Norfolk Boreas Offshore Wind Farm

Chapter 9

Marine Water and Sediment Quality

Environmental Statement

Volume 1

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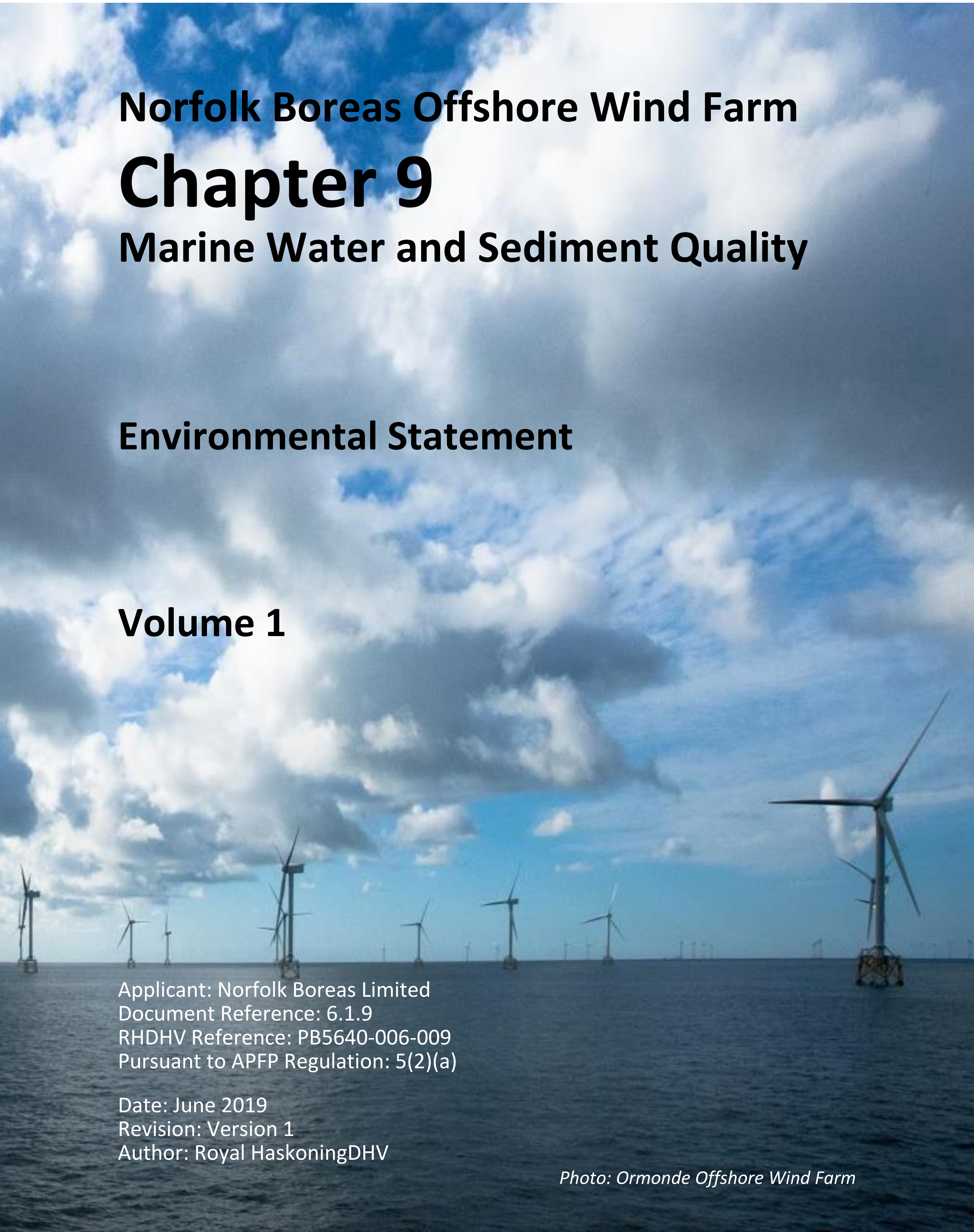

Photo: Ormonde Offshore Wind Farm

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Glossary of Acronyms

AWAC	Acoustic Wave and Current
BGS	British Geological Society
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CIA	Cumulative Impact Assessment
DBT	Dibutyltin
DCO	Development Consent Order
DECC	Department for Energy and Climate Change
DWR	Directional WaveRider
EIA	Environmental Impact Assessment
EPP	Evidence Plan Process
EQS	Environmental Quality Standards
ES	Environmental Statement
ETG	Expert Topic Group
GBS	Gravity Base Structure
HDD	Horizontal Directional Drilling
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
IPC	Infrastructure Planning Commission
MARPOL	The International Convention for the Prevention of Marine Pollution by Ships
MMO	Marine Management Organisation
MPS	Marine Policy Statement
MSFD	Marine Strategy Framework Directive
MW	Megawatt
NLS	National Laboratory Service
Nm	Nautical miles
NPS	National Policy Statements
NSIP	National Significant Infrastructure Project
NV East	Norfolk Vanguard East
NV West	Norfolk Vanguard West
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyl
PEI	Preliminary Environmental Information
PEIR	Preliminary Environmental Information Report
PSD	Particle Size Distribution
PEMP	Project Environmental Management Plan
RBMP	River Basin Management Plan
TBT	Tributyltin
THC	Total Hydrocarbons
VWPL	Vattenfall Wind Power Limited
WFD	Water Framework Directive
ZEA	Zonal Environmental Appraisal

Glossary of Terminology

Array cables	Cables which link wind turbine to wind turbine to offshore electrical platforms
Evidence Plan Process	A voluntary consultation process with specialist stakeholders to agree the approach to the EIA
Interconnector cables	Offshore cables which link offshore electrical platforms within the Norfolk Boreas site
Landfall	Where the offshore cables come ashore at Happisburgh South
Norfolk Boreas site	The Norfolk Boreas wind farm boundary. Located offshore, this will contain all the windfarm array
Norfolk Vanguard	Norfolk Vanguard offshore wind farm, sister project of Norfolk Boreas
Offshore cable corridor	The corridor of seabed from the Norfolk Boreas site to the landfall site within which the offshore export cables would be located
Offshore electrical platform	A fixed structure located within the wind farm area, containing electrical equipment to aggregate the power from the wind turbines and convert it into a more suitable form for export to shore
Offshore export cables	The cables which bring electricity from the offshore electrical platform to the landfall
Offshore project area	The area including the Norfolk Boreas site, project interconnector cable search area and offshore cable corridor
Offshore service platform	A platform to house workers offshore and/or provide helicopter refuelling facilities. An accommodation vessel may be used as an alternative for housing workers
Project interconnector cables	Offshore cables which would link either turbines or an offshore electrical platform in the Norfolk Boreas site with an offshore electrical platform in one of the Norfolk Vanguard sites
Project interconnector search area	The area within which project interconnector cables would be installed
Safety zones	An area around a vessel or structure which should be avoided during offshore construction
Scour protection	Protective materials to avoid sediment being eroded away from the base of the foundations as a result of the flow of water
The Applicant	Norfolk Boreas Limited
The Norfolk Vanguard OWF sites	Term used exclusively to refer to the two-distinct offshore wind farm areas, Norfolk Vanguard East and Norfolk Vanguard West (also termed NV East and NV West)
The project	Norfolk Boreas Offshore Wind Farm, including the onshore and offshore infrastructure

9 MARINE WATER AND SEDIMENT QUALITY

9.1 Introduction

1. This chapter of the Environmental Statement (ES) describes marine water and sediment quality of the Norfolk Boreas Offshore Wind Farm (herein 'the project' or 'Norfolk Boreas') including the Norfolk Boreas site and the offshore cable corridor from the site to the landfall at Happisburgh South and the project interconnector search area within which cables would be installed to connect to Norfolk Boreas to Norfolk Vanguard offshore wind farm.

2. It provides a summary description of key aspects relating to existing marine water and sediment quality followed by an assessment of the magnitude and significance of the effects upon the baseline conditions resulting from the construction, operation and decommissioning of the project, as well as those effects resulting from cumulative interactions with other existing or planned projects.

3. This chapter of the ES was written by Royal HaskoningDHV and incorporates interpretation of survey data collected by Fugro (2017; 2018). Due to the absence of existing contamination in the sediment (discussed in section 9.6.2) and the embedded mitigation which would avoid any potential sediment contamination as a result of the construction, operation and decommissioning of Norfolk Boreas (section 9.7.1), the focus of this impact assessment in section 9.7 is on water quality.

4. Vattenfall Wind Power Limited (VWPL) (the parent company of Norfolk Boreas Limited) is also developing Norfolk Vanguard, a 'sister project' to Norfolk Boreas. Norfolk Vanguard's development schedule is approximately one year ahead of Norfolk Boreas and as such the Development Consent Order (DCO) application was submitted in June 2018.

5. Norfolk Vanguard may undertake some enabling works for Norfolk Boreas, but these are only relevant to the assessment of impacts onshore. This assessment does however, include interconnector cables between the Norfolk Boreas and Norfolk Vanguard projects (herein, 'project interconnector cables'). If Norfolk Vanguard does not proceed then project interconnector cables would not be required.

6. The assessment process has been informed by the following:

- Chapter 8 Marine Geology, Oceanography and Physical Processes;
- Interpretation of survey data specifically collected for the project including sediment data;
- Sediment data collected for other projects;
- Discussion and agreement with key stakeholders; and
- Application of expert-based assessment and judgement by Royal HaskoningDHV.

7. The potential effects on marine water quality have been assessed conservatively using realistic worst-case scenarios for the project (section 9.7.2).

8. All figures referred to in this chapter are provided in Volume 2 of the ES.

9.2 Legislation, Guidance and Policy

9. The assessment of potential impacts on marine water and sediment quality has been made with specific reference to the relevant National Policy Statement (NPS) (discussed further in Chapter 3, Policy and Legislative Context). These are the principal decision-making documents for Nationally Significant Infrastructure Projects (NSIPs). Those relevant to marine water and sediment quality are:

- Overarching NPS for Energy (EN-1) (DECC, 2011a); and
- NPS for Renewable Energy Infrastructure (EN-3) (DECC, 2011b).

10. The specific assessment requirements for marine water and sediment quality are provided in Table 9.1.

Table 9.1 NPS assessment requirements relevant to marine water and sediment quality

NPS Requirement	NPS Reference	ES Reference
Infrastructure development can have adverse effects on the water environment, including transitional waters and coastal waters. During the construction, operation and decommissioning phases, discharges would occur. There may also be an increased risk of spills and leaks of pollutants to the water environment. These effects could lead to adverse impacts on health or on protected species and habitats and could, in particular, result in surface waters, ground waters of protected areas failing to meet environmental objectives established under the Water Framework Directive	EN-1 Paragraph 5.15.1	Potential impacts of the project on water quality are assessed in section 9.7 and in the Water Framework Directive (WFD) Compliance Assessment found in Appendix 9.1. Impacts to habitats and species are assessed in Chapter 10 Benthic and Intertidal Ecology, Chapter 11 Fish and Shellfish Ecology and Chapter 12 Marine Mammals.
Where the project is likely to have adverse effects on the water environment, the application should undertake an assessment of the existing status of, and impacts of the proposed project, on water quality, water resources and physical characteristics of the water environment as part of the	EN-1 Paragraph 5.15.2	The existing baseline is presented in section 9.6 and the baseline for relevant WFD marine bodies is provided in Appendix 9.1.

