwater noise and vibration

158. It was proposed in the scoping report that underwater noise and vibration be scoped out of the EIA. However, the MMO responded to say that due to recent evidence they wish to discuss this further and have since sited three papers as evidence that noise could cause impacts to benthic species during operation:

- Solan et al, 2016. Anthropogenic sources of underwater sound can modify how sediment-dwelling invertebrates mediate ecosystem properties." *Scientific reports* 6.
- Wale et al, (2013a). Size-dependent physiological responses of shore crabs to single and repeated playback of ship noise. *Biology Letters*, *9* (2),
- Wale, et al, (2013b) Noise negatively affects foraging and antipredator behaviour in shore crabs." *Animal Behaviour* 86, no. 1 (2013): 111-118.

5.2.5.1 Approach to assessment

159. The assessment will consider the above studies as well as any other available data in the context of the type of noise and noise levels generated by an operational wind farm. However, all of the above studies have been conducted under laboratory conditions in confined aquaria and therefore are likely to show responses to greater noise levels that are expected at an operational wind farm. The confidence in this assessment is therefore likely to be low.

160. This assessment will also be put in the context of studies of the benthic communities which exist within operational wind farms such as at Horns Rev where monitoring studies found no impact to the native infaunal communities in the vicinity of the turbines and that a species diverse community established on the foundations structures (Vattenfall, 2005).

5.2.6 Impact: Potential Impacts on sites of marine conservation interest

161. As with construction, the O&M of Norfolk Boreas has potential to impact on designated sites outlined in section 3.3.

5.2.6.1 Approach to assessment

162. As proposed in section 5.1.5 above subsections of each impact (5.2.1 to 5.2.5) subsections will be included within the PEIR assessment. The results of each of the O&M impacts described above will be considered in the context of the potential to impact specific features of the site. The impact in the context of the conservation objectives of the site will be presented in the RIAA. See section 6 for further detail.

5.3 Potential Impacts during Decommissioning

163. The types of effect would be comparable to those identified for the construction phase, namely:

- Temporary physical disturbance;
- Increased suspended sediment concentrations and smothering;
- Potential re-mobilisation of contaminated sediments; and
- Underwater noise and vibration.

5.3.1 Approach to Assessment

164. The approach to assessment will be as for construction outlined in section 5.1.

5.4 Potential Cumulative Impacts

165. The potential for projects to act cumulatively on benthic ecology will be considered in the context of the likely spatial and temporal extent of impacts as well as the combined impact on a sensitive or important habitats or species in the wider region. It is currently anticipated that the key projects to consider will be:

- Norfolk Vanguard and East Anglia THREE, due to their close proximity to Norfolk Boreas especially in relation to their potential to impact cumulatively with Norfolk Boreas on the Haisborough, Hammond and Winterton SAC the Cromer Shoal Chalk Beds MCZ and the North Norfolk Sandbanks and Saturn Reef SAC.
- Marine aggregate dredging; located approximately 27km south of the export cable corridor; and
- Decommissioning of oil and gas infrastructure within the Norfolk Boreas site and its immediate vicinity.

166. Each potential impact described for the construction and O&M phases of Norfolk Boreas will be considered in the CIA.

5.4.1 Approach to Assessment

167. The CIA will review the impact assessments for other projects where this is publicly available and will make assumptions regarding Norfolk Vanguard based on VWPL's plans for this project to determine the magnitude of the cumulative impact along with Norfolk Boreas.

5.5 Inter-relationships

168. The construction, operation and decommissioning phases of the proposed Norfolk Boreas project would cause a range of effects on benthic ecology. The magnitude of these effects will be assessed using expert assessment, drawing from a wide science base that includes project-specific surveys and previous numerical modelling activities.

169. These effects not only have the potential to directly affect the identified benthic ecology receptors but may also manifest as impacts upon receptors other than those considered within the context of marine and intertidal benthic ecology. The assessments of significance of these impacts on other receptors will be provided in table from within the PEIR chapter.

6 BENTHIC AND INTERTIDAL ECOLOGY HRA

170. This section provides a draft of the HRA screening (Stage 1) for benthic and intertidal ecology for the Norfolk Boreas project as well as a proposed methodology for Stage 2 of the HRA. The final version will be included in the draft Report to Inform Appropriate Assessment (RIAA) which will be submitted for consultation with statutory consultees along with the PEIR.

171. Natura 2000 sites in the southern North Sea, which have benthic habitats (Habitats Directive Annex I) as an interest feature, are considered for HRA Screening. **Table 6.1** provides the list of these sites and presents rationale for why it is proposed that they are screened in or out of the assessment.

6.1.1 Approach to Screening

172. The sites which could potentially be affected by Norfolk Boreas are screened in to the HRA on the basis of the following:

- A component of the proposed project directly overlaps a site whose interest features includes a habitat; and
- The distance between the proposed project and the offshore habitat interest feature is within the range for which there could be an interaction e.g. the pathway is not too long for sediment deposition.

6.1.2 Potential Effects (Source)

173. The conservation objectives for offshore Annex I habitats are to "maintain or restore the habitat in Favourable Condition".

174. The formal advice associated with the Haisborough, Hammond and Winterton SAC (JNCC and Natural England, 2013), which is the only site designated for benthic ecology features which overlaps the offshore project area, identifies six pressure categories which may cause deterioration of natural habitats within SACs, either alone or in combination (and thus affect Favourable Condition). These have been identified as:

- Physical loss;
- Physical damage;
- Non-physical disturbance;
- Toxic contamination;

- Non-toxic contamination[1]; and
- Biological disturbance[2]

175. The potential effects on offshore habitats from Norfolk Boreas have been identified as in section 5:

176. Within the Norfolk Boreas offshore project area (the Norfolk Bores site and offshore cable corridor), construction activities such as the installation of foundations, cables and ancillary structures and the placement of jack-up vessel legs, will cause physical disturbance and indirect disturbance.

177. Operation of Norfolk Boreas would create more long term impacts (i.e. for the 25 year predicted lifespan of the proposed project) through the loss of existing habitat and introduction of new substrate as rock or concrete matrasses used as cable and foundation scour protection as well as the foundation structures themselves. Some of these will be classed as “long term temporary” as the infrastructure would be removed during decommissioning and some would be classed as pertinent if there is no certainty that particular infrastructure could be removed.

178. Other temporary impacts identified during operation will be caused by maintenance activities such as the use of jack up vessels and the replacement and repair of any cables.

179. Decommissioning impacts will be primarily caused by the removal of structures from the seabed. Decommissioning would cause similar impacts to that identified during construction.

6.1.3 Proximity of source to feature (i.e. SAC) (pathway and receptor)

180. The significance of such impacts would be dependent on the characteristics of the habitats and communities (receptors) present within the footprint of the impact and, in particular, the capacity of the affected communities to recover from those impacts identified.

181. Impacts to offshore habitats will be small scale when put in the context of the wider Southern North Sea Basin environment, being localised to Norfolk Boreas and in many cases to individual elements of the proposed project.

[1] For some sites this includes changes in nutrient and / or organic enrichment and / or in salinity.
[2] For some sites this includes the introduction of non-native species and / or the selective extraction of species.

6.2 Screening (Stage 1 of HRA) (receptor)

182. Table 6.1 provides the list of 30 sites within the southern North Sea which have benthic features as a primary or secondary reason for designation. In summary, it is proposed that all sites are screened out with the exception of the Haisborough, Hammond and Winterton SAC.

183. In response to comments made by Natural England on the Norfolk Vanguard PEIR, the potential pathway of effects on benthic ecology to impact upon food source for Red-throated divers, which are proposed as a designated feature for the Greater Wash pSPA will be considered within the ornithology HRA.

184. Based on the Norfolk Vanguard PEIR Marine Physical Process impact assessment the majority of suspended sediments are predicted to be deposited locally to the area of disturbance, with only a very small proportion of mud becoming more widely dispersed before settling on the seabed (Royal HaskoningDHV, 2017b).

185. Based on comparable plume modelling studies for East Anglia ONE (ABPmer, 2012), the range of indirect effects associated with the deposition of suspended sediments is predicted to extend to approximately 50km within a band of a few hundred metres in the direction of the tidal flow (north to south). This deposited sediment is likely to become rapidly incorporated into the existing mobile seabed sediment layer.

186. The North Norfolk Sandbanks and Saturn Reef SAC and Inner Dowsing, Race Bank and North Ridge SAC lie outside the area of direct impact but within the area of suspended sediment deposition. Within the predicted deposition area, the deposited sediment layer is predicted to be generally less than 0.2mm with a maximum of 2mm in some locations. No LSE on the sandbank or *S.spinulosa* reef features of the North Norfolk Sandbanks and Saturn Reef SAC is predicted in relation to a potential for up to 2mm of deposited sediment.

Table 6.1 List of SACs in the southern North Sea with their respective categories of Annex 1 habitat interest feature and screening decisions

Site Code	Country	SAC name	Category of interest feature	Distance (km)	Screened in/out	Rationale
BEMNZ0001	Belgium	Vlaamse Banken SAC	H1170 Reefs; H1110 Sandbanks which are slightly covered by sea water all the time	150.95 km	Out	Beyond the range of potential impact
BEMNZ0005	Belgium	Vlakte Van de Raan SAC	H1110 Sandbanks which are slightly covered by sea water all the time	150.15 km	Out	Beyond the range of potential impact
FR3102002	France	Bancs Des Flandres SAC	H1110 Sandbanks which are slightly covered by sea water all the time	175.76 km	Out	Beyond the range of potential impact
FR3100474	France	Dunes De La Plaine Maritime Flamande SAC	H1110 Sandbanks which are slightly covered by sea water all the time; H1140 Mudflats and sandflats not covered by seawater at low tide	199.19 km	Out	Beyond the range of potential impact
FR3100478	France	Falaises Du Cran Aux Oeufs et du Cap Gris-Nez, Dunes du Chatelet, Marais de Tardinghen et Dunes de Wissant SAC	H1110 Sandbanks which are slightly covered by sea water all the time; H1140 Mudflats and sandflats not covered by seawater at low tide; H1170 Reefs	230.90 km	Out	Beyond the range of potential impact
FR3100479	France	Falaises et Dunes de Wimereux, Estuaire de la Slack, Garennes et Communaux d'Ambleteuse-Audresselles SAC	H1130 Estuaries; H1140 Mudflats and sandflats not covered by seawater at low tide; H1170 Reefs	241.86 km	Out	Beyond the range of potential impact
FR3100477	France	Falaises et Pelouses du Cap Blanc Nez, du Mont d'Hubert, des Noires Mottes, du Fond de la Forge et du Mont de couple SAC	H1140 Mudflats and sandflats not covered by seawater at low tide; H1170 Reefs	224.89 km	Out	Beyond the range of potential impact

