Norfolk Boreas Offshore Wind Farm

Chapter 5

Project Description

Environmental Statement

Volume 1

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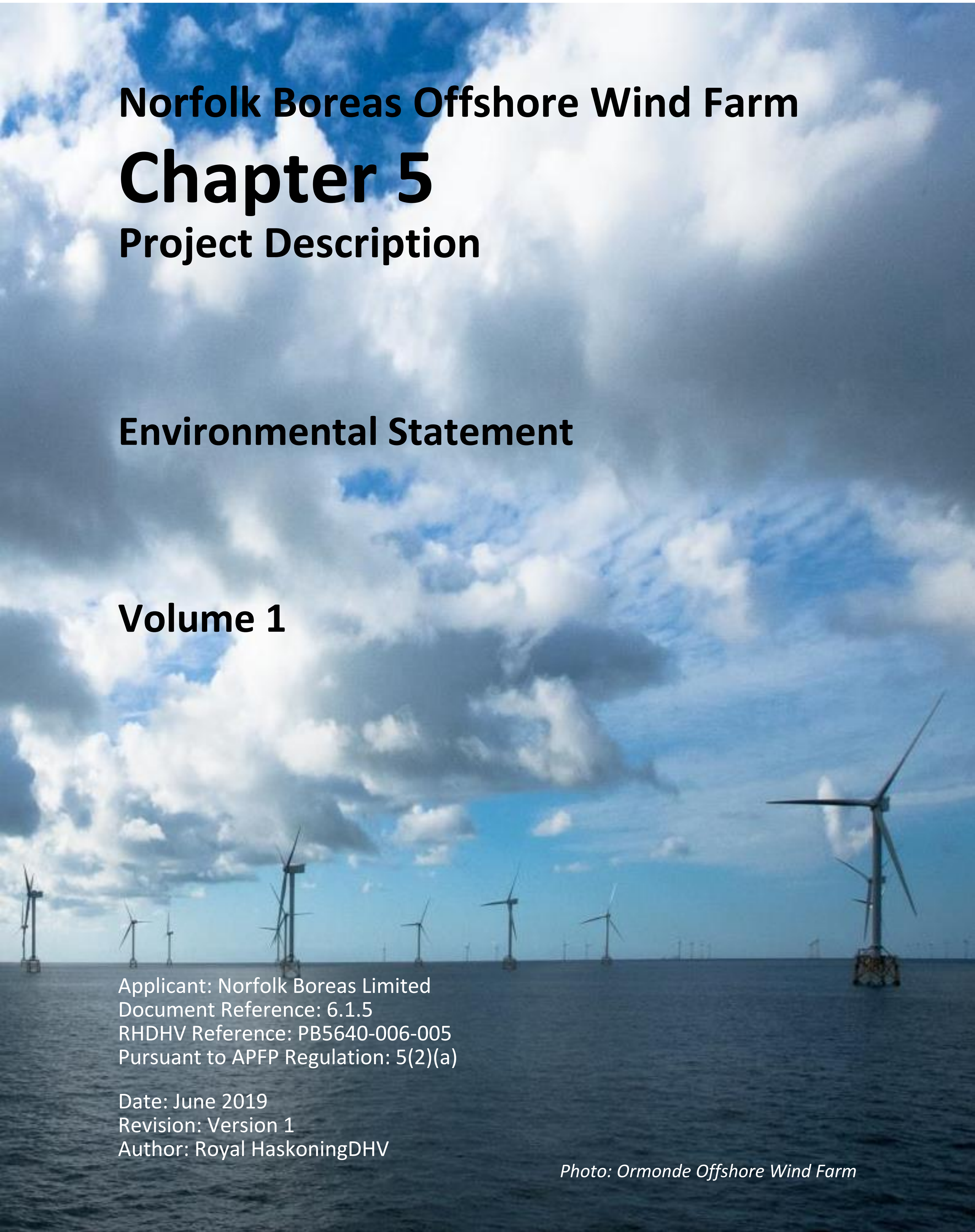

Photo: Ormonde Offshore Wind Farm

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Glossary of Acronyms

AC	Alternating Current
AIS	Air Insulation Switchgear
CAA	Civil Aviation Authority
CBS	Cement Bound Sand
CoCP	Code of Construction Practice
DC	Direct Current
DCLG	Department of Communities and Local Government
DCO	Development Consent Order
DML	Deemed Marine Licence
DP	Dynamic Positioning
DTS	Distributed Temperature Sensing
EIA	Environmental Impact Assessment
EMF	Electromagnetic Field
EPR	Ethylene Propylene Rubber
ES	Environmental Statement
HAT	Highest Astronomical Tide
HDD	Horizontal Directional Drilling
HDPE	High Density Polyethylene
HGV	Heavy Goods Vehicle
HVAC	High Voltage Alternate Current
HVDC	High Voltage Direct Current
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IDB	Internal Drainage Board
kJ	Kilojoule
LAT	Lowest Astronomical Tide
LiDAR	Light Detection and Ranging
LGV	Large Goods Vehicle
MBS	Maritime Buoyage System
MCA	Maritime and Coastguard Agency
MGN	
MIND	Mass Impregnated Non-Draining
MW	Megawatt
NPPF	National Planning Policy Framework
NV	Norfolk Vanguard
O&M	Operation and Maintenance
OWF	Offshore Wind Farm
RMS	Root Mean Square
ROV	Remotely Operated Vehicle
RSBL	Reference Seabed Level
SAC	Special Area of Conservation
SAR	
SCADA	Supervisory Control and Data Acquisition

SF_6	Sulphur hexafluoride
SNCBs	Statutory Nature Conservation Bodies
SoS	Secretary of State
SuDS	Sustainable Drainage Systems
THLS	Trinity House Lighthouse Service
XLPE	Cross-linked polyethylene

5 PROJECT DESCRIPTION

5.1 Introduction

1. This chapter of the Norfolk Boreas Environmental Statement (ES) provides a description of the components required for construction, operation, maintenance and decommissioning of Norfolk Boreas offshore wind farm and includes a consideration of the methods used for installation, maintenance and decommissioning.

2. As outlined in Chapter 1 Introduction and detailed throughout this chapter, the offshore wind farm comprises of a 725km^2 area located approximately 73km from the Norfolk coastline within which wind turbines would be located. Norfolk Boreas would have a maximum export capacity of 1,800 megawatts (MW). The offshore wind farm would be connected to the shore by offshore export cables installed within the offshore cable corridor from the wind farm to a landfall point at Happisburgh South, Norfolk. From there, onshore cables would transport power over approximately 60km to the onshore project substation at Necton, Norfolk.

3. Once built, Norfolk Boreas would have an export capacity of up to 1,800MW, with the offshore components comprising:

- Wind turbines;
- Offshore electrical platforms;
- Offshore Service platform;
- Met masts;
- Measuring equipment (light detection and ranging (LiDAR) and wave buoys);
- Array cables;
- Interconnector cables or project interconnector cables; and
- Export cables.

4. The key onshore components of the project are as following:

- Landfall;
- Onshore cable route, accesses, trenchless crossing technique (e.g. Horizontal Directional Drilling (HDD)) zones and mobilisation areas;
- Onshore project substation; and
- Extension to the Necton National Grid substation and overhead line modifications.

5. Vattenfall Wind Power Limited (VWPL) (the parent company of Norfolk Boreas Limited) is also developing Norfolk Vanguard, a ‘sister project’ to Norfolk Boreas. Norfolk Vanguard is of the same maximum capacity and comprises two distinct areas, Norfolk Vanguard East (NV East) and Norfolk Vanguard West (NV West) (‘the

Norfolk Vanguard offshore windfarm (OWF) sites') which are adjacent to the Norfolk Boreas site (Figure 5.1). Norfolk Vanguard's development schedule is approximately one year ahead of Norfolk Boreas and as such the Development Consent Order (DCO) application was submitted in June 2018.

6. Norfolk Vanguard shares a grid connection location and also much of the offshore and onshore cable corridors with Norfolk Boreas therefore; VWPL has adopted a strategic approach to planning infrastructure for the two projects with the aim of optimising overall design and reducing impacts and disruption where practical.

7. In order to minimise impacts associated with onshore construction works for the two projects, VWPL is aiming to carry out enabling works for both projects at the same time. As such Norfolk Vanguard Limited as part of their DCO application, are seeking to obtain consent to undertake the following:

- Installation of ducts to house Norfolk Boreas cables along the entirety of the onshore cable route from the landfall zone to the onshore project substation;
- A47 junction works for both projects and installation of a shared access road up to the Norfolk Vanguard substation;
- Overhead line modifications at the Necton National Grid substation, which would accommodate both projects.

8. If both projects secure consent these works will be provided for within the Norfolk Vanguard DCO. This is the preferred option and considered to be the most likely however, Norfolk Boreas needs to consider the possibility that Norfolk Vanguard may not proceed to construction. In order for Norfolk Boreas to stand as an independent project, this possibility must be provided for within the Norfolk Boreas DCO. Thus, consent will be sought for the following two alternative scenarios within the DCO, and both scenarios have therefore been assessed as part of the Environmental Impact Assessment (EIA):

- **Scenario 1** – Norfolk Vanguard proceeds to construction and installs ducts and other shared enabling works for Norfolk Boreas.
- **Scenario 2** – Norfolk Vanguard does not proceed to construction and Norfolk Boreas proceeds alone. Norfolk Boreas undertakes all works required as an independent project.

9. Appendix 5.1 contains a detailed comparison of what is included in the two different scenarios across all onshore elements of the project and a full description of the onshore works required for Scenario 1 are provided in section 5.6 and for Scenario 2 in section 5.7.

5.1.1 Project Design Envelope

10. Chapter 3 Policy and Legislative Context provides a background to the project design envelope approach.

11. The project design envelope sets out a series of design options for the project. The project design envelope has a reasoned minimum and maximum extent for a number of key parameters. The final design would lie between the minimum and the maximum extent of the consent sought, for all aspects of the project; this includes spatial and temporal elements and proposed construction methodologies to be employed. The project design envelope is used to establish the extent to which the project would impact on the environment. The detailed design of the project could then vary within this ‘envelope’ without rendering the assessment inadequate or falling outside the scope and boundaries of the DCO.

12. Therefore, the information presented in this chapter outlines the options and flexibility required along with the range of potential design and activity parameters upon which the subsequent impact assessment chapters are based. The project design envelope on which the ES is based was “frozen” in January 2019 to allow the DCO to be completed and submitted in June 2019.

13. Each impact assessment chapter contains a section detailing the worst case assumptions (See Chapter 6 EIA Methodology for further details) for specific receptors and impacts. These worst case assumptions sections are derived from the information provided in this chapter.

5.1.1.1 Need for flexibility

14. Detailed design work for the project will occur post consent following financial close and procurement of contractors, materials and infrastructure. The project design envelope assessed within the EIA process must provide sufficient flexibility to enable Norfolk Boreas Limited and its contractors to use the most up to date, efficient and cost-effective technology and techniques in the construction, operation and decommissioning of the project. The flexibility of approach in the project envelope is essential in order to enable the commercial success of the project. It is anticipated that should a DCO be granted for the project it will include consent conditions requiring the development and agreement of a number plans setting out greater detail on key consent issues prior to construction works occurring. Post-consent/pre-construction site investigation will further inform the detailed design.

15. Key aspects for which project envelope flexibility is required include:

- Turbine capacity and parameters due to the potential evolution of technology prior to offshore construction of Norfolk Boreas around 2025 or 2026;

- High voltage direct current (HVDC) export system concepts, to enable the use of the most up-to-date and cost-effective technology and design;
- Build-out scenarios/ phasing options to enable Norfolk Boreas Limited to construct the offshore wind farm in a way which produces power to the National Grid as early as possible whilst maximising efficiencies during construction;
- Construction and maintenance methodologies, as above, to enable competitive procurement and the most cost effective option to be adopted;
- Ability to construct Norfolk Boreas under two Scenarios, 1 where Norfolk Vanguard is built and 2 where Norfolk Vanguard does not proceed.

16. This chapter outlines the range of parameters for the aspects of the project where flexibility is required.

5.1.2 Project Description Terminology

17. This project description uses specific terms for different elements of the offshore and onshore project areas and infrastructure. These terms are also used within the technical chapters (Chapter 8 to Chapter 31). For clarity, these terms are summarised in Table 5.1.

Table 5.1 Project description terminology

Terminology	Description
Array cables	Cables which link wind turbine to wind turbine, and wind turbine to offshore electrical platforms.
Cable logistics area	Existing hardstanding area to allow the storage of cable drums and associated materials and to accommodate a site office, welfare facilities and associated temporary infrastructure to support the cable pulling works.
Cable pulling	Installation of cables within pre-installed ducts from jointing pits located along the onshore cable route.
Ducts	A duct is a length of underground piping, which is used to house electrical and communications cables.
Evidence Plan Process	A voluntary consultation process with specialist stakeholders to agree the approach to the EIA and information to support the HRA.
Interconnector cables	Offshore cables which link offshore electrical platforms within the Norfolk Boreas site.
Jointing pit	Underground structures constructed at regular intervals along the onshore cable route to join sections of cable and facilitate installation of the cables into the buried ducts.
Landfall	Where the offshore cables come ashore at Happisburgh South.
Landfall compound	Compound at landfall within which HDD drilling would take place.
Landfall compound zone	Area within which the landfall compounds would be located.
Link boxes	Underground chambers or above ground cabinets next to the cable trench housing low voltage electrical earthing links.
Mobilisation area	Areas approx. 100 x 100m used as access points to the running track for duct installation. Required to store equipment and provide welfare facilities. Located adjacent to the onshore cable route, accessible from local highways network suitable for the delivery of heavy and oversized

Terminology	Description
	materials and equipment.
Mobilisation zone	Area within which a mobilisation area would be located.
National Grid new / replacement overhead line tower	New overhead line towers to be installed at the National Grid substation.
National Grid overhead line modifications	The works to be undertaken to complete the necessary modification to the existing 400kV overhead lines.
National Grid overhead line temporary works	Area within which the work will be undertaken to complete the necessary modification to the existing 400kV overhead lines.
National Grid substation extension	The permanent footprint of the National Grid substation extension.
National Grid temporary works area	Land adjacent to the Necton National Grid substation which would be temporarily required during construction of the National Grid substation extension.
Necton National Grid substation	The grid connection location for Norfolk Boreas and Norfolk Vanguard.
Norfolk Boreas site	The Norfolk Boreas wind farm boundary. Located offshore, this will contain all the wind farm array.
Norfolk Vanguard	Norfolk Vanguard offshore wind farm, sister project of Norfolk Boreas.
Offshore service platform	A platform to house workers offshore and/or provide helicopter refuelling facilities. An accommodation vessel may be used as an alternative for housing workers.
Offshore cable corridor	The corridor of seabed from the Norfolk Boreas site to the landfall site within which the offshore export cables will be located.
Offshore electrical platform	A fixed structure located within the Norfolk Boreas site, containing electrical equipment to aggregate the power from the wind turbines and convert it into a suitable form for export to shore.
Offshore export cables	The cables which transmit power from the offshore electrical platform to the landfall.
Offshore project area	The area including the Norfolk Boreas site, project interconnector search area and offshore cable corridor.
Onshore 400kV cable route	Buried high-voltage cables linking the onshore project substation to the Necton National Grid substation.
Onshore cable route	The up to 35m working width within a 45m wide corridor which will contain the buried export cables as well as the temporary running track, topsoil storage and excavated material during construction.
Onshore cables	The cables which take power and communications from landfall to the onshore project substation.
Onshore infrastructure	The combined name for all onshore infrastructure associated with the project from landfall to grid connection.
Onshore project area	The area of the onshore infrastructure (landfall, onshore cable route, accesses, trenchless crossing zones and mobilisation areas; onshore project substation and extension to the Necton National Grid substation and overhead line modifications).
Onshore project substation	A compound containing electrical equipment to enable connection to the National Grid. The substation will convert the exported power from HVDC to HVAC, to 400kV (grid voltage). This also contains equipment to help maintain stable grid voltage.
Onshore project substation temporary construction compound	Land adjacent to the onshore project substation which would be temporarily required during construction of the onshore project substation.

Terminology	Description
Overhead Line	An existing 400kV power line suspended by towers.
Pre sweeping	The practice of dredging the seabed to prepare it for foundation or cable installation. It is either used to provide a level surface on which to place foundations or to allow cables to be installed at a sufficient depth to minimise the chance of them becoming exposed.
Project interconnector cable	Offshore cables which would link either turbines or an offshore electrical platform in the Norfolk Boreas site with an offshore electrical platform in one of the Norfolk Vanguard sites.
Project interconnector search area	The area within which the project interconnector cables would be installed.
Running track	The track along the onshore cable route which the construction traffic would use to access workfronts.
Safety zones	An area around a vessel which should be avoided during offshore construction.
Scour protection	Protective materials to avoid sediment being eroded away from the base of the foundations as a result of the flow of water.
The Applicant	Norfolk Boreas Limited
The Norfolk Vanguard OWF sites	Term used exclusively to refer to the two distinct offshore wind farm areas, Norfolk Vanguard East and Norfolk Vanguard West (also termed NV East and NV West) which will contain the Norfolk Vanguard arrays.
The project	Norfolk Boreas Wind Farm including the onshore and offshore infrastructure.
Transition pit	Underground structures that house the joints between the offshore export cables and the onshore cables
Trenchless crossing compound	Pairs of compounds at each trenchless crossing zone to allow boring to take place from either side of the crossing.
Trenchless crossing zone	Areas within the onshore cable route which will house trenchless crossing entry and exit points.
Workfront	A length of onshore cable route within which duct installation works will occur, approximately 150m.

5.1.3 Site Description

5.1.3.1 Offshore

18. Norfolk Boreas comprises a wind farm site located in the southern North Sea, approximately, 73km from the coast of Norfolk (at the nearest point). The offshore site (herein termed the “Norfolk Boreas site”) includes areas of sand ridges with associated peaks and troughs. Water depths across the site range between 20.4m and 42.8m Lowest Astronomical Tide (LAT). The minimum water depth is at the top of a sand bank located in the south-east of the site and the maximum water depth is in the trough between this sandbank and another sandbank in the southern central part of the site. Water depths within the offshore cable corridor, close to the Norfolk Boreas site are typically 40 to 50m below LAT. Progressing towards the coast, water depths decrease progressively to 10m below LAT about 500m to 1,000m from the coast.

19. The Norfolk Boreas site experiences tidal velocities of up to 1.0m/s, with the greatest velocities being experienced in the north of the site.

20. The offshore project area substrate is relatively homogeneous, with the majority of the area characterised by medium sand.

21. The Norfolk Boreas site is located within the southern North Sea Special Area of Conservation (SAC) and the offshore cable corridor also passes through the Haisborough, Hammond and Winterton SAC. Further Information is provided with the Information for the Habitats Regulations Assessment report (DCO document 5.3).

5.1.3.2 Landfall

22. The coast of north-east Norfolk is an almost continuous line of glacial till cliffs. The coast is exposed and therefore very dynamic. Rapid cliff erosion is occurring in places including at Happisburgh South, and severe storm events can rapidly change beach levels and the degree of exposure of the natural or defended coastline. The area surrounding the landfall area is characterised by arable farming.

23. The Kelling to Lowestoft Ness shoreline management plan (AECOM, 2012) states that the intended management policy at Happisburgh South is Managed Realignment over the next 100 years, meaning that beach and cliff erosion will be allowed to occur but in a controlled manner (i.e. minimising the rate of coastal erosion in the short term using appropriate temporary measures with a view to allowing time for measures to be introduced to allow people to adapt to the changes in the medium and long term).

24. Appendix 4.5 provides a detailed study which was commissioned by VWPL and undertaken by Royal HaskoningDHV on coastal erosion in the landfall area. The study, which has informed the site selection and design of the landfall works, concluded that the east Norfolk coastline has been eroding for a long time and is likely to continue to do so for the foreseeable future. Many coastal defences which were constructed in the 20th century are reaching the end of their life. Broadly, the intent of management for the long term is to return to a more naturally functioning (and therefore eroding) coastline.

5.1.3.3 Onshore

25. The site selection process for the onshore project area has sought to avoid settlements, sensitive habitats and other physical constraints (see Chapter 4 Site Selection and Assessment of Alternatives). As a result the project is located in an area where the dominant land use is agricultural. There are a number of towns and villages that the onshore project passes near to including: Happisburgh, North Walsham, Aylsham, Reepham, Dereham and Necton.

5.2 Consultation

26. VWPL as owner of the Norfolk Boreas and Norfolk Vanguard projects has undertaken extensive community and stakeholder consultation to inform the design of both projects, in particular the site selection (see the Consultation Report DCO document 5.01). Chapter 4 Site Selection and Assessment of Alternatives summarises the consultation that has been taken into account during the onshore and offshore site selection process and Chapter 7 Technical Consultation provides more information on the technical consultation undertaken and the influence this has had on the project.

27. VWPL has reviewed responses received during informal and formal consultation undertaken on both Norfolk Boreas and Norfolk Vanguard. In light of the feedback, a number of strategic decisions have been made in relation to the project design for both projects. One of those decisions is to move from maintaining the options of both High Voltage Alternate Current (HVAC) and High Voltage Direct Current (HVDC) electrical transmission within the project envelope to committing to utilising only HVDC technology to export the electricity generated to the UK National Grid connection point. This decision reduces the environmental impacts of the project in two key respects. It removes the need for a cable relay station and reduces the onshore cable route width (see section 5.6 and 5.7).

28. Another key commitment made in response to consultation is to use long HDD at the landfall in order to avoid any works or need for vehicular access on the beach and cliff (see section 5.6.1).

29. Table 5.2 provides an outline of consultation in relation to the project description. However, where stakeholders have requested design changes and additional information specific to a topic, these are detailed in the relevant technical chapters.

Table 5.2 Norfolk Boreas Consultation responses

Consultee	Document & Date	Comment	Response / where addressed in the ES
Secretary of State (SoS)	Scoping Opinion, June 2017	The SoS would expect the Environmental Statement (ES) to include a section that summarises the site and surroundings. This would identify the context of the Proposed Development, any relevant designations and sensitive receptors. This section should identify land that could be directly or indirectly affected by the Proposed Development and any associated auxiliary facilities, landscaping areas and potential off site mitigation or compensation schemes that are to be included as part of the Proposed Development. To this end, the SoS welcomes the proposed approach as outlined at Section 1.6.3 of the Scoping Report ('Characterisation of the Existing Environment') and expects that, following refinement of the cable route and the identification of the sites for the landfall, transition pits, jointing boxes and substation, further and more specific details on the existing (baseline) environment will be provided within the ES	Section 5.1.3 provides an overview of the site and surroundings. Chapter 21 Land use and Agriculture identifies all land which could be affected by the project. The location of the landfall site and transition pits is described in section 5.1.3.2 with further information provided in section 5.6.1. The location of the onshore project substation is described in section 5.1.3.3, 5.6.3 and 5.7.3. The exact location of the jointing pits will not be determined until post consent.
SoS	Scoping Opinion, June 2017	The Applicant should be aware that the description of the Proposed Development in the ES must be sufficiently certain to meet the requirements of Paragraph 17 of Schedule 4 Part 1 of the EIA Regulations 2009 and there should therefore be more certainty by the time the ES is submitted with the DCO.	This chapter provides a detailed description of the project. In order to ensure the EIA is of high quality and is undertaken in accordance with best practice, Norfolk Boreas Limited has sought to apply the 2017 Regulations in the preparation of the ES.
SoS	Scoping Opinion, June 2017	The Applicant should clearly define what elements of the Proposed Development are integral to the NSIP and which is 'Associated Development' under the Planning Act 2008 (as amended) (PA2008) or is an ancillary matter. Associated Development is defined in the PA2008 as development which is associated with the principal development. Guidance on Associated Development can be found in the Department of Communities and Local Government (DCLG) publication 'Planning Act 2008: Guidance on associated development applications for major infrastructure projects'.	All elements of the project described in this chapter are integral to the project and with therefore will be included within the final DCO submission and are assessed throughout this ES.

Consultee	Document & Date	Comment	Response / where addressed in the ES
		Any proposed works and/or infrastructure required as Associated Development, or as an ancillary matter, (whether on or off-site) should be assessed as part of an integrated approach to environmental assessment. The SoS welcomes the Applicants intention to assess the additional works at the Necton substation and the reconfiguration of 400kV overhead lines as part of the EIA.	
SoS	Scoping Opinion, June 2017	The SoS recommends that the ES should include a clear description of all aspects of the Proposed Development, at the construction, operation and decommissioning stages, and include: • land use requirements, including the area of the offshore elements; • site preparation; • construction processes and methods; • transport routes; • operational requirements including the main characteristics of the production process and the nature and quantity of materials used, • as well as waste arisings and their disposal; • maintenance activities including any potential environmental or navigation impacts; and • emissions - water, air and soil pollution, noise, vibration, light, heat, radiation.	This chapter describes all aspects of the project during the construction, operation and maintenance and decommissioning stages and includes details of what the land use, site preparation and construction process would be throughout. Transport routes are summarised in section 5.7.2.5.3 and described in further detail in Chapter 24 Traffic and Transport. A waste assessment is provided in Appendix 19.3 Maintenance activities are described throughout this chapter including in sections 5.6.2.6 and 5.7.2.8 Emissions are described throughout the chapter including in sections 5.4.4.2 and 5.7.2.2.4
SoS	Scoping Opinion, June 2017	The SoS understands that by the time the Norfolk Boreas application is submitted more detail will be available in respect of Norfolk Vanguard including the locations of specific elements. Therefore, the SoS expects the ES to clearly explain the relationships between the two developments and conduct the assessment accordingly	The relationship between the two projects is clearly explained throughout this ES. Chapter 4 Site selection and Assessment of Alternatives describes how the two projects have been strategically developed together.
SoS	Scoping Opinion, June 2017	The number of offshore substation platforms should be set out within the ES.	A maximum of two offshore substations would be required, see section 5.4.4.1.

