Norfolk Vanguard Offshore Wind Farm

Chapter 9

Marine Water and Sediment Quality

Environmental Statement

Volume 1

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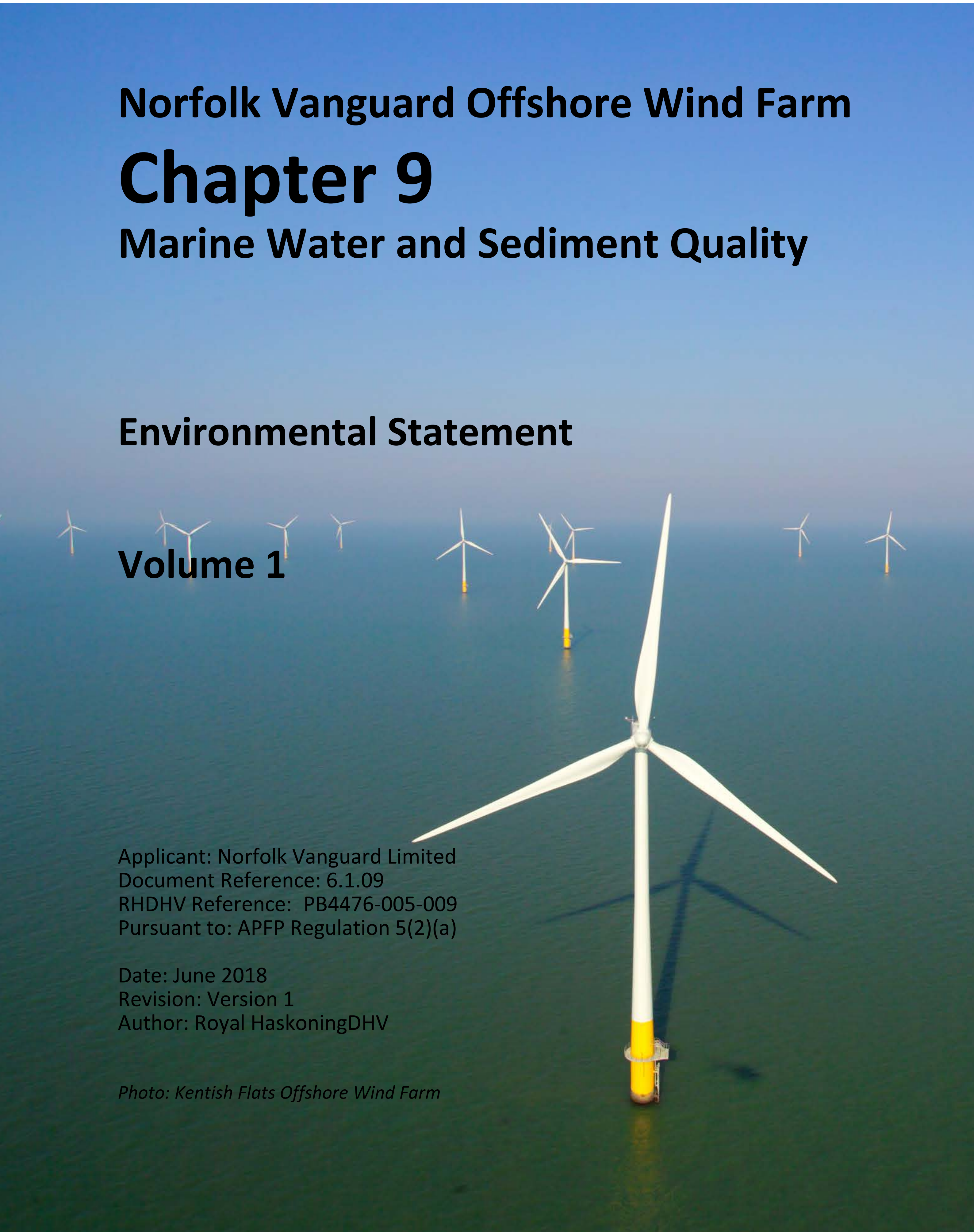

Photo: Kentish Flats Offshore Wind Farm

Environmental Impact Assessment
Environmental Statement
Document Reference: PB4476-005-009

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For and on behalf of Norfolk Vanguard Limited

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Glossary

AWAC	Acoustic Wave and Current
CME	Canadian Council of Ministers of the Environment
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CIA	Cumulative Impact Assessment
DBT	Dibutyl Tin
DCO	Development Consent Order
DECC	Department for Energy and Climate Change
DIN	Dissolved Inorganic Nitrogen
EIA	Environmental Impact Assessment
EPP	Evidence Plan Process
EQS	Environmental Quality Standards
ES	Environmental Statement
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
NLS	National Laboratory Service
nm	Nautical miles
NMMP	National Marine Monitoring Programme
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
PEL	Probable Effect Levels
PEMP	Project Environmental Management Plan
PSD	Particle Size Distribution
RBMP	River Basin Management Plan
TBT	Tributyl Tin
TEL	Threshold Effect Level
THC	Total Hydrocarbons
WFD	Water Framework Directive
ZEA	Zonal Environmental Appraisal

Terminology

Array cables	Cables which link the wind turbine generators and the offshore electrical platform.
Interconnector cables	Buried offshore cables which link the offshore electrical platforms
Landfall	Where the offshore cables come ashore at Happisburgh South
Offshore accommodation platform	A fixed structure (if required) providing accommodation for offshore personnel. An accommodation vessel may be used instead
Offshore cable corridor	The corridor of seabed from the Norfolk Vanguard OWF sites 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 turbine generators 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 overall area of Norfolk Vanguard East, Norfolk Vanguard West and the offshore cable corridor
Safety zones	A marine zone outlined for the purposes of safety around a possibly hazardous installation or works / construction area under the Energy Act 2004.
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 Vanguard Limited
The OWF sites	The two distinct offshore wind farm areas, Norfolk Vanguard East and Norfolk Vanguard West
The project	Norfolk Vanguard Offshore Wind Farm, including the onshore and offshore infrastructure

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9 MARINE WATER AND SEDIMENT QUALITY

9.1 Introduction

1. This chapter describes the existing environment with regard to marine water and sediment quality and assesses the potential impacts of the Norfolk Vanguard Offshore Wind Farm (herein 'the project' or 'Norfolk Vanguard') during the construction, operation and decommissioning phases. Where the potential for significant impacts is identified, mitigation measures are presented.

2. Certain elements of the assessment are informed by Chapter 8 Marine Geology, Oceanography and Physical Processes and in turn this assessment informs the Water Framework Directive Compliance Assessment (Appendix 20.2 from Chapter 20 Water Resources and Flood Risk), as well as Chapter 10 Benthic and Intertidal Ecology, Chapter 11 Fish and Shellfish Ecology and Chapter 12 Marine Mammals.

3. Due to the absence of existing contamination in the sediment (discussed in section 9.5.2.1) and the embedded mitigation designed to avoid any potential contamination as a result of the project (section 9.7.1), the key focus of the impact assessment in section 9.6 is on water quality rather than sediment quality.

4. The assessment of potential impacts on marine water and sediment quality has been made with specific reference to the relevant legislation and guidance (as presented in section 9.2) of which the primary source is the National Policy Statements (NPS).

9.2 Legislation, Guidance and Policy

5. The assessment of potential impacts on marine water and sediment quality has been made with specific reference to the relevant NPS. These are the principal decision making documents for Nationally Significant Infrastructure Projects (NSIPs). Those relevant to the project are:

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

6. The specific assessment requirements for marine water and sediment quality, as detailed in the relevant NPS, are noted in the following paragraphs. EN-1 Paragraph 5.15.1 states that:

- "Infrastructure development can have adverse effects on the water environment, including groundwater, inland surface waters, 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''.

7. EN-1 Paragraph 5.15.2 continues to state:

- "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 Environmental Statement or equivalent''.

8. Paragraph 2.6.189 of EN-3 notes that:

- "The construction, operation and decommissioning of offshore energy infrastructure can affect marine water quality through the disturbance of seabed sediments or the release of contaminants with subsequent indirect effects on habitats, biodiversity and fish stocks''.

9. Of further relevance to water and sediment quality are paragraphs 2.6.191 and 2.6.192 of EN-3 where it is stated that:

- "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''.
- "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''.

10. 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 Water Framework Directive (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.

11. These key European Directives are transposed into UK law through a number of regulations, set out below and discussed further in Chapter 3 Policy and Legislative Context.

9.2.1 Water Framework Directive

12. The WFD was adopted and came into force in 2000. It establishes a legislative framework for the protection of surface waters (including rivers, lakes, transitional waters and coastal waters) and groundwater throughout the EU. The WFD was transposed into law in England and Wales by the Water Environment (Water Framework Directive) (England and Wales) Regulations 2003 and most recently updated April 2017 as the Water Environment (Water Framework Directive) (England and Wales) Regulations 2017.

13. UK surface waters have been divided into a number of discrete units termed 'water bodies', with typologies that relate to both their physical and ecological characteristics. Based on ecology and water quality, these water bodies have then been classified into different status classes which have specific objectives in relation to achieving good ecological status. The Directive seeks to protect and enhance the quality of the following types of waterbodies:

- Surface freshwater (including lakes, streams and rivers);
- Groundwater;
- Groundwater dependent ecosystems;
- Estuaries; and
- Coastal waters up to one nautical mile (nm) from mean low water.