NPS Requirement	NPS Reference	ES Reference
Environmental Statement or equivalent		
The construction, operation and decommissioning of offshore energy infrastructure can affect marine water quality through the disturbance of sea bed sediments or the release of contaminants with subsequent indirect effects on habitats, biodiversity and fish stocks	EN-3 Paragraph 2.6.189	Potential impacts during construction are assessed in section 9.7.3. Contaminant analysis of samples collected from the seabed indicate very low levels of contaminants.
The Environment Agency regulates emissions to land, air and water out to 3 nautical miles (nm). Where any element of the wind farm or any associated development included in the application to the Infrastructure Planning Commission (IPC) (now the Planning Inspectorate) is located within 3nm of the coast, the Environment Agency should be consulted at the pre-application stage on the assessment methodology for impacts on the physical environment	EN-3 paragraph 2.6.191	The Environment Agency have been consulted with through the Norfolk Boreas Evidence Plan Process (see Chapter 7 Technical Consultation for further detail).
Beyond 3nm, the Marine Management Organisation (MMO) is the regulator. The applicant should consult the MMO and Centre for Environment, Fisheries and Aquaculture Science (Cefas) on the assessment methodology for impacts on the physical environment at the pre-application stage	EN-3 paragraph 2.6.192	The MMO have been consulted with through the Norfolk Boreas Evidence Plan Process (see Chapter 7 Technical Consultation for further detail).

11. The principal European and International policy and legislation used to inform the assessment of potential impacts on marine water and sediment quality for this project includes:

- Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy (the WFD);
- Directive 2008/105/EC Priority Substances establishing Environmental Quality Standards for contaminants in water;

- Directive 2008/56/EC establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive (MSFD));
- Directive 2006/7/EC concerning the management of bathing water quality; and
- The International Convention for the Prevention of Marine Pollution by Ships (MARPOL Convention) 73/78.

12. These key European Directives are transposed into UK law through a number of regulations which are discussed further in Chapter 3 Policy and Legislative Context.

9.2.1 Other UK Policies and Plans

13. Other UK policies and plans of relevance to this chapter are the Marine Policy Statement (MPS) (HM Government, 2011) and the East Inshore and East Offshore Marine Plans (HM Government, 2014). These documents guide decision making with regard to marine developments and signpost the relevant legislation to be followed. These are discussed further in Chapter 3, Policy and Legislative Context.

14. The MPS provides the high-level approach to marine planning and general principles for decision making. It also sets out the framework for environmental, social and economic considerations that need to be taken into account in marine planning. Section 2.6.4 of the MPS states that:

15. "*Developments and other activities at the coast and at sea can have adverse effects on transitional waters, coastal waters and marine waters. During the construction, operation and decommissioning phases of developments, there can be increased demand for water, discharges to water and adverse ecological effects resulting from physical modifications to the water environment. 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*."

16. With regard to the East Inshore and East Offshore Marine Plans (HM Government 2014) Objective 6 "*To have a healthy, resilient and adaptable marine ecosystem in the East Marine Plan areas*" is of relevance to this chapter as this covers policies and commitments on the wider ecosystem, set out in the MPS including those to do with the MSFD and the WFD, as well as other environmental, social and economic considerations. Elements of the ecosystem considered by this objective include:

17. "*water quality characteristics critical to supporting a healthy ecosystem and pollutants that may affect these*".

9.3 Consultation

18. Consultation regarding marine water and sediment quality has been conducted through:

- A combined (physical processes, marine water and sediment quality, benthic and fish) Expert Topic Group (ETG) which includes Natural England, the MMO, the Environment Agency and North Norfolk County Council. Two rounds of meetings have been held as part of the Norfolk Boreas Evidence Plan Process (an explanation of the Evidence Plan Process is provided in Chapter 7 Technical Consultation).
- Environmental Impact Assessment (EIA) Scoping Report (Royal HaskoningDHV, 2017a).
- A short technical report to consult on the survey data collected to seek approval from the MMO and Natural England as to whether sediment sampling and analysis undertaken to date is sufficient to inform the impact assessment (Royal HaskoningDHV, 2017b). This was subsequently updated with the inclusion of Particle Size Distribution (PSD) and additional benthic ecology information in November 2017 (Royal HaskoningDHV, 2017b). In response to this report, Natural England and the MMO confirmed in writing that they were content that the sediment sampling was suitable to inform the impact assessment and additional analysis was not required (see section 9.6.2 for further information).
- A Marine water and sediment quality Method Statement was submitted to the ETG in February 2018. The document provided the proposed method for the assessment of potential effects on the baseline due to the proposed project.
- Section 42 consultation on the Preliminary Environmental Information Report (PEIR) (Norfolk Boreas Limited, 2018). The consultation was undertaken between 31st October and 11th December 2018 on a PEIR document that was essentially a draft ES.

19. Full details of the project consultation process are presented in Chapter 7 Technical Consultation and the Consultation report (document reference 5.1). All responses received during the stages of consultation relevant to this chapter are summarised in Table 9.2.

20. In addition to the responses specific to Norfolk Boreas, consultation received by the Norfolk Vanguard project, has also influenced the Norfolk Boreas assessment. However, in order to finalise the Norfolk Boreas DCO submission it has been necessary to impose a date beyond which information could not be incorporated into the Norfolk Boreas application. The 20th March 2019, which was the Norfolk

Vanguard examination Deadline 5 was chosen as the cut off point (see Chapter 7 Technical Consultation for further detail).

Table 9.2 Consultation responses

Consultee	Document & Date	Comment	Response / where addressed in the ES
Secretary of State	Scoping Opinion June 2017	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 inform the assessment was updated in the PEIR and within this ES Chapter (see section 9.6.1).
Secretary of State	Scoping Opinion June 2017	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 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.	This is clarified in sections 9.7.3.3 and 9.7.3.5.
Secretary of State	Scoping Opinion June 2017	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	A Project Environmental Management Plan (PEMP) will be developed and agreed with the MMO post consent. An outline of this document has been submitted as part of this application (document reference 8.14) which details all measures outlined by the SoS.

Consultee	Document & Date	Comment	Response / where addressed in the ES
		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.	
MMO	Scoping Opinion June 2017	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 reproduced in section 9.6.2.
MMO	Scoping Opinion June 2017	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	Scoping Opinion June 2017	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 used to inform the assessment was updated and agreed with the ETG. Reported in section 9.6.1.
Natural England	Scoping Opinion June 2017	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.	Consulted on during development of the method statement and PEIR and outputs reported in section 9.6.2.
Natural England	Contaminant analysis agreement November 2017	We acknowledge and welcome that the project exceeded the agreed scope by doubling the number of contaminant samples from 5 to 10. The level of contamination is sufficiently low and generally within Cefas Action Level 1 limits (two out of the ten samples marginally exceeded the Cefas Action Level 1 limits for arsenic) not to be of concern to Natural England	None required.

Consultee	Document & Date	Comment	Response / where addressed in the ES
MMO	Contaminant analysis agreement November 2017	The MMO is content that the updated contaminant report characterises the sediment quality of the array sufficiently to assess the risks posed by the release of contaminated sediments during construction and would expect the final ES to assess the risks related to the re-suspension of surficial sediments. No additional sampling is required	See section 9.7.3.6.
MMO	ETG meeting February 2018	The MMO is confident that the basic EIA methodology is appropriate and based on standard considerations. A point to note is that, from the repeated reference to expert judgement or expert based assessment, it is not clear whether these are specific processes and therefore different. For example 'expert-based' implies that expert judgement is not the sole criterion in this case. This should be clarified.	See section 9.4.1 and explanation provided throughout section 9.7 where applicable.
MMO	ETG meeting February 2018	Main impacts identified during the construction and decommissioning are suspended sediment, drilling and cable laying. Other potential sources of contamination from these activities, such as spills and accidental release, require further consideration. This should include information on the likely scale of such incidental releases, and contamination, given that accidents by definition cannot be scoped out entirely. Please note that scour impacts are separate from impacts of turbid wakes on suspended sediment concentration. This hydrodynamic effect and its potential impact on suspended sediment requires further consideration due to its importance for primary production in the water column.	Assessment of the impacts of accidental release of contaminants was scoped out during the scoping processes. The scoping opinion containing the following paragraph: "*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*

Consultee	Document & Date	Comment	Response / where addressed in the ES
			and therefore further assessment is not required." Additionally, a PEMP will be developed post consent an outline of which is submitted as part of this application (document reference 8.14).
MMO	ETG meeting February 2018	The MMO has no objection for contaminated sediment to be scoped out of the EIA. The MMO would like to note however, that it is common practise to include a chapter on the characterisation of the disposal site in the ES. With the analysis and interpretation already completed, this should not add undue additional effort.	A separate site characterisation report has been produced as part of this application (document reference 8.15).
MMO	ETG meeting February 2018	Should the sediment release be negligible, the MMO is confident that the impact of scour on suspended sediment concentrations can be scoped out. Any further discussion of this statement should be supported by evidence and particularly by reference to the method used to determine where scour protection is needed. This should include a definition of criteria and analysis/methods for determining where and whether scour protection is needed.	See section 9.7.1.
Natural England	ETG meeting February 2018	We highlight that full consideration is given to the extent of the phased build approach as it would significantly increase impacts.	See section 9.7.
Environment Agency	ETG meeting February 2018	The Environment Agency has no major concerns with the methods described in so far as they affect issues and areas within our remit.	None required.
North Norfolk District Council	ETG meeting February 2018	Any comments and guidance regarding landfall and coastal processes will remain the same for Boreas as was from Vanguard unless something substantial changes and assuming the same landfall position.	None required.
Natural England	PEIR Response November 2018	In respect of J-Tube and Ladder cleaning, this activity typically involves either jet washing marine growth and bird guano off turbine foundation pieces, or cutting the growth from around the J-tube. The ES project description does not detail the number of occasions this would occur or the volumes of material being deposited in the marine environment. This does not seem to have been considered at all within the ES. Therefore, either information needs to be	The impacts of cleaning the foundations are assessed in section 9.7.4.2.

Consultee	Document & Date	Comment	Response / where addressed in the ES
		provided or this should not be considered as part of the works consented.	
MMO	PEIR Response December 2018	In Section 8.6.9 of the PEIR, the figures relating to suspended sediment appear contradictory. Paragraph 114 states "Suspended sediment concentrations across the Norfolk Boreas site could range from 1 to 35mg/l. During the Land Ocean Interaction Study (NERC, 2016), measurements near to Norfolk Boreas recorded a maximum concentration of 83mg/l ..." However higher readings are also stated throughout the section. The MMO seeks clarification on the correct suspended sediment concentrations.	This is relevant to this chapter because it uses the same baseline data as that presented in Chapter 8 Marine Geology, Oceanography and Physical processes. The older values for suspended sediment concentrations are superseded by bespoke measurements taken within the Norfolk Vanguard East site. These are used for a proxy or the Norfolk Boreas site. The latest values are now presented in both chapters.

9.4 Assessment Methodology

9.4.1 Impact Assessment Methodology

21. The impact assessment methodology in this chapter generally follows that outlined in Chapter 6 EIA Methodology with topic specific definitions for sensitivity and magnitude provided below.