Consultee	Document & Date	Comment	Response / where addressed in the ES
SoS	Scoping Opinion, June 2017	The Scoping Report explains that a 200m onshore cable corridor has been defined which allows for a 50m easement strip for both Norfolk Boreas and Norfolk Vanguard and a further 50m per project for micro-siting. The SoS is unclear whether the application for the Proposed Development would include the full 200m width for the two onshore cable corridors. This should be clarified within the ES and the assessment undertaken on the worst case basis that would be permitted through the DCO.	As explained in section 5.6.2 the cable route has now been refined to be up to 45m wide.
SoS	Scoping Opinion, June 2017	The Scoping Report notes that there is rapid cliff erosion on the coast of north east Norfolk. The ES should explain how erosion rates have been taken into account in determining the depth of cable burial at the landfall, the depths of transition pits and the set-back distance of the cable relay station from the coastline.	As explained in Chapter 4 Site Selection and Assessment of Alternatives the transition pits would be located at a sufficient distance from the cliff to ensure that they are not compromised by the predicted levels of coastal erosion predicted in Appendix 4.3. The commitment by Norfolk Boreas Limited to a HVDC solution removes the requirement for cable relay stations.
SoS	Scoping Opinion, June 2017	In respect of the Necton substation extension and any overhead line re-alignment works, the SoS expects the ES to include greater clarity in the description of the Proposed Development and its interaction with any works that may be subject to separate consent by National Grid or any other organisation. Paragraph 239 of the Scoping Report implies that the necessary works will be completed by the Applicant either as part of the construction of Norfolk Boreas or Norfolk Vanguard. It should be clear whether such works are being considered as part of the Proposed Development or as part of the cumulative assessment.	Further information is provided in section 5.7.4
SoS	Scoping Opinion, June 2017	The Scoping Report identifies the need for jointing pits at regular intervals along the cable route (every 500-1000m) and that the precise location of the jointing pit would be determined during detailed design. It also notes the need for link boxes at 'a number of locations within the cable corridor'. The ES should identify a worst case scenario for the number of	Further information on link boxes is provided in section 5.6.2.3. Worst case scenarios are determined in chapters 19 to 31 of this ES.

Consultee	Document & Date	Comment	Response / where addressed in the ES
		jointing pits and link boxes. The SoS welcomes the proposal to locate jointing pits at the edge of field boundaries or roads wherever possible. Where any such commitments are made in specific locations, these should be secured for example perhaps through a construction method statement or Code of Construction Practice (CoCP)/Construction Environmental Management Plan (CEMP). The SoS welcomes reference at section 1.6.6 of the Scoping Report to a CoCP being provided as part of the application documents.	
SoS	Scoping Opinion, June 2017	The Scoping Report has identified a number of potential design options, particularly within the offshore area e.g. the size of turbine, type of foundation, the numbers of substations, the need for scour protection and offshore cable installation processes. The Applicant should ensure that they carefully define and justify their worst case scenario to be assessed within ES; bearing in mind that the worst case may differ between topics. The Applicant should also be mindful of the need for consistency in the project description across multiple references within the ES.	This chapter clearly defines the maximum dimensions for all criteria. Technical chapters (8 to 31) of this ES identify the worst case scenario in a dedicated section of each chapter.
SoS	Scoping Opinion, June 2017	The Scoping Report has identified the overall size of the substation compound and the maximum height of buildings and notes that the appearance of the substation will depend on whether HVAC or HVDC would be used. The ES should provide details of the number of and dimensions of the buildings required for each option, along with site layouts. The Applicant should also carefully consider how this will be assessed, particularly in terms of the landscape and visual impacts.	Section 5.6.3 and 5.7.3 provide detail of the onshore project substation parameters. Chapter 29 Landscape and Visual Impact Assessment assesses the impacts of the onshore project substation.
SoS	Scoping Opinion, June 2017	In relation to the overhead line modification, it is acknowledged that limits of deviation may be required to allow flexibility at the detailed design phase. However, in order to undertake a meaningful assessment, the SoS would expect the locations to be defined by the time of application.	The locations of the overhead line modification are defined in section 5.7.4 and displayed in Figure 5.6.
SoS	Scoping Opinion, June 2017	The SoS acknowledges that at this stage of the design it is not possible to provide details of the access roads. However, it is expected that by the time the DCO application is made, these details should be known.	Information on the anticipated access roads is summarised in section 5.7.2.5.3 and described in

Consultee	Document & Date	Comment	Response / where addressed in the ES
		Therefore, the ES should identify the locations, detail their construction methodology and identify those which would be temporary and those which would be permanent.	further detail in Chapter 24 Traffic and Transport
SoS	Scoping Opinion, June 2017	Information on the operation and maintenance of the Proposed Development should be included in the ES and should cover but not be limited to such matters as: • the number of full/part-time jobs; • the operational hours and if appropriate, shift patterns; and • the number and types of vehicle movements generated during • the operational stage (including heavy goods vehicles (HGVs), large goods vehicles (LGVs) and staff vehicles).	The expected employment figures for the project are provided in Chapter 31 Socio-economics. The number and types of vehicle movements and likely operational hours and shift patterns have been taken into account in Chapter 24 Traffic and Transport.
SoS	Scoping Opinion, June 2017	Key maintenance activities associated with the onshore component would take place every summer (taking up to two months) and would potentially require 24/7 working during this period. The SoS would expect to see specific consideration of any 24/7 maintenance working as part of the relevant topic chapters of the ES, and in particular potential impacts on nearby sensitive receptors (including tourism locations) and any mitigation measures proposed.	Further detail on duration and timings of key activities is provided within this chapter. This information is considered in the relevant technical chapters (8 to 31) of this ES.
SoS	Scoping Opinion, June 2017	In terms of decommissioning, the Secretary of State acknowledges that the further into the future any assessment is made, the less reliance may be placed on the outcome. However, the purpose of such a long term assessment is to enable the decommissioning of the works to be taken into account in the design and use of materials such that structures can be taken down with the minimum of disruption. The process and methods of decommissioning should be considered and options presented in the ES.	Sections 5.6.4.7, 5.7.3.8 and 5.7.4.7 provide information regarding decommission and the potential options currently under consideration.
SoS	Scoping Opinion, June 2017	[in relation to decommissioning] The Scoping Report explains that ground at the substation and cable relay station would be covered in topsoil and re-vegetated to return the site to its initial state. The ES should explain in more detail what is meant by ‘initial state’ and how this would be	The detailed activities and methodology for decommissioning would be determined later within the project lifetime, in line with relevant policies at that time, as it is recognised that industry best practice, rules and legislation change

Consultee	Document & Date	Comment	Response / where addressed in the ES
		achieved.	over time. A full EIA would be carried out ahead of any decommissioning works being undertaken.
SoS	Scoping Opinion, June 2017	The Applicant proposes that all identified onshore impacts will be assessed against both scenarios within the ES. The SoS also notes that the ES will consider both HVAC and HVDC options. The Applicant will need to take care to ensure the presentation of information is clearly presented and easy to understand for all of the different options.	Norfolk Boreas Limited's commitment to HVDC transmission has reduced the number of options making the assessment less complex and easier to understand. Onshore chapters (19 to 31) define how the assessment of impacts has been applied to scenarios separately; this is often done by separating out the two assessments under different headings.
SoS	Scoping Opinion, June 2017	In accordance with EN-1, the Applicant should demonstrate the efforts made to ensure that activities will be confined to the minimum areas required for the works.	A definition of works are presented within this chapter and shown in Figure 5.1 to 5.6. Although the locations of some infrastructure have not yet been determined, i.e. jointing bays, it should be clear from the description in this chapter and the Figures that only land required to build the project is included within the Red Line Boundary
Natural England	PEIR response, November 2018	"Outline Operations and Maintenance Plan In respect of J-Tube and Ladder cleaning, this activity typically involves either jet washing marine growth and bird guano off turbine foundation pieces, or cutting the growth from around the j tube. The ES project description does not detail the number of occasions this would occur or the volumes of material being deposited in the marine environment. This does not seem to have been considered at all within the ES. Therefore, either information needs to be provided or this should not be considered as part of the works consented."	A description of these type of activities has been included within section 5.4.18 of this chapter. The impacts of such activities have been assessed in section 9.7.4.2 of Chapter 9 Marine water and sediment quality.
Natural England	PEIR response, November 2018	The type, number and length of cable repairs assessed with the ES is inconsistent and is different to those outlined in the O&M. As above this	The number of anticipated cables repairs is defined in section 5.4.18.3. Assessments of impacts

Consultee	Document & Date	Comment	Response / where addressed in the ES
		will need to be addressed or should not be considered as part of the works to be consented.	associated with these cable repairs are included within Chapters 8 to 18 of the ES.
MMO	PEIR response, November 2018	The MMO seeks clarification on the programme duration outlined in Chapter 5 Table 5.25. For example, the approximate duration for foundation installation is stated as 20 months; however, the construction phase blocked in blue colouring on the timeline suggests foundation installation is scheduled to occur over a 27 month period. The MMO requests that this is clarified and assessed accordingly in the EIA.	Indicative construction programmes for the project have been further refined from those which were presented within the PEIR (section 5.4.15), however it is not possible at this stage of the project to define exactly when each element of work will be undertaken therefore the time period presented in the "Approximate duration" column is the anticipated duration of the works i.e. how long the work would take, and the time blocked out in blue/ orange is the period of time within which the duration of works would be undertaken. This has been made clearer in section 5.4.15.
MMO	PEIR response, November 2018	In respect of J-Tube and Ladder cleaning, this activity typically involves either jet washing marine growth and bird guano off turbine foundation pieces, or cutting the growth from around the j tube. The ES project description does not detail the number of occasions this would occur or the volumes of material being deposited in the marine environment. This does not seem to have been considered at all within the ES. Therefore, either information needs to be provided or this should not be considered as part of the works consented.	Information regarding the cleaning activities which would be required is presented within section 5.4.18.1.1. It has been assessed in chapter 9 Marine Water and Sediment Quality.
Network Rail	PEIR response, November 2018	Consideration should be given to ensure that the construction and subsequent maintenance can be carried out without adversely affecting the safety of, or encroaching upon Network Rail's adjacent land. In addition, security of the railway boundary will require to be maintained at all times	Where the onshore cable route crosses the Network Rail train line, cable ducts would be installed using a suitable trenchless method, avoiding any need to access the Network Rail land (scenario 2 only – see section 5.7.2.4). Installation and maintenance of cables (scenario 1 and 2) can also be carried out without access to or impact on the Network Rail land (see section 5.6.2.1)

Consultee	Document & Date	Comment	Response / where addressed in the ES
Environment Agency	PEIR response, November 2018	Climate Change Where energy infrastructure has safety critical elements (e.g. electricity substations), the applicant should apply the high emissions scenario (high impact, low likelihood) to those elements. The applicant should define those elements of the development that are 'safety critical'. But as an indicator, where an element of the design must remain operational during a high impact low-likelihood scenario, to ensure that occupants/staff and the environment remain safe from the potential impacts (e.g. flooding), then the particular element should be considered safety critical.	Section 5.9 considers the potential threat of natural disasters which includes the potential effects due to climate change on project infrastructure.
Maritime and Coastguard Agency (MCA)	PEIR response November 2018	Construction scenarios MCA would like to see continuous construction which is progressive across the wind farm with no opportunity for two separate areas to be constructed with a gap in the middle.	Norfolk Boreas Limited considers that the effects of disparate construction sites are mitigated, notably through the use of aids to navigation during the entire construction phase. Embedded mitigation is listed in section 15.7.1 of Chapter 15 Shipping and Navigation.
MCA	PEIR response November 2018	MCA Supports safety zones during construction, maintenance and decommissioning phases. Should be noted that operational safety zones may have maximum 50m radius from individual turbines. Justification and evidence for 50m operational safety zone would be required.	A safety zone application would be produced and agreed with the MCA post consent, noting that the application for safety zones is assumed as embedded mitigation in section 15.7.1 of Chapter 15 Shipping and Navigation. This may include provision for operational safety zones around manned platforms.
MCA	PEIR response November 2018	Turbine layout design will require MCA approval prior to construction to minimise risk to surface vessels, including rescue boats and SAR aircraft. Structures must be aligned in straight rows and columns, including any platforms with a minimum of two lines orientation. Any additional navigation safety and / or SAR requirements as per MGN 543 Annex 5 (v2) will be agreed at the approval stage.	The layout and any additional navigational safety and / or SAR requirements would be agreed with the MCA post consent in line with the Design Rules (Chapter 15 Shipping and Navigation).

Consultee	Document & Date	Comment	Response / where addressed in the ES
North Norfolk District Council	PEIR response November 2018	The comparison summary within PEIR Appendix 5.1 is a welcome addition in helping identify the different elements of the project under the two different scenarios.	An updated version of Appendix 5.1 is included within this ES.
North Norfolk District Council	PEIR response November 2018	North Norfolk District Council welcomes the statement from Vattenfall of the intention to seek to ‘minimise impacts associated with onshore construction works’ for the Boreas and Vanguard projects and, if both projects secure consent, the installation of ducts to house Norfolk Boreas cables along the entirety of the onshore cable route from the landfall zone to the onshore project substation and strategic landscape and planting schemes designed to mitigate the impacts of both projects where possible would be provided for within the Norfolk Vanguard DCO.	Norfolk Boreas Limited acknowledges this support.
North Norfolk District Council	PEIR response November 2018	In North Norfolk, many local communities are dependent on the agricultural and tourism economy. Whilst it is recognised that the commitment by Vattenfall to complete both projects together will be dependent on securing the appropriate contracts for difference payments for both schemes, there are considerable public benefits in reducing the maximum construction envelope including shortening the timeframe for ground disturbance which will help lessen construction impacts over a prolonged period of time on these economic sectors.	Norfolk Boreas’ clear intention is to try to minimise disturbance through the installation of the ducts for both projects at the same.
North Norfolk District Council	PEIR response November 2018	NNDC welcomes the commitment from Vattenfall to bring the offshore cables onshore via the use of the horizontal directional drill (HDD) method. The commitment in particular to use the ‘long drill’ option for Norfolk Vanguard and Norfolk Boreas schemes is something the Council were seeking following the Vanguard PEIR stage, primarily to reduce the potential significant adverse impacts from open trench construction on the stability of cliffs in the Happisburgh area. Based on the evidence seen to date, NNDC remains firmly of the view that HDD techniques (long HDD drill) are the most appropriate techniques to be used to bring the offshore cables onshore as this will have the least damaging impact on the nearshore, will result in fewer adverse impacts on	The Commitment to use a “long HDD” remains and is assessed within this ES.

Consultee	Document & Date	Comment	Response / where addressed in the ES
		coastal processes and will reduce the potential to destabilise the cliffs at Happisburgh compared to open trenching techniques.	
EIFCA	PEIR response November 2018	Eastern IFCA is keen to promote parity by encouraging regulators of non-fishing activities that could damage or disturb sensitive features (e.g. cable laying, remedial works and cable protection) to prevent or at least minimise such activities in areas closed to fishing for the protection of these features.	Norfolk Boreas Limited's preferred method of cable installation is to bury cables within the seabed to a target depth of between 1m and 3m.
EIFCA	PEIR response November 2018	Policy CAB1 of the East Marine Plans states, "preference should be given to proposals for cable installation where the method of installation is burial." (HM Government, 2014). The PEIR documentation states Vattenfall's commitment to burying cable throughout the cable corridor except for cable crossing locations, however it also states that there could be unexpected hard substrate which could result in the protection of up to 10 km per cable pair (20 km in total) for the offshore cable corridor, of which 4 km per pair (8 km in total) could be within the SAC. Alternatives to burial, including rock placement, concrete mattressing, use of ground or sand bags, frond mattressing and/or the use of uradact or similar shells are not in keeping with the East Marine Plans. Every effort should be made to maximise the length of cables that are buried and maintain burial over time. Using cable armouring instead of burial increases the likelihood of adverse environmental and fisheries impacts. It is anticipated that 20 km per export cable pair will become unburied over the life of the project (including 10 km in the Haisborough, Hammond and Winterton SAC and 10 km outside of it). Reburial will most likely be required in relatively short sections (e.g. 1 km) at a time, with a temporary seabed disturbance width of ~3 m. If these are left unburied, the presence of exposed export cable can result in snagging of fishing gear. Aside from damage to cables, this poses a significant safety risk, particularly for small vessels operating in the area, and could result in semi-permanent exclusion of fishing activities from the area. This is therefore a concern for Eastern IFCA.	It is Norfolk Boreas Limited's intention that all cables will be buried to the target depth and that cables will remain buried for the operational life of the project. Further work would be completed post consent to determine exactly where and how the cables would be buried. In order to determine the exact locations of cable burial an assessment will be completed

Consultee	Document & Date	Comment	Response / where addressed in the ES
National Farmers Union	PEIR response November 2018	The Land Interest Group (LIG) would like confirmation that the decision to go HVDC can be delivered and that the cables will be installed in ducts as described for the Norfolk Vanguard project. We understand that the easement width under Scenario 2 will be 13m and if under Scenario 1 the full easement width will be 20m. Please could we have a breakdown of why 13 and 20m will be needed permanently? The benefits of HVDC are clear. Our clients feel that every effort should be made to enable an HVDC solution to be adopted to minimise the onshore impacts including environmental, land out of production and the wider social and economic issues. The cost of an HVDC system must not be the deciding factor on the selection of the technology chosen.	Under Scenario 1, Norfolk Boreas will install cables within ducts previously installed by Norfolk Vanguard. Under Scenario 2, Norfolk Boreas will install ducts for the purposes of its own cables and subsequently install cables within those ducts. It is therefore confirmed that Norfolk Boreas cables will be installed within ducts under Scenario 1 or Scenario 2. Full details of the what is required for the cable route easement is provided in sections 5.7.2 and 5.6.2. Norfolk Boreas Limited have committed to a HVDC electrical solution and the DCO application will be made on that basis. Following the consultation Norfolk Boreas Limited replied to this response providing the consultee detailed answers to their questions.
National Farmers Union	PEIR response November 2018	The PEIR states that the minimum depth of cables would be 1.05 metres. Please be advised that a depth of 1.20 metres is the minimum that can be accepted otherwise the cable will interfere with deep farming operations, the growing of certain crops and interaction with land drains. We note it has been stated that the cables will be laid in accordance to National Grid UK Power Networks ECS 02-0019	Norfolk Boreas Limited have committed to burying the ducts up to 1.20m in ground which is used for “deep ploughing”. Table 5.35 and Table 5.41 makes this commitment which will be taken forward to the DCO application As outlined in Table 5.35 ducts would be buried to 1.05m in ‘normal’ agricultural land and 1.2m in areas of ‘deep ploughing’ to top of duct.
National Farmers Union	PEIR response November 2018	It is noted that a running track up to 8 metres wide may be required on a scenario 2. Please confirm why this width is required. The construction is noted, however there does not appear to be any provision for drainage. How do Vattenfall propose to deal with run off from the running track?	The running track as described in section 5.7.2.2.3 will be limited to 6m wide, which is the minimum distance required for two construction vehicles to pass. A separation distance of 2m would be

Consultee	Document & Date	Comment	Response / where addressed in the ES
			maintained from the edge of the running track and the trench for safety, drainage and duct storage.
Atkins on behalf of BBL Pipeline company	PEIR response April 2019	The response contained a number of points that will require consideration during the detailed design stage of the Norfolk Boreas project. These included: Locating cables sufficiently distant from the BBL pipeline, minimising the number of crossings and when crossings are required, grouping multiple cables together at as few a crossing points as possible.	The full response will be used to inform the crossing agreements with BBL at the detailed design phase.
Key comments from the Norfolk Vanguard Project			
Natural England	PEIR Response December 2017	Any protection over cable crossings needs to be carefully installed to ensure that it does not exacerbate or encourage scouring to occur, particularly within the SAC. Further consultation with Natural England will be needed.	A range of cable protection options are presented in section 5.4.14, in order to allow the most appropriate type to be selected during final design. The details will be consulted on through the Scour Protection and Cable Protection Plan, an outline plan is provided with the DCO application (document reference 8.16) and through the Norfolk Boreas Haisborough Hammond and Winterton SAC Site Integrity Plan, and in principle version of which is provided with this DCO application (document reference 8.20).

5.3 Overview of the Project

30. The project would consist of between 90 and 180 wind turbines, each having a rated capacity of between 10MW and 20MW, with a total export capacity of up to 1,800MW. The location of the Norfolk Boreas site is shown in Figure 5.1.

31. The offshore cable corridor would link the Norfolk Boreas site with the cable landfall location at Happisburgh South. The onshore cable route would then link the landfall with the grid connection point near to the village of Necton.

32. Norfolk Boreas Limited has made the decision to deploy HVDC technology for the transmission of power from the array to the onshore project substation. The worst-case configuration in terms of maximum amount of infrastructure installed for the HVDC solution is shown in Plate 5.1.

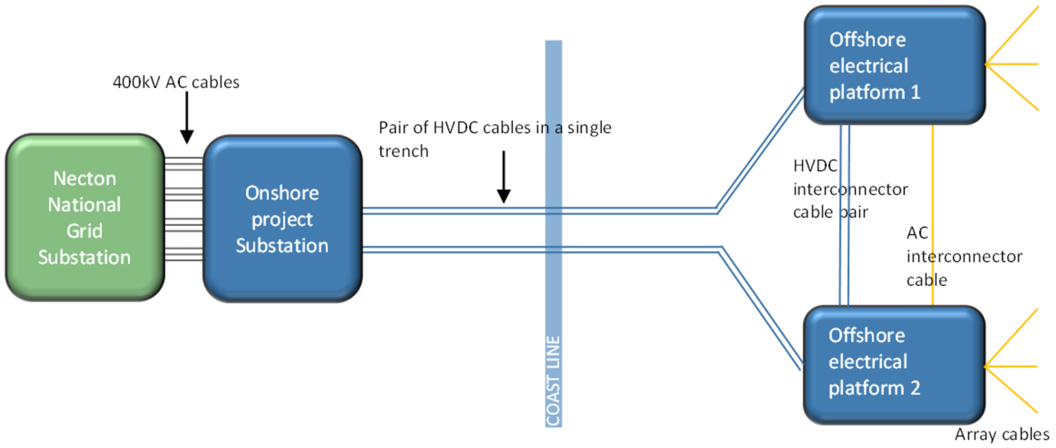

Plate 5.1 Maximum requirements HVDC

33. Other HVDC export concepts for Norfolk Boreas are under consideration, including options which involve interconnection (via a ‘project interconnector’ between Norfolk Vanguard and Norfolk Boreas, or even ‘sharing’ of some export infrastructure between the two projects. This is discussed further in section 5.4.12. If project interconnectors were used there would only be a requirement one offshore electrical platform within the Norfolk Boreas site and the number of export cable pairs would be reduced to one, therefore Plate 5.1 represents the overall worst case.

34. The final DCO submission will be for all offshore and onshore infrastructure associated with the project under either scenario, including, the array, project interconnector, offshore cable corridor, landfall, onshore cable route (including duct installation and cable pulling), the onshore project substation, extension to the existing Necton National Grid substation, overhead line modifications around the National Grid substation, access alterations and landscape, planting schemes.

35. Norfolk Boreas Limited is currently considering constructing the project using a single phase or a two phased approach (up to a total of 1,800MW).

36. Construction of the project under either approach would be anticipated to commence at the earliest in 2021 for the onshore works, and at the earliest around 2025 for the offshore works. Section 5.4.15 outlines an indicative offshore construction programme for each phasing approach. Sections 5.6.5.6 and 5.7.5.7 outline the indicative onshore construction programme scenarios.

5.3.1 Key Project Characteristics

37. This section summarises the key characteristics of the offshore, landfall and onshore project design which are described further in sections 5.4, 5.5, 5.6 and 5.7. As outlined in section 5.1 two different scenarios are being assessed, where the key characteristics differ between scenarios this is stated.