14. The WFD applies to all water bodies, including those that are man-made. The consideration of the proposed scheme under the WFD will, therefore, need to be applied to all water bodies that have the potential to be impacted by the proposed scheme.

9.2.2 Marine Strategy Framework Directive

15. The objective of the MSFD (2005/56/EC) (MSFD) is to achieve "*good environmental status*'' in Europe's seas by 2020, to enable the sustainable use of the marine environment and to safeguard its use for future generations.

16. The MSFD aims to be complementary to and provide the overarching framework for a number of other key Directives and legislation at the European and UK level, such

as the Habitats Directive, the Birds Directive, the WFD, the Common Fisheries Policy and the UK Marine and Coastal Access Act.

17. In coastal waters out to 1nm, both the WFD and the MSFD apply. However, in these areas, the MSFD only applies for aspects of good environmental status that are not already addressed by the WFD. These include issues such as the impacts of marine noise and litter, and certain aspects of biodiversity, but not water quality.

9.2.3 Bathing Waters Directive

18. The Bathing Water Regulations 2013 transpose Council Directive 2006/7/EC concerning the management of bathing water quality into UK law and reporting commenced in 2015.

19. Compliance is measured using two microbiological parameters, *Escherichia coli* (e-coli) and intestinal *Enterococci*, and bathing waters are classed as either poor, sufficient, good or excellent. The revised Bathing Water Directive requires all bathing waters to be classed as at least ‘sufficient’.

9.2.4 MARPOL Convention 73/78

20. The UK is also a signatory to the International Convention for the Prevention of Pollution from Ships (the MARPOL Convention 73/78) and all ships flagged under signatory countries are subject to its requirements, regardless of where they sail. The convention includes regulations aimed at preventing and minimising pollution from ships, both accidental and that arising from routine operations.

9.2.5 Other UK Policies and Plans

21. 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.

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

- *“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."*

23. 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:

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

9.3 Consultation

24. To inform the Environmental Impact Assessment (EIA) and this Environmental Statement (ES), Norfolk Vanguard Limited has undertaken a thorough pre-application consultation process, which has included the following stages:

- Scoping Report submitted to the Planning Inspectorate (October 2016);
- Scoping Opinion received from the Planning Inspectorate (November 2016);
- Marine Water and Sediment Quality Method Statement (February 2017) submitted to the Environment Agency, MMO, Cefas, Natural England, North Norfolk District Council and the Wildlife Trust as part of the Evidence Plan Process (EPP); and
- EPP – Expert Topic Group Meeting (16th February 2017), attended by a number of stakeholders, including the MMO, Cefas, Natural England, Environment Agency and the Wildlife Trust. During this meeting the existing baseline for marine water and sediment quality was outlined and the method for assessment discussed. The method statement and minutes of the EPP are provided in Appendices 9.2 and 9.16 of the Norfolk Vanguard Consultation Report.
- Section 42 consultation on the Preliminary Environmental Information Report (PEIR) (Norfolk Vanguard Limited, 2017). No comments relating directly to Marine Water and Sediment Quality were received during the Section 42 consultation. Comments from the Environment Agency relating to the WFD assessment are addressed in Chapter 20 Water Resource and Flood Risk of this ES (specifically, Appendix 20.2)

25. A summary of the consultations carried out at key stages throughout the development of the project, of particular relevance to marine water and sediment quality is presented in Table 9.1.

Table 9.1 Consultation responses

Consultee	Date /Document	Comment	Response / where addressed in the ES
Norfolk Vanguard			
Secretary of State	Scoping Opinion (November, 2016)	Table 2.3 of the Scoping Report (concentrations of dissolved trace metals in sub-surface seawater from offshore locations) contains data from 1991-1992. 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.	This comment is addressed in section 9.5 which includes more recent data from the Clean Seas Environmental Monitoring Programme
Secretary of State	Scoping Opinion (November, 2016)	Table 2.5 of the Scoping Report refers to Canadian Sediment Quality Levels. If the applicant intends to apply these levels within their assessment, the Secretary of State recommends their use is agreed with the relevant bodies.	The Marine Water and Sediment Quality Method Statement (Appendix 9.2 of the Consultation Report) outlined the criteria that would be used in the assessment and was agreed with stakeholders through the EPP
Secretary of State	Scoping Opinion (November, 2016)	Paragraph 335 of the Scoping Report states that “Any sediment plumes are likely to settle out within a short distance of the activity and limit the overall footprint of the affected area.” The Scoping Report does not provide any evidence to support this assertion, nor does it quantify what a ‘short distance’ would likely be. The Secretary of State also considers that the sediment plumes would be directly related to the method and intensity of construction activity, which is yet to be determined. As such, the assertion that designated bathing waters (3.1km and 3.5km 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.	Chapter 8 Marine Geology, Oceanography and Physical Processes provides evidence of the likely sediment plume associated with Norfolk Vanguard. The results of Chapter 8 inform the assessment of water and sediment quality. The bathing waters are assessed in sections 9.7.4.3 and 9.7.4.5.
Secretary of State	Scoping Opinion (November, 2016)	Paragraph 340 of the Scoping Report proposes to scope out accidental release of contaminants during construction, operation and decommissioning on the basis that good practise techniques and procedures would be employed and that all	The embedded mitigation in relation to the prevention of pollution is provided in section 9.7.1. An Outline Project Environmental

Consultee	Date /Document	Comment	Response / where addressed in the ES
		vessels would comply with the International Convention for the Prevention of Pollution from Ships (MARPOL) 73/78. The Secretary of State 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 Secretary of State seeks assurances that such measures would be employed and therefore considers the matter should still be covered within the ES, along with details of the measures to be employed and how they are secured by the DCO (through the marine license or otherwise). The Secretary of State would expect a draft version of any plans containing such measures to be provided with the DCO application.	Management Plan (PEMP), (document reference 8.14) is submitted as part of the Development Consent Order (DCO) application. This document outlines commitments to managing pollution prevention.
Secretary of State	Scoping Opinion (November, 2016)	The Scoping Report explains that a proportion of the benthic survey sub-samples will be analysed for contaminants and compared to Environmental Quality Standards. It further proposes that, given the likely level of impact as informed by evidence from the East Anglia ONE and East Anglia THREE ES', the assessment of potential impacts on marine water and sediment quality for the proposed development should take the form of a desk-based review. The Secretary of State considers this to be acceptable, however advises that sufficient information is provided within the ES and that conclusions drawn are clearly justified.	A site specific survey was undertaken to inform the EIA and the results are outlined in section 9.6.4.3. Further details are available in Appendix 10.1 (of Chapter 10 Benthic and Intertidal Ecology).
Secretary of State	Scoping Opinion (November, 2016)	The Scoping Report proposes to scope out operational impacts on marine water and sediment quality (with the exception of cumulative impacts) on the basis that any scour effect at each turbine would be highly localised and not expected to result in significant change to water quality; as any re-suspension of contaminated sediments by scouring effects would be localised and as no significantly contaminated sediments are expected in the area that could be released. The Secretary of State considers that insufficient evidence has been provided to justify scoping out these topics at this stage; for example there is no	The 2016 site survey data (analysed after the Scoping Report) confirmed that there are no contaminated sediments in the area surveyed (see section 9.5.2.1). In addition, further to the project information provided in the Scoping Report, Norfolk Vanguard Limited is committed to embedded

Consultee	Date /Document	Comment	Response / where addressed in the ES
		definition of 'highly localised', nor what would constitute a 'significant change to water quality'. In addition, it has not yet been confirmed that there are no contaminated sediments within the offshore area; therefore the results of the survey work will need to be analysed to determine the significance of any proposed risk of the release of contaminated sediments.	mitigation of using scour protection where significant scour could occur (see section 9.7.1), therefore removing the potential for impacts from the release of suspended sediments during operation. The potential for secondary scour around scour protection was also discussed during the EPP and it was agreed at an export topic group meeting on 5th July 2017 (Appendix 9.16 of the Consultation Report) that this is not a potential issue and therefore the impacts of scour during operation are not assessed further.
Secretary of State	Scoping Opinion (November, 2016)	The Secretary of State welcomes the proposed tourism and recreation assessment and notes the North Norfolk WFD bathing waters and blue flag beaches in the vicinity of the proposed development. Potential impacts on water quality at these locations and the resultant impacts on tourism and recreation should be considered. Appropriate cross reference should be made to the Marine Water and Sediment Quality chapter.	Designated bathing waters are assessed in relation to water quality effects in section 9.7.4
Natural England	Scoping Opinion (November, 2016)	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. We advise that more information to support the conclusion that the Norfolk Vanguard sites would not release contaminants or have associated impacts on water quality during operation activities should be presented.	The most recent data (2016) including sediment quality data collected as part of site investigations for Norfolk Vanguard (Fugro, 2017) has now been included to inform the baseline – see section 9.6.
Cefas	Evidence Plan Process meeting (16th February 2017)	There is a need for agreement on whether any more contaminant samples need to be analysed.	A survey of the Norfolk Vanguard offshore project area was undertaken in 2016 (see section 9.6 and Appendix

Consultee	Date /Document	Comment	Response / where addressed in the ES
			10.1 of Chapter 10). The results of the initial contaminants analysis were provided to Cefas and it was agreed (by email: 03/04/17) that no further sampling was required

9.4 Assessment Methodology

9.4.1 Impact Assessment Methodology

26. The assessment of impacts within this chapter follows the general methodology set out in Chapter 6 EIA Methodology.

27. The assessment of water quality impacts is based on the environmental quality standards (EQS) outlined in the WFD or through the comparison of survey data to the baseline environment where possible (for example in the relation to suspended solid concentrations). Assessment of sediment quality and the potential risk to water quality is based on the use of recognised sediment quality guidelines and action levels providing indications as to the level of likely concern.