22. Impacts associated with installation of the project interconnector (between the Norfolk Boreas and Norfolk Vanguard project) cables, array cables and interconnector (within the Norfolk Boreas site) cables are assessed together where appropriate. This is the approach taken in Chapter 8 Marine Geology, Oceanography and Physical processes and is justified because the extent to which processes act on the Norfolk Boreas site and the project interconnector search area are similar and the seabed conditions are similar. Hence, the potential effects on the project interconnector cables and the array and interconnector cables are analogous.

9.4.1.1 Sensitivity

23. 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).

24. The sensitivity is assessed using expert judgement and described with a standard semantic scale. Definitions for each term are provided in Table 9.3. Expert judgements regarding receptor sensitivity is closely guided by the conceptual understanding of baseline conditions.

Table 9.3 Definitions of sensitivity levels for a marine water and sediment quality receptors

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.

25. Water quality in the offshore project area 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.

9.4.1.2 Magnitude

26. 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.

27. 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).

28. The magnitude of effect is assessed using expert judgement and described with a standard semantic scale. Definitions for each term are provided in Table 9.4.

Table 9.4 Definitions of magnitude Levels for assessing effects

Sensitivity	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) Environmental Quality Standard (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 would be quickly reversed once activity ceases.

9.4.1.3 Impact significance

29. 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 9.5 as a framework to guide how a judgement of the significance is determined.

Table 9.5 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*

30. Through use of this matrix, an assessment of the significance of an impact is made in accordance with the definitions in Table 9.6.

Table 9.6 Impact significance definitions

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.

31. Note that for the purposes of this ES, 'major' and 'moderate' impacts are generally considered 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.

32. 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 would be employed to reduce accidental releases to the environment. A separate outline Project Environmental Management Plan (PEMP) (document reference 8.14) has been submitted as part of the DCO application. The final PEMP which will detail all the measures designed to prevent any spills or leaks will be produced and agreed with the MMO prior to construction. Therefore, accidental spills and leaks are not considered further in this chapter.

9.4.2 Cumulative Impact Assessment

33. Cumulative impacts are assessed through consideration of the extent of influence of changes to marine water quality arising from the project alone and those arising from the project cumulatively or in combination with other offshore wind farm developments (particularly Norfolk Vanguard and East Anglia THREE) but also considering any other nearby seabed activities, including marine aggregate extraction and marine disposal.

34. The approach is based on Chapter 6 EIA Methodology and draws on findings of earlier studies undertaken to inform the East Anglia ZEA (ABPmer, 2012a) which considered cumulative effects arising from development of the whole of the former East Anglia zone, the ES for East Anglia THREE (EATL, 2015), ES for East Anglia ONE (EAOW, 2012b) and ES for Norfolk Vanguard (Norfolk Vanguard Limited, 2018) which considered cumulative effects from those projects and other nearby project activities.

9.4.3 Transboundary Impact Assessment

35. 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, 2017a) and in agreement with the Evidence Plan Process (February 2018), transboundary impacts have been screened out of this chapter.

9.5 Scope

9.5.1 Study Area

36. Consideration of the potential effects of Norfolk Boreas on marine water and sediment quality are carried out over the following spatial scales:

- The Norfolk Boreas site: including the wind turbine foundations, supporting infrastructure (offshore service platform, meteorological masts and electrical platforms), array cables and interconnector cables. Note, this includes the wider area that may be impacted by sediment plumes (this is informed by Chapter 8 Marine Geology, Oceanography and Physical Processes as this chapter considers the spatial extent of any potential sediment plume associated with construction of the project).
- The project interconnector search area, including project interconnector cables which would be installed under the worst case scenario; and
- The offshore cable corridor which connects the Norfolk Boreas site to the landfall.

9.5.2 Data Sources

37. 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. All information used to inform this assessment is presented in Table 9.7.

Table 9.7 Data sources

Data	Year	Coverage	Confidence	Notes
Suspended sediment Metocean Survey	Fugro EMU 2013. 2012-2013	Former East Anglia FOUR site (NV East)	High	Acoustic Wave and Current (AWAC) meter and Directional Waverider (DWR) buoy
Clean Seas Environmental Monitoring Programme (CESAMP) – water quality	Various – latest report Defra 2016	UK Seas – water quality	High	The Quality Status Report 2010 describes the current status and trends in water quality for regional seas including the North Sea

Data	Year	Coverage	Confidence	Notes
Sediment Analysis	Fugro EMU (2013)	North Sea, within East Anglia THREE and former East Anglia FOUR sites.	High	15 surface sediment grabs sampled for contaminants from within the East Anglia THREE and former East Anglia FOUR sites and offshore cable corridor (see Figure 9.2). One of these is located within the project interconnector search area (see Figure 9.2)
Contaminant analysis of benthic grab sampling collected as part of the Benthic Ecology Characterisation Survey for Norfolk Vanguard (Fugro, 2017)	2016	The offshore cable corridor and Norfolk Vanguard West.	High	13 surface sediment grabs sampled for contaminants at sites located within Norfolk Vanguard East and Norfolk Vanguard West and the offshore cable corridor. One of these sites are within the project interconnector search area (see Figure 9.2)
Contaminant analysis of benthic grab sampling collected as part of the Benthic Ecology Characterisation Survey for Norfolk Boreas (Fugro, 2018)	2017	The Norfolk Boreas Site	High	10 surface sediment grabs sampled for contaminants at locations within the Norfolk Boreas site (see Figure 9.2)
Metocean Survey	Dec 2012 – November 2018	Norfolk Vanguard OWF sites	High	AWAC and directional waverider buoy
Bathing water profiles (Environment Agency, 2019a)	Updated annually.	Coastal waters around England – water quality	High	Water quality at designated bathing water sites in England are assessed by the Environment Agency between May and September. Data is published by the Environment Agency online.
Environment Agency Catchment Data Explorer (Environment Agency, 2019b)	Updated at each River Basin Planning round	Rivers, estuaries and coastal waters around England.	High	Database for information related to river basin management plans (RBMP) in England. Contains information on river basin districts and catchments and WFD compliance data.

38. Grab samples of surface sediments were collected as part of a comprehensive benthic survey undertaken in 2010 across the former East Anglia Zone and geophysical and grab sampling was undertaken in the former East Anglia FOUR (now Norfolk Vanguard East) was undertaken in 2012.

39. Project-specific surveys were undertaken for Norfolk Vanguard to supplement the data collected for the former East Anglia FOUR site. A geophysical survey was also completed for Norfolk Vanguard West and the offshore cable corridor between September and November 2016 (Fugro, 2017). These cover the project interconnector search area and the offshore cable corridor and are herein referred to as the "offshore cable corridor surveys".

40. Geophysical and grab survey samples have also been taken from the Norfolk Boreas site as part of the benthic ecology site characterisation survey (Fugro, 2018). These surveys are herein referred to as the "Norfolk Boreas site surveys".

41. A selection of these samples were used for contaminant analysis (see Table 9.7 and Figure 9.2 for the number analysed).

42. Geophysical information is important for Chapter 8 Marine Geology, Oceanography and Physical Processes when assessing the potential increases in suspended solids concentrations associated with seabed disturbance. This information can also be used within this topic 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) alongside the site specific contaminant data available.

9.5.3 Assumptions and Limitations

43. Given the limited data regarding site specific offshore water quality, information from more general monitoring programmes such as the Clean Seas Environmental Monitoring Programme and WFD water body status have been used to inform this assessment.

44. Information regarding coastal suspended sediments is not available, however the modelling informing Chapter 8 Marine Geology, Oceanography and Physical Processes predicts the potential change in concentrations therefore allowing an assessment of the magnitude of change that is likely during the various construction activities.

9.6 Existing Environment

9.6.1 Water Quality

9.6.1.1 Clean Seas Environmental Monitoring Programme

45. Information is available from Defra 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 assessment Charting Progress (2005) showed 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. Norfolk Boreas is located in region 2 of this assessment. Charting Progress 2 (2014,) 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.

9.6.1.2 Water Framework Directive

46. The offshore cable corridor runs through the WFD Norfolk East coastal water body (GB650503520000) (see Figure 9.1). 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 considered moderate due to dissolved inorganic nitrogen concentrations in the water. In the River Basin Management Plan reasons for the elevated inorganic nitrogen 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 EQS. The WFD assessment of impacts of Norfolk Boreas on this water body is included in Appendix 9.1 of this assessment.

9.6.1.3 Designated Bathing Waters

47. There are eight designated bathing waters within the WFD water body identified in 9.6.1.2 above (see Figure 9.1). 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, respectively. Both bathing waters have been classified as having excellent bathing water quality since 2013 (Environment Agency, 2019a).

9.6.1.4 Suspended solids concentrations

48. Details of data sources regarding suspended sediment concentrations likely to be naturally present within the offshore project area is provided in Chapter 8 Marine Geology, Oceanography and Physical Processes (section 8.6.9). To summarise, measurements of suspended sediment concentrations were carried out at the AWAC station in Norfolk Vanguard East (immediately to the south of the Norfolk Boreas site).

49. Overall, suspended sediment concentrations in Norfolk Vanguard East were between 0.3 and 108mg/l throughout the year. Concentrations were less than 30mg/l for 95% of the time and less than 10mg/l for 70% of the time. Given the proximity of Norfolk Boreas to Norfolk Vanguard East and the similar physical and seabed sediment

conditions, these measurements are used as an analogy for Norfolk Boreas. Hence, the baseline suspended sediment concentrations across Norfolk Boreas are estimated to vary from 0 to 100mg/l, and likely to be less than 30mg/l most of the time.

9.6.2 Sediment Quality

9.6.2.1 Particle Size Distribution

50. PSD data is described in Chapter 8 Marine Geology, Oceanography and Physical Processes. To summarise, the dominant sediment type within the Norfolk Boreas site is sand with median particle sizes between 0.17 and 0.33mm (fine to medium sand). Relatively low mud and gravel content were recorded. Only 10% of the samples contained greater than 10% mud.

51. Within the offshore cable corridor, sediment distribution is variable depending on location. However, the dominant sediment size is again sand. Higher proportions of mud (greater than 10%) were found in 25% of samples with two samples containing greater than 60% mud. Samples located closer to the coast contained greater than 50% gravel.

52. Within the project interconnector search area, the dominant sediment type is again medium-grained sand with low mud and gravel content.

9.6.2.2 Sediment contamination within the Norfolk Boreas site

53. To inform the baseline for sediment quality, benthic and contaminant surveys were undertaken in August 2017 across the Norfolk Boreas site (Figure 9.2). This survey aimed to characterise the physical, biological and chemical nature of the seabed. Data was not collected within the offshore cable corridor (shared between Norfolk Boreas and Norfolk Vanguard) as it was agreed through the EPP with the regulators, prior to undertaking the surveys, that the information collected to inform the Norfolk Vanguard EIA was sufficient to inform this EIA.

54. As part of this survey, sediment grab samples were obtained from locations within the Norfolk Boreas site (see Figure 9.2). Of the 35 samples collected, eight were selected for contaminant analysis on the basis of the percentage of fine material present (as requested by the MMO, see Table 9.1) and two were selected to ensure even coverage across the site.

55. 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).