38. The key offshore components of the project would comprise:

- Offshore wind turbines and their associated foundations;
- Scour protection around foundations as required;
- Offshore electrical platforms supporting required electrical equipment, and possibly incorporating offshore facilities (e.g. accommodation).
- An offshore service platform to house workers offshore and / or provide helicopter refuelling facilities as required;
- Subsea cables comprising;
    - Array cables: These cables connect wind turbines with each other and with offshore electrical platforms;
    - Interconnector cables: These cables provide interconnections between the offshore electrical platforms within the Norfolk Boreas site;
    - Project interconnectors: These cables connect an offshore electrical platform or turbines located within the Norfolk Boreas site with an electrical platform located within one of the Norfolk Vanguard OWF sites;
    - Offshore export cables: These cables join the offshore electrical platforms with the landfall area;
    - Cable protection on subsea cables as required; and
    - Communications cables which may be installed along with some or all of the electrical cables.
- Meteorological masts (met masts) and their associated foundations for monitoring wind speeds during the operational phase (additional to existing met masts within the former East Anglia Zone);

- Monitoring equipment including Light Detection and Ranging (LiDAR) and wave buoys; and
- A number of Navigational buoys around the Norfolk Boreas site which will be determined in consultation with the Maritime and Coastguard Agency (MCA) and Trinity House.

39. The landfall works would comprise:

- Up to two ducts installed under the cliff by Horizontal Directional Drilling (HDD). An additional drill is included in the impact assessment worst case scenarios where applicable, to provide a contingency in the unlikely event of a HDD failure; and
- Up to two onshore transition pits to house the connection between the offshore cables and the onshore cables.

40. The key onshore components of the proposed project would comprise:

- Ducts installed underground to house electrical and communication cables;
    - Under Scenario 1 ducts would be installed during construction of Norfolk Vanguard; and
    - Under Scenario 2 ducts would be installed as part of Norfolk Boreas.
- Onshore cables installed within ducts;
- Trenchless crossing points at certain locations (see section 5.7.2.4 and Figure 5.4) such as some roads, railways and sensitive habitats (e.g. rivers of conservation importance): These would be installed by Norfolk Vanguard under Scenario 1 and Norfolk Boreas under Scenario 2;
- Temporary construction compounds and mobilisation areas;
- An onshore project substation and associated onshore 400kV cables; and
- Extension works at the Necton National Grid substation including:
    - Extension of the existing National Grid substation to accommodate the grid connection for Norfolk Boreas; and
    - Modification of the existing overhead lines in the vicinity of the Necton National Grid substation: Only required under Scenario 2 as under Scenario 1, Norfolk Vanguard would have completed this work.

5.4 Offshore

5.4.1 Offshore Infrastructure Summary

41. Table 5.3 outlines the key characteristics of the offshore elements of the project. These are discussed in more detail separately within the text.

Table 5.3 Offshore project characteristics

Parameter	Characteristic
Export capacity	Up to 1,800MW
Lease period	50 years
Indicative construction duration	3 years (preceded by up to 1 year pre-construction work)
Anticipated design life	Approx. 30 years
Number of wind turbines	Between 90 and 180 turbines ranging from 10MW to 20MW.
Norfolk Boreas site area	725km^2
Offshore cable corridor area	226km^2
Project interconnector search area	276km^2
Water depth Norfolk Boreas site (LAT)	20.4m and 42.8m
Distance from Norfolk Boreas site to shore (closest point of site to the coast)	73km
Maximum number of export cables	Four (laid as pairs in two trenches)
Maximum turbine rotor diameter	303m
Maximum hub height above highest astronomical tide (HAT)	198.5m
Maximum tip height above HAT	350m
Maximum offshore cable corridor length	100km
Maximum length of export cables	500km (400 within the offshore cable corridor and 100 within the Norfolk Boreas site)
Maximum total export cable trench length	250km (Based on a total of 4 cables, with cables laid in pairs)
Maximum array cable length	600km
Maximum number of interconnectors (between platforms located within the Norfolk Boreas site).	3 (a pair of HVDC cables in one trench and a single AC cable in a second trench)*.
Maximum number of project interconnectors (between an offshore electrical platform or turbines within the Norfolk Boreas site and an electrical platform within the Norfolk Vanguard site)	10 (a pair of HVDC cables in one trench and a single AC cable in a second trench and 8 AC cables (see section 5.4.12 for further detail) *.
Maximum length of interconnector cable trenching (which would be installed within the Norfolk Boreas site)	90km (a pair of HVDC cables in one trench and a single AC cable in a second trench. Therefore 60km of trench)*.

Parameter	Characteristic
Maximum length of project interconnector cable installed within the project interconnector search area	120km of cable A maximum of 92km of cable trench*.
Minimum turbine clearance above sea level	22m (Mean High Water Springs)
Indicative minimum and maximum separation between turbines	In row and inter row spacing 720m to 6060m
Wind turbine foundation type options	• Piled monopile; • Suction caisson monopile; • Piled tripod or quadropod; • Suction caisson tripod or quadropod; • Gravity Base; and • TetraBase
Maximum number of met masts	Up to two
Maximum height of met masts above Highest Astronomical Tide (HAT)	200m
Met mast foundation type options	• Piled monopile; • Suction caisson monopile; • Piled tripod or quadropod; • Suction caisson tripod or quadropod; and • Gravity Base.
Maximum number of offshore electrical platforms	Up to two
Maximum number of offshore service platforms	One
Topside maximum height of offshore electrical platforms above HAT	100m
Topside maximum height of offshore service above HAT	100m
Offshore platform (electrical and accommodation) foundation type options	• Six legged jacket -piled; • Six legged Jacket - suction caissons • Four legged jacket -piled • Four legged jacket suction caissons. • Gravity base
Buoys	• Up to two LiDAR, two wave buoys and a number (to be determined in consultation with the MCA and Trinity house post consent) of navigational buoys would be deployed.

* Either “Interconnector cables” would be installed or “project interconnector cables” would be installed. Under no scenario would both be required.

5.4.1.1 Maximum total footprints of all offshore structures

42. This section collates the total footprint for offshore infrastructure discussed in further detail throughout section 5.4.

5.4.1.1.1 Temporary construction footprint

43. Table 5.4 shows the reasonable worst case footprints associated with seabed preparation for foundation and cable installation within the Norfolk Boreas site.

Table 5.4 Total maximum area of disturbance/preparation in the Norfolk Boreas site during construction

Infrastructure	Worst Case Scenario type	Worst Case Scenario footprint (m^2)
Seabed preparation – turbines	180 x 10MW based on 40m diameter gravity foundation requiring an area 50m in diameter of seabed preparation.	353,429
Seabed preparation – offshore electrical platforms	2 platforms - based on approximate 75m x 100m preparation	15,000
Seabed preparation - offshore service platform	1 platform based on approximate 75m x 100m preparation	7,500
Seabed preparation - met masts	2 met masts – based on 40m diameter preparation area	2,513
Wave buoy	No seabed preparation required	
LiDAR	No seabed preparation required	
Array cable pre-sweeping/pre-grapnel run	Width 20m x 600,000m	12,000,000
Interconnector pre-sweeping/pre-grapnel run.	Width 20m x 60,000m*	1,200,000
Export cable pre-sweeping within the Norfolk Boreas site	Width 30m x 50,000m	1,500,000
Jack up vessel footprint - turbines	2 vessels per turbine – based on six-legged vessel with footprint of $792m^2$	285,120
Vessel anchor footprint	1 vessel anchoring per turbine – based on anchor footprint of $150m^2$ per vessel	27,000
Jack up vessel footprint – platforms and met masts	2 vessels per platform / met mast – based on six-legged vessel with footprint of $792m^2$	7,920
Potential boulder clearance in the Norfolk Boreas site**	5m diameter x 105 boulders x 2	4,123
Total disturbance footprint based on seabed preparation for foundations		**15,402,606**

* Should the project interconnector be required rather than this, it would result in a maximum of 40km of cable trenching within the Norfolk Boreas site rather than the 60km shown here.

** The area of disturbance as a result of lifting the boulder and the area of disturbance of the boulder being placed back on the seabed are also assessed

5.4.1.1.2 Offshore cable corridor temporary construction footprint

44. Table 5.5 shows the reasonable worst case temporary footprints associated with cable installation in the offshore cable corridor.

Table 5.5 Total area of disturbance/preparation in the offshore cable corridor during construction

Infrastructure	Worst Case Scenario type	Worst Case Scenario footprint (m^2)
Export cable pre-sweeping/pre-grapnel run	$360,000m^2$ of pre-sweeping in the offshore cable corridor based on analysis provided in Appendix 5.2	360,000 total footprint, of which $72,000m^2$ may be outside the footprint of the maximum cable installation disturbance width of 30m

Infrastructure	Worst Case Scenario type	Worst Case Scenario footprint (m^2)
Export cable installation	Based on 200,000m trench length x 30m disturbance width	6,000,000
Vessel anchor footprint during cable jointing	Four cable joints in total (two per cable pair)	600
Potential boulder clearance in the offshore cable corridor	5m diameter x 22 boulders	864
Total disturbance footprint based on seabed preparation and cable installation		**6,073,464**

* The area of disturbance as a result of lifting the boulder and the area of disturbance of the boulder being placed back on the seabed are also assessed

5.4.1.1.3 Project interconnector search area temporary construction footprint

45. Table 5.6 shows the reasonable worst case temporary footprints associated with cable installation in the project interconnector search area.

Table 5.6 Total area of disturbance/preparation in the project interconnector search area during construction

Infrastructure	Worst Case Scenario type	Worst Case Scenario footprint (m^2)
Project interconnector cable installation within the search area	Based on 92,000m trench length x 20m disturbance width	1,840,000
Vessel anchor footprint during cable jointing	Two cable joints in total (one per cable pair if solution (b) is used*)	300
Potential boulder clearance	5m diameter x 28 boulders	1,100
Total disturbance footprint based on seabed preparation and cable installation		**1,841,400**

* see section 5.4.12 for further detail

5.4.1.1.4 Norfolk Boreas site permanent footprint

46. Table 5.7 shows the reasonable worst case operational footprint associated with foundations and cable protection within the Norfolk Boreas site.

Table 5.7 Total long term infrastructure footprints in the Norfolk Boreas site

Infrastructure	Worst Case Scenario type	Worst Case Scenario footprint (m^2)
Worst case turbine footprint	10MW gravity base foundations with scour protection	5,654,867
Array cable protection	60,000m in the case where cables cannot be buried x 5m width; 100m cable length per turbine (x 180 turbines) x 5m width; 100m per crossing (x10 crossings) x 5m width	400,000
Interconnector cable protection	6000m surface laid x 5m width; 100m cable length per cable on approach to platform (× 4 cable approaches × 10m width)	34,000

Infrastructure	Worst Case Scenario type	Worst Case Scenario footprint (m^2)
Export cable protection	5000m surface laid x 5m width; 100m cable length per cable on approach to platform (× 2 cable approaches × 10m width)	25,500
Offshore electrical platforms	GBS with scour protection	35,000
Offshore service platforms	GBS with scour protection	17,500
Met masts	20m diameter at seabed with scour protection (7,854m^2per foundation)	15,708
Wave buoy	2 x floating with anchors	300
LiDAR	2 x monopiles + scour protection	157
Total operational footprint		**6,183,032**

5.4.1.1.5 Offshore cable corridor and project interconnector search area long term footprint

47. The maximum long term footprint associated with the cable protection for offshore export cables would be 0.23km^2 (see section 5.4.14) and the maximum long term footprint within the project interconnector search area would be 0.06km^2.

5.4.2 Wind Turbines

48. A range of 10MW to 20MW wind turbines is included in the project design envelope in order to future proof the DCO to accommodate foreseeable advances in wind turbine technology. For 1,800MW there could be up to 180 turbines or as few as 90 turbines (or any other configuration within this range).

49. Due to the large size of the Norfolk Boreas site and the fact that wind turbines may be installed in up to two phases, up to two different turbine models may be used across the project. It is likely that each phase of construction would only use one wind turbine model.

50. Each wind turbine would comprise a tubular steel tower atop a foundation structure, a nacelle secured at the top of the tower and a rotor with two or three blades rotating around a horizontal axis.

51. The basic turbine parameters anticipated for the project are shown in Plate 5.2 and Table 5.8.

Table 5.8 Wind turbine parameters

Item	10MW	15MW	20MW
Min lower blade tip above HAT (m)	22	22	22
Min hub height above HAT (m)	117	137	173.5
Max hub height above HAT (m)	142	162	198.5
Max upper blade tip above HAT (m)	237	277	350
Maximum rotor diameter	190	230	303
Maximum rotor swept area per turbine (m^2)	28,353	41,548	72,107
Max blade chord (m)	8	10	10
Mean blade chord (m)	3	4	4

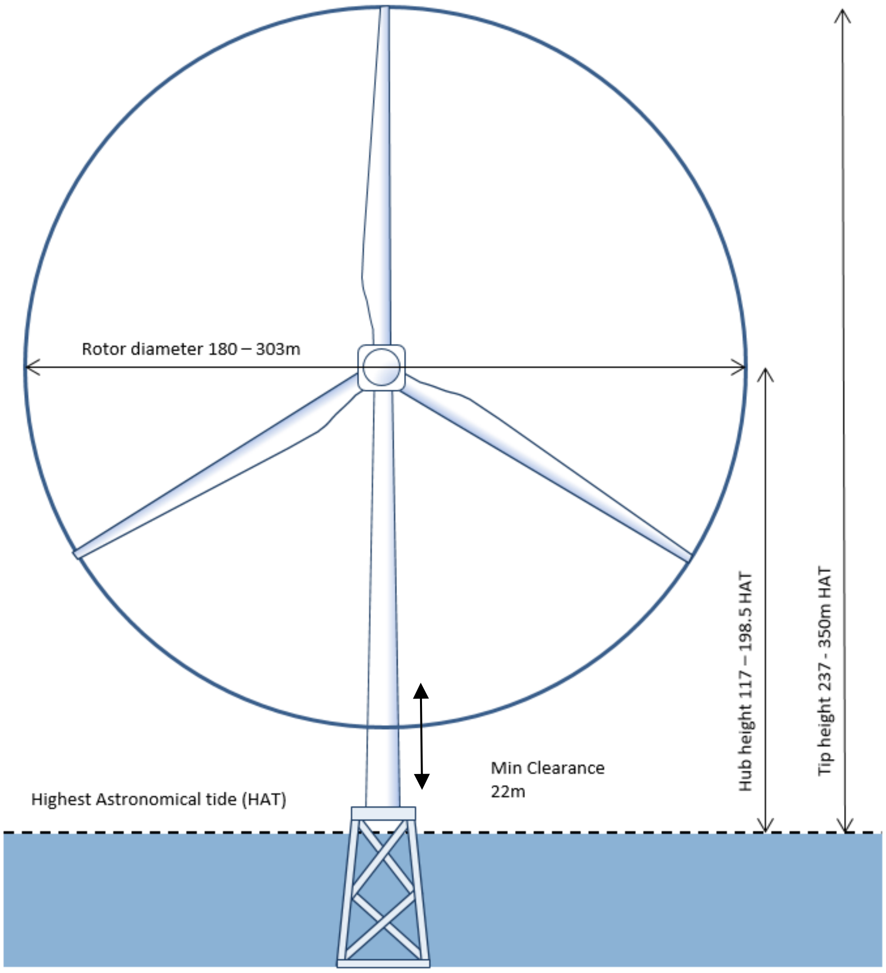

Plate 5.2 Schematic illustrating the maximum turbine dimensions

5.4.2.1 Wind turbine layout

52. A detailed design of the layout of the wind farm would be completed during the post-consent phase of the project. The final design will be informed by further wind

resource, geophysical, geotechnical studies and would be in line with navigational requirements.

53. To optimise energy output, detailed wake modelling would be undertaken which would consider possible layouts and different turbine models as well as wind conditions. Ideally the layout would be designed to ensure that the wind turbines would have laminar wind flow in front of the rotor disc. In the wake behind the rotor disc, the wind flow would be turbulent with wake effects detected up to 20 rotor diameters behind turbines.

54. The wind farm layout can only be described in general terms at this stage of the project. Table 5.9 provides the project design envelope for the typical distances between wind turbines; the in-row spacing is the distance separating turbines in the main rows, which would be orientated facing the prevailing wind, or as close to this as is practical and inter-row spacing is the distance between the main rows. In-row spacing and inter-row spacing may vary across the wind farm sites.

55. Some areas of the offshore wind farm sites would be likely to remain undeveloped due to constraints such as ground conditions or to allow for wake recovery.

Table 5.9 Spacing between wind turbines

Item	Distance between wind turbines (D = rotor diameters)	Equivalent distances (m)
In-row spacing	4D to 7D	720 to 2121
Inter-row spacing	4D to 20D	720 to 6060

56. The project could be constructed in either two phases (section 5.4.15) or one continuous construction phase (up to a maximum export capacity of 1,800MW). Section 5.4.15 outlines the indicative offshore construction programmes, with an anticipated construction duration of up to three years, preceded by nearly a year of preconstruction works.

5.4.2.2 Installation process

5.4.2.2.1 Pre-installation works

Pre-construction surveys

57. Pre-construction surveys would be undertaken in advance of any foundation installation works to plan any necessary micrositing, clearance operations and sandwave levelling.

UXO clearance

58. A pre-construction UXO survey would be undertaken and the results would inform micrositing where possible and/or identify any requirement for UXO clearance. Norfolk Boreas Limited has reviewed the 2017 geophysical survey data from the site

and estimated up to 30 clearance operations could be required in the Norfolk Boreas site and 28 within the offshore cable corridor. Appendix 5.3 provides a review of typical UXO items which may be found in the Norfolk Boreas offshore project area.

Boulder clearance

59. Pre-construction surveys would identify any requirement for boulder clearance. Norfolk Boreas Limited has reviewed the Fugro (2016; 2017, unpublished) geophysical survey data to assess presence of boulders. Given the low numbers of boulders in the offshore project area, it is likely that micrositing around these would be possible. However, an estimate of clearance of up to 105 boulders within the Norfolk Boreas site, 22 within the project interconnector search area and 22 within the offshore cable corridor of up to 5m in diameter has been included in the assessments in order to be conservative. Boulders would be relocated within the offshore project area. The assessment includes an area of impact for the boulder being removed from the seabed as well as an area of impact for the boulder being replaced on the seabed.

Pre-sweeping

60. Some foundation types may require sandwaves to be levelled in order to provide a flat area on which to place the foundation. This would be achieved by dredging material from the seabed prior to installation, termed ‘pre-sweeping’. The potential requirement for each foundation type is described throughout section 5.4.3.

Topside installation

Transport

61. The nacelle and turbine blades could both be transported to site and installed by an installation vessel or transported on a barge where they would be lifted off and then installed via a separate installation vessel.

Construction

62. The components would be lifted into position on an already installed foundation. The installation of the wind turbines would typically involve multiple lifting operations, with up to four tower sections erected, followed by the nacelle with pre-assembled hub, and then the blades. The installation would typically take 1 day if there are no weather delays. The installation vessel would either be of a heavy lift jack-up vessel type or anchored floating vessel type.

63. Traditional installation methods consist of tower segments lifted in place and bolted together, with the hub and nacelle conjoined in the case of single blade installation.

64. Although not current practice, it is possible that wind turbines (nacelle, blades and tower) could be fully assembled and commissioned onshore and transported to site

as a single unit installation. This method is being explored by the wind industry but it is not possible to commit to this method as it is not technically proven at this stage.

Electrical connection

65. Section 5.4.13.2.5 describes the process for connecting electrical cables to the turbines.

5.4.3 Foundations

66. There are many possible foundation types currently available or under design to support offshore wind turbines and/or offshore platforms. For the project design envelope the following have been considered:

- Quadropod and tripod (Plate 5.4)- jacket foundations with either three or four feet attached to the seabed with either 3 or 4 suction caissons or piles;
- Suction caissons (Plate 5.5)– cylindrical tubes which are installed by reducing the pressure inside the tube to draw the caisson into the seabed;
- Monopiles (Plate 5.6) – large cylinders which are hammered into the seabed;
- Gravity base structures (Plate 5.3) – which rely on the weight of the structure to anchor it to the seabed; and
- Tension leg floating foundations (Plate 5.7 and Plate 5.8) – a floating platform which is attached to the seabed by taut mooring lines to a gravity anchor or up to four suction caissons or piled anchors.

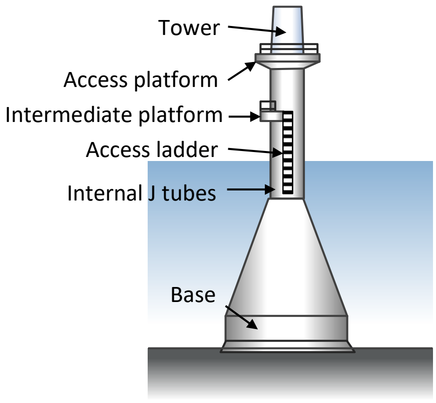

Plate 5.3 Typical gravity based structure

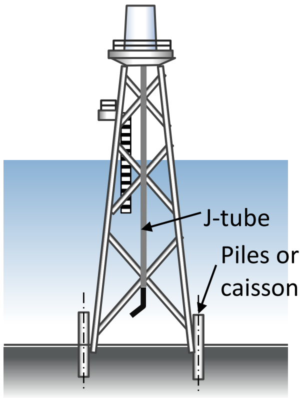

Plate 5.4 Typical jacket structure

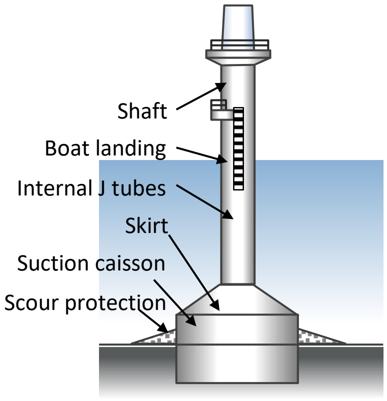

Plate 5.5 Typical suction caissons

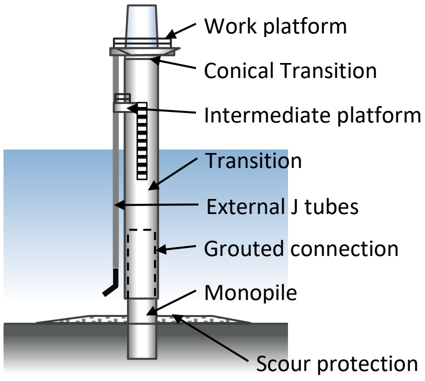

Plate 5.6 Typical monopile structure

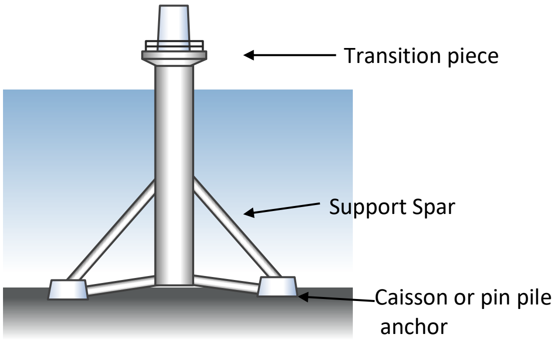

Plate 5.7 TetraBase foundation concept

[1] Plate 5.3 to Plate 5.7 are illustrative examples of the typical foundations currently in use within the industry; different designs are possible for each type of foundation within the envelope of parameters described in this chapter.

67. There could be more than one type of foundation installed for the project. The foundation type used would be determined by a number of constraints including: ground conditions, water depths, turbine model used, wind conditions and market options.

68. The foundations would be manufactured onshore and most likely delivered to site as a fully assembled unit with all ancillary structures attached. However, there are currently different logistical approaches being explored within the industry.

69. Fabrication / construction methods and requirements would depend on the foundation type selected.

5.4.3.1 Quadropod and tripod foundations

70. There are many different variants of the jacket structure (Plate 5.4) but those being considered for the project are:

- Pre-piled or post-piled;
- 3-legged or 4-legged;

- Straight or battered legs; and
- Pin piled or suction caisson.

71. Potential pin pile and suction caisson dimensions are outlined in Table 5.10. All parameters provided are based on a quadropod; tripods would have the same parameters with one less pile/caisson per foundation.

72. Pile penetration depths of up to 70m below the seabed may be required. Based on the geophysical and geotechnical studies (Fugro 2016; 2017, unpublished) it is considered likely that piles could be driven into the seabed at all locations, however in some locations there is a possibility that drilling may be required. For the purposes of this assessment it has been assumed that drilling could be required at up to 50% of the foundation locations. This is considered a very precautionary approach as the data indicates this would be far less. Other techniques, such as vibration piling, are also being considered. Piles are usually installed vertically but concepts are being considered that install piles at an angle (up to 45 degrees). This would be confirmed post consent on receipt of more detailed geotechnical information. The maximum hammer energy used to install the pin piles would be 2,700 kilojoule (kJ) and the maximum volume of drill arising from one quadropod installation is discussed in section 5.4.3.1.4.

73. Suction buckets could be used to anchor the jacket foundation instead of pin piles. These would be of greater diameter than the usual jacket piles but would require no pile driving.