28. In the first instance, Cefas Action Levels are commonly used to provide an indication of contaminant levels within sediments. Whilst these levels were specifically developed to assess dredged material, they are an accepted way of assessing the risks to the environment from other marine activities as part of the EIA process. The Cefas Action Levels are set out in Table 9.2.

Table 9.2 Cefas Action Levels (taken from MMO 2018)

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 (PCB) (sum of ICES 7)	0.01	None
PCBs (sum of 25 congeners)	0.02	0.2
Polycyclic aromatic Hydrocarbons (PAH)	0.1 (exception dibenz[a,h]anthracene which is 0.01)	None
Total Hydrocarbons (THC)	100	None

29. 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 required before the risk can be identified. Therefore, for EIA, in the same way, if contaminant levels in the material under consideration persistently exceed Action Levels, additional assessment is required.

30. This additional assessment can be undertaken by applying the more stringent Canadian sediment quality guidelines (CCME, 2002) which also consist of two sets of concentrations: Threshold Effect Levels (TEL) and Probable Effect Levels (PEL) for many of the contaminants outlined in Table 9.2. The Canadian sediment quality guidelines also include PELs for individual PAHs which do not have Cefas Action Level 2 concentrations, however where PAHs are an identified problem (see Table 9.3). The difference between these values and the Cefas Action Levels is that ecotoxicological information has been used from field and laboratory testing and therefore the TEL and PEL concentrations represent concentrations where adverse effects may or may not occur; the lower level (TEL) represents a concentration below which adverse biological effects are expected to occur only rarely (in some sensitive species for example) and the higher level (PEL), defines a concentration above which adverse effects may be expected in a wider range of organisms.

31. Other additional assessment could also be undertaken by calculating the potential partitioning of contaminants from the sediment into the water using partition coefficients or, where significant risk to water quality has been identified through persistent exceedance of Action Level 2, use of water quality modelling.

Table 9.3 Selected Canadian SQG values (taken from CCME, 2002)

Contaminant	Units	TEL	PEL
Arsenic	mg/kg	7.24	41.6
Cadmium	mg/kg	0.7	4.2
Chromium	mg/kg	52.3	160
Copper	mg/kg	18.7	108
Mercury	mg/kg	0.13	0.7
Lead	mg/kg	30.2	112
Zinc	mg/kg	124	247

Contaminant	Units	TEL	PEL
Acenaphthene	µg/kg	6.71	88.9
Acenaphthylene	µg/kg	5.87	128
Anthracene	µg/kg	46.9	245
Benz(a)anthracene	µg/kg	74.8	693
Benzo(a)pyrene	µg/kg	88.8	763
Chrysene	µg/kg	108	846
Dibenz(a,h)anthracene	µg/kg	6.22	135
Fluoranthene	µg/kg	113	1,494
Fluorene	µg/kg	21.2	144
Napthalene	µg/kg	34.6	391
Phenanthrene	µg/kg	86.7	544
Pyrene	µg/kg	153	1,398

32. There are three main phases of development that are considered in conjunction with the baseline, over the life-cycle of the proposed project, namely:

- Construction;
- Operation and maintenance; and
- Decommissioning.

33. The impact assessment incorporates a combination of the sensitivity of the receptor and the magnitude of the change to determine a significance of impact.

34. During the three phases listed above, it has been identified that activities releasing sediment into the water column are likely to present the most risk to water quality. Where these activities are assessed, reference to information provided in Chapter 8 Marine Geology, Oceanography and Physical Processes is made.

9.4.1.1 Sensitivity

35. 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).

36. The sensitivity 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 sensitivity levels for marine water and sediment quality

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 the 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 change with very little or no impact upon the baseline conditions detectable.

9.4.1.2 Magnitude

37. 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. The 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 are provided in Chapter 6 EIA Methodology. 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).

38. The magnitude of effect is assessed using expert judgement and described with a standard semantic scale. Definitions for each term are provided in Table 9.5.

Table 9.5 Definitions of magnitude levels for marine water and sediment quality

Magnitude	Definition
High	Large scale change to key characteristics of the water quality status of the receiving water feature. Water quality status degraded to the extent that a permanent or long term change occurs. Inability to meet (for example) EQS.
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 is 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 EQS are compromised.
Negligible	Although there may be some impact upon water quality status, activities are predicted to occur over a short period. Any change to water quality status will be quickly reversed once activity ceases.

9.4.1.3 Impact significance

39. Following the identification of receptor sensitivity and magnitude of the effect, it is possible to determine the significance of the impact. A matrix is presented in Table 9.6 as a framework to guide how a judgement of the significance will be determined.

Table 9.6 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*

40. Through use of this matrix, an assessment of the significance of an impact will be made using expert judgement in accordance with the definitions in Table 9.7.

Table 9.7 Impact significance definitions

Impact Significance	Definition
Major	Very large or large change in receptor condition, both negative 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.

Impact Significance	Definition
Moderate	Intermediate change in receptor condition, which are likely to be important considerations at a local level.
Minor	Small change in receptor condition, which may be raised as local issues but are unlikely to be important in the decision making process.
Negligible	No discernible change in receptor condition.

41. Note that 'major' and 'moderate' impacts are generally deemed to be significant (in EIA terms). In addition, whilst minor impacts are not significant in their own right, it is important to distinguish these from other non-significant (negligible) impacts as they may contribute to significant impacts cumulatively.

42. Where the potential for an accidental spill or leak is concerned, the assessment is based on the risk of a spill or other accidental pollution event occurring. This is considered in relation to control and mitigation measures that are available to minimise the risk.

9.4.2 Cumulative Impact Assessment

43. Cumulative impacts on marine water and sediment quality have been considered by taking into consideration other plans, projects and activities that may impact cumulatively or in-combination with the development of the Norfolk Vanguard project. These projects include other offshore wind farm developments including; East Anglia THREE, East Anglia ONE and Norfolk Boreas but will also give consideration to other nearby activities including marine aggregate extraction.

44. For a general introduction to the methodology used for the cumulative impact assessment (CIA), please refer to Chapter 6 EIA Methodology. The CIA draws from findings of earlier studies undertaken to inform the East Anglia Zonal Environmental Appraisal (ZEA) (EAOW, 2012a) which considered cumulative impacts arising from the development of the whole zone and work undertaken for the EIA for East Anglia ONE (EAOW, 2012b) and East Anglia THREE (EATL, 2015).

9.4.3 Transboundary Impact Assessment

45. The localised nature of the potential impacts on marine water and sediment quality means that significant transboundary impacts are unlikely. In accordance with the Scoping Report (Royal HaskoningDHV, 2016), Scoping Opinion (the Planning Inspectorate, 2016), and EPP agreements based on the Method Statement (see section 9.2), transboundary impacts have been scoped out and are therefore not considered further in this Chapter.

9.5 Scope

9.5.1 Study Area

46. Consideration of the potential effects of Norfolk Vanguard on marine water and sediment quality considers the impacts on two study areas:

- The Offshore Wind Farm (OWF) sites: Norfolk Vanguard (NV East) and Norfolk Vanguard (NV West), including the wind turbine foundations, supporting infrastructure (accommodation, meteorological and electrical platforms), array cables, and inter-connector 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 OWF).
- The offshore cable corridor which connects the OWF sites to the landfall.

9.5.2 Data Sources

9.5.2.1 Site specific surveys

47. In order to provide specific information in relation to the project, a site characterisation survey was conducted by Fugro between 30 October and 10 November 2016. This survey aimed to characterise the physical, biological and chemical nature of the seabed throughout the offshore cable corridor and NV East and West OWF sites. The full survey report can be found in Appendix 10.1 of Chapter 10 Benthic and Intertidal Ecology.

48. Sediment grab samples were obtained from a number of locations along the offshore cable corridor and within NV East and NV West. Of the grab samples, 66 were obtained for Particle Size Distribution (PSD) and 30 for contaminant analysis. A $0.1m^2$ Mini Hamon grab was used to obtain PSD samples and a $0.1m^2$ Day grab was used to obtain contaminant samples.

49. 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. Of the 30 sediment samples obtained, seven samples from the offshore cable corridor, three samples from NV East and three samples from NV West were analysed to provide coverage across the offshore project area and to determine whether analysis of the remaining samples was required. Following agreement from Cefas that the analysis of these 13 samples was adequate to inform the marine water and sediment quality assessment, the remaining samples were discarded.

50. The following contaminants were analysed:

- Arsenic;
- Mercury;
- Cadmium;
- Chromium;
- Copper;
- Lead;
- Nickel;
- Zinc;
- Polychlorinated biphenyls (PCBs);
- Polycyclic Aromatic Hydrocarbons (PAHs);
- Organotins (Dibutyl (DBT) and Tributyl (TBT)); and
- Total hydrocarbons (THC).

9.5.2.2 Published data

51. The information presented in this section has been collated from relevant published literature and studies that have been produced for other projects in the former East Anglia Zone. Information available on government websites has also been consulted. Table 9.8 summarises the key data sources used.