56. The context of the contaminants found within sediments of the Norfolk Boreas site is established through the use of recognised guidelines and action levels, in this case Cefas Action Levels have been applied because they provide good coverage of contaminants, across a broad range of contaminant types (MMO, 2018). These levels are used 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 considered to be of significant concern and are low risk in terms of potential impacts on the marine environment. 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 (MMO, 2018).

57. 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 9.8.

Table 9.8 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

Contaminant	Action Level 1 (mg/kg)	Action Level 2 (mg/kg)
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.

58. The data summarised in Table 9.9 illustrates that sediment contamination within the Norfolk Boreas site is low. Only two sample locations 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 this region of the southern North Sea. These are associated with estuarine and geological inputs and seabed rock weathering therefore they are in line with sample results for metals at East Anglia THREE and Norfolk Vanguard (see Table 9.10). 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 considered unnecessary. This was agreed with the MMO, Natural England and Cefas (see Table 9.2).

Table 9.9 Sediment contamination data for the Norfolk Boreas site compared to the Cefas Action Levels (yellow indicates exceedance of Action Level 1, there are no Action Level 2 exceedances)

Contaminant		Sample site									
	Unit	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

Contaminant	Sample site										
	Unit	ST31	ST03	ST10	ST14	ST23	ST30	ST16	ST05	ST35	ST22
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
Total Hydrocarbons	mg/kg	4.29	2.35	6.97	4.63	10.8	2.31	23.7	16	3.53	1.96

Table 9.10 Offshore sediment contamination data for Norfolk Vanguard and East Anglia THREE compared to the Cefas Action Levels (yellow indicates exceedance of Action Level 1, red indicates exceedance of Action Level 2)

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

9.6.2.3 Sediment contamination within the offshore cable corridor

78. Table 9.11 presents the information available for the offshore 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 and therefore is not considered to be of concern. Sample station 56_CR is located towards the eastern end of the offshore cable corridor (Figure 9.2)

Table 9.11 Data collected in the offshore cable corridor

	Concentration (mg/kg)						
Contaminant	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

Contaminant	Concentration (mg/kg)						
	24_CR	48_CR	45_CR	56_CR	38_CR	26_CR	41_CR
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
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

9.6.2.4 Sediment contamination within the project interconnector search area

59. The project interconnector search area is partly located within Norfolk Vanguard East, Norfolk Vanguard West and the offshore cable corridor as can be seen on Figure 9.2. Note, that this search area has increased in size since the proposals presented in the PEIR. All sediment samples, including those undertaken to inform the Norfolk Vanguard EIA, are therefore shown in Figure 9.2 to identify which locations are likely to represent sediment quality in this area. The data is summarised in Table 9.12 below.

Table 9.12 Data collected in the project interconnector search area (note 05_MS just outside of the search area, but has been included for context).

Contaminant	Concentration (mg/kg)		
	03_MS	05_MS	16_MS
Arsenic	20.4	16.7	10.7
Mercury	<0.01	<0.01	<0.01

Contaminant	Concentration (mg/kg)		
	03_MS	05_MS	16_MS
Cadmium	<0.04	<0.04	<0.04
Chromium	5.3	7.8	11.6
Copper	1.45	<1	1.95
Lead	5.12	5.96	5.69
Nickel	3.4	3.5	5.5
Zinc	12	13.3	18.6
Acenaphthene	<0.001	<0.001	<0.001
Acenaphthylene	<0.001	<0.001	<0.001
Anthracene	<0.001	<0.001	<0.001
Benzo(a)anthracene	<0.001	<0.001	0.00429
Benzo(a)pyrene	0.00152	<0.001	0.00543
Benzo(b)fluoranthene	0.00234	<0.001	0.0074
Benzo(e) pyrene	<0.005	<0.005	0.00605
Benzo(ghi)perylene	0.00187	<0.001	0.00526
Benzo(j)fluoranthene	<0.01	<0.01	<0.01
Benzo(k)fluoranthene	<0.001	<0.001	0.00341
Chrysene + Triphenylene	<0.003	<0.003	0.00579
Chrysene	<0.003	<0.003	0.00418
Dibenzo(ah)anthracene	<0.001	<0.001	<0.001
Dibenzothiophene	<0.005	<0.005	<0.005
Fluoranthene	0.00186	<0.001	0.00933
Fluorene	<0.005	<0.005	<0.005
Indeno(1,2,3-c,d)pyrene	0.0015	<0.001	0.00491
Naphthalene	<0.005	<0.005	<0.005
Perylene	<0.005	<0.005	<0.005
Phenanthrene	<0.005	<0.005	0.00845
Pyrene	0.00160	<0.001	0.00779
Triphenylene	<0.002	<0.002	<0.002
Total Hydrocarbons	10	3.06	26.2

60. 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 03MS is only marginally above Action Level 1 and is in line with results at other sites and therefore is not considered to be of concern.

9.6.3 Anticipated Trends in Baseline Conditions

61. The baseline conditions for marine water and sediment quality are considered to be relatively stable within the offshore project area with multiple data sets covering several years exhibiting similar patterns.

75. The existing environment within the study area has been largely shaped by a combination of the physical processes which exist within the southern North Sea (Chapter 8 Marine Geology Oceanography and Physical Processes) and anthropogenic impacts (which influence pollutant levels). These processes will continue to influence the area in the future, and conditions are likely to remain in the same range as past patterns.

9.7 Potential Impacts

9.7.1 Embedded Mitigation

62. Norfolk Boreas Limited has committed to a number of techniques and engineering designs/modifications as part of the project during the pre-application phase in order to avoid a number of impacts or reduce impacts as far as possible. Embedding mitigation into the project design is a type of primary mitigation and is an inherent aspect of the EIA process.

63. A range of different information sources have been considered when embedding mitigation into the design of the project (for further details see Chapter 5 Project Description, Chapter 4 Site Selection and Assessment of Alternatives). These include engineering requirements, ongoing consultation with stakeholders and regulators through the ETG, commercial considerations and environmental best practice.

64. Norfolk Boreas Limited 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 outline PEMP has been developed (document reference 8.14). The final PEMP would be agreed with the MMO prior to construction.

65. In view of the low contaminant release risk in the offshore project area and the commitment to the PEMP, no impacts are predicted as a result of pollutants and contamination. Therefore, the potential for pollutants to be accidentally released into the environment is not considered further in this chapter.

66. Additionally, for piled foundation types, pile-driving would be used in preference to drilling where it is practicable to do so (i.e. where ground conditions allow). This would minimise the quantity of sub-surface sediment that would be released into the water column from the installation process. Micro-siting would also be used

where possible to minimise the requirements for seabed preparation prior to foundation installation.

67. For all types of foundations, scour protection material would be installed where required during the construction process 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. As a result, the potential increase in suspended solids resulting from scour is not considered further in this chapter.

68. Norfolk Boreas Limited has made the decision to use an HVDC solution rather than a HVAC solution to reduce the number of offshore export cables and volume of cable protection (as advised in Natural England's recommendations document (Natural England, 2018). This results in the following mitigating features:

- There would be two HVDC export cable trenches instead of six HVAC export for Norfolk Boreas;
- The volume of sediment arising from pre-sweeping and cable installation works is reduced;
- The area of disturbance for pre-sweeping and cable installation is reduced;
- The space required for cable installation is reduced, increasing the space available within the cable corridor for micrositing to avoid sensitive features including designated features within the Haisborough Hammond and Winterton SAC; and
- The potential requirement for cable protection in the unlikely event that cables cannot be buried is reduced.

69. Following the consultation on the PEIR, Norfolk Boreas Limited has made the decision to remove floating foundations from the project design envelope. This decision has resulted in a large reduction in the volumes of sediment that could be disturbed as a result of foundation installation.

9.7.2 Worst Case

70. As discussed in section 9.4, assessment of effects of project interconnector cables are assessed in conjunction with those related to the array and interconnector cables.

71. The offshore project area consists of:

- The Norfolk Boreas site;
- The offshore cable corridor with landfall at Happisburgh South; and
- The project interconnector search (Figure 9.1);

72. The detailed design of the Norfolk Boreas project (including numbers of wind turbines etc.) has not yet been determined and may not be finalised until sometime after any DCO has been granted. Therefore, realistic worst-case scenarios in terms of potential impacts on marine water and sediment quality are adopted to undertake a precautionary and robust impact assessment. The specific elements/activities of Norfolk Boreas that could impact on marine water and sediment quality are detailed in the following sections.

73. The project design envelope on which the ES is based was "frozen" in January 2019 to allow the DCO to be completed and submitted in June 2019.

9.7.2.1 Foundations

74. Within the Norfolk Boreas site, several different sizes of wind turbine are being considered in the range between 10MW and 20MW. To achieve the maximum capacity of 1,800MW, there would be between 90 and 180 turbines.

75. In addition, up to two offshore electrical platforms, one offshore service platform, two meteorological (met) masts, two LiDAR platforms and two wave buoys, plus offshore cables are considered as part of the worst-case scenario.

76. A range of foundation options for the above-sea structures are currently being considered, these include:

- Wind turbines - jacket, gravity base structures, suction caisson, monopile and TetraBase;
- Offshore electrical platforms – Jackets with pin-pile or suction caissons or multi-legged gravity base;
- Service platform – likely to be similar to offshore electrical platforms;
- Met masts - GBS, monopile or jackets with pin-pile;
- LiDAR - floating with anchors or monopile; and
- Wave buoys – floating with anchors.

77. The largest disturbance areas for wind turbine foundations would occur if the GBS foundation type were used.

9.7.2.2 Construction programme

78. Norfolk Boreas Limited is currently considering constructing the project in one of the two following phase options:

- A single phase of up to 1,800MW; or
- Two phases of up to a combined 1,800MW capacity.

79. The indicative offshore construction window is anticipated to be up to approximately three years (see Table 5.26 and 5.27 in Chapter 5 Project description) for the full 1,800MW capacity.

9.7.2.3 Cable installation

80. There would be four main types of cable used in the offshore section of Norfolk Boreas. These are as follows:

- Array cables - cables that connect wind turbine to wind turbine and connect wind turbine to offshore electrical platform;
- Interconnector cables - one pair of HVDC cables and a single AC that connect two offshore electrical platforms within the Norfolk Boreas site; or
- Project interconnector cables – HVDC or AC cables which connect an offshore electrical platform or wind turbines within the Norfolk Boreas site with an offshore electrical platform within the Norfolk Vanguard OWF site. This would be located within the project interconnector search area (Figure 9.1); and
- Offshore export cables - cables that connect an offshore electrical platform within the Norfolk Boreas site with the landfall.

81. There would only be a requirement for either the interconnector cables or the project interconnector cables but never both. The need for the project interconnector cables could only occur if Norfolk Vanguard proceeds to construction and even then, it would depend on the final electrical solution. Section 5.4.12 of Chapter 5 Project Description describes in further detail the three electrical solutions currently being considered.

82. When assessing the impacts caused by installation, operation and maintenance of the project interconnector cables it is only the parts of these cables that are located within the project interconnector search area that are considered and not the sections within the Norfolk Boreas site. This is due to the fact that the worst case scenario for impacts within the Norfolk Boreas site assesses 90km (installed within 60km of cable trench) of interconnector cables and 600km of array cables. No matter which of the electrical solution is eventually chosen cable installation within the Norfolk Boreas site will not exceed these quantities.