Table 5.10 Dimensions for pin pile foundations (based on quadropod)

Wind turbine size (MW)	Maximum seabed diameter (m)	Maximum penetration (m)	Maximum footprint on the seabed (excluding scour protection) (m^2)	Maximum area of scour protection per foundation (incl. structure footprint area) (m^2)
Piles				
10	3	70	28	706.9
20	5	70	78.5	1,964
Suction caissons				
9	12	12	452	11,310
20	15	15	707	17,672

5.4.3.1.1 Material requirement for jacket foundations

74. Jacket foundations would comprise mainly steel. However, it is possible that some secondary structures, such as handrails, gratings and ladders, could be produced using other metals, such as aluminium, or composites. Concrete could also be used at the top of the jacket structure as part of a transition piece arrangement or to form the working platform and furthermore, the connection between the jacket structure and piles is often formed using cement grout.

5.4.3.1.2 Seabed preparation and penetration for jacket foundations

75. The majority of jacket foundations would not require any seabed preparation. However, depending on the jacket concept and installation method selected, there might be some requirement to carry out minor seabed levelling at some locations; this would be to provide a more level formation for placement of a pile installation template. The template can accommodate small inclinations but some dredging may be required to accommodate installation in areas with steeper slopes. The volume and area impacted by seabed preparation would be significantly less than that for a gravity base foundation (see section 5.4.3.3.2). Sediment disposal is discussed in section 5.4.3.1.6.

5.4.3.1.3 Installation method of jacket foundations

76. For jacket foundations, the piles could be pre-piled (piles driven first and then the foundation installed over the top) or post-piled (piles driven through sockets in the foundation). It is anticipated that piles would generally be driven but alternative installation techniques, such as drilling or vibration, may be required depending on ground conditions. Drill arisings, should drilling be used are detailed in section 5.4.3.1.3. Should alternative techniques be incorporated (e.g. vibration), the parameters associated with the worst case scenarios (e.g. noise, duration and drill arisings), would be within those detailed for drilling and pile driving.

77. For pre-piled jackets, the overall installation methodology would typically be as follows:

- Piles and pile installation template transported to site via barge (or by installation vessel);
- Jack-up rig (alternatively a floating vessel) with pile installation equipment and heavy craneage set up at pile installation;
- Pile installation template placed on seabed;
- Piles placed on seabed and driven to depth;
- Pile installation template removed and installation vessel demobilised;
- Installed pile locations surveyed and jacket dimensions adjusted (if required);
- Delivery of jacket to site via barge (or by installation vessel);
- Lifting of jacket onto piles via floating heavy lift or jack-up vessel; and
- Levelling of jacket, grouting and/or or mechanical locking of jacket-to-pile connections.

78. For post-piled jackets, the sequence would typically be as follows:

- Jacket and piles transported to site via barge (or by installation vessel);
- Jack-up rig (alternatively floating vessel) with pile installation equipment and heavy craneage set up at jacket installation location;
- Seabed preparation carried out if required;

- Lifting of jacket from barge and lowering onto seabed;
- Lifting of piles from barge and stabbing into sleeves on jacket;
- Piles driven to depth;
- Levelling of jacket via jacking off piles; and
- Grouting and/or mechanical locking of jacket to pile connections.

5.4.3.1.4 Drill arisings

79. Pin piles may be driven, drilled or drilled-driven into the seabed. As previously described, it is estimated up to 50% of the locations could need drilling if these foundation options are chosen. The maximum quadropod drill arisings for 1,800MW would be approximately 176,670m^3, based on 45 x 20MW quadropod foundations with 5m drill diameter and 50m penetration. Sediment disposal is discussed in section 5.4.3.1.6.

5.4.3.1.5 Piling

80. A drivability assessment would be conducted at the post-consent phase when further information is available regarding the ground conditions to determine the required piling requirements (e.g. hammer energy, blow rate). At this stage it is estimated that the maximum hammer energy used for pin pile installation would be 2,700kJ. A soft start (gradual ramping up of hammer energy over consecutive blows) procedure, starting with a hammer energy of approximately 10% of the maximum energy and taking one hour to ramp up to the maximum energy would be employed using approximately 15 hammer blows per minute. Once the soft start procedure is complete hammer blows would be a maximum of 30 per minute totalling a maximum of 9,000 strikes over 6 hours, with an installation time of 1 hour 30 minutes for each pin-pile.

81. The maximum predicted time for installation of a piled quadropod foundation is 12 hours for the largest, 5m diameter pin piles (with a six hour predicted as an average) or 6 hours for the 3m diameter pin pile (with a three hour predicted average).

5.4.3.1.6 Spoil removal and disposal for jacket foundations

82. If seabed preparation or drilling is required these would generate some spoil material that would require disposal. It is proposed the spoil would be disposed of within the Norfolk Boreas site, with the spoil subsequently winnowed away by the natural tide and wave driven processes (see Chapter 8 Marine Geology, Oceanography and Physical Processes).

5.4.3.1.7 Scour protection for jacket foundations

83. Depending on metocean conditions scour protection may be required around the foundations to protect against currents and waves that may cause erosion of the seabed. An estimate of the total footprint of the scour protection is shown in Table 5.10.

84. Scour protection would comprise quarried rock, well graded with d_{50}=200 to 400, (i.e. half the stones would be less than a specified median (200 to 400mm diameter) and half would be greater). The quantities and extent of scour protection would be dependent on current speed, sediment type and the foundation details; however a conservative estimate of five times the foundation diameter is included within the Project Design Envelope.

85. Alternative scour protection solutions such as 'frond systems' are also being considered. These comprise continuous lines of overlapping buoyant polypropylene fronds that when activated create a viscous drag barrier that significantly reduces current velocity. The frond lines are secured to a polyester webbing mesh base that is itself secured to the seabed by anchors pre-attached to the mesh base by polyester webbing lines. Grouted mattresses are also being considered.

5.4.3.2 Monopile foundations

86. Monopile foundations comprise a steel cylindrical pile and a steel cylindrical transition piece (Plate 5.6). Conical transitions are sometimes used to reduce the diameter of the structure at the top of the foundation.

87. The worst case dimensions considered for monopile foundations are provided in Table 5.11.

Table 5.11 Monopile dimensions

Wind turbine size (MW)	Maximum seabed diameter (m)	Maximum penetration (m)	Maximum footprint on the seabed (excluding scour protection) (m^2)	Maximum area of scour protection per foundation (incl. structure footprint area) (m2)
10	10	50	79	1,963
20	15	50	177	4,418

5.4.3.2.1 Material requirement for monopiles

88. Monopile foundations usually comprise mainly steel. However, it is possible that some secondary structures, such as handrails, gratings and ladders, could be produced using other metals, such as aluminium, or composites. Also, concrete could be used to form the working platform.

5.4.3.2.2 Seabed preparation for monopiles

89. Monopiles would be positioned to avoid or reduce seabed preparation where possible; however where sand waves are present the seabed might need to be levelled first by excavation to the trough of the sand wave. The worst case assumption is that excavation to 5m depth could be required. The worst case excavation volumes for monopiles are predicted to be significantly less than those

required for gravity base foundations which are provided in Table 5.12. Sediment disposal is discussed in section 5.4.3.2.7.

90. Dependent on the nature of the metocean conditions and final monopile design, it may be necessary to install scour protection around the base of the foundation. It is likely that if scour protection would be required for monopile foundations a filter layer would be installed first which would then be piled through. The scour protection works are likely to be installed by a dynamically positioned stone dumping vessel equipped with a fall pipe.

5.4.3.2.3 Installation method for monopiles

91. The installation of steel monopile foundations would typically consist of the following key stages:

- Prepare seabed (if necessary) prior to installation;
- Confirmation investigation of seabed to ensure no obstructions are present;
- Delivery of steel monopiles and transition piece to site via barge or by installation vessel. It may also be possible to tow floated piles to site using tugs;
- Mobilisation of jack-up rig (alternatively floating vessel) with heavy craneage at installation location. It may also be necessary to mobilise a support vessel;
- Monopile upended by crane to vertical position;
- Monopile lowered to seabed;
- Locating of driving hammer onto top of pile using craneage, and monopile driven to required depth. Where ground conditions are difficult, it may also be necessary to carry out drilling using drilling equipment operated from the installation vessel before completing the driving;
- Lifting of transition piece on to top of monopile using craneage from installation vessel, levelling of transition piece and grouting of connection; and
- Installation of scour protection.

5.4.3.2.4 Drill arisings

92. Monopiles may be driven, drilled or drilled-driven into the seabed. As previously discussed, it is estimated up to 50% of the locations could need drilling if these foundation options are chosen. The maximum amount of monopile drill arisings for 1,800MW would be approximately 397,608m^3, based on 45 x 20MW monopile foundations with 15m drill diameter and 30m penetration. Sediment disposal is discussed in section 5.4.3.2.7.

5.4.3.2.5 Piling

93. A drivability assessment would be conducted at the post-consent phase when further information is available regarding the ground conditions to determine the required piling requirements (e.g. hammer energy, blow rate). At this stage it is estimated that the maximum hammer energy used for monopile installation would

be 5,000kJ for the largest 15m diameter monopiles. A soft start (gradual ramping up of hammer energy over consecutive blows) procedure, starting with a hammer energy of approximately 10% of the maximum energy and taking one hour to ramp up to the maximum energy would be employed using approximately 15 hammer blows per minute. Once the soft start procedure is complete hammer blows would be a maximum of 30 per minute totalling a maximum of 10,350 per foundation (average 6,000 per foundation). The maximum predicted time for installation of a monopile foundation is six hours (with a three hour predicted average).

5.4.3.2.6 Spoil removal and disposal for monopile foundations

94. If seabed preparation or drilling is required these would generate some spoil material that would require disposal. It is proposed the spoil would be disposed of within the Norfolk Boreas site (see Chapter 8 Marine Geology, Oceanography and Physical Processes).

5.4.3.2.7 Scour protection for monopile foundations

95. Dependent on the specific conditions and design, the total extent of the scour protection is estimated to be approximately five times the pile diameter. The maximum area that would be occupied by this material is provided in Table 5.11.

96. The types of scour protection being considered for monopile foundations would be the same as those considered for jacket foundations as described in section 5.4.3.1.7. The predicted area of scour protection is provided in Table 5.11.

5.4.3.3 Gravity base structures

97. There are many possible shapes and sizes of gravity base foundations currently on the market or in design. A typical foundation comprises a base, a conical section and a cylindrical section. One of the main factors affecting size is whether the structure would be transported on a barge or vessel and lifted into place or whether it would be floated or semi-floated with the assistance of a barge/pontoon to site. The buoyant structures are significantly larger in size.

98. The base would be hexagonal, octagonal or circular. Bases with a cruciform plan shape may also be considered and occupy a similar footprint.

99. The base would be between one and 12m high, depending on the design. It is likely that the shaft would be cone shaped at the bottom, tapering to a cylinder at the top (Plate 5.3) with an outer diameter of approximately 5 to 9m.

100. Some alternative gravity base concepts do not have a cone transition, just a cylindrical shaft, with an outer diameter of approximately 5 to 9m. The bases of these flat base gravity structures are much higher, typically up to 20m, but the footprint sizes are similar and within the same project design envelope.

101. Gravity base structures might also use a skirt at their base which penetrates the seabed giving more stability to the structure. The penetration could vary from around 0.1 to 5m. Under base grouting may also be used to strengthen the sediment beneath the foundation and fill small voids.

102. The maximum estimated footprint sizes at the seabed for gravity base foundations are outlined in Table 5.12.

Table 5.12 Gravity base structure and seabed preparation dimensions

Wind turbine size (MW)	Maximum gravity base diameter (m)	Maximum seabed preparation diameter (m)	Maximum footprint per base (m^2)	Maximum seabed preparation area (m^2)	Maximum volume of excavation* (m^3)
10	40	50	1,257	1,963	9,817
20	50	60	1,963.5	2,827	14,137

* required for seabed levelling

5.4.3.3.1 Material requirement for gravity base structures

103. Gravity base structures are generally concrete with steel reinforcement. They are produced in a large range of sizes, depending on design, water depths and whether the structure is intended to be buoyant during installation. There are also hybrid concepts that include a steel tower.

104. Secondary structures, such as handrails, gratings, fenders and ladders, would be produced using steel (or possibly another metal or composite material). The working platform could also be made from steel.

105. The ballast material is most likely to be sand dredged local to the site depending on the suitability of the material.

106. Some gravity base structure solutions require an injection of a cement grout mix under the foundation to strengthen the soil and/or fill voids. If underbase grouting is used, it is estimated up to 75m^3 of cement grout could be required per foundation.

5.4.3.3.2 Seabed preparation and penetration for gravity base structures

107. Gravity base structures may require seabed preparation to level the seabed, provide a base with adequate bearing capacity and to ensure adequate contact between the foundation base and seabed.

108. Sand waves of varying size are known to be present across the offshore project area of varying magnitude. Gravity base structures are not suitable in areas of very large and mobile sand waves but they could be used in areas where smaller sand waves are present. At these locations the seabed may need to be excavated to the trough of the sand wave and the underside of the base would be placed at this level on a bedding layer.

109. At some locations, excavation of upper sediments may be required to reach a competent formation level.

110. Seabed preparation would consist of dredging works and the installation of a bedding and levelling layer. The dredging works would be likely to be carried out using a trailer suction hopper dredger. The bedding and levelling layer installation would be undertaken by a fall pipe vessel. Sediment disposal is discussed in section 5.4.3.3.4.

111. Gravity base structure foundations would likely be installed where no, or little ground preparation is required and micro-siting would be used to minimise any dredging requirements. However, the worst case scenario envisaged is an excavation to level an area of sand waves up to 5m in depth, with estimated reasonable worst case volumes as provided in Table 5.12.

5.4.3.3.3 Installation method of gravity base structures

112. Gravity base structures would be delivered to site via one of two methods, depending on the foundation design:

- Floating, towed to site and sunk via ballasting; or
- Traditional, transported to site by barge and installed by heavy lift crane.

113. For the floating structures, a bespoke barge would be used to support the foundation during its journey to site. For the traditional solution, it is likely that a heavy lift vessel would be required to perform the installation. This could be a jack-up or floating vessel.

114. The installation of gravity base structures is heavily dependent on design and fabrication methods and definitive methodology for installation.

115. The overall installation methodology would typically be as follows:

- Prepare seabed (if necessary, see section 5.4.3.3.2);
- Gravity base structure transported to site via barge or floated to site, hauled by tugs;
- Mobilise heavy lift floating crane (if foundation is a non-buoyant solution);
- Lift foundation from barge and lower to prepared area of seabed, or adjust buoyancy of floating foundation and sink to prepared area of seabed;
- Install backfill as necessary; and
- Install scour protection (likely to be rock dumping).

116. Backfilling works, if required, could be undertaken by a trailer suction hopper dredger. The scour protection works are likely to be installed by a dynamically positioned stone dumping vessel equipped with a fall pipe. The scour materials would be placed in one or multiple layers.

5.4.3.3.4 Spoil removal and disposal for gravity base structures

117. For gravity base structures, it is possible that greater seabed preparation would be required. Again, this is dependent on the nature of the ground conditions present underneath the bases (for example, if sand waves are present). In extreme cases, it may be necessary to remove material up to a depth of up to 5m.

118. Examples of amount of materials requiring excavation are given in sections above. In these examples it would be preferable to use some of this material as backfill or potentially ballast within the foundation, but in an extreme case all of it may need to be removed if it is unsuitable for backfilling. The dredged sand would be deposited within the Norfolk Boreas site.

5.4.3.3.5 Scour protection for gravity base structures

119. As with jacket foundations, scour protection might be required, that would typically consist of quarried rock. An estimate of the total footprint of the scour protection and is shown in Table 5.13.

120. More scour protection would be needed when the base is buried at depth due to sand waves and scour protection could extend to cover 5 times the diameter of the base. The maximum estimated area of scour protection required per foundation is provided in Table 5.13.

Table 5.13 Wind turbine gravity base structure and scour protection footprints

Wind turbine size (MW)	Gravity base diameter (m)	Total area of scour protection (m^2)*	Rationale for scour protection
10	40	31,416	5 × diameter (40m) around foundation
20	50	49,087	5 × diameter (50m) around foundation
Total maximum across the wind farm site		5,654,867	180 × 31,416m^2 = 5,654,867 m^2 *or* 90 × 49,087m^2 = 4,417,830m^2

* This includes the area which would be occupied by the foundation as well as the scour protection.

121. The scour protection is likely to be installed by a dynamically positioned stone dumping vessel equipped employing a fall pipe. The scour materials would be placed in one or multiple layers.

122. Alternative methods of installing scour protection, such as grouted mattresses, are also under consideration.

123. If this foundation type is adopted, further work would be undertaken post consent to determine the extent of scour protection required

5.4.3.4 Suction caisson foundations

124. The use of suction caisson foundations in the offshore wind industry is a relatively new concept and was first commercially used for VWPL's Aberdeen offshore wind farm project which is currently nearing the end of construction. The technology is however well advanced in the oil and gas industry as an alternative to piles.

125. Suction caissons comprise a steel cylindrical tower (the shaft) with cylindrical skirt, which penetrates into the seabed (Plate 5.5). A single caisson monopile could be used or a jacket with three (tripod) or four (quadropod) suction caissons.

126. The base height of the skirt above seabed is typically 5m or more, although it may be possible to install it below seabed to reduce scour effects.

127. Table 5.14 shows the dimensions for monopile suction caissons and scour protection footprints (see Table 5.10 for suction caisson quadropods).

Table 5.14 Suction caisson monopile dimensions footprints

Wind turbine size (MW)	Suction bucket diameter	Penetration depth (m)	Total area of scour protection (m^2)*	Rationale for scour protection
10	25m	15	12,272	5 × diameter (25m)
20	35m	30	24,053	5 × diameter (35m)

* This includes the area which would be occupied by the foundation as well as the scour protection.

5.4.3.4.1 Material requirement for suction caisson foundations

128. Suction caisson foundations would comprise a mainly steel structure with some secondary structures, such as handrails, gratings and ladders, made of metals, such as aluminium, or composites. Also, concrete could be used to form the working platform.

5.4.3.4.2 Seabed preparation and penetration for suction caisson foundations

129. In areas where the seabed is level, the suction caisson foundation may not require significant seabed preparation. However, measures may be required in areas in which sand waves are present to provide a level formation for the installation and to allow scour protection to be later placed around the foundation. It is possible that excavation to the trough of the sand wave would be necessary before installing the suction caisson. Based on the assumption that the skirt is buried, a worst case excavation volume (5m in depth) has been estimated. The worst case excavation volumes for suction caissons are predicted to be significantly less than those required for gravity base foundations which are provided in Table 5.12. It is proposed the spoil would be disposed of within the Norfolk Boreas site.

5.4.3.4.3 *Installation method for suction caisson foundations*

130. Suction caisson foundations are most likely to be towed to site by tugs as they are designed to be buoyant. The caisson skirt and shaft are generally delivered and installed as a single part.

131. The overall basic installation methodology would typically be as follows:

- Prepare seabed (if necessary) prior to installation;
- Confirmation investigation of seabed to ensure no obstructions are present;
- Suction caisson foundation towed to site via barges;
- Suction caisson foundation is ballasted and lowered to seabed;
- Initial penetration occurs under foundation self-weight;
- Pumps are attached to caisson and water evacuated. Typically, there are a number of chambers within the caisson in order to implement a controlled installation and to control levels. Sometimes water jetting is used at the tip of the skirt to facilitate penetration;
- Install backfill as necessary; and
- Install scour protection (likely to be rock dumping).

5.4.3.4.4 *Scour protection for suction caisson foundations*

132. The types of scour protection being considered for suction caisson foundations would be the same as those considered for jacket foundations, as described in section 5.4.3.1.7. The predicted area of scour protection is provided in Table 5.11.

5.4.3.5 TetraBase foundations

133. TetraBase foundations are being considered for the project due to their advantages in fabrication and installation. This foundation type which consists of tripod shaped frame (Plate 5.7) could be anchored under its own weight or pin pile or suction bucket anchor variants can be applied when seabed conditions do not allow gravity anchoring. If gravity anchored the footprint would not exceed the dimensions used suction buckets.

134. The maximum dimensions of the TetraBase foundation are provided in Table 5.15.

Table 5.15 Tetrabase foundation dimensions

Wind turbine size (MW)	Maximum Diameter at seabed (m)	Maximum penetration (m)	Maximum footprint on the seabed (excluding scour protection) (m^2)	Maximum area of scour protection per foundation (incl. structure footprint area) (m^2)
Piled option				
10	3	70	28	706.9
20	5	70	78.5	1,964
Suction caisson option				
10	12	12	452	11,310
20	15	15	707	17,672

5.4.3.5.1 Fabrication

135. Fabrication of the TetraBase foundation would be modular, in that all components would be factory-made with no special processes (welding, painting, etc.) outside factory environment. They could also be assembled at quayside, similar to turbine assembly. If this approach was taken the process would be fast and would involve assembly in the port of embarkation. No facilities at the quayside would be needed other than a flat area.

5.4.3.5.2 Seabed preparation for TetraBase foundations

136. It is unlikely that TetraBase foundations would require any form of seabed preparation. However, depending on the ground conditions and anchor type selected (gravity, pin pile or suction bucket), there might be some requirement to carry out minor flattening at some locations; this would be to provide a more level area on which to install the foundation. The structure would be able to accommodate inclinations but some dredging may be required to cover areas with steeper slopes. The volume and area impacted by seabed preparation would be significantly less than that of a gravity base foundation (see section 5.4.3.3.2). Sediment disposal would be as discussed for Jacket foundations in section 5.4.3.1.6.

5.4.3.5.3 Installation method for TetraBase foundations

137. Scour protection requirements for this type of foundation are expected to be very similar to those identified for a Jacket foundation 5.4.3.1.7. An estimate of the total footprint of the scour protection is shown in Table 5.15.

138. TetraBase foundation installation methodology would be as follows:

- Easy launch using slip or semisubmersible barge;
- The turbine can be mounted in harbour and towed to site, i.e. there is no need for installation vessels, using land-based crane;
- No separate vessel mobilization for foundation installation, and no installation vessel required at any stage of the process;
- Pre-commissioning at quayside is possible;
- Easy towing to site using conventional vessels
- One-stop installation- foundation and turbine installed in one simple process;
- Gravity stabilised in most conditions – no piling required; and
- When piling is required, pin piles will be limited to three piles.

5.4.4 Offshore Platforms

5.4.4.1 Offshore electrical platforms

139. Up to two offshore electrical platforms would be located within the Norfolk Boreas site. At this stage of the project it is not possible to provide precise number or locations, since these would depend upon many factors such as wind turbine layout

design and the chosen electrical solution. Some of the power from Norfolk Boreas could be exported via an offshore electrical platform located within the Norfolk Vanguard OWF sites (see section Solution (b)5.4.12.2).

140. The electrical platforms within the Norfolk Boreas site would consist of a topside structure configured in a multiple deck arrangement. Decks would either be open with modular equipment or the structure could be fully clad. All weather sensitive equipment would be placed in environmentally controlled areas.

141. Of the three solutions discussed in section 5.4.12, solution (c) (section 5.4.12.3) represents the worst case scenario. This is due to the fact that the two platforms, although smaller, combine to create a greater footprint than the single platforms that would be required under the other two solutions (a) and (b).

5.4.4.1.1 Offshore electrical platform: foundation type and construction method

142. The electrical platforms would require bespoke foundations on which to place the topsides that contain the equipment outlined in Table 5.18. The dimensions provided are large enough to support any of the three size platforms under consideration. The following options for electrical platform foundation are being considered:

- Up to and including six legged jackets (piled or suction caisson).
- Multi-legged Gravity base

143. The Multi-legged gravity base option would be a self-installing structure, which would be towed to site and then the legs would be flooded or filled to sit on the prepared seabed. Piles may be used to minimise future movement. The footprint of this type of solution would be within the parameters described in Table 5.16 which provides the worst case parameters for offshore electrical platform foundations.

Table 5.16 Offshore electrical platform foundation dimensions

Parameter	Six-legged pin pile	GBS (multi-legged)
900MW offshore electrical platforms (two required within the Norfolk Boreas site)		
Maximum footprint per platform (m^2)	252 (based on 6 legs each requiring 3 pin piles of 5m diameter)	7,500 (based on approximately 75 x 100m)
Maximum penetration of drill depth (m)	20	N/A
Maximum drill arisings per platform* (m^3)	7,069	N/A
Maximum area of scour protection per platform (m^2)	1,060 (based on 5 x pile diameter)	17,500
Maximum area of scour protection for two platforms(m^2)	**2,120**	**35,000**
Maximum seabed preparation area per foundation (m^2)	Unlikely to be any	7,500

* should drilling be required

144. The construction methods used to install electrical platform foundations would be similar to those described for the wind turbine foundations described in sections 5.4.3.1 and 5.4.3.3.

5.4.4.1.2 Installation method

145. The foundation installation process for the offshore electrical platform options would be as described in sections 5.4.3.1.3 and 5.4.3.3.3.

146. The topsides could be installed using the following options:

- By a suitable crane vessel (or vessels working together) in a single lift;
- By a suitable crane vessel (or vessels working together) in separate lifts of deck and sub-modules;
- Using a rail-skid transfer from a large jack-up; or
- Self-installing.

5.4.4.1.3 Piling

147. Piling for offshore electrical platforms would be as described in section 5.4.3.1.5 with the following key parameters outlined in Table 5.17.