Site Code	Country	SAC name	Category of interest feature	Distance (km)	Screened in/out	Rationale
FR3102003	France	Récifs Gris-Nez Blanc-Nez SAC	H1110 Sandbanks which are slightly covered by sea water all the time; H1170 Reefs	222.68 km	Out	Beyond the range of potential impact
FR3102004	France	Ridens Et Dunes Hydrauliques Du Detroit Du Pas-De-Calais SAC	H1110 Sandbanks which are slightly covered by sea water all the time	233.13 km	Out	Beyond the range of potential impact
NL1000001	Netherlands	Waddenzee SAC	H1110 Sandbanks which are slightly covered by sea water all the time; H1130 Estuaries; 1140 Mudflats and sandflats not covered by seawater at low tide	105.83 km	Out	Beyond the range of potential impact
NL9802001	Netherlands	Noordzeekustzone SAC	H1110 Sandbanks which are slightly covered by sea water all the time; H1140 Mudflats and sandflats not covered by seawater at low tide	96.41 km	Out	Beyond the range of potential impact
NL2008001	Netherlands	Doggersbank SAC	H1110 Sandbanks which are slightly covered by sea water all the time	128.14 km	Out	Beyond the range of potential impact
NL4000017	Netherlands	Voordelta SAC	H1110 Sandbanks which are slightly covered by sea water all the time; 1140 Mudflats and sandflats not covered by seawater at low tide	118.44 km	Out	Beyond the range of potential impact
UK0030076	UK	Alde, Ore and Butley Estuaries SAC	H1130 Estuaries; H1140 Mudflats and sandflats not covered by seawater at low tide	112.86 km	Out	Beyond the range of potential impact
UK0030368	UK	Bassurelle Sandbank SAC	H1110 Sandbanks which are slightly covered by sea water all the time	269.47 km	Out	Beyond the range of potential impact
UK0017072	UK	Berwickshire and North Northumberland Coast SAC	H1150 Coastal lagoons; H8330 Submerged or partially submerged sea caves	374.44 km	Out	Beyond the range of potential impact

Site Code	Country	SAC name	Category of interest feature	Distance (km)	Screened in/out	Rationale
UK0030357	UK	Braemar Pockmarks SAC	H1180 Submarine structures made by leaking gases	645.16 km	Out	Beyond the range of potential impact
UK0013690	UK	Essex Estuaries SAC	H1130 Estuaries; H1140 Mudflats and sandflats not covered by seawater at low tide	163.61 km	Out	Beyond the range of potential impact
UK0013036	UK	Flamborough Head SAC	H8330 Submerged or partially submerged sea caves	213.04	Out	Beyond the range of potential impact
UK0013107	UK	Thanet Coast SAC	H1110 Sandbanks which are slightly covered by sea water all the time; 1140 Mudflats and sandflats not covered by seawater at low tide; H1170 Reefs	185.65 km	Out	Beyond the range of potential impact
UK0030369	UK	Haisborough, Hammond and Winterton SAC	H1110 Sandbanks which are slightly covered by sea water all the time; H1170 Reefs	36.67 km	In	Overlap with the offshore cable corridor
UK0030170	UK	Humber Estuary SAC	H1130 Estuaries; H1140 Mudflats and sandflats not covered by seawater at low tide; H1110 Sandbanks which are slightly covered by sea water all the time; H1150 Coastal lagoons	169.77	Out	Beyond the range of potential impact
UK0030370	UK	Inner Dowsing, Race Bank and North Ridge SAC	H1110 Sandbanks which are slightly covered by sea water all the time; H1170 Reefs	118.80 km	Out	The magnitude of any impact on the features of this site result is negligible and would result in no LSE
UK0030371	UK	Margate and Long Sands SAC	H1110 Sandbanks which are slightly covered by sea water all the time	136.24 km	Out	Beyond the range of potential impact

Site Code	Country	SAC name	Category of interest feature	Distance (km)	Screened in/out	Rationale
UK0030358	UK	North Norfolk Sandbanks and Saturn Reef SAC	H1110 Sandbanks which are slightly covered by sea water all the time; H1170 Reefs	23.32 km	Out	The magnitude of any impact on the features of this site result is negligible and would result in no LSE
UK0014780	UK	Orfordness - Shingle Street SAC	H1150 Coastal lagoons	113.69 km	Out	Beyond the range of potential impact
UK0030354	UK	Scanner Pockmark SAC	H1180 Submarine structures made by leaking gases	576.45 km	Out	Beyond the range of potential impact
UK0017075	UK	The Wash and North Norfolk Coast SAC	H1110 Sandbanks which are slightly covered by sea water all the time; H1140 Mudflats and sandflats not covered by seawater at low tide; H1160 Large shallow inlets and bays	109.77 km	Out	Beyond the range of potential impact

6.3 Information to inform the Appropriate Assessment (Stage 2)

187. It has not been possible to rule out Likely Significant Effect (LSE) on the Haisborough, Hammond and Winterton SAC during stage 1 (screening) therefore information to inform Appropriate Assessment will be required for this site.

6.3.1 Stage 2 Assessment for the Haisborough, Hammond and Winterton SAC

188. The Haisborough, Hammond and Winterton SAC overlaps with the offshore cable corridor, and therefore there is potential for its designated features, "Sandbanks which are slightly covered by sea water all the time" and "Reefs" to be impacted during construction, O&M or decommissioning of Norfolk Boreas. The following impacts will be considered further during Stage 2 of the assessment:

- Construction
  - Temporary physical disturbance; and
  - Smothering due to increased suspended sediment;
- Operation
  - Physical disturbance through maintenance activities;
  - Smothering through increased suspended sediment; and
  - Introduction of new substrate.
- Decommissioning
  - Temporary physical disturbance; and
  - Smothering due to increased suspended sediment;

189. In order to undertake the assessment it is important to understand the location of the designated features within the SAC and the potential for those features to recover from the impacts. Therefore, two studies have been commissioned by VWPL and the reports of these studies have been provided with this Method Statement (ABPmer, 2018 and Envision Mapping Limited, 2018); summaries are included below:

6.3.1.1 Investigation into the recoverability of sand waves

190. To provide information about the possible recovery of the sand banks within the Haisborough, Hammond and Winterton SAC from pre-sweeping activity (see section 2.3.3 for further details) a study was first completed by GMSL to quantify the potential amount of pre-sweeping required within the SAC. This identified that a maximum of 1,400,000m^3 of material would be required to be pre-swept in order to bury six export cables for the Norfolk Boreas project within the SAC to sufficient depth to prevent them from becoming exposed. The GMSL study also proposed two indicative potential areas which could be used as disposal sites for the pre-swept

material which were purposely located within the SAC so that no material was lost from with the SAC sandbank system.

191. VWPL then commissioned ABPmer to undertake a study to ascertain what the probably recovery rates of sand waves effected by the pre-sweeping activity might be (ABPmer, 2018). The study aimed to address two questions:

- Will sandwaves within the SAC reform following any pre-sweep dredging activity?
- If sediment is disposed of within an adjacent disposal site where will that sediment feed back into the existing sand bank system?

192. In order to answer these questions three complementary approaches have been used to complete the assessment:

- A desk based literature review to develop an initial conceptual understanding of the system;
- An investigation of bedform migration rates through interrogation of available detailed bathymetric survey data; and
- Desk based empirical analyses considering potential sediment transport rates.

193. Further detail on the assessment methodology is provided within the report (ABPmer, 2018).

194. The study concluded the following:

- The site is highly dynamic; the net direction of sediment movement is not consistent across and is likely to be driven by tidal movement, wave action and in particular storm action;
- Due to the ongoing migration properties of the sandwave field, the levelled sandwaves within the Haisborough SAC will not reform to their original state following the dredging of the crest. Rather, it is likely the sandwaves will continue to migrate in their new form, moving away from the levelled area, during which time the crests would partially recover to a naturally stable shape as the sandwaves move along the sandbank. As the levelled sandwaves move away from the levelled area, new sandwaves would continue to form and migrate into the same area, as the sandwave migration properties are unimpeded by the proposed bed levelling works;
- Estimated infill of any levelled trenches (and sandwave recovery) is in the order of a few days to a year based on representative forcing conditions at a single water depth, with storm effects having the potential to accelerate the process to days or weeks.
- Any sediment disposed, within the sites identified by GMSL, is likely to re-join the sediment transport regime of the Haisborough SAC with no dredged material being 'lost' from the sandbank system. In the short term, sediment transport will be

directed to the north-northwest and south-southeast of the indicative spoil zones in line with the prevalent sediment transport pathways. In the long term, the transport direction will be determined by the location of the spoil zone with respect to the regional scale bedload parting zone and local recirculation patterns. Material deposited to the east of the bedload parting would more likely move to the north-northwest in the long term and sediment deposited to the west of the parting would more likely move to the south-southeast in the long term; and

- There are not considered to be any onward effects on the form and functioning of the sandwaves and sandbanks within the Haisborough SAC. These are for the same reasons that are presented in the conclusions above.

6.3.1.2 Norfolk Vanguard and Norfolk Boreas Sabellaria Review

195. To understand and define the quality and extent of *S.spinulosa* reef within the offshore cable corridor VWPL commissioned Envision Mapping Limited to undertake a study which used all available data to establish a map of the potential reef within the export cable corridor with particular focus on the area which overlaps the Haisborough, Hammond and Winterton SAC. The report (Envison Mapping Ltd, 2018) provides further detail on the methodology used.

196. The outcome of the study is discussed in section 84 and will be used to inform the assessment for LSE on the Annex 1 reef along with other studies such as Gibb et al (2014)

197. If the LSE is predicted following the assessment possible mitigation measures will be investigated, these include micro-sighting of the export cable route to avoid the known areas of reef. Pre-construction survey would also form part of the mitigation measures, however these are likely to be part of the “embedded mitigation” for the project.

6.4 Next Steps

198. As stated above the final Benthic and intertidal Ecology Screening report will form part of the full HRA Screening document which will be submitted with the Norfolk Boreas PEIR.