9.7.2.3.1 Pre-installation works

Pre-lay grapnel run

83. A pre-lay grapnel run would be undertaken to clear any debris in advance of any cable installation. The maximum width of seabed disturbance along the pre-grapnel run would be 20m. This is encompassed by the maximum footprint of cable installation works associated with ploughing (30m disturbance width).

Pre-sweeping

84. Sand wave levelling (pre-sweeping) is one strategy for cable installation to ensure the cables are installed at a depth that is unlikely to require reburial throughout the life of the project. Sand wave levelling may also be required to create a suitable surface for foundation installation. A final design decision on pre-sweeping would be

made post consent and captured pre construction in the Cable Specification, Installation and Monitoring Plan (required under [condition 14(1)(g) (DCO Schedules 9 and 10) condition 9 (1) (g) (DCO Schedules 11 and 12) and Condition 7 (1)(f) (DCO schedule 13)]) following pre-construction surveys.

167. Indicative areas within the offshore cable corridor where pre-sweeping may be required and the estimated volumes as provided by CWind (Appendix 5.2) are outlined in Chapter 8 Marine Geology, Oceanography and Physical Processes. The sediment released at any one time would depend on the capacity of the dredger. The maximum width of pre-sweeping in the offshore cable corridor would be approximately 37m depending on the depth of sand waves. The 37m pre-sweeping width is based on sand wave depth of approximately 5m with a slope gradient of 1 in 3 and a width of 7m at the base of the dredged area. This would be in discrete areas and not along the full length of the corridor. This would be in discrete areas and not along the full length of the corridor.

9.7.2.3.2 Cable burial

85. Following the pre-installation works described above, the cables would be installed and buried. The following methods may be used for cable burial and would be dependent on the results of the pre-construction survey and post-consent procurement of the cable installation contractor:

- Ploughing (worst-case scenario with a trench width of 10m and disturbance width of 30m);
- Trenching or cutting; or
- Jetting.

86. The maximum length of a single export cable pair would be 125km. Therefore, with a worst case of two cable pairs, up to 250km of cable trench would be required. 200km of which would be located within the offshore cable corridor and 50km of which would be located within the Norfolk Boreas Site.

9.7.2.3.3 Landfall

87. The offshore export cable would make landfall at Happisburgh South using long HDD and duct installation, with cable burial on the seaward side of the drilling exit point. The landfall ducts would exit in the subtidal zone beyond - 5.5m LAT but within 1km of the onshore drilling location.

9.7.2.4 Sediment disposal

88. The worst-case scenario for the volume of sediment arising from seabed preparation in the Norfolk Boreas site would be associated with levelling the seabed for GBS foundations (180 foundations, levelling and area 50m in diameter) resulting in a total

footprint of 353,429 m^2 (1,963m^2 per foundation) potentially disturbing a sediment volume of 1,767,146m^3 (based on a maximum thickness of 5m of sediment levelled). In addition, levelling of 7,500m^2 per electrical platform and service platform and 1,257m^2 per met mast may be required resulting in a footprint of 25,014m^2 and sediment volume of 125,066m^3.

89. Sediment arising from within the Haisborough, Hammond and Winterton SAC would be deposited back into the SAC in locations to be agreed with Natural England and the MMO based on the preconstruction survey. Sediment arising from outside of the SAC would be deposited elsewhere within the area shown in yellow in Figure 5.2.

9.7.2.5 Maintenance

9.7.2.5.1 Turbines

90. Regular maintenance of the wind turbines could be required during operation. These works would have minimal impact on marine water and sediment quality would largely be managed by the application of best working practices to reduce any risk of spills to the environment. Occasional cleaning of the foundations may be required; this would be undertaken using seawater as described in section 5.4.18 of Chapter 5 Project description.

9.7.2.5.2 Cable repairs

91. During the life of the project, there should be no need for scheduled repair or replacement of the subsea cables. However, periodic inspection would be required and where necessary, reactive repairs and reburial would be undertaken.

92. While it is not possible to determine the number and location of repair works that may be required during the life of the project, an estimate of one offshore export cable repair every year is assumed. In addition, the occurrence of one interconnector cable and two array cable repairs every five years has been assessed.

93. In most cases a failure would lead to the following operation:

- Vessel anchor placement;
- Exposing the damaged part of the cable using jetting (3m disturbance width);
- Cutting the cable, assumed to be approximately 300m of export cable or interconnector cable subject to the nature of the repair, or the whole length of an array cable (approximately 2km);
- Lifting the cable ends to the repair vessel;
- Jointing a new segment of cable to the old cable;
- Lowering the cable (and joints) back to the seabed; and
- Cable burial, where possible.

9.7.2.5.3 Cable reburial

94. Cables could become exposed due to migrating sand waves. During the life of the project, periodic surveys would be required to ensure the cables remain buried and if they do become exposed, reburial works would be undertaken.

95. For the offshore export cables, the aim would be to avoid requirement for reburial by using pre-sweeping. However, a worst-case scenario of reburial of up to 20km per export cable pair at approximately five-year intervals is assumed.

96. Given the small scale of the proposed maintenance activities, the changes to suspended sediment concentrations would be negligible in magnitude and short-lived, with no potential significant impact and therefore this is not assessed further. Additionally, the PEMP (an outline of which is provided in document 8.14) would cover any risks associated with accidental pollution.

97. Table 9.13 describes the relevant worst-case scenarios for marine water and sediment quality based on the above.

Table 9.13 Worst case assumptions

Impact	Parameter	Worst Case	Rationale
Construction			
Impact 1: Deterioration in water quality due to increased suspended sediment concentrations during installation of foundations.	1A. Sediment plume created by seabed preparation	Worst-case scenario for a single wind turbine foundation would be a GBS foundation for a 20MW turbine due to this having the largest single footprint. Seabed preparation may be required up to a sediment depth of 5m. The preparation volume for a single 20MW GBS foundation is 2,827m^3 (based on a 60m diameter preparation area). Total maximum seabed preparation volumes for 1,800MW capacity: • 180 GBS foundations (requiring preparation area 50m in diameter and 5m preparation depth) = 1,767,146m^3 • 2 meteorological masts (1,257m^2, 5m depth) = 12,566m^3 • 2 electrical platforms (7,500m^2 x 5m depth) = 75,000m^3 • 1 service platform (7,500m^2 x 5m depth) = 37,500m^3 Total worst-case seabed preparation volume for foundations is **1,892,212m^3.**	Seabed preparation (dredging using a trailer suction hopper dredger and installation of a bedding and levelling layer) may be required up to a sediment depth of 5m. The worst-case scenario considers the maximum volumes for the project and assumes that sediment would be dredged and returned to the water column at the sea surface during disposal from the dredger vessel.
	1B. Sediment plume created by drill arisings	The worst-case scenario for a single turbine would be a 20MW monopile foundation, with a maximum drill arisings volume of 8,836m^3 per turbine (based on penetration of 50m and 15m drill diameter). The worst-case scenario for the whole project is an array of 180 x 10MW monopile foundations, two meteorological masts on pin-pile quadropods, a service platform and two offshore electrical platforms on six-legged pin-piles (18 piles in total) and two LiDAR platforms on monopiles. As a worst case, 50% of the turbines may need to be drilled. For the project as a whole; the maximum amount of drill arisings per monopile for each wind turbine is 8,836m^3 (based on a drill diameter of 15m per pile and an average drill penetration of 50m). Therefore, the drill arisings would be as follows: • 45 x largest quadropod foundations is 397,608m^3. • Meteorological masts - 2 x pin-pile quadropod = 1,131m^3 • Service platform - 1 x six-legged pin-pile = 848m^3	Up to 50% of the turbines and platform foundations may need to be drilled (**NB** if piled foundations with drilling are used, the level of seabed preparation described above for gravity anchor foundations would not be required).

Impact	Parameter	Worst Case	Rationale
		• Offshore electrical platform - 2 x six-legged with 18 pin-pile = 14,137m^3 • Lidar - 2 x monopiles = 189m^3 Total drill arisings volume for foundations in the Norfolk Boreas site is **413,913m^3.**	
Impact 2: Deterioration in water quality due to increased suspended sediment concentrations during installation of cables within the offshore cable corridor	Suspended sediment	Pre-sweeping (dredging) for the offshore export cable may require up to 600,000m^3 within the offshore cable corridor based on calculations by CWind (Appendix 5.2). Following pre-sweeping, trenching (e.g. by jetting or ploughing) would be required to bury the cables. Trenches would have a 'V'-shaped profile with a top width of 10m. The worst case average burial depth for the offshore export cables would be 3m and therefore 3,000,000m^3 of sediment would be disturbed. The offshore export cables would make landfall at Happisburgh South. Cable ducts would be installed at the landfall so that the ends of the export cables can be pulled through from the landward side. The HDD would exit an offshore location, away from the beach (up to 1000m in drill length from the onshore HDD location). Cable burial would be undertaken from the HDD exit point.	Maximum offshore export cable trench length within the offshore cable corridor is 200km based on four HVDC cables in 2 trenches and 100% burial.
Impact 3: Deterioration in water due to increased suspended sediment concentrations during cable installation within the Norfolk Boreas site and project interconnector search area.	Suspended sediment	Worst-case scenario is 600km of array cables, 60km of interconnector and 50km of export cable with 100% burial. Potential for pre-sweeping a 20m wide corridor to clear debris or level sand waves prior to excavation of trenches. Therefore, the volumes would be as follows: • Up to 36,000,000m^3 based on 600km of array cable length in the Norfolk Boreas site that may require pre-sweeping (assuming a width of 30m and average depth of 3m). • Up to 3,000,000m^3 based on 50km export cable length in the Norfolk Boreas site that may require pre-sweeping (assuming an average width of 20m and average depth of 3m). • Up to 3,600,000m^3 based on 60km interconnector cable length in the Norfolk Boreas site that may require pre-sweeping (assuming an average width of 20m and average depth of 3m).	