Table 5.17 Offshore electrical platform piling parameters

Parameter	Pin pile (six legged worst case)
Maximum diameter (m)	5
Maximum hammer energy (kJ)	2,700
Maximum seabed penetration (m)	70
Soft start hammer energy (kJ)	270
Ramp up	20mins at starting energy followed by 40min ramp up to maximum energy
Max number of blows per pile	300
Average number of blows per pile	200
Max piling time per foundation (assuming issues such as low blow rate, refusal, etc.) (hr)	27
Average 'active piling time' per foundation (hr)	12

5.4.4.1.4 Offshore electrical platform equipment

148. Table 5.18 includes a list of equipment which would be housed within the offshore electrical platforms.

Table 5.18 Indicative equipment of HVDC offshore electrical platform

Equipment
Power transformers
Switchgear: Low voltage, medium voltage and high voltage
Instrumentation, protection and control systems
Neutral earthing resistor
Standby generators
Fuel supplies
Auxiliary and uninterruptible power supply systems and transformers

Equipment
Emergency shelter
Craneage
Metering stations
Meteorological equipment
Helipad (optional)
Mess facilities
Cooling system
AC equipment such as phase reactors and AC filters
Alternating current (AC)/ direct current (DC) converter with switching devices: valves (typically IGBT's)
DC equipment, such as DC capacitors and DC filters and associated equipment

5.4.4.2 Oils and fluids in the offshore electrical platforms

149. Some of the equipment at the offshore electrical platforms would contain fluids. The following list covers the key types of fluids that would be required:

- Diesel for the emergency diesel generators (in diesel storage tanks);
- Oil for the transformers;
- Deionised water for the valves cooling system;
- Glycol;
- Sewage and grey water;
- Lead acid for UPS and batteries;
- Engine oil; and
- Sulphur hexafluoride (SF6)

150. To avoid discharge of oils to the environment, the electrical platforms would be designed with a self-contained bund to collect any possible oil spill. Any transfer of oil/fuel between the electrical platforms and service vessel would follow best practice procedures (further information is provided in Chapter 9 water and sediment quality). Procedures would also be put in place should there be a spill to the marine environment. To avoid discharge/spillage of oils it is anticipated that the transformers would be filled for their life and would not need interim oil changes.

151. Any oil spillage from the diesel tank or from the transformer would be collected in a separate oil waste tank. Both oil waste and other wastes (waste water etc.) would be brought to shore in a secure container and disposed according to industry best practice procedures.

152. All waste would be processed on the electrical platforms or transferred as required.

5.4.4.3 Offshore Service platform

153. An offshore service platform could be required to house construction and operation and maintenance personnel and equipment and / or provide refuge and refuelling facilities for operation and maintenance (O&M) helicopters if this is the chosen O&M strategy. This would require a foundation structure likely to be similar to that of the

offshore electrical platforms (section 5.4.4.1.1). Therefore, the maximum dimensions for a single platform are as provided in Table 5.16. The maximum predicted footprint of the foundation including scour protection would be 17,500m^2 and the maximum hammer energy used if piled foundations were used would be 2,700kJ.

5.4.5 Meteorological Masts

154. Up to two operational meteorological masts (met masts) could be installed within the Norfolk Boreas site, neither of which would exceed the hub height of a wind turbine generator (Table 5.8), however for the purposes of this ES the assumed maximum height of the metmast is 200m above HAT. The foundations used may be jacket, gravity base or monopile. The information provided in Table 5.19 illustrates the different size of foundation required to support met masts.

Table 5.19 Meteorological mast foundation dimensions

Parameter	Number/type
Number of met masts across the project	2
Type of foundation being considered	Jacket, gravity base, monopile
Maximum diameter at seabed per mast (m)	20
Total maximum footprint for both masts (m^2)	628
Total maximum footprint plus scour protection for both masts (m^2)	15,708
Maximum seabed preparation area for both masts (m^2)	2,513

5.4.6 Buoys

155. It is anticipated that up to two LiDAR and two wave buoys may be installed across the Norfolk Boreas site. These devices would be anchored to the seabed. The dimensions for wave and LiDAR buoys are provided in Table 5.20. There would also be the requirement for a number of Navigational buoys around the Norfolk Boreas site which would be determined in consultation with the Maritime and Coastguard Agency (MCA) and Trinity House.

Table 5.20 Wave and LiDAR buoy dimensions

Parameter	Wave buoy	LiDAR
Maximum Number installed across the project.	2	2
Max Elevation (m HAT)	5	25
Seabed attachment types	Floating with anchors	Floating with anchors, Monopile
Seabed footprint (per buoy)	Anchor footprint with scour protection approximately 79m^2	5m diameter with scour protection 157m^2

5.4.7 Ancillary Structures

156. Ancillary structures are likely to form part of the final design of the wind farm; however, the requirement and nature of these would be determined at the detailed design phase. Ancillary structures may include: temporary landing places, moorings

or other means of accommodating vessels in the construction and / or maintenance of the authorised development; buoys, beacons, fenders and other navigational warning or ship impact protection works; and temporary works for the benefit or protection of land or structures affected by the authorised development.

5.4.8 Underwater Noise

157. An assessment of the underwater noise levels that could be generated by the project is provided in Appendix 5.4 this includes modelling for a range of construction activates from piling to cable installation and operation noise associated with the turbines. An assessment of the potential noise generated by UXO detonation in the Norfolk Boreas site is provided in Appendix 5.5. This has been used in assessments of impacts of underwater noise created by potential UXO detonation within this ES (see chapters 12 Marine Mammals Ecology and Chapter 11 Fish and Shellfish Ecology).

5.4.8.1 Operational noise

158. An estimation of the underwater noise created by an operational turbine is provided in Appendix 5.4.

5.4.9 Airborne Noise

5.4.9.1 Installation and construction noise

159. Any noise stemming from the construction activities associated with turbine installation would be temporary and would be local to the Norfolk Boreas site.

5.4.10 Oils, Fluids and Effluents

160. Oils in the wind turbines would be biodegradable where possible. All wind turbines would have provision to retain all spilt fluids within nacelle/tower. The volume of oil and fluids will vary depending on wind turbine design, i.e. conventional design or gearless, whether one or two or more rotor bearings are used in the design and the amount of redundancy designed into the system.

161. All chemicals used would be certified to the relevant standard. A brief summary of usual oils and fluids in the systems of a typical wind turbine is provided in Table 5.21.

Table 5.21 Peak quantities for normal turbine operation

Parameter	10MW	20MW
Grease (litres)	1000	2000
Synthetic Oil / Hydraulic Oil (litres)	1000	2000
Nitrogen (litres)	100	200
Water/Glycerol (litres)	1000	2000
Silicone Oil - transformer option (kg)	1500	2000
SF6 gas - MV breaker option (kg)	50	100

5.4.11 Navigation Lighting Requirements and Colour Scheme

162. The wind farm would be designed and constructed to satisfy the requirements of the Civil Aviation Authority (CAA), MCA and Trinity House Lighthouse Service (THLS) in respect of lighting and marking. The following guidance and regulations would be considered (or as updated):

- International Association of Lighthouse Authorities (IALA) Recommendations 0-139 – The Marking of Man-Made Offshore Structures (IALA, 2013).
- Department of Energy & Climate Change (DECC) Standard Marking Schedule for Offshore Installations (DECC, 2011).
- Maritime and Coastguard Agency (MCA) Marine Guidance Notice (MGN) 543 and Annexes – Offshore Renewable Energy Installations (OREIs) – Guidance on UK Navigational Practice, Safety and Emergency Response (MCA, 2016).
- Civil Aviation Authority (CAA) CAP 393 Air Navigation: The Order and Regulations Article 222 (CAA, 2016).
- CAA CAP 764 – Policy and Guidelines on Wind Turbines (CAA, 2016).
- CAA Policy Statement November 2012 – The lighting and marking of wind turbines and meteorological masts in UK territorial waters (CAA, 2012b).

163. The colour scheme for nacelles, blades and towers is generally RAL 7035 (light grey). Foundation steelwork is generally in RAL 1023 (traffic yellow) from HAT up to a minimum of 15m. The Aids to Navigation shall be located within the traffic yellow area.

5.4.11.1 Construction

164. During the construction phase, working areas would be established and marked in accordance with the IALA Maritime Buoyage System (MBS) and THLS consultation. Such areas and markings would be promulgated by appropriate means in advance. Temporary lighting may be required at the request of THLS.

5.4.11.2 Operation

165. During operation, lighting and marking would be as per the above guidance in consultation with CAA, MCA and THLS.

5.4.12 Electrical Infrastructure

166. There are three main HVDC electrical solutions being considered for the Norfolk Boreas Project and they relate to the number of electrical platforms which would be installed across the Norfolk Boreas and Norfolk Vanguard projects. The three solutions are:

- Solution (a) 4 × 900MW electrical platforms;
- Solution (b) 3 × 1,200MW electrical platforms; and

- Solution (c) 2 × 1800MW electrical platform solution.

167. The three main solutions are described below and summarised in Table 5.22. A variation of solution (c) is also being considered. Electrically this variant would be similar to solution (c) but in terms of physical infrastructure would be more similar to solution (a). In terms of the EIA it would be entirely within the design envelope assessed.

5.4.12.1 Solution (a)

168. Under this solution, there would be two offshore electrical platforms on the Norfolk Boreas site, each platform would have a 900MW capacity and each would be connected to shore by a pair of direct current (DC) cables. Energy from the turbines would be transmitted to either one of these platforms and in turn would be transported to shore via the DC cables. The two offshore 900MW electrical platforms would be connected to each other by a pair of interconnector cables comprising a pair of DC cables located within a single trench and a single AC cable located within a separate trench.

169. This solution requires the maximum amount of infrastructure to be located within the Norfolk Boreas site and therefore is assessed in this ES as being the Worst Case Scenario for impacts occurring within the site.

170. Norfolk Vanguard would also contain two 900MW platforms and there would be no requirement to connect the two projects

5.4.12.2 Solution (b)

171. Under this solution there would be one 1,200MW electrical platform located within Norfolk Vanguard East, one located in Norfolk Vanguard West and one located within the Norfolk Boreas site. Energy produced in the northern part of the Norfolk Boreas site would be transmitted to the electrical platform located within the site, whereas energy produced in the south of the Norfolk Boreas site would be transmitted to the electrical platform located within Norfolk Vanguard east.

172. Project interconnector cables would be required to cross “the gap” between the Norfolk Boreas site and Norfolk Vanguard East. These cables would be installed by Norfolk Boreas.

173. Under this solution up to eight AC cables would run from turbines within the southern part of the Norfolk Boreas site to an electrical platform located within Norfolk Vanguard East. In addition, one DC cable pair and a single AC cable may be required to connect the offshore electrical platform located in the northern part of the Norfolk Boreas site with the electrical platform located with Norfolk Vanguard East Platforms. The AC cables would link the turbines within the southern part of Norfolk Boreas to an electrical platform within Norfolk Vanguard East.

174. This solution requires the maximum amount of infrastructure to be located outside of the Norfolk Boreas site and therefore is assessed in this ES as being the Worst Case Scenario for impacts occurring within the project interconnector search area.

5.4.12.3 Solution (c)

175. Under this solution there would be a single 1,800MW electrical platform located within Norfolk Boreas and a single 1800MW electrical platform located within Norfolk Vanguard West. Energy produced from the Norfolk Boreas site would be transmitted to the electrical platform located within the site and then exported to shore via a single pair of DC export cables laid in a single trench.

176. Project interconnector cables would be required to connect the Norfolk Boreas electrical platform with the electrical platform located within Norfolk Vanguard West. This would require one pair of DC cables and one AC cable to be installed within the project interconnector search area connecting both platforms.

Table 5.22 Infrastructure Parameters for HVDC Export Solutions

HVDC export solution covering both the Norfolk Vanguard and Norfolk Boreas projects	Norfolk Boreas specific infrastructure requirements
Solution (a) • 2 x 900MW electrical platforms located within Norfolk Vanguard; and • 2 x 900MW electrical platforms located within Norfolk Vanguard	• 2 electrical platforms; • 1 pair of DC interconnector cables connecting the two electrical platforms located within the Norfolk Boreas site, • 1 AC interconnector cable connecting the electrical platforms located within the Norfolk Boreas site, • 2 pairs of DC export cables connecting the electrical platforms within the Norfolk Boreas site to landfall at Happisburgh South.
Solution (b) • 2 x 1,200MW electrical platforms in Norfolk Vanguard; and • 1 x 1,200MW electrical platform in Norfolk Boreas	• 1 electrical platform; • 1 pair of DC project interconnector cables connecting the electrical platform in Norfolk Boreas to an electrical platform in Norfolk Vanguard East, • 1 AC project interconnector cable connecting the electrical platform in Norfolk Boreas with an electrical platform in Norfolk Vanguard East. • 8 AC cables connecting turbines located in the southern part of the Norfolk Boreas site to the electrical platform in Norfolk Vanguard East • 1 pair of DC export cables connecting the electrical platform within the Norfolk Boreas site to landfall at Happisburgh South.

HVDC export solution covering both the Norfolk Vanguard and Norfolk Boreas projects	Norfolk Boreas specific infrastructure requirements
Solution (c) • 1 x 1,800MW electrical platform in Norfolk Vanguard; and • 1 x 1,800MW electrical platform in Norfolk Boreas	• 1 electrical platform; • 1 pair of DC project interconnector cables connecting the electrical platform in Norfolk Boreas with an electrical platform in Norfolk Vanguard West. • 1 AC project interconnector cable connecting the electrical platform in Norfolk Boreas with an electrical platform in Norfolk Vanguard West. • 1 pair of DC export cables connecting the electrical platform within the Norfolk Boreas site to landfall at Happisburgh South.

5.4.12.4 Offshore cable corridor

177. Export cables would transmit power from the offshore electrical platforms to the onshore project substation. The offshore section of the export cable route extends from the offshore electrical platforms up to the landfall at Happisburgh South; the onshore section goes from the landfall to the onshore project substation at Necton.

178. The majority of the offshore cable corridor is shared with Norfolk Vanguard and as such it extends westwards from Norfolk Boreas and NV East to the landfall site at Happisburgh South. It runs adjacent to, and to the south of, existing gas pipelines over much of this distance. In general, this main part of the corridor is 2km wide. However, a wider section has been included at a dog-leg in the corridor where it crosses the Bacton to Zeebrugge gas pipeline. The reason for the dog-leg is to ensure that the export cable can cross the pipeline at a 90^o angle therefore minimising the size of the crossing point and amount of cable protection required.

5.4.12.4.1 Export cables

179. Cross-linked polyethylene (XLPE) HVDC cables of approximately 150mm diameter would be used to transmit power from the offshore electrical platforms to the landfall location. Similar cables may also be used to provide connections between the offshore electrical platforms. The nominal operating voltage of these cables would be approximately +/-320kV with a maximum worst case of +/- 525kV.

180. Communications facilities would be provided either by installing a separate fibre-optic cable or by integrating a fibre bundle in the armouring of the HVDC cables.

181. HVDC cables are screened so that the electric stresses are contained within the insulation layer. The magnetic fields caused by the electric currents in the conductors cannot be contained in this way. However, it is normal practice to bundle together the flow and return cables of a DC system and install them in a single trench. As the net current in the two cables is zero, the resultant magnetic fields are limited to a small spatial extent.

182. At full load, total heat loss per metre for a pair of large HVDC cables is roughly 100W/m.

5.4.12.4.2 Export, project interconnector and interconnector cables: minimum cable spacing, number and width of cable trenches

183. A minimum separation distance for the subsea cables would be employed primarily to reduce the risk of damaging the adjacent cable during any cable repairs/replacement in the operation and maintenance (O&M) phase.

184. A practical cable corridor width has to allow for:

- Clearance for installation;
- Long-term operation and maintenance capability, including space to effect cable recovery and repairs;
- Potential of third parties requiring the seabed adjacent to the cables; and
- Seabed lease requirements from The Crown Estate and associated costs.

185. Indicative cable spacing arrangements for the offshore export cables is displayed in Plate 5.8. The separation between cables is determined by the potential space required to undertake a cable repair based on the bight length to lift a section of cable, which is a factor of the water depth. Depth throughout the majority of the offshore cable corridor is less than 48m and therefore this represents a conservative worst case scenario.

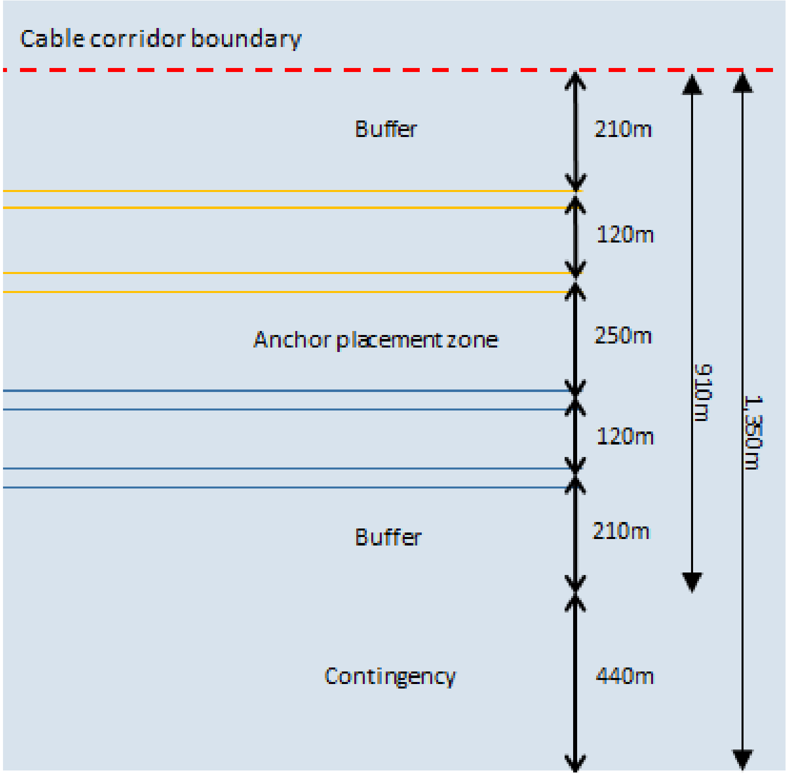

Plate 5.8 Indicative export cable layout (two pairs of cables for Norfolk Vanguard (yellow) and two pairs of cables for Norfolk Boreas (blue)) based on 48m water depth

186. A central anchor placement zone with a width of 250m has been identified to accommodate any vessels needing to set anchors to hold position whilst installing or maintaining the cables. The width of the anchor placement zone is based on previous experience of exclusion zones for anchors which are dependent on the direction the anchor would be recovered. When recovering away from an adjacent cable a 50m safety zone is commonly requested. When recovering towards an adjacent cable the zone increases to 100m.

187. The individual cables would be grouped into pairs which would be laid in one trench with separation distances of 120m allowing for a repair bight.

188. The maximum offshore export cable splay for Norfolk Boreas and Norfolk Vanguard export cables is 1,350m at 48m water depth, allowing space for micrositing within the offshore cable corridor which is between 2km and 4.7km wide.

5.4.12.5 Interconnector cables

189. Interconnector cables which would be required under solution (a) (5.4.12.1) allow for transmission of power between the offshore electrical platforms. Such interconnection may be needed to provide redundancy in the system, in case of failure of one of the export cable systems. Some interconnection cables may operate at the same voltage as the array cables; others may operate at the same voltage as the export cables. A maximum length of 90km of interconnector cables located within 60km of trench is predicted for the project. For the purposes of the

assessment the 60km of trenches would include the sections of project interconnector cable that would be located within the Norfolk Boreas site under solution (b) and (c).

5.4.12.6 Project interconnector cables

190. As previously mentioned under solution (b) and solution (c) a pair of HVDC cables could be required to connect an offshore electrical platform within the Norfolk Boreas site with an offshore electrical platform within one of the Norfolk Vanguard OWF sites. A single AC cable could also be required. Also the under solution (b) up to 8 AC cables would be also be required to connect turbines within the Norfolk Boreas site with an offshore electrical platform located in Norfolk Vanguard East.

191. For solution (c) up to up to 120km of project interconnector cable would be required to be installed within 80km of trench (due to the DC cable pair being installed in a single trench) located within the project interconnector search area. Under solution (b) a maximum of 100km of project interconnector cable would be required to be installed within 92km of trenches located within the project interconnector search area (Figure 5.1). Therefore, solution (b) represents the worst case scenario in terms of the maximum area of disturbance.

5.4.12.7 Array cables

192. The cables between adjacent wind turbines would be relatively short, typically 1 to 3km. However, some of the cables between the offshore electrical platform(s) and the wind turbine strings would be longer, and could be up to 15km in length. A maximum length of 600km of array cable is predicted over the entire project. For the purposes of the assessment the 600km would include the sections of the AC project interconnector cables that would be located within the Norfolk Boreas site under solution (b).

193. The nominal operating voltage of the array cables would be a maximum of 150kV (Root Mean Square (RMS), phase-to-phase). The nominal voltage is likely to be 66kV.

194. Two or three different conductor sizes would be used in the array network. The size of each individual cable would be chosen according to the electrical load that the cable is required to carry. The array cables would be approximately 100-150mm in diameter, three conductor packages enclosed in a protective sheath. The conductors would be stranded copper or aluminium, and would be encased in solid polymeric insulation with metallic screens. The insulation would be XLPE or Ethylene Propylene Rubber (EPR). All cables would contain optical fibres embedded between the cores for communication purposes.

195. The intensity of electromagnetic field (EMF) emitted by subsea cable is very low due to the design and operation of the cable. The screening of the individual conductors

means that the electric stresses are contained within the insulation layer. The magnetic fields caused by the electric currents in the conductors cannot be contained in this way. However, as the three conductors form part of a balanced three-phase system, the net current in the cable is always zero; as a result the magnetic fields are limited to a small spatial envelope close to the cable.

196. At full load, total heat loss per meter for a large 66kV 3-core cable is 150W/m. The heat loss for a 150kV cable would be of a similar quantum.

5.4.13 Cable Installation Methods

5.4.13.1 Pre-lay works

5.4.13.1.1 Pre-installation works

Pre-construction surveys

197. A pre-construction survey would be undertaken in advance of any cable installation works. The results of this survey would be used to plan the routeing of all Norfolk Boreas cables including micrositing where possible.

198. For subsequent phases of cable installation, a further pre-construction survey would be undertaken should there be a gap of over 12 months between completion of the pre-construction survey and commencing the phased installation.

UXO clearance

199. A pre-construction UXO survey would be undertaken and the results would inform micrositing where possible and/or identify any requirement for UXO clearance. On review of the geophysical data from the 2016 (2016, unpublished) cable corridor survey and the 2017 (2017, unpublished) Norfolk Boreas site survey it is estimated that up to 30 clearance operations could be required within the Norfolk Boreas site 28 in the offshore cable corridor and 22 clearance operations within the project interconnector search area. Appendix 5.3 provides a review of typical UXO items which may be found in the Norfolk Boreas offshore project area.

Boulder clearance

200. Pre-construction surveys will identify any requirement for boulder clearance. The geophysical survey data has also been reviewed for the presence of boulders. Given the low number of boulders in the area, it is likely that micrositing around boulders would be possible, however an allowance for clearing 22 boulders within the offshore cable corridor, 105 boulders within the Norfolk Boreas site, and 28 boulders within the project interconnector search area, each of up to 5m, has been included in the assessments in order to be conservative.

201. All boulders would be relocated within the offshore project area boundary; those within the offshore cable corridor would be relocated outside the route of the cable

installation and those found within the Norfolk Boreas site would remain within the site boundaries.

Pre-lay grapnel run

202. Before cable-laying operations commence, it would be necessary to ensure that the route is free from obstructions such as discarded trawling gear or abandoned cables identified as part of the pre-construction survey. A survey vessel would be used to clear all such identified debris, in a 'pre-lay grapnel run'.

203. 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

204. Should a cable be installed in an area of mobile sand waves this could result in exposure and scouring of the cable or the cable being held in suspension over time. To prevent this, the cable could be placed in the troughs of sand waves to a "reference seabed level"[1] that would minimise the potential for cables becoming unburied, as required. If it is not possible to install directly into the seabed reference level, an alternative would be to dredge the top of the sand waves prior to installation down to the seabed reference level. This process is termed the pre-sweep and would be completed as required before the cable could be laid on the seabed.

Pre-sweeping in the offshore cable corridor

205. A detailed export cable installation study (Appendix 5.2) was commissioned by VWPL to assess the project geophysical survey data (Fugro, 2016 unpublished) and confirm the potential for cable burial. This study provided:

- A review of site geology and available installation tools which showed that the sediments are conducive to cable burial;
- The calculation of a non-mobile reference seabed level (RSBL) below which the seabed will not fall during the lifetime of the wind farm;
- Calculations of sediment volumes which would require dredging during pre-sweeping works to enable cables to be buried below the RSBL, both inside and outside the Haisborough, Hammond and Winterton SAC. These volumes are likely to decrease as the route and installation tools are further refined.
- Identification of potential disposal areas within the Haisborough, Hammond and Winterton SAC for material removed from the SAC during pre-sweeping.