199. Stage 2 of the HRA report (RIAA) will be developed through consultation as part of the Norfolk Vanguard and Norfolk Boreas EPPs and a draft will be presented to the ETG for consultation. The final RIAA will be completed as part of the DCO application in June 2019.

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Norfolk Boreas Offshore Wind Farm

Environmental Impact Assessment

Marine Water and Sediment Quality Method Statement

Document Reference: PB5640-004-019

Author: Royal HaskoningDHV
Applicant: Norfolk Boreas Ltd
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Date	Issue No.	Remarks / Reason for Issue	Author	Checked	Approved
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16/01/18	02D	Issue for Vattenfall review	CP	DT	AD
26/01/18	03D	Amended following Vattenfall review	DT		JL
05/02/18	01F	Final version for issue to ETG	DT		JL / AD

This method statement has been prepared by Royal HaskoningDHV on behalf of Norfolk Boreas Limited in order to build upon the information provided within the Norfolk Boreas Environmental Impact Assessment (EIA) Scoping Report. It has been produced following a full review of the Scoping Opinion provided by the Planning Inspectorate. All content and material within this document is draft for stakeholder consultation purposes, within the Evidence Plan Process.

Many participants of the Norfolk **Boreas** Evidence Plan Process will also have participated in the Norfolk **Vanguard** Evidence Plan Process. This document is presented as a complete and standalone document, however in order to maximise resource and save duplication of effort, the main areas of deviation from what has already been presented through the Norfolk Vanguard Evidence Plan Process and PEIR or in the Norfolk Boreas Scoping Report are presented in orange text throughout this document.

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Glossary of Acronyms

DIN	Dissolved Inorganic Nitrogen
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CIA	Cumulative Impact Assessment
DBT	Dibutyltin
DCO	Development Control Order
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EQS	Environmental Quality Standard
ES	Environmental Statement
GBS	Gravity Base Structure
HDD	Horizontal Directional Drilling
HVDC	High Voltage Direct Current
HVAC	High Voltage Alternating Current
ICES	International Council for the Exploration of the Sea
MCZ	Marine Conservation Zone
MW	Mega Watt
MMO	Marine Management Organisation
NLS	National Laboratory Service
OWF	Offshore Windfarm
PAH	Polyaromatic Hydrocarbons
PCB	Polychlorinated Biphenyl
PEI	Preliminary Environmental Information
PEIR	Preliminary Environmental Information Report
PSA	Particle Size Analysis
PSD	Particle Size Distribution
RBMP	River Basin Management Plan
TBT	Tributyl Tin
THC	Total Hydrocarbons
WFD	Water Framework Directive
WTG	Windfarm Turbine Generator
ZEA	Zonal Environmental Appraisal
VWPL	Vattenfall Wind Power Limited

1 INTRODUCTION

1. The purpose of this method statement is to build upon the information provided within the Norfolk Boreas Environmental Impact Assessment (EIA) Scoping Report and the information amassed for the Norfolk Vanguard Preliminary Environmental Information Report (PEIR), to outline the proposed approach to be taken and considerations to be made in the assessment of the marine water and sediment quality effects of the Norfolk Boreas project.

2. This method statement and the consultation around it form part of the Norfolk Boreas Evidence Plan Process (EPP). The aim is to gain agreement on this Method Statement from all members of the Marine Water and Sediment Quality Expert Topic Group (ETG), which will be recorded in the agreement log.

3. This method statement has been produced following a full review of the EIA Scoping Opinion provided by the Planning Inspectorate and responses to the Norfolk Vanguard PEIR. The EIA Scoping Opinion comments received that relate to marine water and sediment quality are summarised in **Table 1.1**.

4. Information provided in this Method Statement is a draft for stakeholder consultation only and is provided in confidence. It is recognised that Norfolk Vanguard ETG meetings are being held in January 2018 and that agreements will be made during those meetings which are not reflected. However due to certain project "Mile Stones" which have been set by the Crown Estate Norfolk Boreas must progress on a programme which requires consultation on the Norfolk Boreas Method Statements prior to the conclusion of the Norfolk Vanguard EPP. Therefore, the material provided in this document represents the best available information at the time of writing.

Table 1.1 Scoping opinion responses relevant to Marine Water and Sediment Quality

Consultee	Comment	Response
Secretary of State	Table 2.3 of the Scoping Report (Concentrations of dissolved trace metals in sub-surface seawater from offshore locations) contains data from 1991-1992. Similarly, Table 2.4 (Summary of potential contaminant levels typically found in surfaces water of the North Sea) contains data from 2001. The Applicant should ensure they use the most up to date data available. If not available, this should be explained within the ES along with justification as to the validity of datasets used.	The information to be used to inform the assessment has been updated in this Method Statement
Secretary of State	"The Scoping Report states that "Modelling of sediment plumes completed as part of the East Anglia ONE EIA (EAOL, 2012) showed that coarser material is likely to settle out within a short distance (between a few hundred meters and 1km) of the activity and limit the overall footprint of the affected area". However, no reference has been made to the distance which finer material may settle. As such, the assertion that designated bathing waters (3.1km and 3.9km	This is clarified in the Marine Physical Processes Method Statement (Doc Ref: PB5640-004-021)

Consultee	Comment	Response
	from the landfall search area) are unlikely to be affected has not been fully justified. Any such statements should be clarified within the ES, with reference to guidance or studies from which the conclusions have been drawn."	
Secretary of State	"Paragraph 358 of the Scoping Report proposes to scope out accidental release of contaminants during construction, operation and maintenance on the basis that good practise techniques and procedures would be employed and that all vessels would comply with the International Convention for the Prevention of Pollution from Ships (MARPOL) 73/78. Table 2.6 also proposes to scope out accidental release of contaminants during decommissioning. The SoS agrees that, with the implementation of such measures, any potential impacts on water and sediment quality are unlikely to be significant and therefore further assessment is not required. However, the SoS seeks assurances that such measures would be employed and therefore considers the matter should still be covered within the ES, along with details of the measures to be employed and how they are secured by the DCO (through the marine license or otherwise). The SoS would expect a draft version of any plans containing such measures to be provided with the DCO application."	It is proposed that relevant control methods are listed in the EIA chapter. A list of example control measures is given within this method statement for guidance only. An Environmental Management Plan will be developed which will include a final list of these control measures.
MMO	The impacts from contaminants may be scoped out depending on the results of 2017 surveys. Survey stations for contaminant analysis should be targeted in the muddier areas, as indicated from previous survey data and UK SeaMap/British Geological Society (BGS) map. (http://jncc.defra.gov.uk/ukseamap) Appropriate gear must be used to sample for contaminants, for example, Day grab or Shipek grab and not Hamon grab. If contaminant levels are similar to those found at reference stations then contaminants can be scoped out.	Samples sent for analysis were targeted in the areas of finer sediment. A Day grab was used to collect sediment samples. The samples were analysed at an MMO approved laboratory. The results are presented within this Method Statement.
MMO	In accordance with the recommendations of the OSPAR Guidelines for the Management of Dredged Material, samples should be taken to provide a good representation of the volume of material to be dredged. The distribution and depth of sampling should reflect the size and depth of the area to be dredged, the amount to be dredged and the expected variability in the horizontal and vertical distribution of contaminants. Whilst some sampling is currently being undertaken, due to the lead in time for DCO projects, sampling may be required prior to the commencement of construction.	The scale and extent of any additional sampling to inform decisions regarding disposal of dredged material will be agreed post consent and will be based on the dredging requirements as established through the detailed design.
Natural England	The data presented in support of this chapter is over 20 years old (circa 1992); where available more recent data should be used to inform the assessment.	The information to be used to inform the assessment has been updated in this Method Statement
Natural England	We agree that the potential for the release of contaminated sediment can be discussed as part of the evidence plan process once the results of the grab sample analysis are available.	Results of the contaminant grab sample analysis are included within this Method Statement

5. The Norfolk Vanguard Marine Water and Sediment Quality Method Statement was submitted to Natural England and Cefas in February 2017 as part of the Evidence Plan Process. That document provided a method statement for the assessment of potential effects on marine water quality due to the proposed project. The Marine Water and Sediment Quality Method Statement was discussed by Vattenfall, Royal HaskoningDHV, Cefas and Natural England at a meeting on 16th February 2017.

6. Given that Norfolk Boreas is located in close proximity to both Norfolk Vanguard West and Norfolk Vanguard East, a similar strategy is proposed here. In addition, the route of the Norfolk Boreas export cable corridor to landfall at Happisburgh South follows that of Norfolk Vanguard.

1.1 Background

7. A Scoping Report for the Norfolk Boreas EIA was submitted to the Planning Inspectorate on the 9th May 2017. Further background information on the project can be found in the Scoping Report which is available at:

https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010087/EN010087-000015-Scoping%20Report.pdf

8. The Scoping Opinion was received on the 16th June 2017 and can be found at:

https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010087/EN010087-000013-Scoping%20Opinion.pdf

1.2 Norfolk Boreas Programme

9. This section provides an overview of the planned key milestone dates for Norfolk Boreas.

1.2.1 Development Consent Order (DCO) Programme

- EIA Scoping Request submission - 09/05/17
- Preliminary Environmental Information (PEI) submission - Q4 2018
- Environmental Statement (ES) and DCO submission - Q2 2019

1.2.2 Evidence Plan Process Programme

10. The Evidence Plan Terms of Reference (Royal HaskoningDHV, 2017a) provides an overview of the Evidence Plan Process and expected logistics, below is a summary of anticipated meetings:

- Agreement of Terms of Reference - Q3 2017
- Post-scoping Expert Topic Group consultation

- Discuss method statements and Project Design Statement Q1 2018
- Expert Topic Group and Steering Group meetings as required - 2018
  - To be determined by the relevant groups based on issues raised
- PEI Report (PEIR) Expert Topic Group and Steering Group meetings - Q4 2018/ - Q1 2019
  - To discuss the findings of the PEI (before or after submission)
- Pre-submission Expert Topic Group and Steering Group meetings - Q1/Q2 2019
  - To discuss updates to the PEIR prior to submission of the ES

1.2.3 Consultation to Date

11. Norfolk Boreas is the sister project to Norfolk Vanguard. A programme of consultation has already been undertaken for Norfolk Vanguard which is of relevance to Norfolk Boreas and this is listed below:

- EIA Scoping Request submission - 03/10/16
- Receipt of Scoping Opinion - 11/11/16
- Steering Group meeting - 21/03/16
- Steering Group meeting - 20/09/16
- Post-scoping Expert Topic Group meetings
  - Discuss method statements and Project Design Statement - Q1 2017
- Expert Topic Group and Steering Group meetings as required - 2017
- Norfolk Vanguard PEIR submission - 2017

12. Responses to the Norfolk Vanguard PEIR (Royal HaskoningDHV, 2017b) were received in December 2017. This method statement has been updated to incorporate any key comments made that affect the proposed methodology for the Norfolk Boreas EIA.