Table 9.8 Data sources

Data	Year	Coverage	Confidence	Notes
Suspended Sediment	Natural Environment Research Council (NERC)(2016)	UK rivers and coasts	High	Large scale study of riverine, atmospheric, estuarine, coastal and shelf processes. Fed into the international Land-Ocean Interactions in the Coastal Zone project. https://www.bodc.ac.uk/projects/data_management/uk/lois/ Results supported by sampling of the North Sea undertaken in 1980 (Eisma and Kalf, 1987).
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: Metals	Department for Environment, Food and Rural Affairs (Defra), 2010)	Southern North Sea	High	The Quality Status Report 2010 describes the current status and trends in water quality for regional seas including the North Sea.
Sediment Analysis	Fugro EMU (2013)	North Sea, within East Anglia THREE and	High	15 surface sediment grabs sampled for contaminants from within the East Anglia THREE and former East Anglia FOUR sites and offshore cable corridor.

Data	Year	Coverage	Confidence	Notes
		former East Anglia FOUR sites.		
Bathing Water Profiles	2017	Coastal waters around England and Wales	High	Water quality at designated bathing water sites in England are assessed by the Environment Agency between May and September. Data is published publicly by the Environment Agency
Environment Agency Catchment Data Explorer	Environment Agency (2017)	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.

9.5.3 Assumptions and Limitations

52. 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 the WFD water body status have been used to inform this assessment.

53. Information regarding coastal suspended sediments is not available, however the analysis undertaken to inform Chapter 8 Marine Geology, Oceanography and Physical Processes predicts the potential change in concentrations (discussed in Section 9.7.4), therefore allowing an assessment of the magnitude of change that is likely during offshore cabling.

9.6 Existing Environment

54. Peer reviewed publications, as well as primary data and grey literature has been consulted in order to provide information relating to the current environmental baseline with respect to marine water and sediment quality in the study areas.

9.6.1 Water Quality

55. The majority of pollutants enter the southern North Sea through the direct discharges of effluents or terrestrial run-off. Additional potential sources include the activities associated with shipping, oil and gas extraction and the dumping of dredged material as well as atmospheric deposition.

9.6.2 Water Framework Directive

56. The offshore cable corridor for the project runs through the WFD Norfolk East coastal water body (GB650503520003) (Figure 9.1). The Norfolk East coastal water body is a 'heavily modified' water body due to flood and coastal protection management and is currently classified to have an overall status of 'moderate'. Classification for physico-chemical parameters is deemed moderate as a result of dissolved inorganic nitrogen (DIN) concentrations in the water. In the RBMP, reasons for the elevated dissolved inorganic nitrogen (DIN) concentrations are listed as diffuse pollution (arable land and therefore field runoff), and point sources associated with sewage discharges. In terms of chemical contaminants, the water body is considered to be at 'good' status, thus indicating no significant exceedances of EQS. The aim for this water body is to achieve 'Moderate Ecological Potential' by 2027 and 'Good Chemical Status' by 2027.

9.6.2.1 Designated bathing waters

57. There are eight designated bathing waters within the WFD water body identified in section 9.6.2. The WFD bathing waters in closest proximity to the landfall search area are Mundesley and Sea Palling, which are located 3.1km to the north and 3.5km to the south respectively. Both bathing waters have been classified as having excellent bathing water quality since 2013 (Environment Agency, 2018).

9.6.2.2 Other activities

58. Aggregate extraction and marine disposal activities can also influence marine water quality. There are currently no aggregate dredging areas within the OWF sites and offshore cable corridor. Those in closest proximity are located approximately 30km south west of NV West and 45km south west of NV East (see Figure 18.3 of Chapter 18 Infrastructure and Other Users).

59. The offshore project area does not overlap with any marine disposal sites. Disposal site TH075 is located in closest proximity to NV East and NV West, approximately 28.8km and 33.4km respectively, to the south of both areas. This disposal site is historic and was used for oil spill modelling and dispersant product testing by Warren Spring Environmental Research Laboratory.

60. Site specific surveys undertaken to support the EIA for the East Anglia ONE project included the collection of five sediment grab samples from within the TH075 disposal site. These samples were tested for volatile and semi-volatile organic compounds (EAOW, 2012b). The analysis found no traces of contamination suggesting that it is likely that any product testing was of such limited extent and sufficiently long ago that no traces remain in surface sediments. The MMO advised that impacts associated with this product test site could be scoped out of further assessment for the East Anglia THREE project. As NV East and NV West are further away from

TH075, it is unlikely that the disposal site will influence sediment quality at either site and therefore they have also been scoped out of this assessment.

61. There are several active oil and gas wells within close proximity (less than 5km) of the Norfolk Vanguard OWF sites and the offshore cable corridor (see Figure 18.2 of Chapter 18). There is potential that these wells could be a source of contamination. However, the site specific information obtained (see section 9.6.4.3) identified no significant levels of hydrocarbon contamination within the seabed sediments and therefore there are unlikely to be associated water and/or sediment quality issues.

9.6.2.3 Clean Seas Environmental Monitoring Programme

62. The Clean Seas Environmental Monitoring Programme supersedes the National Marine Monitoring Programme (NMMP) and was implemented to assess progress against the UK Government and the Devolved Administration's vision of clean, healthy, safe, productive and biologically diverse oceans and seas. The first UK-wide assessment of progress towards that vision; 'Charting Progress', showed in 2005 that the UK seas were productive and supported a wide range of ecosystems, but it also revealed that human activities were adversely affecting marine life. A second report was then produced 'Charting Progress 2' (Department for Environment, Food and Rural Affairs (Defra), 2010), which considers whether current environmental protection measures are working, and aims to provide policy makers, planners and the public with a clear evaluation of progress towards the vision.

63. Norfolk Vanguard is located in region 2 which covers the southern North Sea. Charting Progress 2 (Defra, 2010) 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 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 (Defra, 2010). As a result, the report concludes that levels of contaminants in offshore UK waters are generally low.

9.6.3 Suspended Sediment Concentrations

64. For full details of suspended sediment concentrations naturally present within the Norfolk Vanguard OWF sites and offshore cable corridor, see Chapter 8 Marine Geology, Oceanography and Physical Processes. For ease of reference, a short summary of the findings is provided below.

65. Suspended sediment concentrations across Norfolk Vanguard could be expected to range from 1mg/l to 35mg/l in normal conditions. During the Land Ocean Interaction Study (Natural Environment Research Council, 2016), measurements within the

former East Anglia Zone recorded a maximum turbidity value of 83mg/l and a mean value of only 15mg/l during an 18 month deployment. Sampling of the North Sea undertaken in 1980 identified similar concentrations, ranging from 5-10mg/l (Eisma and Kalf, 1987), aligning with the Land Ocean Interaction Study.

66. Measurements of suspended sediment concentrations were carried out at the AWAC station in NV East between December 2012 and December 2013. Overall, suspended sediment concentrations were between 0.3 and 108mg/l throughout that year. Concentrations were less than 30mg/l for 95% of the time and less than 10mg/l for 70% of the time.

9.6.4 Sediment Quality

9.6.4.1 Sediment grain size

67. Sediment grain size is a significant factor that controls the capacity for both suspended and bed sediments to concentrate and retain metals and organic pollutants (Horowitz, 1987). Finer sediments (clay and silt fractions) have a greater adsorbing capacity and, therefore retain higher concentrations of contaminants. The sediments over much of Norfolk Vanguard are coarse and low in organic content.

68. Grab sample analysis revealed that 90% of the former East Anglia Zone consists of either sand, slightly gravelly sand or gravelly sand. The remaining areas are primarily characterised by sand gravel, with localised areas of muddy sand and (slightly) gravelly muddy sand (EAOW, 2012a).

69. More recent surveys and PSD undertaken in October and November 2016 by Fugro (Appendix 10.1) recorded sediment types within the survey area as typical of the southern North Sea Region, comprising of sand and gravelly sand offshore. Within NV East and NV West, the dominant sediment fraction was slightly gravelly sand, with small pockets of both coarse and fine sediments. Along the offshore cable corridor the dominant fraction was also slightly gravelly sand. A small number of sites recorded a high proportion of muds, with proportions of mud higher than 60% recorded at stations 46 and 58 (Figure 5.4 in Appendix 10.1).

9.6.4.2 Sediment contamination

70. Grab sampling within NV East was undertaken in 2013 to inform the draft East Anglia FOUR Preliminary Environmental Information (PEI). Table 9.9 shows the results from one sample within NV East which was analysed for sediment contaminants and compared with Cefas Action Levels. Concentrations of arsenic, chromium and nickel exceeded Cefas Action Level 1 levels; however, no samples exceed Cefas Action Level 2. Concentrations of DBT, TBT and PCBs were below the detection limits.

Table 9.9 Sediment contaminant levels within NV East compared with Cefas Action Levels (bold values indicate exceedance of Cefas Action Level 1)

Contaminant (mg/kg)	Measurements within NV East	Cefas Action Level 1	Cefas Action Level 2
Arsenic	**47.4**	20	100
Cadmium	0.072	0.4	5
Chromium	**118**	40	400
Copper	29.3	40	400
Mercury	0.003	0.3	3
Nickel	**64**	20	200
Lead	31.3	50	500

9.6.4.3 Site specific survey

71. To inform the baseline for sediment quality, a site specific survey was carried out in 2016. The locations of the sites for which contaminant analysis was undertaken are shown in Figure 9.2.