Impact	Parameter	Worst Case	Rationale
		Total volume **42,600,000m³.**	
		Maximum parameters for project interconnector cables: • 92km trench length based on up to 10 trenches with 100% burial. • Average burial depth of 3m. • Potential for pre-sweeping a 30m wide corridor to clear debris or level sand waves prior to excavation of trenches. Total volume = **5,520,000m³**	Assessment of impacts from any parts of project interconnector cables located within the Norfolk Boreas site would be included within impacts the array and interconnector assessments.
Impact 4: Deterioration in water and bathing water quality due to works at the offshore export cable landfall.	Suspended sediment	The offshore export cables would make landfall at Happisburgh South. Cable ducts would be installed at the landfall so that the ends of the export cables can be pulled through from the landward side. The HDD would exit an offshore location, away from the beach (up to 1000m in drill length from the onshore HDD location). Cable burial would be undertaken from the HDD exit point.	Commitment to this installation method
Impact 5: Deterioration in water quality due to re-suspension of sediment bound contaminants	As per impact 1, 2 and 3	As per impact 1, 2 and 3	The worst case scenario relates to activities that involve the most re-suspension of sediment.
Operation and Maintenance			
Impact 1: Deterioration in water quality due to increased suspended sediment concentrations due to cable repairs/reburial	Suspended sediment	Unplanned repairs and reburial of cables may be required during operations and maintenance: • Reburial of all sections of array cable is estimated once every 5 years – 3m disturbance width x 600km = 1,800,000m². • Two array cable repairs per year are estimated. An array cable may be up to 6km (based on turbine spacing) – 3m disturbance width x 6,000m x 2 = 36,360m². • One interconnector repair per year is estimated – 10m disturbance width x 300m repair length = 3,000m²; or	The worst case scenario relates to activities that involve the most re-suspension of sediment. Either an interconnector cable repair or a project interconnector cable repair are anticipated each year but

Impact	Parameter	Worst Case	Rationale
		• One project interconnector cable repair per year is estimated – 10m disturbance width x 300m repair length = 3,000m^2. • 1 x offshore export cable repair per year with 300m sections removed and replaced. Disturbance width of 3m = 900m^2 per year. • Reburial of up to 20km length per offshore export cable (10km in the Haisborough, Hammond and Winterton SAC and 10km outside the SAC) = 120,000m^2 based on two cables and a disturbance width of 3m = 1,200,000m^2 (1.2km^2) It is estimated that 300m sections would be removed and replaced per repair. If reburial is required, it is likely that this would be in relatively short sections (e.g. 1km) at any one time.	never both as only one of these options would have been installed
Impact 2 Deterioration in water quality due to operations and maintenance Visits	Water quality	Cleaning of foundations would occur during some maintenance visits. Cleaning would involve Jet washing marine growth and guano from the foundations and transition pieces. This activity is likely to occur no more regularly than once a year.	
Decommissioning			
Impact 1: Deterioration in water quality due to increased suspended sediment concentrations during removal of accessible installed components	Suspended sediment concentrations	The worst case scenario would include removal of all of the wind turbine components, part of the foundations (those above seabed level), removal of some or all of the array cables, interconnector cables, project interconnector cables and offshore export cables. Scour and cable protection would likely be left in-situ.	

9.7.3 Potential Impacts during Construction

9.7.3.1 Impact 1A: Deterioration in offshore water quality due to increased suspended sediment concentrations created by seabed preparation during foundation installation

98. The installation of foundations (for wind turbines, service and electrical platforms and meteorological masts) has the potential to disturb seabed sediments from (i) the seabed (surface or shallow near-surface sediments); and (ii) from several tens of metres below the seabed (sub-surface sediments), depending on the foundation type and installation method. The level of disturbance to seabed sediments would be a function of seabed type, the type of foundations and installation method, as well as hydrodynamic conditions.

99. 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 (see Chapter 10 Benthic and Intertidal Ecology). Additionally, sediment plumes can create barriers to movement of marine ecological receptors such as fish and marine mammals (see Chapter 11 Fish and Shellfish Ecology and Chapter 12 Marine Mammals). The potential increases in sediment concentrations are described in Chapter 8 Marine Geology, Oceanography and Physical Processes Impact 1A and are summarised below.

100. The worst-case scenario assumes that sediment would be dredged and returned to the water column at the sea surface as overflow from a dredger vessel. This process would cause localised and short-term increases in suspended sediment concentrations both at the point of dredging at the seabed and, more importantly, at the point of its discharge back into the water column. The disposal of any sediment that would be disturbed or removed during foundation installation would occur within the Norfolk Boreas site. Mobilised sediment from these activities may be transported by wave and tidal action in suspension in the water column.

101. Expert-based assessment in Chapter 8 Marine Geology, Oceanography and Physical Processes suggests however, that, due to the predominance of medium-grained sand across the Norfolk Boreas site, the sediment disturbed by the drag head of the dredger at the seabed would remain close to the bed and settle rapidly. Most of the sediment released at the water surface from the dredger vessel would fall rapidly (minutes or tens of minutes) to the seabed as a highly turbid dynamic plume immediately upon its discharge (within a few tens of metres along the axis of tidal flow).

102. Some of the finer sand fraction from this release and the very small proportion of mud that is present are likely to stay in suspension for longer and form a passive plume which would be advected by tidal currents. Due to the sediment sizes

present, this is likely to exist as a measurable but modest concentration plume (tens of mg/l) for around half a tidal cycle (up to six hours). Sediment would eventually settle to the seabed in proximity to its release (within a few hundred metres up to around a kilometre along the axis of tidal flow) within a short period of time (hours). Whilst lower suspended sediment concentrations would extend further from the dredged area, along the axis of predominant tidal flows, the magnitudes would be indistinguishable from background levels. This judgement is supported by the findings from the modelling simulations undertaken for the East Anglia ONE site using the Delft3D plume model (ABPmer, 2012b) which also used similar grain sizes under similar tidal conditions.

103. The ABPmer (2012b) model predicts that close to the release locations, suspended sediment concentrations would be very high (orders of magnitude greater than natural background levels), but of very short duration (seconds to minutes) as the dynamic plume falls to the seabed. Within the passive plume, suspended sediment concentrations above background levels were low (less than 10mg/l) and therefore within the range of natural variability. Net movement of fine-grained sediment retained within the passive plume was to the north, in accordance with the direction of residual tidal flow. Suspended sediment concentrations rapidly returned to background levels after cessation of the release into the water column.

104. It should be noted that this model was based on the installation of 15 foundations releasing almost double the amount of sediment per turbine and therefore it is expected that effects from installation of a foundation in Norfolk Boreas would be less. Additionally, the modelled results show that after the installation of a foundation, the suspended sediment concentrations do not persist, but rapidly return to background levels and therefore the release of sediment from one foundation installation would not last long enough to interact with the next installation. This reflects the sandy nature of the predominant sediments across the project.

105. Based on the above, during a single phase installation, the worst case scenario changes in suspended sediment concentrations due to seabed preparation are predicted to be low in magnitude due to the localised and short term nature of the predicted sediment plumes. Baseline conditions of suspended sediment concentrations are expected to return to normal rapidly following cessation of activity, therefore any impact would only be present during the installation process.

106. The sensitivity of the water in the offshore project area is considered to be low (based on the definitions provided in Table 9.3) and therefore, a **minor adverse** impact significance is predicted. Also, it should be noted that regional sediment transport directions are directed along a north-south axis with no east to west component, and so there is no pathway for suspended sediment to reach the East

Anglian coast. As a result, no impacts on nearshore water quality (including bathing waters and WFD water bodies) are predicted.

107. The installation of the foundations in two phases would mean the impact occurs in two separate periods, with a longer additive duration of disturbance. However due to the fact that the majority of sediment would rapidly fall out of suspension (section 8.7.6.1 of Chapter 8 Marine geology, oceanography and Physical Processes) and that impacts during the second phase would be located in a different area from the first, this would not materially change the assessment compared with a single-phased approach. Therefore, the minor adverse significance rating is applicable to both construction phase options.

9.7.3.2 Impact1B: Deterioration in offshore water quality due to increased suspended sediment concentrations due to drill arisings for installation of piled foundations.

108. Sub-seabed sediments within the Norfolk Boreas site would become disturbed during any drilling activities that may be needed at the location of piled foundations. The disposal of any sediment that would be disturbed or removed during foundation installation would occur within the Norfolk Boreas site. The worst-case scenario for a release from an individual wind turbine assumes a monopile foundation for the largest 20MW wind turbine.

109. Norfolk Boreas Limited estimates that the maximum number of foundations that could require drilling would be 50%. Hence, for the total volume released during the construction phase, the worst-case scenario for drilling is associated with the maximum number of 20MW monopiles. This is considered a very conservative assumption as initial analysis of the geophysical data indicates that piling would be possible at the majority (if not all) possible turbine locations. Most of the drill sediment would be sand or aggregated clasts which are deposited close to the drill location (see Chapter 8 Marine Geology, Oceanography and Physical Processes).

110. Small quantities of fine-sediment may also be released which would disperse widely. This would however, result in only low suspended sediment concentrations within the water column and would only last for a few days of construction activity associated with each turbine.

111. This is supported by the East Anglia ONE modelling studies (EAOW, 2012b) which simulated the release of 982m^3 of variably graded fine sediment (sand, clay and silt) into the water column once every two days to model the construction of eight consecutively drilled foundations over a 15-day simulation period. The release volume is approximately nine times less than that of the individual worst case scenario for the largest monopile foundations being considered for Norfolk Boreas (8,836m^3).

112. As described in Chapter 8 Marine Geology, Oceanography and Physical Processes the larger release volumes associated with the worst-case scenario for Norfolk Boreas and similar tidal currents compared to East Anglia ONE may combine to result in larger concentrations above background levels than previously modelled. However, these are likely to still be modest (tens of mg/l) due to the low volumes of disaggregated fine-grained sediment in the drill arisings. Hence, the principle of wide dispersion in relatively low concentrations remains valid. Also, a conservative assumption was made in the modelling that all drilled sediment would disperse. However, in reality, some of the drill arisings would arrive at the sea surface as larger aggregated clasts which would settle rapidly.

113. Overall therefore, elevations in suspended sediment concentrations above background levels are likely to be low (less than 10mg/l) and within the range of natural variability (see section 9.6.1.4). Sediment concentrations arising from one foundation installation are also considered unlikely to persist sufficiently long enough for them to interact with subsequent installations. Additionally, the changes in suspended sediment concentrations (magnitudes, geographical extents and durations of effect) would move across the site with progression of the construction sequence and hence geographic location of the zone of effect would change as installation progresses.

114. Based on the above, during a single phase installation, the worst case scenario changes in suspended sediment concentrations due to drilling activities are predicted to be low in magnitude and the sensitivity of the water quality in the offshore project area is considered to be low (based on the definitions provided in Table 9.3). Baseline conditions of suspended sediment concentrations are expected to return to normal rapidly following cessation of activity and therefore any impact would only be present during the installation process. Overall therefore a **minor adverse** impact is predicted. Again because of the regional sediment transport processes (see 9.7.3.1) no impact on nearshore water quality (including bathing waters or WFD water bodies) is predicted as a result of this activity.

115. As for impact 1A, although the installation of the foundations in two phases would mean the impact occurs in two separate periods, with a longer additive duration of disturbance, this would not materially change the assessment. This assessment is therefore applicable to both construction phases under consideration.

9.7.3.3 Impact 2: Deterioration in water quality due to increased suspended sediment concentrations during installation of cables within the offshore cable corridor

116. Details of how the offshore cable would be installed are discussed in Chapter 5 Project Description and would be confirmed in the final project design post consent.

117. The installation of the offshore cables has the potential to disturb the seabed sediment to an average depth of 3m, either directly though the installation method chosen, or through seabed levelling of sand waves. During excavation (by whichever method), sediment plumes could be formed by the release of sediment into the water column. The released sediment would then disperse both vertically and laterally, resulting in increased suspended sediment concentrations and sediment deposition surrounding the cable corridor and, depending on the extent of sediment transport, further afield. Cabling is a relatively short term activity (days as opposed to months) and therefore the effect is generally relatively short-lived.

118. As detailed in Chapter 8 Marine Geology, Oceanography and Physical Processes, there are similarities in water depth, sediment types and metocean conditions between the offshore cable corridor for East Anglia ONE and the Norfolk Boreas offshore cable corridor. As a result the assessment provided in Chapter 8 Marine Geology, Oceanography and Physical Processes uses this information to inform the potential for effects on suspended sediment concentrations.