1.2.4 Survey Programme

13. Norfolk Boreas sediment quality and contamination grab sampling campaign surveys were completed in summer 2017 and further detail is provided in section **Error! Reference source not found.**

2 PROJECT DESCRIPTION

2.1 Context and Scenarios

14. Vattenfall Wind Power Limited (VWPL) is developing Norfolk Boreas and Norfolk Vanguard in tandem, and is planning to co-locate the export infrastructure for both projects to minimise overall impacts. This co-location strategy applies to the export cable route and the cable landfall.

15. The Norfolk Vanguard project is approximately 12 months ahead of Norfolk Boreas in terms of the Development Consent Order (DCO) process. As such, the Norfolk Vanguard team is leading on site selection for both projects. Although Norfolk Boreas is the subject of a separate DCO application, the project would adopt these strategic site selection decisions.

16. There is a possibility that the Norfolk Vanguard project would not be constructed. In order for Norfolk Boreas to stand up as an independent project, this scenario must be provided for within the DCO for Norfolk Boreas. Thus, two alternative scenarios are being considered in the context of this Method Statement; Scenario 1 where Norfolk Vanguard has been fully constructed before any construction of Norfolk Boreas begins, and Scenario 2 where Norfolk Vanguard is not constructed.

17. For both scenarios, Norfolk Boreas would consent and construct all required offshore infrastructure so there is no difference in the approach to the assessment of marine water and sediment quality between the scenarios for Norfolk Boreas alone. The only offshore difference is that under Scenario 1, Norfolk Vanguard would be considered within the Cumulative Impact Assessment (CIA), together with the parameters of Norfolk Boreas.

2.2 Site Selection Update

18. The Norfolk Boreas Scoping report presented three potential landfall locations. Data was reviewed on a broad range of environmental factors, including existing industrialised landscape, the presence of the Cromer Shoal Chalk Beds Marine Conservation Zone (MCZ), coastal erosion and archaeology alongside statutory and non-statutory consultation.

19. After publication of the scoping report, VWPL concluded, taking account of all engineering and environmental factors, as well as public feedback, that the most suitable landfall location would be Happisburgh South. The decision to go to Happisburgh south was presented to the Norfolk Vanguard Evidence Plan Expert Topic groups in June and July 2017 and in the Norfolk Vanguard PEIR (Royal HaskoningDHV, 2017b).

20. Happisburgh South also has the benefit of being large enough to accommodate landfall works of both Norfolk Vanguard and Norfolk Boreas, therefore reducing the spatial extent of impacts associated with the two projects.

21. Ongoing public and stakeholder consultation as well as initial EIA data collection will be used to inform any further site selection work for the EIA and DCO application. However, the offshore site boundaries are now established and are not anticipated to change for the PEIR. Impacts that cannot be avoided through site selection will aim to be reduced through sensitive siting, alternative engineering solutions (mitigation by design) and additional mitigation measures, where possible. Mitigation options would be developed in consultation with stakeholders.

2.3 Indicative Worst Case Scenarios

22. The following sections set out the indicative worst case scenarios for marine water and sediment quality. The Norfolk Boreas EIA will provide further detail on the Project Description describing the final project design (also known as Rochdale Envelope) for the DCO application. Each chapter of the Environmental Statement (ES) will define the worst case scenario arising from the construction, operation and decommissioning phases of the Norfolk Boreas project for the relevant receptors and impacts. Additionally, each chapter will consider separately the anticipated cumulative impacts of Norfolk Boreas with other relevant projects on the receptors under consideration.

23. The parameters discussed in this section are based on the best available information For Norfolk Boreas at the time of writing and are subject to change as the project progresses.

24. The indicative worst case scenario for marine water and sediment quality is based upon construction and operation methodologies (e.g. types of foundation, cable installation) with the greatest potential for sediment re-suspension and disturbance.

2.3.1 Wind Turbine Generator Foundations

25. In terms of marine sediment and water quality, it is the foundation options that are of interest in determining the potential worst case scenario for the wind turbines. This is because installation of the foundations is the point at which seabed disturbance could occur, either in relation to seabed preparation or during drilling and discharge of arisings.

26. A range of 7MW to 20MW wind turbines is included in the Norfolk Boreas project design in order to future proof the EIA and DCO to accommodate foreseeable advances in technology. The foundations of 15MW and 20MW turbines are anticipated to have the same physical parameters (parameters of other aspects of

the turbines may differ). As a result, if the worst case scenario for a given parameter is associated with the largest wind turbines, 120 x 15MW would be the worst case scenario, rather than 90 x 20MW, due to the greater number of devices making up the maximum site capacity of 1,800MW. The maximum number of wind turbines would be achieved by 257 x 7MW.

27. A range of foundation options is also included; monopile, jackets on pin piles (on three or four legs), jackets on suction caissons (on three or four legs), gravity base structures (GBS) and floating foundations with tension leg mooring system. Ongoing review by the Norfolk Boreas engineering team has identified that this is necessary in order to future proof the EIA and DCO to include the types of foundations that are likely to be available at the time of Norfolk Boreas construction.

28. The worst case scenario for foundation type is that which causes the largest disturbance to the seabed and/or release of drilling material at the surface and therefore release of seabed sediment into the surrounding water column. Additionally, disposal of material to be removed for seabed preparation could also release sediment into the water column. **Table 2.1** details the potential for sediment re-suspension during the installation of each foundation option. The worst case scenario for sediment disturbance is GBS foundations for 7MW turbines. The worst case for drill arisings is from 15MW quadropods with pin piles.

Table 2.1: Indicative potential for sediment release for each foundation option during construction. The worst case volumes which will be used in the assessment are presented in bold

Foundation Type	Comments associated with the potential for sediment release	Potential volume of sediment that could be suspended
Monopiles	<u>Seabed preparation</u> Sediment could be released as a result of seabed preparation and drilling if either are required. In relation to seabed preparation, if sand waves are present, the seabed might need to be levelled first by excavation to the trough of the sand wave.	Seabed preparation may be required by removing up 5m of sediment Approximate volume of seabed preparation material disturbed across the project 7MW monopile =72,924m^3 (257 x 56.75m^2 x 5m) Approximate volume of seabed preparation material disturbed across the project 15-20MW monopile = 106,026m^3 (120 x 176.71m^2 x 5m)
	<u>Drill arisings</u> Drill arisings may be released at the surface (subject to a disposal licence) providing potential for sediment plumes. Alternatively spoil material may require removal and disposal Piles are generally expected to be driven but drilling may be required at up to 50% of the locations if these foundation options are chosen	Approximate volume of drill arisings across the project with 7MW monopiles = 77,100m^3 (257 x average drill arisings of 600m^3 x 50%) Approximate volume of drill arisings across the project with 15-20MW monopiles = 42,000m^3 (120 x drill average arisings of 700m^3 x 50%)

Foundation Type	Comments associated with the potential for sediment release	Potential volume of sediment that could be suspended
Pin piles (quadropod)	As with the monopile, drill arisings may be released at the surface providing potential for sediment plumes. Alternatively spoil material may require removal and disposal No significant seabed preparation works are anticipated for pile installation. There might be a requirement to carry out minor flattening at some locations but unlikely to be significant in relation to other options Piles are generally expected to be driven but drilling may be required at up to 50% of the locations if these foundation options are chosen	Four pin piles (quadropod) represent the worst case scenario for drill arisings due to having the greatest number of piles The maximum volume of drill arisings for 7MW quadropods = 72,705m^3 (257 x 565.5m^3 x 0.5) The maximum volume of drill arisings for 15-20MW quadropods = **117,810m^3**. (120 x 1,963.5m x 50%)
Suction caissons (quadropod)	No drilling is required for suction caissons It is possible that excavation to the trough of the sand wave would be necessary before installing the suction caisson	Seabed preparation may be required up to a sediment depth of 5m. Four suction caissons (quadropod) represent the worst case scenario for seabed preparation Approximate volume of seabed preparation sediment disturbed across the project using 15-20MW suction caisson quadropods = 227,072m^3 (120 x 176.71m^2 x 4 x 5) Approximate volume of seabed preparation sediment disturbed across the project using 7MW suction caisson quadropods = 227,072m^3 (257 x 176.71m^2 x 4 x 5)
GBS	No drilling is required for GBS. Seabed preparation may require dredging works and the installation of a bedding and levelling layer with the potential for release of suspended solids at the seabed. The dredging works are likely to be carried out using a trailer suction hopper dredger	Seabed preparation may be required up to a sediment depth of 5m The preparation area per 15-20MW GBS = 2,828m^2 (based on a 60m preparation diameter) with a seabed preparation volume of up to 14,137m^3 The preparation area per 7MW GBS = 1,964m^2 (based on a 50m preparation diameter) with a seabed preparation volume of up to 9,817m^3 The 15-20MW represents the worst case scenario for seabed preparation at any one time / location however **257 x 7MW wind turbines represents the worst case scenario across the Norfolk Boreas site which would be 2,523,098m^3.**
Floating	The suction pile anchor option may require a small amount of seabed preparation however the gravity anchor would not require any.	The volume of potential re-suspended sediment will be significantly less than that of gravity base foundations.

2.3.2 Scour Protection

29. The release of sediments is generally considered to be worse when scour protection is not provided since the seabed is allowed to naturally scour thus periodically releasing sediments into the water column, particularly during storm conditions. A number of options will be considered (and detailed within the ES) to protect the foundations from scour if required, including rock dumping, frond mats and mattressing.

30. As it is intended to use scour protection anywhere it is needed, the impact of scour as a result of turbine presence can be scoped out of the impact assessment. This is because scour protection will reduce the sediment released to negligible quantities.