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[1] A depth at which the sediment is stable exhibiting little or no movement.

- Explanation of how offshore export cable route adjustments/micrositing can be undertaken due to contingency in the offshore cable corridor width.

206. Indicative pre-sweeping areas and volumes for the offshore cable corridor provided by CWind in Appendix 5.2 are outlined in Table 5.23. 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 and not along the full length of the corridor. The size of area affected by pre-sweeping is displayed in Table 5.4, Table 5.5 and Table 5.6.

Table 5.23 Parameters for pre-sweeping activity for the offshore export cables

Parameter	Maximum for the section of offshore cable corridor within the Haisborough, Hammond and Winterton SAC	Maximum for the offshore export cables (including the SAC volume and area)
Volume of material to be moved		
Per trench (pair of export cables) (m^3)	250,000	1,800,000
Total for two trenches (m^3)	500,000	3,600,000

Sediment disposal

207. Any dredged material would be disposed of within the offshore cable corridor and/or within the Norfolk Boreas site. Material originating within the Haisborough, Hammond and Winterton SAC would be placed in a disposal site within the section of the offshore cable corridor that overlaps with the SAC (Figure 5.2).

Removal of existing disused cables

208. Where the offshore cable corridor crosses an ‘out of service’ cable, these may be recovered from the seabed before the start of installation or cut and the ends secured by clump weights. The removal would be dependent on depth of burial, and if it breaks during recovery a number of grappling operations may be required.

5.4.13.2 Cable burial methods

5.4.13.2.1 Ploughing

209. In this method, a forward blade cuts through the seabed, while laying the cable behind. Ploughs used for cable burial can either be used as post lay burial tools or as simultaneous lay and burial tool. Post lay burial using ploughs is not usual for a number of reasons including danger of damage to cable. Simultaneous laying and burial using cable plough is effective for export cables but has a number of difficulties for array cables.

210. If the cables are bundled, it can be technically challenging due to the bigger cross section area of bundled cable having to pass through the plough, therefore

simultaneous laying and burial has been substituted by post lay burial on some projects.

211. Even if the primary method adopted for laying the export cables is ploughing, there could be locations where other methods to bury and protect the cable are required, i.e. for any jointing loops, corner areas and where ploughing would be unable to negotiate obstacles, cable crossings, etc.

212. Ploughing tools can be pulled directly by a surface vessel or can be mounted onto self-propelled caterpillar tracked vehicles which run along the seabed taking power from a surface vessel. The plough inserts the cable as it passes through the ground.

213. Typical dimensions for a plough are 15m x 6.5m x 7m, with a dry weight of 41 tonnes. This particular example has a cable burial depth of up to 3m.

214. The rate of the burial progress using ploughing would depend on a number of factors (e.g. seabed conditions and nominal tow tension). An installation rate of approximately 150-300 m/h is expected.

5.4.13.2.2 Trenching or cutting

215. This method consists of three operations. First a trench is excavated or cut while placing the sediment and fill next to the trench. The cable is subsequently laid in the trench and lastly the sediment or fill is returned to the trench. Trenching can be a challenging method to use compared with other methods listed here; however, this technique may be required for sections of cable runs where it is most practical.

216. Trenching or cutting would only be used as the last option on areas where other methods for protecting the cable are not economically and/or technically feasible.

217. Pre-lay cutting of trenches (or ‘pre-trenching’) has become more popular in recent years. This is an option where a large trench is cut in one or multiple passes to the correct depth before the cable is laid back in the trench at a later date. The trench can be backfilled naturally or if required with a backfill plough or other method of material replacement. The use of backfill ploughs is normally not favoured due to the danger of damaging the cable.

218. An installation rate of approximately 30-80m/h is expected.

5.4.13.2.3 Jetting

219. Two methods of water jetting are typically available:

- Lay the cable and jet at a later date:
    - The cable is laid on the seabed first and afterwards a jetting machine is positioned above the cable. Jets flush water beneath the cable fluidising the sediment whereby the cable, by its own weight, or by a depressor, sinks to

    the depth set by the operator. As the sediment is fluidised a minor amount of sediment spill is expected. The sledge can be pulled directly by a surface vessel or can be mounted onto self-propelled caterpillar tracked vehicles which run along the seabed taking power from a surface vessel; or

- Lay the cable and jet at the same time:
    - In this method water jets are used to jet out a trench and the cable is placed into the trench behind the jetting lance. Concurrent cable lay and jet is suitable for export cables but presents difficulties with array cables.

220. Jetting tools can be pulled directly by a surface vessel or can be mounted onto a Remotely Operated Vehicle (ROV) e.g. self-propelled caterpillar tracked vehicles which run along the seabed taking their power from a surface vessel.

221. Typical dimensions for an ROV jetting system are 5m x 4.2m x 3m, with a dry weight of 13 tonnes. A machine of this type is capable of operating submerged for up to 10 days.

222. In shallow waters a vertical injector could be used. This is a large jetting/cutting plough which is strapped to the side of a barge and the cable is laid in the foot of the trench. This technique can provide deeper burial than traditional methods, which may be useful in areas of high seabed mobility or whilst crossing areas of high risk.

223. An installation rate of approximately 150-450m/h is expected.

5.4.13.2.4 Offshore export cable trench sizes

224. The export cables would be buried where possible, with typical target depths of between 1m and 3m (with potentially greater overall burial depths where pre-sweeping is used). The final burial depth would be decided when a detailed study has been completed pre-construction to assess the relevant factors for each part of the cable route.

225. The trench shape and width would be determined by the installation method. In addition, its design and size is influenced by a number of factors including safety, soil characteristics, outer cable diameter, trench depth, minimum available width of excavator bucket, type of crossings, and any special purpose requirements for the above mentioned scenarios.

226. Depending on the burial method used, a sloped trench (“V” shape) may be created. The methods that do not result in a side slope are:

- Simultaneous lay and bury methods with a cable plough cut a vertical slot (sometimes with water jet assistance) and lay the cable into the bottom of the slot. This slot would close very shortly after cable lay due to the natural tides.

- Post-lay burial with seabed tractor or ROV-based jetting tools just liquefy a slot of soil and depress the cable into the liquefied soil. This method could result in a 10m width trench for 5m deep.
- Post-lay mass flow burial, or lowering, of the cable blasts a hole in the seabed into which the cable drops. Side slope of the hole would be dependent on the tool arrangement and the soil type.

227. However, the most conservative case in terms of trench slope (and therefore width) would be the ploughing method. In this case the range of the side slope angle varies usually between 30^{o} and 10^{o}. A trench width of 10m could be achieved if a 45^{o} tool would be used, although this slope would only be suitable in cohesive and stable soil conditions.

228. However, taking into account the type of seabed expected in an offshore cable corridor, with ripples and sand waves, 45^{o} would incur too greater risk, due to the fact that, in sands, side slopes of approx. 45^{o} are unlikely to be sustainable for more than a few tidal cycles. Therefore, relatively stable trenches in sand would require side slopes of approx. 30^{o}.

229. The following picture explains how a submarine trench would look if ploughing were to be used for trenching.

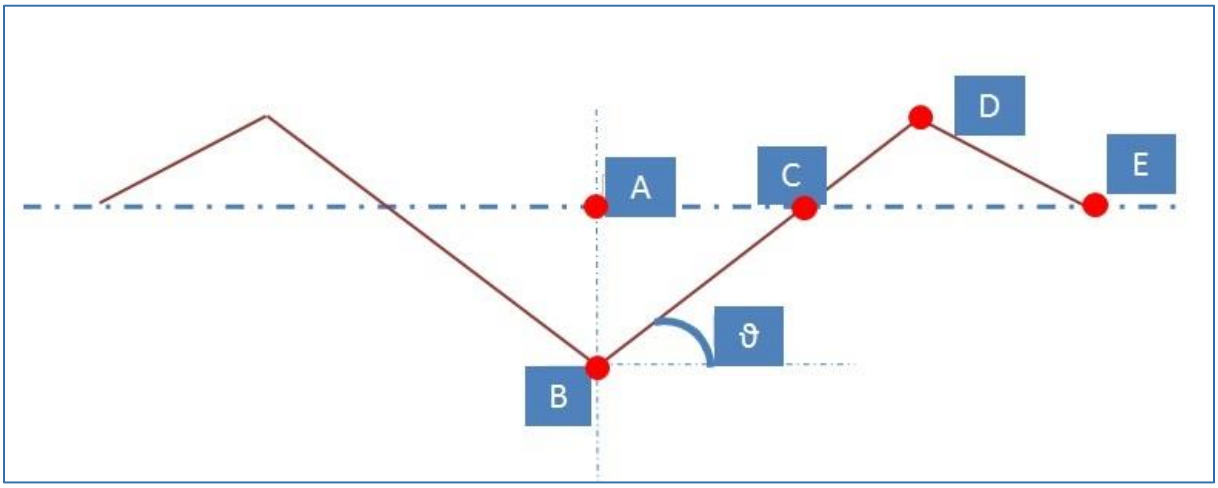

Plate 5.9 Ploughed trench cross section

230. In Plate 5.9 (above), **ϑ** represents the blade angle of the plough, which drives the angle of the trench side slope.

231. The following values (Table 5.24) of trench width would be obtained for different trench depths based on Plate 5.9.

Table 5.24 Expected trench width for specific depths

AB* length (m)	AC* length (m)	ϑ (⁰)	Trench width (2 x AC*) (m)	Spoil width at each side (CE*) (m)
1	1.7	30	3.4	3
1.5	2.6	30	5.2	4.5
2	3.5	30	6.9	6
2.5	4.3	30	8.6	7.5
3	5.2	30	10.0	9

*Dimensions as shown in Plate 5.9

232. Taking 3m depth as the maximum case, the width resulting for a ploughed trench of 30^0 would be 10m. Should the subsequent spoil be taken into account, the total disturbance width would be 10 + 9 + 9 = 28m. A conservative 30m temporary disturbance width is assessed for the export cables in this ES which would encompass the pre-grapnel run, pre-sweeping and trenching works.

233. In principle, no material is expected to be permanently displaced during cable burial as the trench would be backfilled with its own material through natural sediment movement processes.

5.4.13.2.5 Array cable installation

234. The array cables would be surface laid with cable protection within 100m of each wind turbine and then buried using a mix of the following methods described in sections 5.4.13.2.1 to 5.4.13.2.3:

- Ploughing;
- Pre-trenching or cutting; and/or
- Jetting.

235. The maximum temporary disturbance width for array cable installation would be 20m, encompassing the pre-grapnel run, pre-sweeping and trenching works.

236. Each section of cable is laid from the cable lay vessel either from a static coil or a revolving turn carousel, turntable or drum depending upon the characteristics of the cable. The cable is led via a cable pick-up arrangement and an associated cable track way through linear cable engines and is led over board through a cable chute/stinger usually mounted at the stern of the vessel. For smaller array cable sizes it is possible to use barges to lay the cable and these are generally at multiple short lengths.

237. Divers would not be used for cable installation. The hook up would be done by the support of ROVs. The cable would be pulled into the turbine via a J-tube (or alternative cable entry system), and later connected to the turbine. A typical methodology for installing the cable into a J-tube is as follows, although alternative cable entry details and installation methods are being considered:

- A cable barge or a specialist cable installation vessel would be mobilised to the site. The cables would be supplied either on cable reels or as a continuous length;
- The vessel would transit to site and take up station adjacent to a wind turbine structure and either holds station on dynamic positioning (DP) or sets out a mooring pattern using anchors. A cable end would be floated off from the cable reel on the vessel towards the wind turbine structure and connected to a pre-installed messenger wire in the J-tube. The messenger wire would then allow the cable to be pulled up the J-tube;
- The cable would be pulled up the J–tube in a controlled manner with careful monitoring. When the cable reaches the cable temporary hang-off (at a later date a cable jointer would terminate the cable and install the permanent hang-off), the pulling operation ceases and the cable joint is made. The cable would be laid away from the J-tube on the first wind turbine towards the J-tube on the second wind turbine.
- When the cable installation vessel nears the J-tube on the second wind turbine structure, the cable end would be taken from the reel, ready for pulling up the J-tube; and
- The cable end would then be attached to the messenger wire from the bell mouth of the second J-tube. A tow wire would then be taken from the cable installation vessel and connected to the messenger line at the top of the J–tube and the pulling operation is repeated in the same manner as was employed at the first J-tube.

5.4.13.3 Jointing of offshore cables

238. The jointing of subsea cables offshore requires a window of good weather time as the cables would be hanging down from the vessel posing a risk to the crew should the vessel be moving. Typically jointing can take between one and ten days after both cable ends are secured on-board the jointing vessel. Additional time is needed to recover the cables pre-jointing and to re-bury the cable post-jointing.

5.4.14 Cable Protection

239. There may be some locations where array, export, interconnector, or project interconnector cables cannot be buried due to cable crossings or cables becoming unburied overtime due to mobile sediments, and so the use of alternative methods of protection may be required.

5.4.14.1 Types of cable protection

240. Cable protection options include:

- Rock placement - the laying of rocks on top of the cable;

- Concrete mattresses, which are prefabricated flexible concrete coverings that are laid on top of the cable. The placement of mattresses is slow and as such is only used for short sections of cable;
- Grout or sand bags could be placed over the cable; this method is also generally applied on smaller scale applications;
- Frond mattresses can be used to provide protection by stimulating the settlement of sediment over the cable. This method develops a sandbank over time protecting the cable but is only suitable in certain water conditions. This method may be used in close proximity to offshore structures. An example of a typical frond mattress is shown in Plate 5.10; and
- Uraduct or similar, is a protective shell which can be fixed around the cable to provide mechanical protection. Uraduct is generally used for short spans at crossings or near offshore structures where there is a high risk from falling objects. Uraduct does not provide protection from damage due to fishing trawls or anchor drags.

Plate 5.10 Concrete mattress (Source: www.archiexpo.com)

Plate 5.11 Frond concrete mattress (Source: www.pipeshield.com)

5.4.14.2 Unburied cable

241. The maximum width and height of cable protection for unburied cable would be 5m and 0.5m, respectively. It is not anticipated that there would be any unburied cable due to ground conditions during the construction phase. However, cable protection for cables which become unburied during the operational life of the project has been estimated. Lengths for cable protection within the Norfolk Boreas site are provided in Table 5.7 and the following is assumed within the offshore cable corridor and project interconnector search area:

- Export cables - estimated 20km per cable pair;
  - 40km length;
  - 0.20km^2 area.
- Project interconnector (within the project interconnector search area) - estimated 10% of length
  - 92km length plus 10 × 100m on approach to platform;
  - 0.46km^{2}area.

242. Norfolk Boreas Limited is committed to minimising the placement of cable protection within the Haisborough, Hammond and Winterton SAC and is confident that burial would be possible throughout the SAC. However, to allow for the unlikely event that hard substrate is encountered in the SAC, placement of cable protection for up to 4km per cable pair (8km in total within the SAC) over the life of the project has been assessed in the ES. This is included within the total for the export cables, described above.

5.4.14.3 Cable crossings

243. Where the offshore cable is required to cross an obstacle such as an existing pipeline or cable, protection would be installed to protect the obstacle being crossed. At the crossing, the power cable would be laid on top of this protection rather than being buried. Each crossing would require a carefully agreed procedure between the cable owners.

244. The maximum width and length of cable protection for cable crossings would be 10m and 100m, respectively. The maximum height of cable crossings would be 0.9m.

245. For the export cables a maximum of eleven possible[2] cable crossings and two pipeline crossings per cable pair has been included within the assessment. This

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[2] Data provided by KisOrca (2018) indicates that there are two in service cables and one disused cable that cross the offshore cable corridor, this data also concords with that supplied by The Crown Estate. However, data provided by Global Marine indicate that there could be a further eight out of service cables that cross the offshore cable corridor. There is very little confidence in Global Marine data as it is older (2010) and not verified by any other data set. However it has been included here to capture the worst case scenario

includes two in-service pipelines two in-service cables, up to seven out of service cables (which may or may not still be on the seabed, see chapter 18 Infrastructure and other users) and two Norfolk Vanguard export cables. Up to six of these crossing are within the Haisborough Hammond and Winterton SAC (although only one pipeline and one cable are active). If all of these crossings require a cable crossing to be constructed it would result in cable crossing footprint of up to 0.026km^2 across the offshore cable corridor.

246. Up to 10 crossings are estimated for the array cables which would create a footprint of 0.010km^2

247. Up to 10 cable crossings are anticipated within the project interconnector search area resulting in an area of up to 0.010km^2.

5.4.14.4 Landfall cable protection

248. Cable protection may be required at each of the landfall HDD exit points. This could entail one mattress (6m length x 3m width x 0.3m height) plus rock dumping (5m length x 5m width x 0.5m height) at each exit point (up to two cable pairs), with a total footprint of 36m^2.

5.4.14.5 Summary of potential cable protection requirements

249. The total areas which could be occupied by cable protection are provided in Table 5.25.

Table 5.25 Estimation of area occupied by and volume of cable protection

Element	Area effected	Length (m)	Width (m)	Height (m)	Total area (m2)	Total volume (m3)
Array cable protection - unburied (10% of total length)	Norfolk Boreas site	60,000	5	0.5	300,000	150,000
Array cable protection - approaching turbines	Norfolk Boreas Site	18,000	5	0.5	90,000	45,000
Array cable protection - crossings	Norfolk Boreas site	1000	10	0.9m in total, including existing cable	10,000	9,000
Interconnector cable protection - approaching electrical platforms	Norfolk Boreas site	400	10	0.5	4,000	500
Interconnector cable protection - unburied	Norfolk Boreas site	6,000	5	0.5	30,000	15,000
Project Interconnector cable protection - approaching electrical platforms	Project interconnector search area	1000	5	0.5	5,000	2500
Project Interconnector cable protection - unburied	Project interconnector search area	9,200	5	0.5	46,000	23,000
Project Interconnector crossings	Project interconnector search area	1000	10	0.9m in total, including existing cable	10,000	9,000
Export Cable protection on approach to platforms	Norfolk Boreas site	100	5	0.5	500	250
Export cable protection - unburied within the (2.5km length per pair of cables)	Norfolk Boreas site	5,000	5	0.5	25,000	12,500
Export cable protection - unburied (20km length per pair of cables)	Offshore cable corridor	40,000	5	0.5	200,000	100,000
Export cable protection - crossings (based on 26 crossings)	Offshore Cable Corridor	2,600	10	0.9m in total, including existing cable	26,000	23,400
Protection at the landfall HDD exit locations - mattress	Offshore Cable corridor	12	3	0.3	36	11
Protection at the landfall HDD exit locations – rock dumping	Project interconnector search area	10	5	0.5	50	25
Total					**712,086 (0.71km^2)**	**374,436**

5.4.15 Indicative Offshore Construction Programmes

250. Project construction in the UK is currently dependent on funding mechanisms to drive financial investment decisions and construction periods could be elongated or shortened by the requirements within any funding contract. The final design (e.g. number of turbines, platform, cables, etc.) would also affect the construction programme as well as weather conditions during construction. An indicative offshore construction window of approximately three years is estimated (excluding preconstruction activities which could last approximately 9 months). Offshore working hours during construction are anticipated to be 24/7.

251. Indicative programmes based on single and two phase buildouts are provided below. The time period presented in the “Approximate duration” column is the anticipated duration of the works i.e. how long the work would take, and the time blocked out in blue/ orange is the period of time within which the duration of works would be undertaken as shown in Table 5.26 and Table 5.27, if a multi-phase construction approach was taken, the overall duration of the construction works could last slightly longer.

252. If Norfolk Vanguard is not progressed (Scenario 2) the construction programme of Norfolk Boreas as shown below could be bought forward by up to one year. Onshore construction programmes are provided in Table 5.39 and Table 5.43.

Table 5.26 Indicative Norfolk Boreas construction programme – single phase

		2024				2025				2026				2027				2028			
Indicative Programme	**Approximate duration**	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Pre-construction survey	12 months			■	■	■	■														
UXO survey and licensing	12 months			■	■	■	■														
UXO clearance following licencing	9 months							■	■	■											
Foundation seabed preparation	3 months									■											
Foundation installation	18 months										■	■	■	■	■	■					
Scour protection installation	12 months									■	■	■	■								
Offshore electrical platform Installation works	12 months										■	■	■	■							
Array, interconnector & project interconnector cable seabed preparation	6 months									■	■										
Array & interconnector & project interconnector cable installation	18 months										■	■	■	■	■	■					
Export cable installation seabed preparation	6 months								■	■											
Export cable installation	18 months									■	■	■	■	■	■						
Cable protection installation	18 months										■	■	■	■	■	■					
Wind turbine installation	18 months														■	■	■	■	■	■	
Total construction works	36 months								■	■	■	■	■	■	■	■	■	■	■	■	

Table 5.27 Indicative Norfolk Boreas construction programme – two phases

Indicative Programme	Approximate duration	2024				2025				2026				2027				2028			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Pre-construction survey	12 months			■	■	■	■														
UXO survey and licensing	12 months			■	■	■	■														
UXO clearance following licencing	9 months							■	■	■											
Foundation seabed preparation	3 months									■											
Foundation installation	2 x 9 months										■	■	■		■	■	■				
Scour protection installation	2 x 6 months									■	■			■	■						
Offshore electrical platform Installation Works	2 x 6 months										■	■			■	■					
Array, interconnector & project interconnector cable seabed preparation	2 x 3 months									■				■							
Array, interconnector & project interconnector cable installation	2 x 9 months										■	■	■		■	■	■				
Export cable installation seabed preparation	2 x 3 months								■				■								
Export cable installation	2 x 9 months									■	■	■		■	■	■					
Cable protection installation	2 x 9 months										■	■	■		■	■	■				
Wind turbine installation	2 x 9 months														■	■	■		■	■	■
Total construction works	39 months								■	■	■	■	■	■	■	■	■	■	■	■	■

5.4.16 Construction Vessels

253. The number and specification of vessels employed during the construction of Norfolk Boreas would be determined by the marine contractor and the final construction strategy. It is anticipated that several types of construction vessel could work in parallel during the construction of the project.

254. The final selection of the port facilities required to construct and operate the project has not yet been determined, however local options include Hull, Great Yarmouth or Lowestoft, with Great Yarmouth currently considered the most likely location.

255. The following list (Table 5.28) intends to show examples of the type and number of vessels required for key construction activities. Approximately 1180 vessel movements are estimated during construction. However, a maximum of 57 vessels on site at any one time is predicated.

Table 5.28 Examples of vessels for construction

Activity type	Vessel type	Indicative number of vessels
Seabed preparation	Dredging vessel	5
Foundation Installation	Tugs and barges storage and transport	5
Foundation Installation	Jack-up vessel	2
Foundation Installation	Dynamic Position Heavy Lift Vessel	2
Foundation Installation	Support vessels	10
Foundation Installation	Scour Vessel	5
Wind turbine installation	Jack-up vessel	2
Wind turbine installation	Dynamic Position Heavy Lift Vessel	2
Wind turbine installation	Accommodation vessel	2
Wind turbine installation	Wind farm service vessel	10
Wind turbine installation	Support vessels	5
Offshore electrical platform installation	Substation Installation Vessels	5
Offshore electrical platform installation	Tug with accommodation barge	2
Offshore electrical platform installation	Supply vessel	1
Offshore electrical platform installation	Support vessels	5
Cable installation	IA Cable Vessels	5
Cable installation	Accommodation vessel	2
Cable installation	Export Cable Vessels	5
Cable installation	Export cable support vessel	5
Cable installation	Landfall Cable Installation Vessels	2
Cable installation	Pre-trenching/backfilling vessel	2
Cable installation	Cable jetting and survey vessel	5
Cable installation	Filter Layer Vessel	2
Commissioning	Commissioning Vessels	10

Activity type	Vessel type	Indicative number of vessels
Other vessels	Accommodation Vessels	2
Other vessels	Crew transfer	10
Total		**113**

5.4.16.1 Vessel footprints

256. The footprint associated with jack up barges and anchored vessels during foundation construction are shown in Table 5.29.

Table 5.29 Construction vessel footprints

	Jack up	Anchors
Number of legs/anchors	6	6
Footprint area per placement (m^2)	792	150.0
Operations per turbine	2	1
Number of turbine (and platform) locations	180 (+6 platforms)	180
Total footprint (m^2)	**323,136**	**27,900**

5.4.17 Safety Zones

257. The safety zones that could be applied for the project construction are presented in Table 5.30 below. These would be determined on the basis of a detailed safety case.

Table 5.30 Potential safety zones during construction, operation and decommissioning

Type of safety zone	Area covered
Construction*	A 500m safety zone around active construction works as evidenced by the presences of a construction vessel.
Commissioning**	A 50m safety zone around partially or fully completed structures prior to the overall wind farm commissioning.
Major Maintenance* during windfarm operation	Up to 500m around the site of major or exceptional maintenance works (for example where jack-up vessel or similar are being used).
Decommissioning	No safety zones currently proposed; a separate application would be made prior to decommissioning where considered necessary.
* The Construction safety zones are required to ensure a safe distance is maintained from vessels engaged in high risk activities such as jacking operations and heavy lifts.	
**The commissioning safety zones are required to ensure small vessels are not adversely affected by propeller or thruster wash from vessels used for transfer whilst also ensuring no additional risk is created for personnel during access and egress. This zone also reduces risk of injury to third parties from items dropped from aloft.	