119. To summarise, in water depths greater than 20m LAT, peak suspended solid concentrations are predicted to be less than 100mg/l outside of the immediate vicinity of the release location. In shallower waters (less then 5m LAT) the potential for dispersion is more limited and therefore peak concentrations of suspended sediment would approach 400mg/l. These plumes would be localised to within 1km of the release location and would persist for no longer than a few hours. Following cessation of activities, the plume is predicted to rapidly disperse.

120. During the single phase construction period, disturbance to seabed sediments and potential generation of plumes would be limited in temporal and spatial extent due to the temporary nature of the activity and the dominance of sand sized material along the offshore cable corridor and therefore the magnitude of the impact is anticipated to be low. Furthermore, the designated Bathing Waters are not located within the 1km area identified as being the most at risk of experiencing elevated levels. As stated above the sensitivity of the water quality in the offshore project area is considered to be low (based on the definitions provided in Table 9.3) and therefore an overall impact of **minor adverse** significance is anticipated.

121. Under the two-phase approach the principal difference compared to the single phase assessment is associated with the installation programme. There is no difference in the worst case length of cable to be installed. Due to the low magnitude of the impact for the single phase, this assessment is considered applicable to the two construction phases being considered.

9.7.3.4 Impact 3: Deterioration in offshore water quality due to increased suspended sediment concentrations during cable installation within the Norfolk Boreas site and Project Interconnector Search Area.

122. As for the installation of the offshore export cables, the array, interconnector and project interconnector cable installation has the potential to disturb the seabed sediment in two ways: through seabed levelling which may be required prior to cable installation to ensure that the cable does not become exposed post installation and through the cable installation process itself[1].

123. The level of disturbance to seabed sediments would be a function of seabed type, the installation method as well as hydrodynamic conditions and as detailed in Chapter 8 Marine Geology, Oceanography and Physical Processes, the expert-based assessment indicates that the changes suspended sediment concentration would be minimal. This is because the predominant grain size is sand and the quantity of sediment released into the water column would be very small.

124. Mud-sized material (which would represent only a very small proportion of the disturbed sediment) would persist longer in the water column forming a passive plume which would be advected by tidal currents further. Due to the sediment sizes present, this is likely to exist as a measurable but modest concentration plume (tens of mg/l) for around half a tidal cycle. Sediment would eventually settle to the seabed in proximity to its release (within a few hundred metres up to around a kilometre along the axis of tidal flow) within a short period of time (hours). Whilst lower suspended sediment concentrations would extend further from the cable, along the axis of predominant tidal flows, the magnitudes would be indistinguishable from background levels.

125. The magnitude of the impact is therefore anticipated to be low and, combined with low sensitivity of the receptor (as outlined in section 9.7.3.1), the overall significance is predicted to be **minor adverse** for the single phase approach. Again because of the regional sediment transport processes (see 9.7.3.1) no impact on nearshore water quality including bathing waters or WFD water bodies is predicted as a result of this activity.

126. Under the two phased approach the principal difference compared to the single phase assessment is associated with the installation programme. Although the installation of the foundations in two phases would mean the impact occurs in two separate periods with a longer additive duration of disturbance, this would not materially change the assessment since the impacts are short-lived and of low

[1] It should be noted that there would only be a requirement for either the interconnector cables or the project interconnector cables but never both.

magnitude. This assessment is therefore applicable to both construction phases being considered.

9.7.3.5 Impact 4: Deterioration in water quality due to works at the offshore export cable landfall

127. At the Happisburgh South landfall, cables would be installed via long HDD. The HDD exit point would be in the subtidal zone, seaward of the low water mark and at least in at least 5.5m LAT of water. The exit point would require excavation of a trench to bury the nearshore portions of the export cables on the seaward side of the landfall HDD. This excavation has the potential to increase suspended sediment concentrations close to shore).

128. During the landfall excavation process the suspended sediment concentrations would be elevated above prevailing conditions, but are likely to remain within the range of background nearshore levels (which would be higher close to the coast because of increased wave activity) and lower than those concentrations that would develop during storm conditions. Additionally, as previously discussed, any suspended sediment plumes arising would be localised to within approximately 1km of the release location.

129. The two nearest designated bathing waters are located at least 3km from the proposed landfall location and the cable corridor is located approximately 1.5km from the bathing water at Sea Palling at the closest point. The route does run through the WFD coastal water body Norfolk East (Figure 9.1). Whilst compliance with the bathing waters directive and WFD is not dependent on meeting requirements in relation to suspended sediment concentrations, the impact on bathing waters has been assessed to provide a conservative assessment. The detailed assessment in relation to the WFD water body is provided in Appendix 9.1 as impacts in relation to WFD compliance parameters are assessed in a different way.

130. Overall therefore, given the level of disturbance to seabed sediments and that potential generation of plumes would be limited in temporal and spatial extent due to the temporary nature of the activity (i.e. within 1km of cabling) and the dominance of sand sized material in the landfall area and the distance to the designated bathing waters (over 3km) the magnitude of the impact is anticipated to be low. Combined with the low sensitivity of the receptor (as explained in section 9.7.3.1), the overall impact significance is considered to be **minor adverse**.

131. For the two phased approach, the only difference would be that the landfall operations would be undertaken as two discrete events rather than a single event. Whilst this would increase the occurrence of disturbance events, there would be less volume disturbed during each event compared to the single-phase approach.

9.7.3.6 Impact 5: Deterioration in water quality (offshore and nearshore) due to re-suspension of sediment bound contaminants

132. The sediment data presented in section 9.6.2 above indicates that there is very little sediment contamination within the Norfolk Boreas offshore area. As a result the magnitude of effect is considered to be negligible. Given that the receptor is considered to be of low sensitivity the re-suspension of contamination from construction activities is anticipated be of **negligible** significance.

133. This assessment applies to both a single and two phased approach to construction.

9.7.4 Potential Impacts during Operation

134. Norfolk Boreas Limited is committed to using scour protection where significant scour could occur, therefore removing the potential for impacts from the release of suspended sediments during operation. Pre-construction surveys would inform the final locations and design of the turbines/foundations and would inform the need for scour protection.

9.7.4.1 Impact 1: Deterioration in water quality due to increased suspended sediment concentrations due to cable repairs/reburial

135. Cable repairs and reburial could be needed, as outlined in 9.7.2.5 and in Table 9.13. Turbine repairs may also need to be carried out as required. The disturbance areas for reburial and repairs of cables are, however, extremely small in comparison to construction areas.

136. Due to the short duration and small scale of any maintenance works (if required) there would be an impact of negligible magnitude. Combined with the low sensitivity of the water, the overall impact is considered to be of **negligible adverse** significance.

9.7.4.2 Impact 2: Deterioration in water quality due to maintenance

137. Cleaning of offshore infrastructure would involve jet washing with seawater and therefore only natural materials, marine growth, bird guano and sea water would enter the marine environment.

138. Whilst it is not possible to quantify the exact volume of the materials to be deposited, they would be very small scale. The indicative number of operational visits are included as part of the operation and maintenance activities described in Chapter 5 Project Description, section 5.4.18. It is likely that only a small proportion of these visits would result in any cleaning activity. Therefore, the magnitude of the impact would be negligible combined with the low sensitivity of the water, the overall impact is considered to be of **negligible adverse** significance.

9.7.5 Potential Impacts during Decommissioning

9.7.5.1 Impact 1: Deterioration in water quality due to increased suspended sediment concentrations during removal of accessible installed components

139. The scope of the decommissioning works would most likely involve removal of the accessible installed components. This is outlined in Chapter 5 Project Description and the detail would be agreed with the relevant authorities at the time of decommissioning. Offshore, this is likely to include removal of all of the wind turbine components, part of the foundations (those above seabed level), removal of some or all of the array cables, interconnector or project interconnector cables and offshore export cables. Scour and cable protection would likely be left in-situ.

140. The magnitude of effects would be comparable to, or more likely less than those identified for the construction phase, due to the fact that dredging or seabed preparation would not be required to remove the foundations. There may however, be a requirement to use jetting to remove the cables where needed.

141. Given that only negligible or minor impacts were identified for all construction impacts, it is anticipated that impacts for the decommissioning phase would be similar magnitude or less (i.e. of minor or negligible significance).

9.8 Cumulative Impacts

142. A number of activities have been identified as having the potential to give rise to cumulative effects on water quality due to their proximity to the Norfolk Boreas offshore project area:

- Installation of foundation structures for Norfolk Boreas with East Anglia THREE and Norfolk Vanguard[2] projects;
- Installation or decommissioning of the offshore export cable (including works at the landfall) for Norfolk Boreas with Norfolk Vanguard; and
- Installation or decommissioning of the offshore export cable (including works at the landfall) for Norfolk Boreas and marine aggregate dredging activities in adjacent areas of the seabed.

143. The offshore export cables for Norfolk Boreas would pass north of a series of marine aggregate extraction areas offshore from Great Yarmouth. The southern edge of the offshore cable corridor is within 10km of the most northern extraction areas and there is the potential for some interaction between their dredging plumes and plumes from offshore export cable installation. This is because they are within one spring tidal excursion distance from each other.

[2] Cumulative impacts with Norfolk Vanguard would only occur under Scenario 1 where Norfolk Vanguard is built (see Chapter 5 Project Description section 5.1 for further detail).

144. These potential interactions are included in the Cumulative Impact Assessment (CIA) table below (Table 9.14) and are in accordance with those assessed in Chapter 8 Marine Geology, Oceanography and Physical Processes. The projects identified for potential cumulative impacts with Norfolk Boreas have been consulted on as part of the EPP with stakeholders.

145. Interaction with the proposed East Anglia ONE project is excluded from the CIA. This is because the EIA for East Anglia THREE (EATL, 2015) provided evidence for no operational interaction between East Anglia ONE and East Anglia THREE. Given that Norfolk Boreas is considerably further away from East Anglia ONE than East Anglia THREE, then there would also be no interactions from this or any other offshore wind farms of comparable or greater distance to Norfolk Boreas.

146. In addition, the distance between the two offshore cable corridors of East Anglia THREE and Norfolk Boreas is sufficient for there to be no sediment interactions during the construction phases of the two projects (see Chapter 8 Marine Geology, Oceanography and Physical Processes).

147. The Norfolk Boreas Landfall is located to the south of the proposed Bacton to Walcott Coastal Management Scheme which will deposit sand in front of Bacton Gas Terminal. The effect of this beach nourishment is likely to be evident at the landfall location at Happisburgh South (i.e. some of the nourished sand will migrate from the main sand engine driven by longshore sediment transport). However, as the sand is due to be deposited between April and November 2019 and the Norfolk Boreas HDD work would occur at the earliest in 2022, the impacts from the two projects would not overlap. Therefore, there will be no cumulative impacts between Norfolk Boreas and Bacton to Walcott Coastal Management Scheme.