2.3.3 Offshore cabling

31. Two electrical solutions are being considered for Norfolk Boreas, a High Voltage Alternating Current (HVAC) scheme and a High Voltage Direct Current (HVDC) scheme. The decision as to which option will be used for the project is not expected to be taken until after consent and will depend on availability, technical considerations and cost. Both electrical solutions will have implications on the required offshore infrastructure which are detailed in the following sections.

32. The preferred construction technique and depth of burial for the offshore electrical infrastructure will be decided pre-construction based on ground investigation. Possible installation techniques include:

- Ploughing;
- Jetting;
- Dredging;
- Mass flow excavation; and
- Trenching.

33. In terms of potential impacts to marine water and sediment quality, indicative worst case offshore cabling parameters are as follows:

- Number of cables;
  - Up to six subsea HVAC export cables (worst case) or four subsea HVDC export cables;
  - Up to three subsea HVAC or HVDC interconnector cable systems linking the offshore substation platforms; and
  - Array cabling - subject to the number of wind turbines and layout.
- Export cable length 140km per cable (from substation to landfall) for both HVAC and HVDC electrical solutions;

- Maximum total export cable length 840km based on six HVAC cables;
- Interconnector cable length up to 50km per system for HVAC and HVDC electrical solutions;
- Array cable length up to 750km;
- Temporary footprints during installation;
    - Export cable – temporary trench width 10m for installation with a 20m pre-sweeping (dredging) corridor;
    - Interconnector cable – temporary trench width 10m for installation with a 20m dredging corridor for the HVDC electrical solution and a 30m dredging corridor for the HVAC electrical solution; and
    - Array cable jetting or ploughing – trench width 1m with additional temporary disturbance of 3m wide.
- Maximum burial depth would be 3m for the majority of the route. In soft sediments, burial up to 5m may be necessary.

34. Increases in suspended sediment concentration may result from disturbance arising from cable installation activities. To be conservative, and regardless of technique, the assessment for marine physical processes (see the Marine Physical Processes Method Statement, Doc Ref: PB5640-004-021 for further detail) will assume that the whole volume of sediment from the trench dimensions is released for dispersion and for the entire length of the cable as a worst case scenario (i.e. there are no sections that would be laid on the seabed and protected). The marine water and sediment quality assessment will use the findings of the marine physical processes assessment to inform the potential effect associated with sediment disturbance.

2.3.4 Offshore electrical platforms/accommodation platform

35. Up to three 600MW substation platforms (HVAC) or two 900MW convertor platforms (HVDC) would be required. Foundation options include:

- Piled monopile (10m diameter per substation)
- Suction caisson monopile (20m diameter caisson per substation);
- Piled tripod (3m diameter pile per substation);
- Suction caisson tripod (3x3m diameter caissons per substation);
- Piled quadropod (4 x 3m diameter pile per foundation); and
- Suction caisson quadropod (4 x 3m diameter caisson).

36. For marine water and sediment quality, the worst case scenario for the platforms will depend on the chosen foundations. The worst case scenario for sediment disturbance is GBS foundations, 40m diameter in relation to sea bed preparation and piled quadropod foundations for drill arisings. The same applies to the accommodation platform.

2.3.4.1 Meteorological Masts

37. Up to two operational meteorological masts (met masts) may be installed within Norfolk Boreas. Foundation options include:

- Jacket with pin piles;
- Jacket with suction caissons;
- GBS;
- Suction caisson monopole; and
- Piled Monopile;

38. For the marine sediment and water quality assessment the worst case scenario is again related to foundation types (GBS 20m diameter for sea bed preparation and quadropod pin piled foundations for drill arisings).

2.3.5 Construction Vessels

39. Vessels associated with construction also have the potential to impact on marine water and sediment quality as a result of accidental spills and leaks of oil, fuel and other construction relation materials. It is proposed that relevant control methods are listed in the ES as opposed to specifically trying to define the potential impact. This is because these incidences are not planned effects.

40. A list of example control measures is given within this method statement as examples only. A further defined list will be included within the ES.

41. Jack up vessels would disturb the seabed. The maximum number of anchors or jack-ups representing the worst case scenario will be defined in the PEIR but the worst case scenario is likely to be that jack-up vessels with four legs per barge (up to 176.71m^2 per leg, 706.86m^2 combined leg area) would be used for wind turbine installation contributing a total maximum footprint area of 363,316m^2 (based on two jacking operations per wind turbine for 257 x 7MW turbine sites).

2.3.6 Landfall

42. The landfall is the location where the export cables are brought ashore and jointed to the onshore cables within transition pits. Norfolk Boreas would share a landfall with Norfolk Vanguard at Happisburgh South.

43. The export cables would be required to be installed in ducts under the existing sea defences and to be jointed to the onshore cables at the transition pits located on the landward side of the landfall site. Ducts would be installed using HDD which is a trenchless installation technique. The HDD would exit at one of the following two locations:

- On the beach, above the level of mean low water spring (classified as short HDD); or
- At an offshore location, seaward the beach (up to 1,000m in drill length) (classified as long HDD).

44. In the case of a short HDD, temporary beach closures may be required during drilling exit and duct installation to maintain public safety. Beach access would be required for an excavator and 4x4 vehicles. Full re-instatement of the site upon completion of the landfall works will be undertaken.

45. The worst case scenario for marine sediment and water quality would be the offshore location for installation since this would require working in the water thus there is the potential for release of sediment into the water column. Works on the beach would be undertaken in the dry thus removing any potential risk to water quality.

2.3.7 Construction Programme

2.3.7.1 Phasing

46. It is envisaged that Norfolk Boreas would either be built in one single 1,800MW phase; two phases of 900MW or three phases of 600MW. The location of each phase across the Norfolk Boreas site would be determined based on constraint identification throughout the EIA process as well as post consent site investigations. The EIA will therefore assess up to the capacity of 1,800MW.

47. Norfolk Boreas construction is likely to be staggered and may have temporal overlap between phases. The objective is to ensure each phase is complete and generating electricity in as short a time as possible. For each potential impact during construction, the assessment will commence with a description of the single-phase approach and then will highlight any pertinent differences associated with the two and three-phased approaches. Under Scenario 1, an indicative three phase programme would be:

- Phase 1 - Construction and commissioning 2027;
- Phase 2 - Construction and commissioning 2028; and
- Phase 3 - Construction and commissioning 2029.

48. Under Scenario 2, an indicative three phase programme would be:

- Phase 1 - Construction and commissioning 2027;
- Phase 2 - Construction and commissioning 2028; and
- Phase 3 - Construction and commissioning 2029.

2.3.7.2 Foundations

49. The construction programme with the longest duration has the greatest potential to impact marine water and sediment quality. It is expected that installation of all foundations would take up to 12 months across a two year period.

2.3.7.3 Offshore Cable Laying

50. Under a single phased approach cable laying could take up to 14 months. Under two- or three-phase approaches the principal difference compared to the single phase assessment is that installation of the cables would occur over two or three distinct phases, each lasting up to nine months or five months, respectively, but the overall time spent installing the cables would remain similar.

2.3.8 Landfall

51. For an indicative HDD length of 500m, it is anticipated that site establishment, drilling of six ducts and demobilisation would take approximately 30 weeks when considering 12 hour (7am-7pm), seven-day shifts. A 24-hour operation could be employed for drilling activities, subject to planning and environmental restrictions, and could reduce the installation to approximately 20 weeks. Cable pulling would be undertaken subsequent to the duct installation.

2.3.9 Operation and Maintenance (O&M) Strategy

52. Once commissioned, the wind farm would have an indicative design life of 25 years. All offshore infrastructure including wind turbine foundations, cables and offshore substation platforms would be monitored and maintained during this period in order to maximise efficiency.

53. As for construction, there is the potential for leaks and spills during this process. However, it is proposed that a similar approach to the construction phase is applied to this phase in that detailed control measures within operational plans will be put in place to reduce the risk as far as possible. As a result, further consideration within the EIA is not proposed.

2.3.10 Decommissioning

54. Decommissioning would most likely involve the removal of accessible installed components comprising:

- All of the wind turbine components;
- Part of the foundations (those above seabed level); and
- The sections of the array cables close to the offshore structures, as well as sections of the export cables.

55. The process for removal of foundations is generally the reverse of the installation process.

2.3.11 Cumulative Impact Scenarios

56. Cumulative impacts will be assessed through consideration of the extent of influence of changes to marine water and sediment quality arising from the proposed project alone and those arising from the proposed project cumulatively or in combination with other offshore wind farm developments (particularly Norfolk Vanguard and East Anglia THREE) but also giving consideration to any other nearby seabed activities, including marine aggregate extraction and marine disposal. The consideration of the landfall and cable installation activities alongside the potential impacts associated with the Bacton Sand Engine will also be required.

57. Other windfarms in the south of the former zone (East Anglia ONE, East Anglia ONE North and East Anglia TWO) are considered to be located a such a distance as to not act cumulatively with Norfolk Boreas to impact upon marine water and sediment quality and will therefore be screened out of the assessment.

58. A list of proposed project for consideration in the CIA is provided in section 5.6.

2.3.12 Transboundary Impact Scenarios

59. The localised nature of the potential impacts on marine water and sediment quality mean that significant transboundary impacts are unlikely. In accordance with the EIA Scoping Report (Royal HaskoningDHV, 2017c), transboundary impacts have been screened out of the EIA.

3 BASELINE ENVIRONMENT

3.1 Desk Based Review

3.1.1 Available Data

67. The EIA Scoping Report for Norfolk Boreas (Royal HaskoningDHV, 2017c) provides an overview of the baseline environment using available information. This section outlines the approach to further characterising the baseline environment for the EIA.

68. The existing environment in terms of marine water and sediment quality has been informed using information from the former East Anglia Zone reports, data collected for Norfolk Vanguard as well as site specific data for Norfolk Boreas.

3.1.2 Overview of Data Sources

69. Marine water and sediment quality data sources include:

- Clean Seas Environmental Monitoring Programme (CSEMP) (Defra, 2016);
- Sediment analysis of benthic grab sampling in East Anglia THREE and FOUR (now Norfolk Vanguard East) (EATL, 2015);
- Sediment analysis of benthic grab sampling collected as part of the Benthic Ecology Characterisation Survey for Norfolk Vanguard (Fugro, 2016);
- Sediment analysis of benthic grab sampling collected as part of the Benthic Ecology Characterisation Survey for Norfolk Boreas (Fugro, 2017);
- Bathing water profiles (Environment Agency, 2017); and
- Environment Agency Catchment Data Explorer (Environment Agency, 2017).