5.4.18 Offshore Operation and Maintenance

258. This section provides an overview of maintenance activities. An outline Operations and Maintenance Plan (document reference 8.11) has been submitted as party of this application.

5.4.18.1 Maintenance activities

259. Once commissioned, the wind farm would have a design life of approximately 30 years. All offshore infrastructure including wind turbines, foundations, cables and offshore substations would be monitored and maintained during this period in order to maximise operational efficiency and safety for other sea users.

260. The operation and control of the wind farm would be managed by a Supervisory Control and Data Acquisition (SCADA) system, connecting each turbine to the onshore control room. The SCADA system would enable the remote control of individual turbines, the wind farm in general, as well as remote interrogation, information transfer, storage and the shutdown or restart of any wind turbine if required.

261. During the life of the project, there should be no need for scheduled repair or replacement of the subsea cables, however, reactive repairs and periodic inspection may be required. Periodic surveys would also be required to ensure the cables remain buried and if they do become exposed, re-burial works would be undertaken.

262. Typical maintenance activities would include:

- General wind turbine service;
- Oil sampling / change;
- UPS (uninterruptible power supply) battery change;
- Service and inspections of wind turbine safety equipment, nacelle crane, service lift, high voltage system, blades;
- Cable repair and replacement;
- Foundation inspection and repair; and
- Cable crossing inspection and repair.

5.4.18.1.1 Wind turbines

263. There are a number of potential maintenance strategies for the wind farm. The wind farm could be maintained from shore using a number of varying O&M vessels (e.g. crew transfer vessels, supply vessels) possibly supported by helicopters – the onshore option. Alternatively, the wind farm could be maintained primarily using crew transfer vessels operated on a daily basis from an offshore accommodation vessel or offshore service platform, with crew transfer vessels transiting to and from vessel or platform to their place of work each day. Helicopter operations may still be utilised with this option. For all options, a maximum of 14 helicopter round trips per week is anticipated.

264. Although it is not anticipated that large components (e.g. wind turbine blades or substation transformers) would frequently require replacement during the operational phase, the failure of one of these components is possible. Should this be

required, large jack-up vessels may need to operate continuously for significant periods to carry out these major maintenance activities.

265. It has been assumed that a maximum of two locations could be visited by one jack-up vessel to the Norfolk Boreas site per day during operation. Assuming a jack up vessel with a seabed footprint of 792m^2, this would lead to a total area of up to 0.58km^2 per year.

266. During some of the O&M visits (Table 5.31) cleaning of the foundations and ancillary structures may occur. This is would involve jet washing marine growth and bird guano from the turbine structures, and cutting the growth from around the j tube. The jet washing would be done with seawater and therefore only natural materials would enter the marine environment.

5.4.18.2 Vessel and helicopter operations

267. A number of vessel and / or helicopter visits to each turbine would be required each year to allow for scheduled and unscheduled maintenance.

268. If the onshore operation option is chosen, this would mean crew vessels sailing to and from the wind farm on a daily basis from shore, possibly supported by helicopters. If the offshore operation option is preferred, the majority of small crew vessels would be operated on a daily basis from the offshore accommodation vessel or offshore service platform, although further support vessels are also still likely to transit to and from shore each day and helicopter operations may still be utilised. Offshore electrical platforms would typically require an average of 1 visit/week, although as a result of an unscheduled maintenance there would be several visits until reparation is finished. Table 5.31 provides a breakdown of the maximum anticipated trips per year to the wind farm during operation.

Table 5.31 Anticipated trips per year to the wind farm during operation

Vessel type	Vessel movements
Large O&M Vessel	40
Accommodation O&M	40
Small O&M Vessel	300
Lift Vessel	5
Cable Maintenance Vessel	5
Auxiliary Vessels	90
Total	**480**
Helicopter Trips to Site per week	14

269. During O&M activities Norfolk Boreas Limited would seek to agree appropriate safety zones around wind turbines and work areas. Safety zones are described above in Table 5.30.

5.4.18.3 Cable failures

270. During the life of the project, repairs may be required and periodic inspection would be undertaken. Periodic surveys would also be required to ensure the cables remain buried and if they do become exposed, remedial works would be undertaken.

271. Based on statistical analysis and experience from existing wind farms, the estimated rate of cable failure would be approximately:

2.86 failures / 1,000km / year

272. This figure is based on existing and previous technology and does not allow for advances in cable technology in the future and as a result, is considered to be conservative. Based on this, the following unplanned cable repairs are estimated per year:

- One export cable repair;
- Two array cable repairs;
- One interconnector, or One project interconnector repair.

273. While it is not possible to determine the number and location of repair works it is estimated that one repair every 10 years may be required within the Haisborough, Hammond and Winterton SAC. This estimated rate of repair has been included in the assessment.

274. In most cases a failure would lead to the following series of operations: taking out the damaged part of the cable, cutting the cable, inserting a joint, bringing a new segment of cable and jointing the new segment with the old cable.

275. The cable would be unburied using jetting (or removal of mattress/rock protection) and then once the repair is done the opposite (reinstalling the mattress, rock dumping, jetting or other methods of cable burial or protection). However, in a number of cables the fault might be very close to the substation or wind turbine and if there is sufficient slack it could be directly pulled in, making this operation much easier, although more rare.

276. The replacement section, which is likely to be a few hundred meters, would be deployed by the installation vessel in a bight, laid to one side of the original cable route. The cable repair bight length would be dependent on the water parameters of the cable laying vessel.

277. For array cables, the entire length of a cable (likely to be between 0.68km and 6km subject to turbine spacing) could require replacement and therefore 6km has been assumed as the worst case.

5.4.18.4 Cable re-burials

278. As previously discussed, cables could become exposed due to moving sand waves and due to erosion of other soft/mobile sediment (not just sand waves). During the life of the project, periodic surveys could be required to ensure the cables remain buried and if they do become exposed, remedial works would be undertaken.

279. The operator would need to be aware of whether the cables are exposed (and so pose a risk). This would require bathymetric surveys to be performed. A proportionate risk-based approach would be to use those early years of operation to build up a picture of sand wave mobility and erosion/deposition rates and find the area with the most variation, thus the surveys could then be made of cables in those areas with the highest risk of exposure.

280. In order to detect the exposure of cables, there are many techniques which can be used. Some operators have been testing the use of Distributed Temperature Sensing (DTS), which uses strain in the communications cable as a measure of cable temperature, given that an exposed cable is cooler since the water conducts the heat better than soil. The use of this system is common for export cables but not for array cables.

281. The following reburial requirements have been estimated based on the worst case scenario that no pre-sweeping is undertaken and cable is simply buried under the seabed level (pre-sweeping would minimise the need for reburial):

- Estimated export cable reburial at 5 year intervals:
    - Up to 10km per cable pair within the Haisborough, Hammond and Winterton SAC; and
    - Outside the SAC: up to 10km per cable pair.
- Reburial of 25% of the array cable is estimated every 5 years; and
- One interconnector (either the interconnector or the project interconnector) repair per year is estimated.

282. An In Principle Monitoring Plan (document reference 8.12) is submitted with the DCO application which outlines the proposed monitoring, the details of which would be agreed post consent with the relevant Regulators and statutory nature conservation bodies (SNCBs). Post-construction surveys are likely to be a requirement of the DCO and / or deemed marine licences (DMLs).

5.4.18.5 O&M port

283. The O&M facility is to be located in a service port (yet to be chosen). It is envisaged that O&M needs, in terms of laydown areas and facilities would be minimal compared to requirements during the construction phase.

284. An office, storage or warehouse facility and quayside loading area would be needed. During the first operational years of the project, operations might be coordinated and implemented from the onshore facility. As more turbines are installed it is the expectation that the majority of accommodation needs are to be offshore.

285. It is expected that an O&M strategy would be based on a concept of large service vessels operating for long durations at the offshore site, however this would not be confirmed until a wind turbine provider is selected. After more wind turbines are installed, these may be supplemented with offshore accommodation vessels or fixed offshore service platforms, with helicopter support.

5.4.19 Offshore Decommissioning

286. The scope of the decommissioning works would be determined by the relevant legislation and guidance at the time of decommissioning and would most likely involve the accessible installed components. 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.

287. The process for removal of foundations is generally the reverse of the installation process. The anticipated techniques for the various foundation types are as described below.

288. It is anticipated that decommissioning would be undertaken in the same phased approach as used for construction. Based on previous estimates and experience it is anticipated that decommissioning of each phase would take approximately 1 year.

289. As an alternative to decommissioning, the owners may wish to consider re-powering the wind farm. Should the owners choose to pursue this option, this would be subject to a new application for consent.

5.4.19.1 Jacket foundations

290. The overall removal methodology for pin pile foundations would typically be as follows:

- Removal of turbine, mast, switchgear and ancillaries, and cutting of cables (leaving buried array cables in-situ);
- Local jetting and/or suction around legs of jacket to a depth of approximately 1-2m below seabed level;
- Deployment of underwater remote abrasive cutting equipment from service vessel;
- Mobilisation of heavy lift DP vessel or jack-up rig and attachment of crane slings to jacket;

- Abrasive cutting of pile legs at a depth of approximately 1-2m below the seabed;
- Lifting of jacket by crane on DP vessel or jack-up rig onto barge; and
- Transportation of jacket to port and dry dock for dismantling and reuse/recycling where possible.

291. Note that it would not be intended to reinstate the local excavations remaining at the pile leg locations as it is anticipated that given the active natural sediment transport in the site this would refill naturally.

5.4.19.2 Gravity base structures

292. The overall removal methodology for gravity base structures would typically be as follows:

- Removal of turbine, mast, switchgear and ancillaries, and cutting of cables (leaving buried array cables in-situ);
- Mobilisation of heavy lift DP vessel or fleet of tugs (dependent on whether foundation design is buoyant or requires heavy lift);
- Removal of marine growth and sediment from base and jetting under base plate to remove adhesive effects of grout (if present) or cohesive bearing material. If a deep skirt has been used, the skirt may require cutting;
- It may also be necessary to locally remove scour protection via dredging;
- For buoyant design: controlled de-ballasting of foundation using remote pumping equipment and/or installation of buoyancy aids. Careful consideration would need to be given for the disposal of the ballasting material (i.e. whether it is disposed of locally or requires to be transported to a particular offshore disposal area);
- For design requiring heavy lift: lifting of foundation from seabed onto barge (as per installation, a bespoke transportation barge may be required dependent on the design);
- For buoyant design: foundation would become buoyant on de-ballasting;
- Transportation of foundation to port and dry dock (via towing or on barge dependent on foundation type) for deconstruction and reuse/recycling of materials where possible.

5.4.19.3 Suction caisson foundations

293. The overall removal methodology for suction caisson foundations would typically be as follows:

- Removal of turbine, mast, switchgear and ancillaries, and cutting of cables (leaving buried array cables in-situ);
- Mobilisation of service vessel with pumping equipment and ROV, and mobilisation of tugs. It may also be necessary to mobilise a DP vessel with

craneage to facilitate with the refloating and subsequent manipulation of the foundation;
- Removal of sediment and marine growth from suction caisson lid, and jetting of pump connections on lid. It may also be necessary to locally remove scour protection via dredging;
- De-ballasting or adding of buoyancy aids to foundation as required by design;
- Connection of pumping equipment to suction caisson valves;
- Controlled pumping of water into caisson chambers. The caisson would rise from its installed position to the surface as the internal pressure overcomes the side wall friction. Some manipulation from craneage on a DP vessel may also be required;
- Towing of foundation to port and dry dock for dismantling and reuse/recycling where possible.

5.4.19.4 Monopile foundations

294. The overall removal methodology for steel monopile foundations would typically be as follows:

- Removal of turbine, mast, switchgear and ancillaries, and cutting of cables (leaving buried array cables in-situ);
- Mobilisation of service vessel;
- Local jetting and/or suction around base of monopile to a depth of approximately 1-2m;
- Deployment of underwater remote abrasive cutting equipment from service vessel;
- Mobilisation of heavy lift DP vessel or jack-up rig and attachment of crane slings to top of monopile and transition piece;
- Abrasive cutting of monopile at a depth of approximately 1-2m below the seabed;
- Lifting of combined monopile/ transition piece by crane on DP vessel or jack-up rig onto barge;
- Transportation of monopile/ transition piece to port and dry dock for dismantling and reuse/recycling where possible.

295. Note that it would not be intended to reinstate the local excavations remaining at the monopile locations as it is anticipated that this would refill naturally over time.

296. It should be noted that other reuse / disposal options are potentially available once the foundation is removed. This could be applicable for any of the foundation types but careful site planning would need to be undertaken to ensure that hazards to navigation are not introduced.

5.4.19.5 TetraBase foundations

297. Decommissioning of the TetraBase foundations would either be similar to the jacket foundations section (5.4.19.1) if the piles or suction caisson anchoring option is used.

298. If the chosen option for the TetraBase foundation is for it to stand with gravity only on a levelled seabed, floating devices would be secured around the foundation to de ballast the foundation which would then float to the surface and be towed to the quay side.

5.4.19.6 Removal of scour protection

299. If scour protection materials had been used, it would be likely that they would be left in place. There would be some disturbance of the scour protection materials during the removal of the foundations but they would simply fall to the seabed and flatten over time.

5.4.19.7 Removal of cabling

300. General UK practice would be followed, i.e. buried cables would simply be cut at the ends and left in-situ.

5.5 Onshore Overview

301. VWPL (the parent company of Norfolk Boreas Limited) is also developing Norfolk Vanguard, a ‘sister project’ to Norfolk Boreas. In order to minimise impacts associated with onshore construction works for the two projects, VWPL is proposing to carry out enabling works under the Norfolk Vanguard DCO for both projects at the same time. Whilst it is anticipated that Norfolk Vanguard will be constructed, Norfolk Boreas needs to consider the possibility that Norfolk Vanguard does not proceed to construction, therefore the Norfolk Boreas DCO is seeking to consent the following two alternative scenarios:

- **Scenario 1** – Norfolk Vanguard proceeds to construction, and installs ducts and other shared enabling works for Norfolk Boreas.
- **Scenario 2** – Norfolk Vanguard does not proceed to construction and Norfolk Boreas proceeds alone. Norfolk Boreas undertakes all works required as an independent project.

302. Table 5.32 outlines the key elements of onshore construction works to be carried out by Norfolk Boreas under each scenario, a further detailed comparison is provided in Appendix 5.1. Full descriptions of the onshore construction works required under Scenario 1 and Scenario 2 are provided in sections 5.6 and 5.7, respectively.

Table 5.32 Overview of key onshore construction elements for Scenario 1 and Scenario 2 to be undertaken by Norfolk Boreas

Onshore elements	Scenario 1	Scenario 2
Landfall		
Landfall compounds	✓	✓
Cable duct installation via HDD	✓	✓
Transition pits and link boxes	✓	✓
Cable pulling	✓	✓
Onshore Cable Route		
Pre-construction works	✓ (limited as majority completed by Norfolk Vanguard)	✓
Cable duct installation via open cut trenching	× (installed by Norfolk Vanguard)	✓
Cable duct crossings (e.g. hedgerows, underground services, roads or tracks, watercourses)	× (installed by Norfolk Vanguard)	✓
Trenchless crossings (e.g. HDD) and associated trenchless compounds	× (installed by Norfolk Vanguard)	✓
Mobilisation areas	× (not required)	✓
Running track	✓ (approx. 12km)	✓ (approx. 60km)
Accesses	✓	✓
Cable pulling	✓	✓
Cable logistics area	✓	✓
Jointing pits and link boxes	✓	✓
Onshore Project Substation		
Pre-construction works	✓	✓
A47 junction improvement	× (installed by Norfolk Vanguard)	✓
Access road to onshore project substation	✓ (extension of road installed by Norfolk Vanguard by approx. 300m)	✓ (approx. 1.8km)
Construction of onshore project substation	✓	✓
Screening	✓	✓
National Grid Substation Extension and Overhead Modifications		
Pre-construction works	✓	✓
Extension to existing Necton National Grid Substation	✓ (easterly direction)	✓ (westerly direction)

Onshore elements	Scenario 1	Scenario 2
National Grid Overhead line modifications	✗ (installed by Norfolk Vanguard)	✓
Screening	✓	✓

5.6 Onshore Under Scenario 1

303. This section describes the onshore construction works and infrastructure required under the most likely Scenario 1. Under Scenario 1 Norfolk Vanguard proceeds to construction and would have undertaken the following to benefit Norfolk Boreas:

- Installation of ducts to house Norfolk Boreas cables along the entirety of the onshore cable route from the landfall zone to the onshore project substation;
- A47 junction works for both projects and installation of a shared access road up to the Norfolk Vanguard substation; and
- Overhead line modifications at the Necton National Grid substation, which will accommodate both projects.

304. Under Scenario 1 the following onshore elements of the project will be constructed by Norfolk Boreas:

- Landfall;
- Cable pulling through pre-installed ducts;
- Onshore project substation;
- Extension to the Necton National Grid substation; and
- Landscaping, surface water management and planting schemes.

5.6.1 Landfall

5.6.1.1 Cable landfall location

305. The landfall location at Happisburgh South (Figure 5.3) was chosen as the result of a detailed site selection process which is described in Chapter 4 Site Selection and Assessment of Alternatives.

306. The landfall comprises a stretch of coastline approximately 0.25km from Beach Road in the north to Upton Way in the south.

307. The landfall zone extends approximately 500m inland to allow the transition pits to be located out with any areas at high risk of natural coastal erosion shown in Figure 5.3.

308. The landfall (including transition pits) encompasses agricultural land (See Chapter 21 Land Use and Agriculture for further information on the land use at the landfall location).

5.6.1.2 Cable landfall construction method

309. The offshore export cable will come to land using long Horizontal Directional Drilling (HDD) and duct installation under the cliff. The landfall ducts will exit in the subtidal zone beyond 5.5m LAT and approximately 1km from the onshore drilling location, to avoid impacts on the intertidal zone. Ducts, and subsequent cables, would be buried at sufficient depth below the coastal shore platform and cliff base to have no effect on coastal erosion. Chapter 8 Marine Geology, Oceanography and Physical Processes explains that erosion would continue to be driven by natural processes which would not be affected by Norfolk Boreas. Natural coastal erosion throughout the lifetime of the project has been allowed for within the project design by ensuring appropriate set back distances from the coast for the HDD entry point (see Chapter 4 Site Selection and Assessment of Alternatives).

310. Two HDD drills and ducts are required for Norfolk Boreas (with a third drill considered for the purpose of the worst case assessment, providing an additional drill as a contingency in the unlikely event of a drill failure). The underground landfall ducts would be located within the zone displayed in Figure 5.3.

311. The offshore cables would then be installed in the ducts and jointed to the onshore cables at the transition pits on the landward side of the landfall site.

312. By using the HDD method, High Density Polyethylene (HDPE) ducts (through which cables are pulled) would be installed below ground using a surface to surface drilling profile. The enabling works for HDD installation would include:

- Installation of temporary landfall compounds to accommodate the drilling rigs (up to two compounds to support parallel drilling rigs if required), ducting and associated materials and welfare facilities. Each temporary landfall compound would be located within the landfall compound zone shown in Figure 5.3 and would be 60m long by 50m wide.
- The land would be levelled, topsoil removed and stored within the landfall compound and, if necessary, dependant on ground conditions, bog mats or geotextile and hard standing may be laid to protect the subsoil during the drilling operations.
- The landfall compound would be securely fenced and accessed from Whimpwell Street, suitable for haulage equipment, would be instated along the onshore cable route to the drilling site. An indicative site layout for the HDD works is shown in Plate 5.13.

313. The works for HDD installation per duct would include:

- A pilot hole would be drilled from the entry pit and advanced in stages until the required length is reached and the boring head emerges at the exit point. The drill head would be guided by sensors, potentially tracking a wire placed above ground. Drilling fluid (a combination of water and natural clays such as bentonite) would be employed to lubricate the drilling process and cool the drill head. Drilling fluid would be recovered and recycled during the drilling process where possible. Fluid pressures would be monitored throughout the process to minimise the potential for breakout of the drilling fluid. An action plan would be developed and procedures adopted during the drilling activity to respond to any drilling fluid breakout.

- Once the pilot hole is completed, it would be enlarged through several passes with reamers until the necessary diameter for duct installation is achieved.
- The HDD would exit at an offshore location, classified as a 'long HDD'. The long HDD option does not require any restrictions or closures to the beach for public access.
- The ducts would be typically floated into position at the offshore exit point via barges. The ducts would then be flooded with water and pulled into the reamed drill hole from the entry pit. Alternatively the ducts could be welded in sections onshore and pulled from the offshore side.

314. Upon completion of the duct installation, the drilling rig would be removed and drilling fluids/other wastes cleared from the site with the land reinstated. During the cable pulling phase of works, the appropriate transition pits would be excavated and exposed allowing cables to be pulled through the pre-installed ducts and jointed. The transition pit would then be reinstated.

315. An example HDD rig is shown in Plate 5.12 with indicative compound dimensions and equipment shown in Plate 5.13.

Plate 5.12 Example HDD rig (Source: Vattenfall Wind Power Limited)

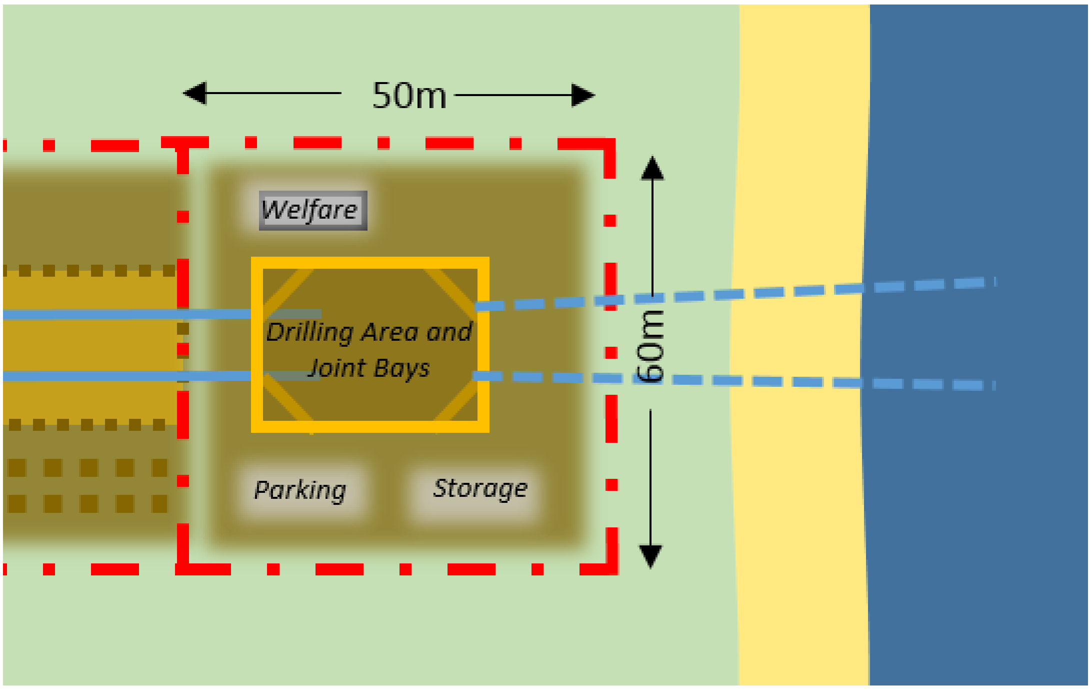

Plate 5.13 Indicative landfall compound

316. Once the ducts have been installed, the offshore cables could then be installed at the optimum time (taking into account weather, tide and the offshore works schedule) by positioning the cables at the offshore exit point and pulling through the ducts to the transition pit.

317. Noise generated from construction at HDD sites is detailed in Chapter 25 Noise and Vibration.

318. The Project Design Envelope for Norfolk Boreas includes the option of concurrent drilling with two parallel drilling rigs.

5.6.1.3 Transition pit and link boxes

319. Each cable circuit would require a separate transition pit to connect the offshore and onshore cables at the landfall. Therefore, two transition pits may be required at landfall. The transition pits would be accommodated within the landfall compound (Figure 5.3). Each transition pit would comprise an excavated area of 15m x 10m x 5m, per circuit, with a reinforced concrete floor to allow winching during cable pulling and a stable surface to allow jointing.

320. A temporary enclosure would be provided to allow a controlled environment to be maintained during jointing activities. A small generator could be required to provide the necessary electrical power for the enclosure, any powered jointing equipment and any pumps to manage groundwater.

321. Following cable pulling and jointing activities, the joints would be buried to a depth of 1.2m using stabilised backfill, pre-excavated material or a concrete box. The remainder of the transition pit will be backfilled with the pre-excavated material and returned to the pre-construction condition, so far as is reasonably possible.