72. Sediment contaminant data is summarised in Table 9.10. Data highlighted in yellow indicates concentrations of contaminants over Cefas Action Level 1 (there are no concentrations greater than Cefas Action Level 2). All organotin and PCB results were below the limits of detection (0.004 mg/kg and 0.0001 mg/kg respectively) and therefore have not been included in the table.

73. The data summarised in Table 9.10 illustrate that sediment contamination within the offshore cable corridor and the OWF sites is low. Only two sites exceeded Cefas Action Level 1 (03_MS and 56_CR) and this was for concentrations of arsenic only. These exceedances are marginal as they are only just over the Action Level 1 concentration. The elevated levels of arsenic which were recorded are typical of the region; in the offshore environment these are associated with estuarine and geological inputs and seabed rock weathering. Since the results indicate relatively low levels of contamination across the site, analysis of the additional stored samples was not considered necessary; this was confirmed with Cefas and the MMO on 3rd April 2017. Owing to the low levels of contamination within the offshore study area and offshore cable corridor, further assessment (i.e. comparison with additional sediment quality guidelines or other methods) is not deemed necessary.

Table 9.10 Sediment contamination analysis results compared to Cefas Action Levels

Contaminant (mg/kg)	Sample Site												
	24CR	48-CR	45-CR	20-MS	03_MS	05_MS	19_MS	56_CR	02_MS	16_MS	38_CR	26_CR	41_CR
Arsenic	12.6	11.9	9.75	7.89	20.4	16.7	17.3	35.2	16.7	10.7	10	5.39	11.4
Mercury	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<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	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Chromium	3.8	12.8	9.1	4.9	5.3	7.8	15.8	4	12.8	11.6	2.2	4.8	<2
Copper	1.66	3.35	1.78	<1	1.45	<1	2.87	<1	2.08	1.95	<1	<1	<1
Lead	7.16	8.36	4.75	2.64	5.12	5.96	6.61	6.36	7.53	5.69	<2	3.59	2.34
Nickel	3.5	6.7	4.4	3.2	3.4	3.5	7.5	2.8	5.3	5.5	1.3	2.25	1.26
Zinc	8.3	22.6	14.4	9.2	12	13.3	21.3	14.2	17.7	18.6	5.8	9.9	5.5
Acenaphthene	<0.001	0.00101	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<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	<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	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Benzo(a)anthracene	<0.001	0.00415	0.00392	<0.001	<0.001	<0.001	0.00192	<0.001	0.00183	0.00429	<0.001	<0.001	<0.001
Benzo(a)pyrene	<0.001	0.00558	0.00392	<0.001	0.00152	<0.001	0.00236	<0.001	0.00234	0.00543	<0.001	0.00142	<0.001
Benzo(b)fluoranthene	<0.001	0.00759	0.00695	<0.001	0.00234	<0.001	0.00327	<0.001	0.00362	0.0074	<0.001	0.0015	<0.001
Benzo(e) pyrene	<0.005	0.00703	0.0058	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.00605	<0.005	<0.005	<0.005
Benzo(ghi)perylene	<0.001	0.0068	0.00514	<0.001	0.00187	<0.001	0.00242	<0.001	0.00284	0.00526	<0.001	0.00111	<0.001
Benzo(j)fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<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	0.00141	<0.001	0.00148	0.00341	<0.001	<0.001	<0.001
Chrysene + Triphenylene	<0.003	0.00629	0.00618	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.00579	<0.003	<0.003	<0.003
Chrysene	<0.003	0.00432	0.00434	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.00418	<0.003	<0.003	<0.003
Dibenzo(ah)anthracene	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<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	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Fluoranthene	<0.001	0.00809	0.00879	<0.001	0.00186	<0.001	0.00395	<0.001	0.00386	0.00933	<0.001	0.00231	<0.001
Fluorene	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<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	0.0015	<0.001	0.00233	<0.001	0.00243	0.00491	<0.001	0.00102	<0.001
Naphthalene	<0.005	0.00616	0.00599	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Perylene	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.00112	<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	<0.005	<0.005	0.00845	<0.005	<0.005	<0.005
Pyrene	<0.001	0.00699	0.00739	<0.001	0.00160	<0.001	0.00351	<0.001	0.00340	0.00779	<0.001	0.00230	<0.001
Triphenylene	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Total Hydrocarbons	5.51	47 3	33.1	1	10	3.06	11.8	<0.9	22.1	26.2	<0.9	5.02	<0.9

9.6.5 Anticipated Trends in Baseline Conditions

74. 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 in the area (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

76. Norfolk Vanguard Limited has committed to a number of techniques and engineering designs/modifications inherent 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.

77. A range of different information sources has been considered as part of embedding mitigation into the design of the project (for further details see Chapter 5 Project Description, Chapter 4 Site Selection and Assessment of Alternatives) including engineering requirements, ongoing discussions with stakeholders and regulators, commercial considerations and environmental best practice.

78. Norfolk Vanguard 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 Project Environmental Management Plan (PEMP) (document reference 8.14) is submitted with the DCO application and a final PEMP will be produced prior to construction. This would include the following mitigation measures embedded into the design:

- Oils and lubricants used in the wind turbines would be biodegradable where possible and all chemicals would be certified to the relevant standard.
- Where possible, structures would be transported to site having been pre-assembled or manufactured on land.
- Where grout is required, careful use would be ensured at all times to avoid excess grout being discharged to the environment.

- All wind turbines would incorporate appropriate provisions to retain spilled fluids within the nacelle and tower. In addition, offshore electrical platforms would be designed with a self-contained bund to contain any spills and prevent discharges to the environment.
- Best practice procedures would be put in place when transferring oil or fuel between offshore electrical platforms and service vessels.
- Appropriate spill plan procedures would also be implemented in order to appropriately manage any unexpected discharge into the marine environment, these would be included in a Marine Pollution Contingency Plan to be agreed post-consent. To avoid discharge or spillage of oils it is anticipated that the transformers would be filled for their operational life and would not need interim oil changes.
- Inclusion of control measures, such as the requirement to carry spill kits and the requirement for vessel personnel to undergo training to ensure requirements of the PEMP (based on the outline PEMP (document reference 8.14)) are understood and communicated.
- All work practices and vessels would adhere to the requirements of the International Convention for the Prevention of Pollution from Ships (MARPOL) 73/78; specifically Annex 1 Regulations for the prevention of pollution by oil concerning machine waters, bilge waters and deck drainage and Annex IV Regulations for the prevention of pollution by sewage from ships concerning black and grey waters.

79. In view of the low contaminant release risk in the offshore project area and the commitment to the application of the embedded mitigation measures listed above, no impacts are predicted as a result of pollutants and contamination. Therefore, the potential for pollutants to be released into the environment is not considered further in this chapter.

80. For all types of foundations, scour protection material would be installed where required during the construction process in order to mitigate the effects of scour and the associated release of suspended sediment and bed level changes in the vicinity of each wind turbine location during the operational phase.

9.7.2 Monitoring

81. An In Principle Monitoring Plan (document reference 8.12) is submitted with the DCO application. The development of the detailed design and a Project Environmental Management Plan (PEMP) will refine the worst case impacts assessed in this EIA. It is recognised that monitoring is an important element in the management and verification of the actual project impacts. The requirement for appropriate design and scope of monitoring will be agreed with the appropriate Regulators and stakeholders prior to construction works commencing.

9.7.3 Worst Case Scenarios

82. The offshore project area consists of:

- The offshore cable corridor with landfall at Happisburgh South;
- Norfolk Vanguard West (NV West); and
- Norfolk Vanguard East (NV East).

83. The detailed design of Norfolk Vanguard (including numbers of wind turbines, layout configuration, requirement for scour protection etc.) will not be determined until after the DCO has been determined. Therefore, realistic worst case scenarios in terms of potential impacts/effects on marine water and sediment quality are adopted to undertake a precautionary and robust impact assessment. The realistic worst case scenarios used are described in the sections below.

9.7.3.1 Foundations

84. Within Norfolk Vanguard, several different sizes of wind turbine are being considered in the range of 9MW and 20MW. In order to achieve the maximum 1,800MW export capacity, there would be between 90 (20MW) and 200 (9MW) wind turbines.

85. In addition, up to two offshore electrical platforms, two accommodation platforms, two meteorological masts, two LiDAR platforms and two wave buoys, plus offshore cables are considered as part of the worst-case scenario.

86. A range of foundation options are currently being considered, these include:

- Wind turbines - jacket, gravity base structure (GBS), suction caisson, monopile and tension leg floating platforms;
- Offshore electrical platforms – GBS, pin-pile or suction caisson;
- Accommodation platforms – GBS, pin-pile or suction caisson;
- Met masts - GBS, monopile or pin-pile; and
- LiDAR - floating with anchors or monopile.

87. The largest disturbance areas are associated with gravity anchors for floating foundations or GBS, where applicable.

9.7.3.2 Layout

88. The layout of the wind turbines will be defined post consent but would be based on the following maxima:

- Up to 1800MW in NV East, 0MW in NV West; or
- 0MW in NV East, up to 1800MW in NV West.

89. Any other potential layouts that are considered up to a maximum of 1,800MW (e.g. 900MW in NV West and 900MW in NV East) lie within the envelope of these

scenarios and therefore will have a smaller effect on marine water and sediment quality than the two potential worst cases.

9.7.3.3 Phasing

90. Norfolk Vanguard Limited is currently considering constructing the project in a single phase or two phases (up to a total capacity of 1,800MW).