3.1.3 Sediment Data

3.1.3.1 Geophysical and physical sediment data

60. Grab samples of surface sediments were collected as part of a comprehensive benthic survey undertaken in 2010 across the former East Anglia Zone. Geophysical and grab sampling was undertaken in the former East Anglia FOUR (now Norfolk Vanguard East) was undertaken in 2012.

61. Project-specific surveys were undertaken for the Norfolk Vanguard project to supplement the data collected for the former East Anglia FOUR site. A geophysical survey was also completed for Norfolk Vanguard West and the export cable corridor between September and November 2016 (Fugro, 2016). Seabed sediment grab sampling was also completed between October and November 2016 in areas of Norfolk Vanguard where additional data was considered beneficial and to cover the entire length of the export cable corridor (Fugro, 2017).

62. Geophysical and grab survey samples have been taken from the Norfolk Boreas site as part of the benthic ecology site characterisation survey (Fugro, 2017).

63. This information will feed into the physical processes assessment as to the potential increase in suspended solids concentrations associated with seabed disturbance. This information can also be used to assess the risk of contamination due to finer grained materials (silts and clays) functioning as a sink for contaminants and therefore having a greater potential to retain contaminants than larger grained materials (Horowitz, 1987).

3.1.3.2 Contaminant sediment data

64. The nearest developments where recent sediment contamination data exists are within the East Anglia THREE project (14 sites sampled for contaminants in 2013) and the Norfolk Vanguard project (13 sites sampled for contaminants including 6 in the array area and 7 in the shared export cable corridor in 2016). The sampled sites are shown in **Figure 1**. This information will supplement the site specific information (see section 3.2 below) to form the baseline for sediment quality.

3.1.4 Water Quality

3.1.4.1 Clean Seas Environmental Monitoring Programme

65. Information is available from Defra resulting from the Charting Progress programme, implemented to assess progress against the UK Government and the Devolved Administration’s vision of clean, healthy, safe, productive and biologically diverse oceans and seas. The first UK-wide assessment of progress towards that vision, Charting Progress, showed in 2005 that the UK seas were productive and supported a wide range of ecosystems, but it also revealed that human activities were adversely affecting marine life. A second report was then produced Charting Progress 2 which considers whether current environmental protection measures are working, and aims to provide policy makers, planners and the public with a clear evaluation of our progress towards the vision.

66. Norfolk Boreas is located in region 2 and the report states that in relation to toxicological hazard from metals in water samples analysed against EU Directive requirements (mainly in estuarine waters) and Shellfish Waters (mainly in coastal waters); nearly 99% of metal concentrations were below the UK Environmental Quality Standards (EQS) values in 2007 although 6% of copper concentrations exceeded the EQS. Areas where these exceedances were recorded were however, located within estuarine environments, not in offshore waters. As a result, the report concludes that levels of contaminants in offshore UK waters are generally low.

3.1.4.2 Water Framework Directive

85. The offshore cable corridor runs through the Water Framework Directive (WFD) Norfolk East coastal water body (GB650503520000). Norfolk East waterbody is a 'heavily modified' water body due to flood and coastal protection management and is currently classified to have an overall status of 'moderate'. Classification for physico-chemical parameters is deemed moderate as a result of dissolved inorganic nitrogen (DIN) concentrations in the water. In the River Basin Management Plan (RBMP) reasons for the elevated DIN concentrations are listed as diffuse pollution (arable land and therefore field runoff), and point sources associated with sewage discharges. In terms of chemical contaminants, the waterbody is considered to be at 'good' status, thus indicating no significant exceedances of Environmental Quality Standards (EQS).

3.1.4.3 Designated Bathing Waters

67. There are eight designated bathing waters within the WFD water body identified in section 3.1.4.2 above. The WFD bathing waters in closest proximity to the landfall area are Mundesley and Sea Palling, which are located 3.1km to the north and 3.5km to the south of the landfall search area, respectively. Both bathing waters have been classified as having excellent bathing water quality since 2013 (Environment Agency, 2017).

3.1.4.4 Suspended solids concentrations

68. Details of data sources regarding suspended sediment concentrations naturally present within the offshore project area is provided in the Marine Physical Processes Method Statement (Doc Ref: PB5640-004-021). This information will be used in the Marine Water and Sediment Quality section to determine the baseline environment for the potential changes to suspended solids concentrations associated with working in and on the seabed.

3.2 Survey Data

3.2.1 Site specific data – Norfolk Boreas site

69. To inform the existing baseline for sediment quality, additional benthic and contamination surveys were completed in August 2017 across the Norfolk Boreas site. This survey aimed to characterise the physical, biological and chemical nature of the seabed. Data was not collected within the cable corridor as it was agreed in discussion with the regulators prior to undertaking the surveys that the information collected to inform the Norfolk Vanguard DCO application was sufficient to inform cable installation for Norfolk Boreas.

70. As part of this survey, sediment grab samples were obtained from locations within the array site (see **Figure 1**). Of the grab samples obtained, 35 were obtained for Particle Size Distribution (PSD). Of these, eight were selected for contaminant analysis on the basis of the percentage of fine material present (as requested by the MMO) and two were selected to ensure good coverage across the site. Recent consultation with the MMO and Natural England have established that the 10 samples analysed will be sufficient to characterise the site for EIA purposes.

71. On completion of the survey, all samples were frozen and stored on the survey vessel until demobilisation, following which they were transferred to the Environment Agency's National Laboratory Service (NLS) for analysis. Analysis was undertaken for the following contaminants:

- Arsenic
- Mercury
- Cadmium
- Chromium
- Copper
- Lead
- Nickel
- Zinc
- Polychlorinated biphenyls (PCBs);
- Polycyclic Aromatic Hydrocarbons (PAHs);
- Organotins (Dibutyltin (DBT) and Tributyltin (TBT)); and
- Total hydrocarbons (THC).

72. The context of the contaminants found within sediments of the Norfolk Boreas site is established through the use of recognised guidelines and action levels. These levels are used in order to indicate general contaminant levels in the sediments. If overall levels do not generally exceed the lower threshold values of these guideline standards, then contamination levels are not deemed to be of significant concern and are low risk in terms of impacts on water quality. For the purposes of this assessment, the Cefas Action Levels have been applied because they provide good coverage of contaminants, across a broad range of contaminant types.

73. The Cefas Action Levels are used as part of a 'weight of evidence' approach to assessing the suitability of material for disposal at sea, but are not themselves statutory standards. The majority of the material assessed against these standards arises from dredging activities but they are considered an acceptable way of assessing the risks to the environment from other marine activities as part of the EIA process. The Action Levels are set out in **Table 3.1.**

Table 3.1 Summary of Cefas Action Levels

Contaminant	Action Level 1 (mg/kg)	Action Level 2 (mg/kg)
Arsenic	20	100
Cadmium	0.4	5
Chromium	40	400
Copper	40	400
Nickel	20	200
Mercury	0.3	3
Lead	50	500
Zinc	130	800
Organotins (Tributyltin (TBT) and Dibutyltin (DBT))	0.1	1
Polychlorinated Biphenyls (sum of ICES 7)	0.01	None
PCBs (sum of 25 congeners)	0.02	0.2
Polycyclic aromatic Hydrocarbons (PAH)	0.1 (exception dibenz[a,h]anthracene which is 0.01)	None
Total Hydrocarbons (THC)	100	None

74. The MMO (using the Cefas Action levels) states that, in general, contaminant levels below Action Level 1 are not considered to be of concern. Material with persistent contaminant levels above Action Level 2 is generally considered to pose an unacceptable risk to the marine environment (and therefore material is unlikely to be considered suitable for disposal to sea). For material with persistent contaminant levels between Action Levels 1 and 2, further consideration of additional evidence is often required before the risk can be quantified. Therefore for EIA, in the same way, if contaminant levels in the sediments under consideration persistently exceed Action Levels, additional assessment is required. This might be the application of additional sediment quality guidelines or undertaking more detailed water quality modelling.

75. **Table 3.2** summarises the sediment contamination data against the Cefas Action Levels. Data highlighted in yellow indicates concentrations of contaminants that exceed Cefas Action Level 1. There were no exceedances of Action Level 2. All organotin and PCB results were below the limits of detection and therefore have not been included in the table.

76. The data summarised in **Table 3.2** illustrates that sediment contamination within Norfolk Boreas is low. Only two sites exceeded the lower Cefas Action Level 1 and this was for concentrations of arsenic at ST03 and ST10. These exceedances are considered to be marginal as they are only just over the Action Level 1 concentration. Additionally, elevated levels of arsenic are typical of the region; in the offshore environment these are associated with estuarine and geological inputs and sea bed rock weathering therefore they are in line with sample results for metals at

East Anglia THREE and Norfolk Vanguard (see **Table 3.3**). There were no Action Level 2 exceedances within the Norfolk Boreas Samples.

77. Since these results indicate low levels of contamination across the site and are in line with samples from other projects, analysis of the reserved stored samples was deemed unnecessary. This was subsequently agreed with the MMO, Natural England and Cefas.