Table 9.14 Potential cumulative impacts

Impact		Potential for cumulative impact	Rationale
Construction			
1	Deterioration in offshore water quality due to increased suspended sediment concentrations due to sediment plume created by seabed preparation during installation of foundations and drill arisings during installation of piled foundations	Yes	Where construction windows could overlap for projects adjacent to Norfolk Boreas i.e. Norfolk Vanguard and East Anglia THREE there is potential for cumulative impact
2	Deterioration in water quality due to increased suspended sediment concentrations during installation of the offshore export cable	Yes	Norfolk Boreas and Norfolk Vanguard share an offshore cable corridor and therefore there is potential for cumulative impacts. Consideration is also given to Marine Aggregate Dredging

Impact		Potential for cumulative impact	Rationale
3	Deterioration in offshore water quality due to increased suspended sediment concentrations during cable installation within the Norfolk Boreas site and project interconnector search area	Yes	Where construction windows could overlap for projects adjacent to Norfolk Boreas i.e. Norfolk Vanguard and East Anglia THREE there is potential for cumulative impact
4	Deterioration in water quality due to works at the offshore export cable landfall	Yes	Where construction windows could overlap for projects adjacent to Norfolk Boreas i.e. Norfolk Vanguard and East Anglia THREE there is potential for cumulative impact
5	Deterioration in water quality (offshore and nearshore) due to re-suspension of sediment bound contaminants	No	The risk of contamination across the site was assessed as low
Operation			
1	Deterioration in water quality due to increased suspended sediment concentrations due to cable repairs/reburial	No	Impacts would be highly localised around the foundations and cables and therefore there would be no cumulative impact.
Decommissioning			
The detail and scope of the decommissioning works would be determined by the relevant legislation and guidance at the time of decommissioning and agreed with the regulator. A decommissioning plan would be provided. As such, cumulative impacts during the decommissioning stage are assumed to be the same as those identified during the construction stage.			

Table 9.15 Summary of Projects considered for the CIA

Project	Status	Indicative offshore development period	Distance from Norfolk Boreas site (km)	Project definition	Project data status	Included in CIA	Rationale
East Anglia THREE Offshore Wind farm	Consented	2022-2026	Nearest 13km	Project description available	Complete/high	Yes	This project would be 13 to the south of Norfolk Boreas. It has potential for interaction during the construction of foundations
Norfolk Vanguard Offshore Wind farm	Pre-Application	2024-2028	1km	Project description available	Incomplete/low	Yes	This project would be adjacent to Norfolk Boreas and would share the offshore cable corridor. It has potential for interaction during the construction and operation and maintenance phases
Marine aggregate dredging	Licenced	In operation	Nearest 27km	Outline only	Complete/high	Yes	The offshore cable for Norfolk Boreas passes north of marine aggregate extraction areas offshore from Great Yarmouth. There is potential for some interaction between their dredging plumes and plumes from cable installation.

Project	Status	Indicative offshore development period	Distance from Norfolk Boreas site (km)	Project definition	Project data status	Included in CIA	Rationale
Bacton and Walcott Coastal Management Scheme	Licenced	Expected construction date 2019	Nearest approximately 60km	Project description available	Complete/high	No	It is anticipated that the works will be undertaken in the period between April and November 2019 and as construction for Norfolk Boreas land fall would start in 2022 at the earliest no overlap in construction periods is anticipated. Modelling for the project indicates that once the sediment has been deposited it would not be particularly mobile and therefore would not act cumulatively with Norfolk Boreas construction to impact on water quality.

9.8.1 Cumulative Construction and Decommissioning Impacts with Adjacent Wind Farms

148. The impacts of the foundation and offshore export cable installation (including works at the landfall) on water quality were identified to be of **minor adverse** impact for Norfolk Boreas alone.

149. The construction programmes of Norfolk Boreas, Norfolk Vanguard and/or East Anglia THREE may overlap depending on the final construction programmes. The Norfolk Boreas cable corridor and its landfall would be common to Norfolk Vanguard and so there is potential for cumulative impacts to arise during the construction stages.

150. The worst case scenario in relation to water quality effects would be for all projects identified above to be constructed at the same time since this would provide the greatest opportunity for interaction of any sediment plumes during construction. As for Norfolk Boreas alone, the vast majority of the suspended sediment arising from each project would fall rapidly to the seabed after the start of construction and therefore the potential cumulative impact would be of low magnitude. Since the receptor sensitivity would also be low it is considered that the cumulative impact of two or three projects constructing in this area at the same time would be **minor adverse**.

151. As a result, it is considered that the cumulative impact for two or three projects would not increase the impact significance predicted as a result of construction of Norfolk Boreas alone.

9.8.2 Cumulative Construction and Decommissioning Impacts with Marine Aggregate Dredging

152. Chapter 8 Marine Geology, Oceanography and Physical Processes provides an assessment of the potential for cumulative effects between the installation of the offshore cable for Norfolk Boreas and marine aggregate dredging activities in adjacent areas of the seabed.

153. To summarise, the worst case scenario is that some interaction could potentially occur between dredging plumes and plumes from Norfolk Boreas cable installation, making the spatial extent of the combined plume slightly greater than for the plumes originating from the offshore cable installation only, however the maximum plume concentrations would be no greater overall (as shown by modelling for the East Anglia ONE EIA, see Chapter 8 Marine Geology, Oceanography and Physical Processes) and therefore the cumulative impact magnitude would be low. It should be noted that Norfolk Boreas is located over 5km from the nearest aggregate

extraction site (North Cross Sands) and therefore the potential the risk of plumes overlapping may be less than assessed for East Anglia ONE.

154. As a result, it is considered that the potential cumulative impacts would also be of low magnitude. With the sensitivity of the water being low, an overall impact significance of **minor adverse** is predicted.

9.9 Transboundary Impacts

155. As discussed in section 9.4.3, transboundary impacts were scoped out during the scoping process.

9.10 Inter-relationships

156. The range of effects on marine sediment and water quality of the project not only have the potential to directly affect water quality but may also manifest as impacts upon receptors other than those considered within this chapter. The assessment of significance of these impacts on other receptors is provided in the chapters listed in Table 9.16.

Table 9.16 Chapter topic inter-relationships

Topic and description	Related Chapter	Where addressed in this Chapter	Rationale
Effects on water column (suspended sediment concentrations)	Chapter 8 Marine Geology, Oceanography and Physical Processes Chapter 10 Benthic and Intertidal Ecology Chapter 11 Fish and Shellfish Ecology Chapter 12 Marine Mammals Chapter 14 Commercial Fisheries	9.7.3.1 (foundation installation) 9.7.3.3 and 9.7.3.4 (cable installation) 9.7.3.5 (landfall) 9.7.5 (decommissioning of all structures)	Impacts to marine water quality may have implications for ecology in the water column.
Effects on water column (contamination)	Chapter 10 Benthic and Intertidal Ecology Chapter 11 Fish and Shellfish Ecology Chapter 12 Marine Mammals Chapter 14 Commercial Fisheries	9.7.3.6 (contamination risk associated with all construction activities)	Impacts to marine water quality may have implications for ecology in the water column.

9.11 Interactions

157. The construction impacts identified and assessed in this chapter have the potential to interact with each other, which could give rise to synergistic impacts as a result of that interaction. The worst case impacts assessed within the chapter take these interactions into account and for the impact assessments are considered conservative and robust. For clarity the areas of interaction between impacts are presented in Table 9.17 along with an indication as to whether the interaction may give rise to synergistic impacts. Note that operation and decommissioning impacts are considered to be small scale and therefore synergistic effects are not anticipated.

158. None of the interactions identified below are likely to give rise to significant impacts on marine water and sediment quality. However, there is potential for these interactions to result in significant impacts for other receptors i.e. benthic ecology, fish ecology and commercial fisheries. The interactions and their potential to lead to significant impacts are therefore assessed within the relevant chapters of this ES.

Table 9.17 Interaction between impacts

Construction					
	Impact 1: Deterioration in water quality due to increased suspended sediment concentrations during installation of foundations.	Impact 2: Deterioration in water quality due to increased suspended sediment concentrations during installation of the offshore export cables.	Impact 3: Deterioration in water due to increased suspended sediment concentrations during array and interconnector cable installation	Impact 4: Deterioration in water and bathing water quality due to works at the offshore export cable landfall.	Impact 5: Change in water quality due to re-suspension of sediment bound contaminants
Impact 1: Deterioration in water quality due to increased suspended sediment concentrations during installation of foundations.	-	Yes	Yes	No	No
Impact 2: Deterioration in water quality due to increased suspended sediment concentrations during installation of the offshore export cables.	Yes	-	Yes	No	No
Impact 3: Deterioration in water due to increased suspended sediment concentrations during array and interconnector cable installation	Yes	Yes	-	No	No
Impact 4: Deterioration in water and bathing water quality due to works at the offshore export cable landfall.	No	No	No	-	No
Impact 5: Change in water quality due to re-suspension of sediment bound contaminant.	No	No	No	No	-

9.12 Summary

159. Construction, operation and decommissioning of the project could impact on sediment and water quality. The magnitude of these effects has been assessed using expert assessment, drawing from a wide science base that includes project-specific surveys and previous numerical modelling activities. Specifically, information provided in Chapter 8 Marine Geology, Oceanography and Physical Processes is integral to the determination of the assessment of effects in this chapter.

160. The effects that have been assessed are all anticipated to result in either minor or negligible adverse impacts and these are listed in Table 9.18 below.

Table 9.18 Potential Impacts identified for marine water and sediment quality

Potential Impact	Receptor	Value/ Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Construction						
Impact 1A: Deterioration in offshore water quality due to increased suspended sediment concentrations created by seabed preparation during foundation installation	Water Quality	Low	Low	Minor	None proposed	**Minor adverse**
Impact1B: Deterioration in offshore water quality due to increased suspended sediment concentrations due to drill arisings for installation of piled foundations.	Water Quality	Low	Low	Minor	None proposed	**Minor adverse**
Impact 2: Deterioration in water quality due to increased suspended sediment concentrations during installation of cables within the offshore cable corridor	Water Quality	Low	Low	Minor	None proposed	**Minor adverse**
9.7.3.4 Impact 3: Deterioration in offshore water quality due to increased suspended sediment concentrations during cable installation within the Norfolk Boreas site and Project Interconnector Search Area.	Water Quality	Low	Low	Minor	None proposed	**Minor adverse**
Impact 4: Deterioration in water and bathing water quality due to works at the offshore export cable landfall	Water Quality	Low	Low	Minor	None proposed	**Minor adverse**

Potential Impact	Receptor	Value/ Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Impact 5: Deterioration in water quality (offshore and nearshore) due to re-suspension of sediment bound contaminants	Water Quality	Low	Negligible	Negligible	None proposed	**Negligible**
Operational						
Impact 1: Deterioration in water quality due to increased suspended sediment concentrations due to cable repairs/reburial	Water Quality	Low	Negligible	Negligible	None proposed	**Negligible**
Impact 2 Deterioration in water quality due to maintenance	Water Quality	Low	Negligible	Negligible	None proposed	**Negligible**
Decommissioning						
Impact 1: Deterioration in water quality due to increased suspended sediment concentrations during foundation removal of accessible installed components	As for construction					
Cumulative						
Cumulative construction and decommissioning impacts with adjacent wind farms	The detail and scope of the decommissioning works would be determined by the relevant legislation and guidance at the time of decommissioning and agreed with the regulator. A decommissioning plan would be provided. As such, cumulative impacts during the decommissioning stage are assumed to be the same as those identified during the construction stage (Impacts 1, 2,3,4 and 5).					
Cumulative construction and decommissioning impacts with marine aggregate dredging	Water Quality	Low	Low	Minor	None proposed	**Minor adverse**

Potential Impact	Receptor	Value/ Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Transboundary						
Scoped out of assessment						

9.13 References

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