9.7.3.4 Construction programme

91. The indicative offshore construction window is anticipated to be four for the full 1800MW capacity. Section 5.4.15 of Chapter 5 Project Description provides indicative construction programmes for the single phase and two phase options.

9.7.3.5 Cable installation footprints

9.7.3.5.1 Pre-installation works

Boulder clearance

92. Pre-construction surveys will identify any requirement for boulder clearance within the offshore project area. Boulder clearance would involve localised relocation of boulders within the offshore project area which would have no overall impact on marine water and sediment quality and is therefore not considered further.

Pre-lay grapnel run

93. A pre-lay grapnel run would be undertaken to clear any identified debris in advance of 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

94. Sand wave levelling (pre-sweeping) has been assessed as a potential strategy for cable installation to ensure the cables are installed at a depth below the seabed surface (reference seabed level) 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 decision on the installation method and use of pre-sweeping would be made after consent during the final design. A Cable Specification, Installation and Monitoring Plan would be produced prior to construction, following pre-construction surveys (as required under DCO Schedules 9 and 10 Part 4 condition [14(1)(g)] and Schedules 11 and 12 Part 4 condition [9(1)(g)].

95. Indicative pre-sweeping volumes and areas for the offshore cable corridor are outlined in Table 9.11. 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 1:3 and a width of 7m at the base of the dredged area. This would

be in discrete areas only and not along the full length of the corridor. No nearshore pre-sweeping is expected.

96. Sediment arising from pre-sweeping in the Haisborough, Hammond and Winterton SAC would be disposed within the section of the offshore cable corridor overlapping the SAC. The exact location(s) for disposal of sediment would be determined in consultation with Natural England and the MMO following the pre-construction surveys. Sediment arising from pre-sweeping in the offshore cable corridor to the east of the SAC would be deposited in this section of the offshore cable corridor or in the OWF sites. Figure 2 of Chapter 5 Project Description displays the disposal sites. No pre-sweeping or disposal is anticipated in the nearshore section of the offshore cable corridor.

97. The worst case scenario for the volume of sediment arising from seabed preparation in the OWF sites would be associated with levelling the seabed for 90 20MW floating tension leg platforms with gravity anchors (approximately 90m x 90m preparation area) resulting in a total footprint of 729,000m^2 (8,100m^2 per foundation) and a potential sediment volume of 3,645,000m^3 (based on a maximum thickness of 5m of sediment levelled). In addition, levelling of 7,500m^2 per offshore accommodation and electrical platform and 1,257m^2 per met mast may be required resulting in a footprint of 32,513m^2 and sediment volume of 162,566m^3. Sediment arising within the OWF sites would be deposited back into the OWF sites.

9.7.3.5.2 Cable burial

98. Following the cable pre-installation works as described in section 9.7.3.5, the cables would be installed and buried where possible. The following methods may be used for cable burial and the final burial technique would be dependent on the results of the pre-construction surveys 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.

99. The maximum length of export cable trenches is 200km from the offshore electrical platforms in NV East to landfall, based on an average length of 100km per trench for a total of two trenches, each containing a pair of cables. The maximum volume of sediment arising from cable burial (using ploughing as the worst case scenario) would therefore be 3,000,000m^3 based on an average burial depth of 3m with a V-shaped cross-section of 10m width at the seabed surface (see section 5.4.13.2.4 of Chapter 5 Project Description. Ploughing would create temporary mounds either side

of the trench and therefore it is expected that only a small proportion of the $3,000,000m^3$ would result in sediment plumes during cable installation.

9.7.3.5.3 Landfall

100. The export cable landfall would be at Happisburgh South using long Horizontal Direction Drilling (HDD) and duct installation, with cable burial on the seaward side of the drilling exit point. The landfall ducts will exit in the subtidal zone beyond -5.5m LAT and approximately 1km from the onshore drilling location.

9.7.3.6 Maintenance

9.7.3.6.1 Turbines

101. Regular maintenance of wind turbines will be required during operation. These works will have no impact on marine water and sediment quality.

9.7.3.6.2 Cable repairs

102. 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.

103. It is not possible to accurately determine the number and location of unscheduled repair works that may be required during the life of the project.

104. An estimate of one export cable repair every year (one repair every five years for the proportion of cable within the SAC) is included in the assessment. In addition, one inter-connector cable repair and two array cable repairs every five years has been assumed as a realistic worst case. Further information on cable repairs is provided in section 5.4.18.3 of Chapter 5 Project Description.

105. In most cases a cable failure would lead to the following repair operation:

- Vessel anchor placement ($150m^2$ footprint)
- Exposing/unburying the damaged part of the cable using jetting (3m disturbance width)
- Cutting the cable, assumed to be approximately 300m export cable or inter-connector cable length subject to the nature of the repair or 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 re-burial, where possible.

106. Given the small scale of the repairs, the changes to suspended sediment concentrations and seabed level would be negligible in magnitude and short-lived, with no potential significant impact and therefore this is not assessed further.

9.7.3.6.3 Cable reburial

107. As previously discussed, buried cables could become exposed due to migrating sand waves, however this is highly unlikely if pre-sweeping to the reference seabed level is used during installation. An In Principle Monitoring Plan (document reference 8.12) is submitted with the DCO application which outlines the types of monitoring that may be required, including a cable burial survey to ensure the cables remain buried and if they do become exposed, re-burial works would be undertaken. The details of any monitoring would be determined post consent in consultation with the relevant Regulators and stakeholders.

108. For the export cables installed without pre-sweeping, a worst case scenario of reburial of up to 20km length per export cable pair at approximately 5 year intervals is assumed in order to provide a conservative assessment. Of this 20km, reburial of up to 10km per cable within the SAC at five year intervals has been estimated based on the worst case scenario that no pre-sweeping is undertaken. However, re-burial requirements would be substantially lower if pre-sweeping is carried out prior to cable installation.

109. Given the small scale of the predicted repairs, the changes to suspended sediment concentrations and seabed level as a result of repair work would be negligible in magnitude and short-lived, with no potential significant impact and therefore this is not assessed further.

Table 9.11 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 20MW gravity anchor for a floating 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 gravity anchor foundation is 40,500m^3 (based on an approximately 90m x 90m preparation area). Total maximum seabed preparation volumes for 1800MW capacity (all in NV East, all in NV West, or split between the sites): • 90 x 20MW floating turbines on gravity anchor foundations (requiring preparation area of approximately 90m x 90m and 5m prep depth) = 3,645,000m^3 • 2 meteorological masts (1,257m^2, 5m depth) = 12,570m^3 • 2 electrical platforms (7,500m^2 x 5m depth) = 75,000m^3 • 2 accommodation platforms (7,500m^2 x 5m depth) = 75,000m^3 Total worst case seabed preparation volume for foundations is 3,807,566m^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 90 x 20MW monopile foundations, two meteorological masts on pin-pile quadropods, two accommodation platforms and two offshore electrical platforms on six-legged pin-piles and 2 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 for 45 x 20MW quadropod foundations is 397,608m^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 the GBS foundation would not be required).

Impact	Parameter	Worst Case	Rationale
		Drill arisings from other platforms: • Meteorological masts - 2 x pin-pile quadropod = 1,131m^3 • Accommodation platforms - 2 x six legged pin-pile = 1,696m^3 • Offshore electrical platforms - 2 x six legged pin-pile = 1,696m^3 • LiDAR - 2 x monopiles = 189m^3 Total drill arisings volume for foundations in the OWF sites is 402,320m^3	
Impact 2: Deterioration in water quality due to increased suspended sediment concentrations during installation of the offshore export cables.	Suspended sediment	Pre-sweeping (dredging) of the offshore export cable route may be required for up to 2,400,000m^3 of dredged sediment, including: • Up to 500,000m^3 pre-sweeping within the Haisborough, Hammond and Winterton SAC based on calculations by CWind (2017); • Up to 100,000m^3 for the rest of the offshore cable corridor based on calculations by CWind (2017); and • Up to 1,800,000m^3 based on 30km export cable length in the OWF sites that may require pre-sweeping (assuming a width of 20m and average depth of 3m). 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 export cables would be 3m and therefore 3,000,000m^3 of sediment would be disturbed for up to 200km of export cable trenching.	Maximum offshore export cable trench length is 200km based on four HVDC cables in 2 trenches (either 2 trenches from West, 2 from East or 1 from each site) and 100% burial. 80km of this will be within the Haisborough, Hammond and Winterton SAC (based on 40km x 2 trenches).
Impact 3: Deterioration in water due to increased suspended sediment concentrations during array and inter connector cable installation	Suspended sediment	Worst case scenario is 600km of array cables with 100% burial. Potential for pre-sweeping a 20m wide corridor to clear debris or level sand waves prior to excavation of trenches. Average depth of 3m. Total volume 36,000,000m^3.	
		Maximum parameters for interconnector cables between offshore electrical platforms are:	In the OWF sites and/or in the offshore cable corridor between

Impact	Parameter	Worst Case	Rationale
		• 150km trench length based on three trenches (50km length) with 100% burial. • Average burial depth of 3m. • Potential for pre-sweeping a 20m wide corridor to clear debris or level sand waves prior to excavation of trenches. Total volume = 9,000,000m^3	NV East and NV West depending on the location of the offshore electrical platforms.
Impact 4: Deterioration in water and bathing water quality due to works at the offshore export cable landfall.	Suspended sediment	The offshore cable will make landfall at Happisburgh South. Cable ducts would be installed at the landfall via long HDD so that the ends of the offshore cables can be pulled through from the landward side. The HDD will exit at an offshore location within the intertidal zone, away from the beach (beyond -5.5m LAT and approximately 1000m in drill length from the onshore HDD location). Cable burial will be undertaken from the HDD exit point.	The worst case scenario for installation of the offshore export cable landfall would involve the maximum sediment disturbance and undertaking of works within the marine environment.
Impact 5: Change in water quality due to re-suspension of sediment bound contaminants	Contaminant concentrations in water	Notes for Impacts 1, 2, 3 and 4 are applicable here.	The worst case scenario relates to activities that involve the most re-suspension of sediment.
Operation			
Embedded mitigation is included as part of the project design to reduce the potential effects on water quality, there are no worst case scenarios to be considered as potentially resulting in significant impacts for the operational phase (see section 9.7.3.6).			
Decommissioning			
Impact 1: Deterioration in water quality due to increased suspended sediment concentrations during removal of accessible installed components	Sediment plume created by disturbance of seabed during removal	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, and offshore export cables. Scour and cable protection would likely be left *in situ.*	Jetting may be undertaken under the base plate to remove adhesive effects of grout. The volume of sediment disturbed during decommissioning would be less than during construction due to no sand wave levelling works being required.