Table 3.2 Sediment contamination data for the array compared to the Cefas Action Levels for Norfolk Boreas

Contaminant	Unit	Sample site									
		ST31	ST03	ST10	ST14	ST23	ST30	ST16	ST05	ST35	ST22
Arsenic	mg/kg	13.3	21	12	32.7	14.9	10.5	9.4	12.9	8.76	14.4
Cadmium		<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Chromium		12.2	10	7.43	13.9	12.9	7.81	14.5	15.6	14.3	11
Copper		1.75	1.19	1.14	1.81	1.35	1.06	3.17	3.08	1.38	1.7
Nickel		5.4	4.41	4.57	6.41	5.22	4.2	6.95	7.85	5.49	6.1
Mercury		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.0108	<0.01	<0.01
Lead		4.39	7.17	4.67	9.91	5.09	4.63	6.62	6.74	4.61	4.87
Zinc		15.2	22.3	17.3	27	18.3	16.1	23.7	22.6	14.8	14.7
Acenaphthene	µg/kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Acenaphthylene		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Anthracene		<1	<1	<1	<1	<1	<1	<1	2.02	<1	<1
Benzo(a)anthracene		<1	<1	<1	<1	<1	<1	2.11	3.82	<1	<1
Benzo(a)pyrene		<1	<1	<1	<1	<1	<1	2.54	3.96	<1	<1
Benzo(b)fluoranthene		<1	<1	<1	<1	1.56	<1	4.07	5.04	<1	<1
Benzo(e) pyrene		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Benzo(ghi)perylene		<1	<1	<1	<1	1.29	<1	3.78	4.13	<1	<1
Benzo(j)fluoranthene		<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Benzo(k)fluoranthene		<1	<1	<1	<1	<1	<1	1.85	2.49	<1	<1
Chrysene + Triphenylene		<3	<3	<3	<3	<3	<3	3.16	4.52	<3	<3
Chrysene		<3	<3	<3	<3	<3	<3	<3	3.55	<3	<3
Dibenzo(ah)anthracene		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Dibenzothiophene		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Fluoranthene		<1	<1	<1	<1	1.55	<1	4.26	9.01	<1	<1
Fluorene		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Indeno(1,2,3-c,d)pyrene		<1	<1	<1	<1	<1	<1	2.39	3.15	<1	<1
Naphthalene		<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Perylene		<5	<5	<5	<5	<5	<5	<5	7.88	<5	<5
Phenanthrene		<5	<5	<5	<5	<5	<5	6.03	6.62	<5	<5
Pyrene		<1	<1	<1	<1	1.3	<1	3.84	7.71	<1	<1
Triphenylene		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Hydrocarbons : Total	mg/kg	4.29	2.35	6.97	4.63	10.8	2.31	23.7	16	3.53	1.96

Table 3.3 Offshore sediment contamination data for Norfolk Vanguard and East Anglia THREE compared to the Cefas Action Levels (see Figure 1 for locations of samples)

Contaminant (mg/kg)	Sample site (Norfolk Vanguard)						Sample site EA3					
	20-MS	03_MS	05_MS	19_MS	02_MS	16_MS	30	33	43	49	58	59
Arsenic	7.89	20.4	16.7	17.3	16.7	10.7	134	8.6	47.4	4.5	11.6	6.6
Mercury	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.003	0.002	0.003	<0.002	0.002	<0.002
Cadmium	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.068	<0.03	0.072	<0.03	<0.03	<0.03
Chromium	4.9	5.3	7.8	15.8	12.8	11.6	157	5.8	118	5.2	6.7	3.9
Copper	<1	1.45	<1	2.87	2.08	1.95	53.2	1.2	29.3	1.6	1.6	1.2
Lead	2.64	5.12	5.96	6.61	7.53	5.69	23.5	5.21	31.3	4.11	5.27	4.14
Nickel	3.2	3.4	3.5	7.5	5.3	5.5	88.6	3.5	64	3.82	5.73	4.12
Zinc	9.2	12	13.3	21.3	17.7	18.6	82.9	15	94.8	7.98	12.2	7.72

3.2.2 Site specific data – offshore cable corridor

78. Since Norfolk Boreas shares the majority of the offshore cable corridor with Norfolk Vanguard, the sediment data collected in the cable corridor for Norfolk Vanguard is relevant. **Table 3.4** presents the information available for the cable corridor compared to the Cefas Action Levels. It can be seen that the results do not indicate contaminants at concentrations above Cefas Action Level 1, apart from arsenic at one site. There were no Action Level 2 exceedances. The exceedance at 56_CR is only marginally above Action Level 1 and is in line with results at other sites therefore is not considered to be of concern.

Table 3.4 Data collected in the cable corridor

Contaminant	Concentration (mg/kg)						
	24_CR	48_CR	45_CR	56_CR	38_CR	26_CR	41_CR
Arsenic	12.6	11.9	9.75	35.2	10	5.39	11.4
Mercury	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01
Cadmium	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Chromium	3.8	12.8	9.1	4	2.2	4.8	<2
Copper	1.66	3.35	1.78	<1	<1	<1	<1
Lead	7.16	8.36	4.75	6.36	<2	3.59	2.34
Nickel	3.5	6.7	4.4	2.8	1.3	2.25	1.26
Zinc	8.3	22.6	14.4	14.2	5.8	9.9	5.5
Acenaphthene	<0.001	0.00101	0.001	<0.001	<0.001	<0.001	<0.001
Acenaphthylene	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Anthracene	<0.001	0.00129	0.00111	<0.001	<0.001	<0.001	<0.001
Benzo(a)anthracene	<0.001	0.00415	0.00392	<0.001	<0.001	<0.001	<0.001
Benzo(a)pyrene	<0.001	0.00558	0.00392	<0.001	<0.001	0.00142	<0.001
Benzo(b)fluoranthene	<0.001	0.00759	0.00695	<0.001	<0.001	0.0015	<0.001
Benzo(e) pyrene	<0.005	0.00703	0.0058	<0.005	<0.005	<0.005	<0.005
Benzo(ghi)perylene	<0.001	0.0068	0.00514	<0.001	<0.001	0.00111	<0.001
Benzo(j)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(k)fluoranthene	<0.001	0.00319	0.0030	<0.001	<0.001	<0.001	<0.001
Chrysene + Triphenylene	<0.003	0.00629	0.00618	<0.003	<0.003	<0.003	<0.003
Chrysene	<0.003	0.00432	0.00434	<0.003	<0.003	<0.003	<0.003
Dibenzo(ah)anthracene	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Contaminant	Concentration (mg/kg) 24_CR	48_CR	45_CR	56_CR	38_CR	26_CR	41_CR
Dibenzothiophene	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Fluoranthene	<0.001	0.00809	0.00879	<0.001	<0.001	0.00231	<0.001
Fluorene	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Indeno(1,2,3-c,d)pyrene	<0.001	0.00528	0.00452	<0.001	<0.001	0.00102	<0.001
Naphthalene	<0.005	0.00616	0.00599	<0.005	<0.005	<0.005	<0.005
Perylene	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Phenanthrene	<0.005	0.00958	0.00953	<0.005	<0.005	<0.005	<0.005
Pyrene	<0.001	0.00699	0.00739	<0.001	<0.001	0.00230	<0.001
Triphenylene	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Total Hydrocarbons	5.51	47 3	33.1	<0.9	<0.9	5.02	<0.9

4 IMPACT ASSESSMENT METHODOLOGY

4.1 Defining Impact Significance

4.1.1 Approach to the Marine Water and Sediment Quality Assessment

79. 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, namely:

- Construction phase;
- Operation and maintenance phase; and
- Decommissioning phase.

The impact assessment will incorporate a combination of the sensitivity of the receptor and the magnitude of the change to determine a significance of impact

80. The assessment of water quality impacts is based on the standards outlined in the WFD or through the comparison of survey data to the baseline environment where possible (for example in the relation to suspended solid concentrations). Assessment of sediment quality and the potential risk to water quality is based on the use and comparison of recognised guidelines and action levels providing indications as to level of likely concern.

4.1.2 Study Area

81. Consideration of the potential effects of Norfolk Boreas on marine water and sediment quality will be 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 cable corridor; and
- Far-field: the wider area that might also be affected indirectly by the project (e.g. due to sediment plumes arising from construction activities).

4.1.3 Sensitivity

82. The sensitivity of a receptor, in this case marine water quality, is dependent upon its:

- *Tolerance* to an effect (i.e. the extent to which the receptor is adversely affected by a particular effect);
- *Adaptability* (i.e. the ability of the receptor to avoid adverse impacts that would otherwise arise from a particular 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).

83. The sensitivity will be assessed using expert judgement and described with a standard semantic scale. Definitions for each term are provided in **Table 4.1**. Expert

judgements regarding receptor sensitivity will be closely guided by the conceptual understanding of baseline conditions.

Table 4.1 Definitions of the Different Sensitivity Levels for a Water Quality Receptor

Sensitivity	Definition
High	The water quality of the receptor supports or contributes towards the designation of an internationally or nationally important feature and/or has a very low capacity to accommodate any change to current water quality status, compared to baseline conditions.
Medium	The water quality of the receptor supports high biodiversity and/or has low capacity to accommodate change to water quality status.
Low	The water quality of the receptor has a high capacity to accommodate change to water quality status due, for example, to large relative size of the receiving water and capacity for dilution and flushing. Background concentrations of certain parameters already exist.
Negligible	Specific water quality conditions of the receptor are likely to be able to tolerate proposed change with very little or no impact upon the baseline conditions detectable.

84. The surrounding water quality is considered to be of low sensitivity because it is not within a confined area and therefore has a high capacity to accommodate change due to its size and therefore ability to dilute/flush any contamination.

4.1.4 Magnitude

85. Prediction of the magnitude of potential effects has been based on the consequences that the proposed project might have upon the marine water quality status.

86. These descriptions of magnitude are specific to the assessment of marine water quality impacts and are considered in addition to the generic descriptors of impact magnitude that will be presented in the EIA. Potential impacts have been considered in terms of permanent or temporary, and adverse or beneficial effects. 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).

87. The magnitude of effect will be assessed using expert judgement and described with a standard semantic scale. Definitions for each term are provided in **Table 4.2**.

These expert judgements regarding magnitude of effect will be closely guided by the conceptual understanding of baseline conditions.

Table 4.2 Indicative criteria for assessing magnitude of effect

Magnitude	Definition
High	Large scale change to key characteristics of the water quality status of the receiving water feature. Water quality status degraded to the extent that a permanent or long term change occurs. Inability to meet (for example) EQS is likely.
Medium	Medium scale changes to key characteristics of the water quality status taking account of the receptor volume, mixing capacity, flow rate, etc. Water quality status likely to take considerable time to recover to baseline conditions.
Low	Noticeable but not considered to be substantial changes to the water quality status taking account of the receiving water features. Activity not likely to alter local status to the extent that water quality characteristics change considerably or EQSs are compromised.
Negligible	Although there may be some impact upon water quality status, activities predicted to occur over a short period. Any change to water quality status will be quickly reversed once activity ceases.

4.1.5 Significance

88. 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 4.3** as a framework to guide how a judgement of the significance will be determined.

Table 4.3 Indicative 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*

89. Through use of this matrix, an assessment of the significance of an impact will be made using expert judgement in accordance with the definitions in **Table 4.4.**

Table 4.4 Indicative Impact Significance Categories

Impact Significance	Definition
Major	Very large or large change in water quality, 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 water quality, which is likely to be an important consideration at a local level.
Minor	Small change in water quality, which may be raised as a local issue but is unlikely to be important in the decision making process
Negligible	No discernible change in water quality.