9.7.4 Potential Impacts during Construction

9.7.4.1 Impact 1A: Deterioration in offshore water quality due to increased suspended sediment concentrations due to sediment plume created by seabed preparation during installation of foundations

110. Sediment preparation for the installation of foundations (for wind turbines, accommodation platforms, offshore electrical platforms, 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 will be a function of seabed type, the type of foundations and installation method, as well as hydrodynamic conditions.

111. 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 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).

112. Seabed sediments and shallow near-bed sediments within the Norfolk Vanguard OWF sites would be disturbed during any levelling (dredging) activities to create a suitable base prior to the installation of GBS foundations. The worst case scenario assumes that sediment would be dredged and returned to the water column at the sea surface as overflow from a dredging vessel. This process would cause localised and short-term increases in suspended sediment concentrations both at the seabed and at the point of discharge into the water column. It should be noted that disposal of any sediment dredged during foundation installation would occur within the Norfolk Vanguard OWF sites.

113. As detailed in Chapter 8 Marine Geology, Oceanography and Physical Processes, mobilised sediment from cable installation activities may be transported by wave and tidal action in suspension in the water column forming a plume. However, the disturbance effects at each wind turbine location are likely to last for no more than a few days, within an overall single-phase foundation installation programme of approximately 20 months. This is because the median particle sizes of seabed sediment samples collected across NV West and NV East are predominantly 0.32mm to 0.39mm (medium sand) and 0.20mm to 0.35mm (medium sand), respectively (see Chapter 8 Marine for further detail). Additionally, for the majority of samples less than 5% consisted of the finer mud fraction. As a result, it is considered that the sediment disturbed by the drag head of the dredger at the seabed would remain close to the bed and settle rapidly (see Chapter 8). Additionally, the majority of the sediment released at the water surface from the dredging 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).

114. Some of the finer sand fraction from this release, and the very small proportion of mud that is present, is likely to stay in suspension for longer and form a passive plume which would become advected by tidal currents. Chapter 8 Marine Geology, Oceanography and Physical Processes suggests that this is likely to exist as a measurable but a low concentration plume relative to natural variation (tens of mg/l) for around half a tidal cycle. Sediment would eventually, however, settle to the seabed 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 are likely to be indistinguishable from background levels (which vary from between 1mg/l to a maximum of 83mg/l). As a result, the magnitude of effect on offshore water quality would be low.

115. This is supported by modelling simulations undertaken for East Anglia ONE (EAOW, 2012b), which are relevant to this assessment because owing to the close proximity of the sites, sediment types across East Anglia ONE are similar to those across NV West and NV East. Additionally, East Anglia ONE is a similar distance from the amphidromic point at which the tidal range is zero, therefore the tidal currents and hence sediment dispersion patterns would be similar. See section 8.3 in Chapter 8 Marine Geology, Oceanography and Physical Processes for further detail.

116. To summarise the findings, the model predicted that close to the release locations, suspended sediment concentrations would be very high (orders of magnitude in excess of natural background levels), but very short in duration (seconds to minutes) as the dynamic plume falls to the seabed. Within the passive plume, suspended sediment concentrations were predicted to be 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.

117. It should be noted that even though only 15 foundations were modelled (compared to the 200 proposed for Norfolk Vanguard) the plume from one foundation was predicted to have fully dispersed before installation of the next foundation thus removing any risk of plume interaction. Modelling of 15 foundations can therefore be scaled up to assess the potential effects associated with the installation of 200 foundations. It is therefore predicted that effects of installation across the whole of the Norfolk Vanguard OWF sites would be similar, although with the point of release moving across the site with progression of the construction sequence.

118. As discussed above, 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 will only be present during the installation process. The sensitivity in the offshore project area is deemed to be low due to the large volume of the receiving water and the capacity for dilution and flushing and therefore an impact of **minor adverse** significance is predicted.

119. 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 compared with a single-phased approach. Therefore, this assessment is applicable to both phased construction options under consideration.

9.7.4.2 Impact 1B: Deterioration in offshore water quality due to increased suspended sediment concentrations due to drill arisings for installation of piled foundations

120. Norfolk Vanguard Limited estimates that the maximum number of foundations that would require drilling would be 50%. This drilling process could cause localised and short-term increases in suspended sediment concentrations at the point of discharge of the drill arisings. Released sediment may then be transported by tidal currents in suspension in the water column.

121. Most of the sediment will be sand or aggregated clasts which are deposited close to the drill location (see Chapter 8 Marine Geology, Oceanography and Physical Processes). Small quantities of fine-sediment released will be widely and rapidly dispersed. This would result in only low suspended sediment concentrations within the water column. The disturbance effects at each wind turbine location are only likely to last for a few days of construction activity, within the overall construction programme lasting up to 20 months for foundation installation (single phase).

122. 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 for a modelled construction period of eight consecutively drilled foundations over a 15-day simulation period.

123. The larger release volumes associated with the worst case scenario for Norfolk Vanguard (8,836m^3) and similar tidal currents compared to East Anglia ONE may combine to result in larger concentrations above background levels than previously modelled. However as described in Chapter 8 Marine Geology, Oceanography and Physical Processes, these are likely to still be modest (tens of mg/l) due to the low volumes of disaggregated fine-grained 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. Due to the small quantities of fine-sediment present at Norfolk Vanguard, the fine-sediment is likely to be rapidly dispersed. Therefore, the drilling process would cause localised and short-term increases in suspended sediment concentrations at the point of discharge of the drill arisings.

124. 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. Sediment concentrations arising from one foundation installation are also considered unlikely to persist sufficiently long enough for them to interact with subsequent installations.

125. 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 will change as installation progresses.

126. 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 due to the localised and short term increases in suspended sediment concentrations at the point of discharge of the drill arisings. Baseline conditions of suspended sediment concentrations are expected to return to normal rapidly following cessation of activity, therefore any impact will only be present during the installation process. Overall, based on the low sensitivity of the water (based on the definitions provided in Table 9.4 and as discussed in section 9.7.4.1) in terms of the potential for water quality impacts, a **minor adverse** impact is predicted.

127. 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 all construction phases under consideration.

9.7.4.3 Impact 2: Deterioration in water quality due to increased suspended sediment concentrations during installation of the offshore export cable

128. Details of how the offshore cable will be installed would be confirmed in the final project design, post consent. The installation of the offshore cables has the potential to disturb the seabed sediment, either directly though the installation method chosen, or through seabed levelling of sand waves. During excavation (by whichever assessed method), sediment plumes could be formed by the release of sediment into the water column. The released sediment will 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. Cable installation is a relatively short term activity (days as opposed to months) and therefore the effect is generally relatively short-lived. Disposal of any sediment dredged during export cable installation would occur within the section of the offshore cable corridor that overlaps with the Haisborough Hammond and Winterton SAC (for sediment arising from the SAC) and/or in the OWF sites (for all sediment arising from outside the SAC).

129. 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 OWF and Norfolk Vanguard. As a result the assessment provided in Chapter 8 Marine Geology, Oceanography and Physical Processes uses the information from East Anglia ONE to inform the potential for effects on suspended sediment concentrations. 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 the concentrations of suspended sediment would approach 400mg/l at their peak. However, 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.

130. During the single phase construction period, disturbance to seabed sediments and potential generation of plumes will 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 route. Furthermore, the designated Bathing Waters are not located within the 1km area identified as being the most at risk of experiencing elevated levels. Therefore, the magnitude of the impact is anticipated to be low.

131. Since the sensitivity of the receptor is low (based on the definitions provided in Table 9.4) and the magnitude of the impact is anticipated to be low, an overall **minor adverse** significance is predicted.

132. 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 both construction phase approaches being considered.

9.7.4.4 Impact 3: Deterioration in offshore water quality due to increased suspended sediment concentrations during array and interconnector cable installation

133. As for the installation of the export cables, the array and 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.

134. Chapter 8 Marine Geology, Oceanography and Physical Processes shows that the changes in suspended sediment concentration due to cable installation would be minimal because the predominant grain size is sand and the quantity of sediment released into the water column would be very small.

135. Mud-sized material (which represents only a very small proportion of the disturbed sediment) would be advected a greater distance than sand-sized material, and persist in the water column for longer, forming a passive plume which would become advected by tidal currents. Due to the sediment sizes present, this is likely to exist as a measurable but modest concentration plume (tens of mg/l) for around half a tidal cycle. 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.

136. The magnitude of the impact is therefore anticipated to be low and, combined with low sensitivity of the receptor, the overall significance is predicted to be **minor adverse** for the single phase approach.

137. Under the two-phase approach, the principal difference compared to the single phase assessment is associated with the installation programme. Although the installation of the cables 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 magnitude. This assessment is therefore applicable to both construction phase approaches being considered.

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

138. At the landfall location at Happisburgh South, long HDD is proposed to be employed for installation of the offshore export cable. Up to three HDD exit points have been assessed (; of these two are required for the paired export cables and one is assessed as a contingency in the unlikely event of a HDD failure). The HDD exit point would be in the subtidal zone beyond -5.5m LAT (and within 1km of the onshore

drilling location). This would require excavation of a trench to bury the offshore cable on the seaward side of the landfall HDD. This excavation has the potential to increase suspended sediment concentrations close to shore.

139. During excavation, the suspended sediment concentrations will likely increase beyond baseline levels, however once complete the high energy nearshore zone is likely to rapidly disperse any suspended sediment over a period of a few hours.

140. As previously discussed in relation to cable installation, any suspended sediment plumes arising would be localised to within approximately 1km of the release location. The two nearest designated bathing waters are located at least 3km from the proposed landfall location, however, the route does run through the WFD coastal water body Norfolk East. Whilst compliance with the bathing waters directive and WFD is not dependent on meeting requirements in relation to suspended sediment concentrations, this has been assessed in order to provide a conservative assessment.

141. Overall therefore, given the level of disturbance to seabed sediments and that potential generation of plumes will be limited in temporal and spatial extent due to the temporary nature of the activity and the dominance of sand sized material in the landfall area, the magnitude of the impact is anticipated to be low.

142. Designated bathing waters are located at least 3km away from the activity and the WFD water body has a high capacity to accommodate change due to the high capacity for dilution and flushing, resulting in low receptor sensitivity. As a result, the impact significance is deemed to be **minor adverse**.

143. The approach to construction phasing would not impact on landfall activities (i.e. all ducts would be installed regardless of the phasing eventually chosen), no further consideration is required.

144. Regarding the WFD water body, compliance parameters such as marine habitats could be affected (for more detailed assessment see the WFD Compliance Assessment in Appendix 20.2).

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

145. Disturbance of seabed sediments has the potential to release any sediment-bound contaminants, such as heavy metals and hydrocarbons into the water column. The data in Table 9.10 illustrate that levels of contaminants within the OWF sites and offshore cable corridor are very low.

146. Only two exceedances of Cefas Action Level 1 were recorded for arsenic at two sites; one within NV West (03_MS) and one within the offshore cable corridor (56_CR)

(Table 9.10). Both were only marginal with 03_MR exceeding the action level by 0.4 mg/kg and 56_CR exceeding by 15.2 mg/kg. Neither of these increases brings the concentrations close to Cefas Action Level 2, therefore the potential magnitude of effect is considered to be negligible.

147. As a result of the low magnitude of effect and low receptor sensitivity ((based on the definitions provided in Table 9.4, the re-suspension of contaminated sediment from construction activities is considered to be of **negligible** significance.

9.7.5 Potential Impacts during Operation

148. Norfolk Vanguard 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 will inform the final locations and design of the turbines/foundations and will inform the need for scour protection.

149. The 2016 site survey data (analysed after the Scoping Report) confirmed that there are no contaminated sediments in the area surveyed (see section 9.5.2.1).

150. The potential for secondary scour around scour protection was also discussed during the Evidence Plan Process, but was agreed in July 2017 that this is not a potential impact.

151. There is therefore **no potential impact** from release of suspended sediments during operation.

9.7.6 Potential Impacts during Decommissioning

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

152. 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 cables and offshore export cables. Scour and cable protection would likely be left *in situ*.

153. 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 will not be required to remove the foundations. There may however, be a requirement to use jetting to remove the cables where needed.

154. 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

155. A number of plans and/or projects have been identified as having the potential to give rise to cumulative effects on water quality due to their proximity to the Norfolk Vanguard offshore project area:

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

156. These potential interactions are included in the Cumulative Impact Assessment (CIA) table below (Table 9.12) and are in accordance with those assessed in Chapter 8 Marine Geology, Oceanography and Physical Processes and as discussed with the MMO, Natural England, Environment Agency and Cefas during the Evidence Plan Process meeting on 5th July 2017. The projects identified for potential cumulative impacts with Norfolk Vanguard have been discussed during ETG meetings with stakeholders. The full list of projects for consideration has been updated following PEIR and agreed in consultation with local authorities.

157. The proposed landfall at Happisburgh South and the offshore cable corridor is to the south of the proposed sand engine (large scale beach nourishment) for a coastal protection scheme in front of Bacton Gas Terminal. The effect of the beach nourishment is likely to be expressed at Happisburgh South (i.e. some of the nourished sand will migrate from the main sand engine driven by longshore sediment transport).

158. The sand engine is expected to be implemented a number of years in advance of the Norfolk Vanguard offshore construction. There is currently insufficient information available for the sandscaping scheme and so the cumulative impacts cannot be assessed at this stage.

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

Table 9.12 Summary of projects considered for the CIA in relation to marine water and sediment quality

Project	Status	Indicative offshore development period	Distance from Norfolk Vanguard site (km)	Project definition	Project data status	Included in CIA	Rationale
East Anglia THREE OWF	Consented	2022-2026	0	Project description available	Complete/high	Yes	This project would be located adjacent to NV East. It has potential for interaction during the construction of foundations.
Norfolk Boreas OWF	Pre-Application	2024-2028	1	Outline only	Incomplete/low	Yes	This project would be adjacent to NV East and if constructed would share the offshore cable corridor. It has potential for interaction during construction.
Marine aggregate dredging	Licenced	In operation	Nearest 27km		Complete/high	Yes	The offshore cable for Norfolk Vanguard 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.

9.8.1 Cumulative Construction and Decommissioning Impacts with Adjacent Wind Farms

160. 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. However, given the phased construction of the foundation and offshore cable installation (including landfall works) for each of these projects, it is unlikely that there would be overlap between the project and the future East Anglia THREE and/or Norfolk Boreas projects. The short duration of sediment disturbance anticipated during these installation/activities also reduces the likelihood that sediment plumes will be formed at the same time.

161. 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 Vanguard alone (i.e. either minor or negligible impact significance).

9.8.2 Cumulative Construction and Decommissioning Impacts with Marine Aggregate Dredging

162. 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 Vanguard and marine aggregate dredging activities in adjacent areas of the seabed. To summarise, the worst case scenario is that some interaction could potentially occur between dredging plumes and plumes from Norfolk Vanguard 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 Vanguard 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.

163. 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 Inter-relationships

164. 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 9.13.

Table 9.13 Chapter topic inter-relationships

Topic and description	Related Chapter	Where addressed in this Chapter	Rationale
Effects on water column (suspended sediment concentrations)	Chapter 10 Benthic and Intertidal Ecology Chapter 11 Fish and Shellfish Ecology Chapter 12 Marine Mammals Chapter 14 Commercial Fisheries	9.7.4.1 and 9.7.4.2 (foundation installation) 9.7.4.3 (export cables) 9.7.4.4 (array and interconnectors) 9.7.4.5 (landfall) 9.7.6.1 (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	9.7.4.6 (contamination risk associated with all construction activities)	Impacts to marine water quality may have implications for ecology in the water column.

9.10 Interactions

165. The 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 9.14 along with an indication as to whether the interaction may give rise to synergistic impacts.

Table 9.14 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 inter connector 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 inter connector 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	-

9.11 Summary

166. The construction and decommissioning phases 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.

167. The effects that have been assessed are all anticipated to result in either minor or negligible impacts and these are listed in Table 9.14 below.

Table 9.14 Potential Impacts Identified for marine sediment and water quality

Potential Impact	Receptor	Value/ Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Construction						
Impact 1A: Deterioration in water quality due to increased suspended sediment concentrations during installation of foundations	Water Quality	Low	Low	Minor	None proposed	**Minor adverse**
Impact 1B: Deterioration in 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 the offshore export cable	Water Quality	Low	Low	Minor	None proposed	**Minor adverse**
Impact 3: Deterioration in water due to	Water Quality	Low	Low	Minor	None proposed	**Minor adverse**

Potential Impact	Receptor	Value/ Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
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	Water Quality	Low	Low	Minor	None proposed	**Minor adverse**
Impact 5: Deterioration in water quality due to re-suspension of sediment bound contaminants	Water Quality	Low	Negligible	Negligible	None proposed	**Negligible**
Operation						
There are no operational effects anticipated on marine sediment and water quality as embedded mitigation will remove the risk of any effects occurring						
Decommissioning						
Impact 1: Deterioration in water quality due to increased suspended sediment concentrations during foundation removal of accessible installed components	As for construction (Impacts 1, 2,3,4 and 5)					
Cumulative						
Cumulative construction and decommissioning impacts with adjacent wind farms	The detail and scope of the decommissioning works will be determined by the relevant legislation and guidance at the time of decommissioning and agreed with the regulator. A decommissioning plan will 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	Water Quality	Low	Low	Minor	None proposed	**Minor adverse**

Potential Impact	Receptor	Value/ Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
impacts with marine aggregate dredging						
Transboundary						
Scoped out of assessment						

9.12 References

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