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

91. Where the potential for an accidental spill or leak is concerned, as detailed in the scoping response, the focus will be on control measures that will be employed in order to reduce accidental releases to the environment. These will be listed within the ES chapter prior to the assessment of other impacts (see section 5.1 below).

5 POTENTIAL IMPACTS

5.1 Embedded mitigation

92. Norfolk Boreas Ltd is committed to the use of best practice techniques and due diligence regarding the potential for pollution throughout all construction, operation and maintenance, and decommissioning activities. As a result, an Environmental Management Plan (EMP) would be produced. This is likely to include the following mitigation measures embedded into the design:

- Oils and lubricants used in the wind turbines would be biodegradable where possible.
- Where possible, structures would be transported to site having been pre-assembled or manufactured on land.
- Where grout is required, good practise and careful use to avoid excess being discharged to the environment would be ensured at all times.
- All wind turbines would incorporate appropriate provisions to retain spilled fluids within the nacelle and tower. In addition, converter and collector stations would be designed with a self-contained bund to contain any spills and prevent discharges to the environment.
- Best practice procedures would be put in place when transferring oil or fuel between converter or collector stations and service vessels.
- Appropriate spill plan procedures would also be implemented in order to appropriately manage any unexpected discharge into the marine environment, these would be included in a Marine Pollution Contingency Plan (MPCP) to be agreed post-consent. To avoid discharge or spillage of oils it is anticipated that the transformers would be filled for their operational life and would not need interim oil changes.
- Inclusion of control measures such as the requirement to carry spill kits and the requirement for vessel personnel to undergo training to ensure requirements of the CEMP are understood and communicated.
- All work practices and vessels will adhere to the requirements of the International Convention for the Prevention of Pollution from Ships (MARPOL) 73/78; specifically Annex 1 Regulations for the prevention of pollution by oil concerning machine waters, bilge waters and deck drainage and Annex IV Regulations for the prevention of pollution by sewage from ships concerning black and grey waters.

5.2 Potential Impacts during Construction

5.2.1 Impact 1: Deterioration in water quality due to increased suspended sediment concentrations during installation of foundations

93. The installation of foundations (for wind turbines, platforms and met masts) has the potential to disturb seabed sediments if seabed preparation is required or via the release of drill arisings if drilling is required. These changes in turbidity decrease the depth to which natural light can penetrate into the water column and may therefore result in a reduction in primary productivity. Additionally, sediment plumes can create barriers to movement of marine ecological parameters such as fish and marine mammals (see the Fish and Shellfish Ecology Method Statement and Marine Mammals Method Statement).

94. The level of disturbance to seabed sediments will be a function of seabed type, the type of foundations and installation method as well as hydrodynamic conditions.

95. Different foundation installation methods are required for different foundation types. Monopiles and pin piles are likely to be driven, drilled or drilled-driven into the seabed. Drilling has the potential to release seabed and sub-seabed sediments, which are raised to the sea surface and released into the water column. For suction caisson and GBS foundations, an area of seabed may need to be ploughed or dredged in order to provide a level surface upon which they are installed. Installation of scour protection or anchors for floating turbines could also disturb seabed sediments.

5.2.1.1 Approach to Assessment

96. The assessment will draw on the results of the Marine Physical Processes assessment which will be informed by the project specific survey data for Norfolk Boreas and information available from the assessment previously undertaken for Norfolk Vanguard, East Anglia THREE and numerical modelling undertaken for East Anglia ONE.

97. As for Norfolk Vanguard, modelling for East Anglia ONE is considered relevant to the Norfolk Boreas project because the worst case scenario details and sediment types are similar to those under consideration here. Results from these studies indicate that the effects on suspended sediment concentrations during construction activities are anticipated to be minimal against natural variation in baseline levels. This is primarily because sediment data indicates very high proportions of coarser sediments present at the site thus limiting the potential risk of significant sediment plumes if seabed preparation is required. Information from the site specific survey will be used to provide further information regarding these assertions.

98. Should drilling and release of drill arisings be required, again information derived from modelling during East Anglia ONE will assist in the assessment for the potential impact associated with this activity.

5.2.2 Impact 2: Deterioration in water quality due to increased suspended sediment concentrations during installation of the offshore export cable

99. A variety of techniques could be used to excavate a trench for each export cable. These include jetting, ploughing, trenching, cutting, mass flow excavation and pre-sweeping (dredging). During pre-sweeping and/or excavation (by whichever method), sediment plumes could be formed by the release of sediment into the water column. The released sediment will then disperse in the water column both vertically and laterally, resulting in increased suspended sediment concentrations and sediment deposition. It should be noted however, that cabling is a relatively short term activity (days as opposed to months) and therefore the effect is relatively short-lived.

100. The significance of impacts associated with temporary increases in suspended sediment will be dependent upon the natural variation experienced within the area and the sensitivity of the receiving water. For example, as outlined in Section 3.1, there are two designated bathing waters in the vicinity of the landfall location and the cable route runs through the WFD coastal water body Norfolk East. Whilst compliance with the bathing waters and WFD is not dependent on meeting requirements in relation to suspended solids concentrations, the presence of a plume during the bathing season is undesirable and/or could have indirect effects on WFD compliance parameters such as marine habitats.

101. It should be noted however, that seabed sediments recorded during surveys to inform the Norfolk Vanguard EIA indicate that throughout the export cable corridor sediments range from sand to gravelly sands. Sediment plumes are therefore expected to be limited in temporal and spatial extent.

5.2.2.1 Approach to Assessment

102. An expert-based assessment will draw from the results of the Marine Physical Processes assessment and conceptual understanding to assess the extent of any increases in suspended sediment and associated sediment plume during installation of the offshore export cable. Specific consideration will be given to the designated bathing waters. The potential effects on WFD compliance parameters will be considered within a separate WFD Compliance Assessment that will be appended to the ES.

5.2.3 Impact 3: Deterioration in bathing water quality due to landfall activities

103. The proposed export cable corridor for Norfolk Boreas will make landfall at Happisburgh South where it will transit through the intertidal zone. It is presently envisaged that cable ducts and a HDD technique would be used. Installation of the ducts and the HDD process has the potential to release small amounts of suspended sediment into the coastal water which could impact on the designated bathing waters should the offshore installation method be used.

5.2.3.1 Approach to assessment

104. Of relevance is the assessment undertaken for the Norfolk Vanguard PEIR where due to the proximity of the designated bathing waters to the landfall locations, impacts on these receptors were specifically considered. Since the landfall area is the same as Norfolk Vanguard it is not proposed to repeat this assessment. Instead, a summary of the findings for Norfolk Vanguard will be presented.

5.2.4 Impact 4: Deterioration in water quality due to resuspension of sediment bound contaminants

105. The re-suspension of sediments could have the potential to release any sediment-bound contaminants, such as heavy metals and hydrocarbons if they are present within them into the water column.

106. Survey data obtained from the site specific survey indicates that levels of contaminants within the Norfolk Boreas site and export cable corridor are low. Exceedance of Cefas Action Level 1 for arsenic was recorded at only two sites within the array and one site within the cable corridor, however the exceedances were only marginal and are in line with the information gathered for other sites. As a result, significant contamination is not anticipated.

5.2.4.1 Approach to assessment

5.3 The Scoping Opinion stated that "The impacts from contaminants may be scoped out depending on the results of 2017 surveys", however recent consultation with the MMO has resulted in this impact being scoped back into the assessment on the understanding that the assessment will conclude an impact of negligible significance.

5.4 Potential Impacts during Operation and Maintenance

5.4.1 Impact 1: Deterioration in water quality due to increased suspended sediment concentrations associated with scouring

107. For all types of foundations, scour protection material is likely to be installed where required during the construction process in order to mitigate the effects of scour and

the associated release of suspended sediment and bed level changes in the vicinity of each wind turbine location during the operational phase. It is therefore proposed that consideration of the release of suspended sediments during operation of Norfolk Boreas is not considered further in the PEIR.

5.5 Potential Impacts during Decommissioning

5.5.1 Impact 1: Overall impacts associated with decommissioning

108. During decommissioning, the foundation structures will be removed which is likely to result in disturbance to sediments. Any impacts are considered likely to be significantly reduced to those identified for the construction phase, namely:

- Increase in suspended sediment concentrations due to foundation removal (but no dredging or seabed preparation will be required);
- Increase in suspended sediment concentrations due to removal of parts of the inter-array, platform link and interconnector cables; and
- Increase in suspended sediment concentrations due to removal of parts of the offshore export cable.

5.5.1.1 Approach to Assessment

109. Since the effects are likely to be less than, or at worst equal, to construction effects, no further consideration of decommissioning is proposed and therefore impacts during decommissioning will be scoped out of requiring further consideration in the PEIR.

5.6 Potential Cumulative Impacts

110. The Norfolk Boreas marine water and sediment quality CIA will consider the staged nature of development within the former East Anglia Zone as well as the relative proximity of Norfolk Boreas to other offshore activities, including the North Sea oil and gas fields, shipping routes, the Hornsea offshore wind farms , and marine aggregate dredging sites. The CIA will also consider cumulative impacts with Norfolk Vanguard (for Scenario 1 only) and East Anglia THREE. The export cables of Norfolk Boreas will be installed along the same cable corridor as Norfolk Vanguard (with separate spurs to each wind farm site). Therefore the current proposed list of projects for consideration in the CIA for impacts to water and sediment quality are:

- Norfolk Vanguard offshore wind farm (Under Scenario 1)
- East Anglia THREE Offshore windfarm;
- Marine aggregate dredging; located approximately 27km south of the export cable corridor;
- Bacton Sandscaping; and

- Decommissioning of the Davy; Boyle; Welland and Tristan oil and gas infrastructure.

5.6.1 Construction: Changes to the Suspended Sediment Concentrations

111. Cumulative construction effects will be restricted to interaction of sediment plumes and their deposition on the seabed. Cumulative effects may arise if the construction of foundations and cables at Norfolk Boreas 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 seabed.

5.6.1.1 Approach to Assessment

112. 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.

5.6.2 Operation: Changes to the Suspended Sediment Concentrations

113. There are no cumulative effects that could occur during the operation of the Norfolk Boreas offshore wind farm.

5.7 Supplementary documentation

114. Sediment analysis of benthic grab sampling collected as part of the Benthic Ecology Characterisation Survey for Norfolk Boreas (Fugro, 2017). This will be an appendix to the Benthic Ecology chapter.

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