322. Link boxes for each of the required transition pits may be utilised. See section 5.6.2.3 for further details.

5.6.1.4 Landfall key parameters

323. Table 5.33 summarises the landfall key parameters.

Table 5.33 Summary of key parameters at landfall

Parameter	Minimum	Maximum	Additional information
Number of Drills	2	3	Maximum considers allowance for a failed drilling attempt
Number of Cable Ducts	2	2	Duct would not be installed in a failed drill.
Diameter of Drill (mm)	500	750	
Length of Drill (m)	700	-	Indicative length of 1000m
Number of Transition Pits	2	2	Pit per circuit (offshore export cable pair).
Depth per Pit (m)	-	5	Below ground level.
Width per Pit (m)	-	10	
Length per Pit (m)	-	15	
Area of construction compound (m^2)		6,000	Considers the option of two works areas operating in parallel, each 60m x 50m.
Amount of material to be excavated (m^3)	-	1,325m^3	Volume of HDD excavated material (based on 750mm diameter bore, 1,000m drill and three drills).

5.6.1.5 Cable pulling at landfall

324. The following sequence of events for the cable pulling at landfall is expected:

- The cable would be floated from a cable laying vessel or barge to the HDD exit location;
- The free end of the cable (or cables) would be attached to a pull-wire that passes through the HDD duct;
- An onshore winch would then be used to pull the end of the cable through the duct and into the transition pit. The end of the cable would then be mechanically terminated at this location; and
- Once the cable is terminated, the floatation buoyancy would be released to allow the cable to sink to the seabed.

5.6.2 Onshore Cable Route

325. The location of the 45m wide onshore cable route is presented in Figure 5.4. From Happisburgh South, the onshore cable route travels north-west, past Ridlington and Witton, towards the northern edge of North Walsham. From North Walsham the onshore cable route heads south-west passing to the north of Aylsham (Figure 5.4 Map 4) and Reepham (Figure 5.4 Map 5) before crossing the River Wensum (Figure 5.4 Map 7). From this point the onshore cable route passes to the north of Dereham before crossing the A47 and entering the onshore project substation near Necton (Figure 5.4 Map 9).

326. The onshore cable route would contain the main HVDC onshore export cables within ducts. The onshore cable route is approximately 45m wide (to accommodate Norfolk Boreas and Norfolk Vanguard) and has been refined from an initial 200m onshore cable corridor (see Chapter 4 Site Selection and Assessment of Alternatives). The onshore cable route has been refined and routed in such a way to minimise potential impacts, and where possible taking account of landowner preferences and to avoid sensitive features, such as mature trees and archaeological features.

327. Under Scenario 1 the cable ducts would have been installed by Norfolk Vanguard, therefore activities within the onshore cable route would be limited to those associated with the pulling of the cable through the pre-installed ducts detailed in section 5.6.2.1 to 5.6.2.3.

5.6.2.1 Cabling pulling

328. Cables will be pulled through the ducts installed by Norfolk Vanguard using either a single phase or two phased approach, to facilitate the commissioning of up to two phases of offshore wind turbine installation. Cable pulling would not require trenches to be reopened, with the cables pulled through the pre-installed ducts from jointing pits located along the onshore cable route. Access to and from the jointing pits would be required to facilitate the works during this phase of the project.

329. This will be achieved through access to the onshore cable route directly from the public highways network (at crossing locations) or existing construction access routes (as illustrated on Figure 5.4) where possible. In some locations, isolated sections of the running track would be left in place from Norfolk Vanguard under Scenario 1 (or from duct installation for Scenario 2) or required to be reinstalled to allow access to more remote jointing locations. This is anticipated to be in the order of 20% of the total cable route length with an estimated breakdown based on an even 3.8km sectionalisation of the route provided in Table 5.34.

Table 5.34 Estimated retained or reinstalled running track for cable pulling and jointing

Route Section	Total section length [km]	Estimated running track requirement [km]	Estimated running track requirement [% of total section length]
MA1-East	6	0.95	16
MA2-West	5.3	1.92	36
MA2-East	6	0.26	4
MA3-West	3	0.67	22
MA3-East	6	2.60	43
MA4-West	3	0.00	0
MA4-East	5	0.00	0
MA4A-West	5	1.74	35
MA5-West	0.8	0.42	52
MA5-East	6	0.45	8
MA6-West	1.7	1.40	82
MA6-East	5.1	0.27	5
MA7-West	4.4	0.75	17
MA7-East	3.6	0.40	11
TOTAL	**60.99**	**11.83**	**19.4**

330. During the cable pulling phase, each section of running track would be used to bring in plant, cable reels and other materials to the jointing pits from the nearest appropriate public highway location (as discussed in Chapter 24 Traffic and Transport). This usage would be repeated for each of the Norfolk Boreas cable pulling phases (i.e. up to two phases in total).

331. To facilitate the cable pulling and jointing, the jointing pit would be excavated and cable drums delivered by HGV low loader to the open jointing pit locations (see section 5.6.2.2). The cable drum would be located adjacent to the jointing pit on a temporary hard standing and a winch attached to the cable, pulling the cable off the drum from one jointing pit to another, through the buried ducts. Cable jointing would be conducted once both lengths of cable that terminate within it have been installed.

332. The cable pulling and jointing process would take approximately five weeks per 800m length of cable, per circuit, including installing and removing any temporary hard standing and delivering the cables to the jointing pits. However, any one jointing pit could be open for up to 10 weeks to allow its neighbouring jointing pit to be opened and the cables pulled from one pit to the next, dependant on the level of parallel work being conducted.

5.6.2.2 Jointing pits

333. Jointing pits would be required along the onshore cable route to allow cable pulling and jointing of two sections of cable. The jointing pits would typically be located at approximately 800m intervals along each circuit, although site specific constraints may result in shorter intervals where necessary. The location of the jointing pits would be determined as part of the detailed design.

334. The jointing pits would be excavated, typically utilising tracked excavators. The excavated subsoil would be stored separately from the topsoil, capped and the profile of the soil maintained during the storage process. The pit could require shoring with wooden battens or other edge protection to enhance integrity and mitigate collapse risks. Each jointing pit would comprise an excavated area of 15m x 6m x 2m, per circuit, with a reinforced concrete floor to allow winching during cable pulling and a stable surface to allow jointing.

335. A temporary enclosure would be provided to allow a controlled environment to be maintained during jointing activities. A small generator could be required to provide the necessary electrical power for the enclosure, any powered jointing equipment and any pumps to manage groundwater.

5.6.2.3 Link boxes

336. Link boxes are required in close proximity (within 10m) to a subset of jointing pit locations to allow the HVDC cable sheaths to be bonded to earth to maximise cable ratings. Link boxes would not be required at all jointing locations and can typically be placed at 5km intervals. Separate link boxes are required for each cable circuit. The number and placement of the link boxes would be determined as part of the detailed design.

337. The link boxes would require periodic access by technicians for inspection and testing. Where possible, the link boxes would be located close to field boundaries and in accessible locations.

338. The link boxes, with dimensions 1.5m x 1.5m, per circuit, would be buried to ground level within an excavated pit, providing access via a secured access panel. Alternatively, above ground link box cabinets (1.2m x 0.8m x 1.8m) may be utilised which are typically sited on a 0.15m deep concrete slab. An example below ground link box is displayed in Plate 5.14.

Plate 5.14 Example below ground link box following reinstatement (Source: Ray Wind Farm, Vattenfall Wind Power Limited)

5.6.2.4 Cable logistics area

339. A cable logistics area (existing hardstanding near Oulton) (Figure 5.4 map 5) has been identified to allow the storage of cable drums and associated materials (e.g. jointing kits) close to the cable route. This facility may also accommodate a site office, welfare facilities and associated temporary infrastructure to support the cable pulling works. However, where possible, deliveries of materials and cable drums will be to the jointing pit locations and workers will travel direct to the work area.

5.6.2.5 Key parameters on cable route Scenario 1

340. Table 5.35 summarises the onshore cable route key parameters with Table 5.36 summarising the jointing pit key parameters.

Table 5.35 Summary of onshore cable route key parameters Scenario 1

Element	Minimum	Maximum	Additional information
Length of cable Route (km)		60	Approximate
Cable Diameter (mm)	100	150	
Type of cable	XLPE or MIND electrical cables, plus communications cables		
Voltage (kV)	320	500	
Burial depth (m)	1.05	-	1.05m ‘normal’ agricultural, 1.2m ‘deep ploughing’ agricultural to top of duct target. Up to 20m at trenchless crossings.

Table 5.36 Summary of jointing pit key parameters

Element	Minimum	Maximum	Additional Information
Number of cable circuits	2	2	Separate jointing pits are required for each cable circuit.
Width (m)	3	6	
Length (m)	10	15	
Depth (m)	1.5	2	
Nominal distance between jointing pits (m)	500	1000	Actual distance dependant on existing infrastructure along the cable route, cable specification and cable delivery limitations. Typically 800m.

5.6.2.6 Operations and maintenance

341. There is no ongoing requirement for regular maintenance of the onshore cables following installation; however access to the onshore cable route would be required to conduct emergency repairs, if necessary. Access to each field parcel along the cable route is available from the identified operational accesses (Figure 5.4) using existing field entry points where possible or accessing the cable route from road crossings.

5.6.2.7 Decommissioning

342. No decision has been made regarding the final decommissioning policy for the onshore cables, as it is recognised that industry best practice, rules and legislation change over time. It is likely the cables would be removed from the ducts and recycled, with the jointing pits and ducts capped and sealed then left in-situ.

5.6.3 Onshore Project Substation

5.6.3.1 General specification

343. The onshore project substation will consist of an HVDC substation.

344. The onshore project substation converts the HVDC electrical power from the Norfolk Boreas export connection to the HVAC format and appropriate voltage required for connection to the National Grid system. Filtering, switchgear and associated protection and control equipment is also located at the onshore project substation to provide compliance with the technical requirements of the National Grid and allow safe operation of the Norfolk Boreas connection.

345. The onshore project substation would consist of up to two similar converter stations, each having a power transfer capability of between 800MW and 1,000MW. The two converter stations will be located within the single onshore project substation footprint. The onshore project substation could be subject to a different arrangement however in the worst case, the onshore project substation would consist of:

- 2x converter buildings - housing DC filter equipment and power electronics to convert HVDC to HVAC power for connection to National Grid;
- 2x outdoor HVAC compounds – each compound will contain one or more 400kV transformers, plus HVAC filters, busbars and cable sealing ends;
- Control building – housing SCADA and protection equipment;
- Access roads – for operation and maintenance access to equipment; and
- Associated connections between equipment via overhead busbar and cabling, including buried earthing system

346. The largest equipment within the onshore project substation would be the converter halls with an approximate height of 19m. The tallest structure within the onshore project substation would be the slender lightning protection masts at a height of 25m. All other equipment will not exceed a height of 13m. The total land requirement for the onshore project substation to the perimeter fence is 250m x 300m.

347. Access to the onshore project substation will be via a shared access road, installed by Norfolk Vanguard, from the A47 up to the adjacent Norfolk Vanguard onshore project substation. This access road will be extended by approximately 300m to facilitate access to the onshore project substation.

348. Table 5.37 below summarises the onshore project substation key parameters.

Table 5.37 Onshore project substation key parameters

Element	Maximum	Additional Information
Length of site (m)	300	
Width of site (m)	250	
Tallest Structure (m)	25	Lightening protection mast
Tallest building (m)	19	Converter hall
Fence Height (m)	2.4 + 1.0	Palisade fence + electrical pulse fencing

5.6.3.2 Location

349. The onshore project substation is proposed to be located within the footprint illustrated in Figure 5.5. A detailed site selection process (described in Chapter 4 Site Selection and Assessment of Alternatives) has been undertaken to determine a suitable location. Siting of the onshore project substation has had due consideration to avoid existing watercourses, hedgerows and other known infrastructure/ constraints to minimise impacts where possible.

5.6.3.3 Onshore project substation temporary construction compound

350. During construction of the onshore project substation, a temporary construction compound will be established to support the works. The compound will be formed of hard standing (refer to section 5.7.2.5.1) with appropriate access to the A47 to

allow the delivery and storage of large and heavy materials and assets required for construction of the onshore project substation.

351. The compound would be of dimensions 200m x 100m and accommodate construction management offices, welfare facilities, car parking, workshops and storage areas. Water, sewerage and electricity services will be required at the site and supplied either via mains connection or mobile supplies such as bowsers, septic tanks and generators.

352. The location of the onshore project substation temporary construction compound would be sited within the zone identified in Figure 5.5, in close proximity to the onshore cable route and onshore project substation with due consideration for avoiding existing watercourses, hedgerows and other known infrastructure/ constraints to minimise impacts where possible.

353. In addition a temporary works area (100m x 100m) will be retained or reinstalled at the A47 Spicers Corner junction during the construction of the onshore project substation (refer to section 5.7.2.5.1).

5.6.3.4 Pre-construction works

354. Prior to the construction works beginning, a number of surveys and studies would be undertaken to inform the final detailed design including ecological surveys (see Chapter 22 Onshore Ecology), archaeological surveys (see Chapter 29 Onshore Archaeology and Cultural Heritage), geotechnical investigations, noise modelling and mitigation requirements such as landscaping and drainage assessments.

355. Surface water drainage requirements would be dictated by the final drainage study and would be designed to meet the requirements of the National Planning Policy Framework (NPPF)[3] with run-off limited, where feasible, through the use of infiltration techniques which can be accommodated within the area of development.

356. High level studies have indicated that an attenuation pond with volume 4,050m^3 (approximate dimensions of 58m x 58m x 1.2m) should be employed to allow a sufficient attenuation to greenfield runoff rates into the closest watercourse or sewer connection. The full specification for the attenuation pond and drainage strategy would be addressed as part of detailed design post-consent.

357. Foul drainage would be collected through a mains connection to an existing local authority sewer system if available or septic tank located within the development boundary. The specific approach would be determined during the detailed design

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[3] Limit post development off site run-off to the existing greenfield rate and providing sufficient on site attenuation for rainfall events up to 1 in 100 year rainfall event, plus a 40% allowance for climate change over the lifetime of the development.

phase with consideration for the availability of mains connection and the number of visiting hours for site attendees during operation.

358. Pre-construction works would be conducted to maximise the efficiency of the main construction works this will include:

- Hedge and Tree Netting / Removal – Hedge and tree removal is seasonal and can be influenced by ecological factors. Removing these ahead of the main works provides flexibility to account for seasonal restrictions and mitigates potential programme delays.
- Ecological preparations – pre-construction activities and mitigations agreed with Natural England and local authorities.
- Archaeological preparations – pre-construction activities and mitigations agreed with Historic England and local authorities.
- Pre-construction Drainage – Modifications to existing agricultural drainage would be required to facilitate the installation of the substation. An onshore substation drainage scheme will be produced as part of the project detailed design process and implemented as part of construction works.

359. In addition, under Scenario 1 at the onshore project substation during pre-construction works the existing access road, installed by Norfolk Vanguard, would be extended approximately 300m to facilitate access for the onshore project substation.

5.6.3.5 Screening

360. The onshore project substation site benefits from existing hedgerows and woodland blocks within the local area and would also benefit from additional planting installed by Norfolk Vanguard. However, Norfolk Boreas Limited has committed to additional planting to further screen the onshore project substation. The location of this proposed additional planting is provided in Figure 5.5. Further information on the proposed screening is provided in Chapter 29 Landscape and Visual Impact Assessment.

361. The mitigation planting would be designed to comprise a mix of faster growing ‘nurse’ species and slower growing ‘core’ species. Nurse species, such as alder, birch, and pine would grow quicker, with average growth rates of 350mm per annum, so that after 20 years they would be 8m in height (7m growth on top of a 1m base height). They would provide shelter to bring on core species, such as oak, beech and horse chestnut, with average growth rates of 250mm per annum, so that after 20 years they would be up to 6m in height (5m growth on top of a 1m base height). The nurse species would be sufficiently fast growing to provide substantial screening of the onshore project substation after 20 years. The core species would outlive the nurse species and provide a preferred native woodland with a more robust structure.

5.6.3.6 Construction

362. The onshore project substation would be enclosed by a temporary perimeter fence for the duration of the construction period with a permanent fence installed as part of the construction works.

363. The site would be stripped and graded as required by the final design. Stripped material would be reused on site where possible as part of bunding and shielding as allowed for in the final design. Any excess material would be disposed of at a licenced disposal site. Excavations and laying of foundations, trenches and drainage would commence after grading is complete.

364. At this stage it is not known whether the foundations would either be ground-bearing or piled based on the prevailing ground conditions.

365. The control buildings and converter hall would likely be constructed from a steel frame with cladding panels. The structural steelwork and cladding would be fabricated and prepared off site and delivered for erection. The frame would be erected with the use of cranes and the cladding fitted through a variety of means, dependant on the cladding selected i.e. brick or blockwork, sheet cladding etc.

366. The specialist electrical equipment would then be delivered to site, installed and commissioned. Due to the size and weight of assets such as the transformers, specialist delivery methods would be employed and assets would be offloaded at site with the use of a mobile gantry crane.

367. The onshore 400kV cables from the onshore project substation to the Necton National Grid substation (~1,750m) would likely be installed in a ‘direct bury’ method. This method will require trenches to be excavated between the onshore project substation and the Necton National Grid substation for the cables to be laid directly and jointed before being reinstated. Alternatively, the cables could be installed using a ducted method as described for the onshore cables (see section 5.7.2.2).

368. The route for the onshore 400kV cables under Scenario 1 is shown in Figure 5.5. Up to four trenches would be required, and each trench would accommodate up to three cables, with a total of 12 cables, providing two interconnecting circuits.

369. Construction activities would normally be conducted during working hours of 7am-7pm. Evening or weekend working could be required to maintain programme progress and for specific time critical activities such as transformer oil filling and processing; however these would be kept to a minimum. Perimeter and site lighting would be required during working hours in the winter months and a lower level of lighting would remain overnight for security purposes.

370. The construction programme for the onshore project substation would be expected to be approximately 24 to 30 months.

5.6.3.7 Operations and maintenance

371. The onshore project substation would not be manned, however access would be required periodically for routine maintenance activities, estimated at an average of one visit per week. Normal operating conditions would not require lighting at the onshore project substation, although low level movement detecting security lighting may be utilised for health and safety purposes. Temporary lighting during working hours will be provided during maintenance activities only.

372. Peak operational noise levels will be produced by transformers and harmonic filter reactors, further details are provided in Chapter 25 Noise and Vibration.

373. Noise mitigation measures are provided in Chapter 25 Noise and Vibration.

5.6.3.8 Decommissioning

374. No decision has been made regarding the final decommissioning plan for the onshore project substation, as it is recognised that industry best practice, rules and legislation change over time.

375. A full EIA will be carried out ahead of any decommissioning works being undertaken. The programme for decommissioning is expected to be similar in duration to the construction phase of 24 to 30 months. The detailed activities and methodology for decommissioning will be determined later within the project lifetime, in line with relevant policies at that time, but would be expected to include:

- Dismantling and removal of electrical equipment;
- Removal of cabling from site;
- Removal of any building services equipment;
- Demolition of the buildings and removal of fences; and
- Landscaping and reinstatement of the site.

376. The decommissioning methodology cannot be finalised until closer to decommissioning, but would be in line with relevant policy and legislative requirements at that time.

5.6.4 National Grid Substation Extension

377. The existing Necton National Grid substation would require an extension to accommodate the Norfolk Boreas connection points. The Necton National Grid substation would need to accommodate the circuit breakers which are the connection points for the project with associated busbar (metal bar that conducts electricity within a substation) structures which allow connection onto the existing

400kV overhead line for generation to be transmitted onto the wider National Grid system.

378. Under Scenario 1, extension works to the west of the Necton National Grid substation would have been undertaken to accommodate the Norfolk Vanguard connection points and a further extension to the east would be required to accommodate Norfolk Boreas.

379. Under Scenario 1, modifications to the existing overhead line structures adjacent to the substation would have been completed by Norfolk Vanguard to accommodate both projects.

5.6.4.1 General specification

380. The Necton National Grid substation will be extended in an easterly direction to a length of approximately 135m, with five new Air Insulation Switchgear (AIS) bays installed along the busbar extension. The maximum height of the outdoor busbar and bays at the substation is estimated to be 15m.

381. The National Grid substation extension works will be conducted within the area identified on Figure 5.5, to the east of the existing Necton National Grid substation.

382. Table 5.38 summarises the Necton National Grid substation key parameters.

Table 5.38 Scenario 1 National Grid substation key parameters summary

Element	Maximum	Additional Information
Length of extension site (m)	135	Norfolk Boreas easterly extension site.
Width of extension site (m)	150	Norfolk Boreas easterly extension site.
Total Length of extended site (m)	475	Including existing operational site, Norfolk Vanguard extension and Norfolk Boreas extension
Tallest structure (m)	15	Outdoor AIS busbar and landing gantries

5.6.4.2 National Grid temporary works area

383. During construction of the National Grid substation extension, a temporary works area will be established to support the works. Given project duration, the compound will likely be tarmacked with some concrete hard standing for heavier plant and equipment. Access to the A47 will be provided utilising the existing access road to the site to permit safe delivery of plant and equipment required for construction, with an appropriate traffic management scheme employed for safety.

384. The compound will accommodate construction management offices, welfare facilities, car parking, workshops and storage areas. Water, sewerage and electricity services will be required at the site and supplied either via mains connection or mobile supplies such as bowsers, septic tanks and generators.

385. The location of the National Grid temporary works area will be sited within the zone identified in Figure 5.5, in close proximity to the existing Necton National Grid substation.

386. A temporary construction access would be required to access the extension area during the construction works from the existing access route.

5.6.4.3 Pre-construction works

387. Prior to the construction works beginning at the National Grid substation extension, a series of pre-construction works would be required, as detailed in section 5.6.3.4 for the onshore project substation.

388. Surface water drainage requirements would be dictated by the final drainage study and would be designed to meet the requirements of the NPPF[4]. The Sustainable Drainage System (SuDS) philosophy would be employed to limit run-off, where feasible, through the use of infiltration techniques which can be accommodated within the area of development. The existing attenuation pond at the Necton National Grid substation would be required to be relocated and increased in size to accommodate additional impermeable ground associated with the substation extension for Norfolk Boreas. A total volume of 6,300m^3 is to be assumed (and this would accommodate the existing National Grid substation and both Norfolk Vanguard and Norfolk Boreas proposed extensions) and the proposed search area for the attenuation pond is presented in Figure 5.5.

5.6.4.4 Screening

389. Under Scenario 1, Norfolk Boreas Limited has committed to planting to screen the National Grid substation extension, further details are presented in Chapter 29 Landscape and Visual Impact Assessment. The location of the screening will reflect the extension of the substation in an easterly direction under this scenario and the location of the proposed planting is provided in Figure 5.5.

5.6.4.5 Construction

390. The National Grid substation extension site will be enclosed by a temporary perimeter fence for the duration of the construction period with a permanent fence installed as part of the construction works.

391. The site would be stripped and graded. Stripped material would be reused on site where possible as part of bunding and shielding as allowed for in the detailed design. Any excess material would be disposed of at a licensed disposal site. Excavations

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[4] Limit post development off site run-off to the existing greenfield rate and providing sufficient on site attenuation for rainfall events up to 1 in 100 year rainfall event, plus a 40% allowance for climate change over the lifetime of the development.

and laying of foundations, trenches and drainage would commence after grading is complete.

392. The design and construction of foundations at the National Grid substation extension will be subject to the outcome of geo-technical site investigations, post-consent. It is possible that some piled foundations will be required, but this is considered unlikely. Upon completion of the foundations, the specialist electrical equipment would then be delivered to site and installed and commissioned.

393. Construction activities would normally be conducted during working hours of 7am to 7pm. Evening or weekend working may be required to maintain programme progress. Perimeter and site lighting would be required during working hours and a lower level of lighting would remain overnight for security purposes.

394. The construction programme for the National Grid substation extension would be expected to be approximately 24 to 30 months.

5.6.4.6 Operations and maintenance

395. The operational Necton National Grid substation will be owned and operated by National Grid and would be unmanned. Maintenance of the substation would be undertaken approximately every three years, involving electrical isolation of equipment before it is worked on. Visual checks would be undertaken on a monthly inspection visit to the site. If the substation requires refurbishment or replacement works, vehicles would be used to carry workers in and out of the site and suitable vehicles would be used to bring new materials and equipment to site and to remove old equipment.

396. During operation, the Necton National Grid substation would not be illuminated under normal operating conditions. Temporary site lighting would be provided during working hours when conducting maintenance activities only.

397. Operational noise levels are not anticipated to change from existing levels due to the nature of the extension works. A standby generator exists at the site for emergency use only. Details of the noise emissions are provided in Chapter 25 Noise and Vibration.

5.6.4.7 Decommissioning

398. No decision has been made regarding the final decommissioning plan for the Necton National Grid substation, as it is recognised that industry best practice, rules and legislation change over time.

399. An appropriate impact assessment will be carried out ahead of any decommissioning works being undertaken. The programme for decommissioning is expected to be similar in duration to the construction phase of approximately 24 to 30 months. The

detailed activities and methodology for decommissioning would be determined prior to the end of the lifetime of the project, in line with relevant policies at that time, but would be expected to include:

- Dismantling and removal of electrical equipment;
- Removal of any building services equipment;
- Demolition of the buildings and removal of fences; and
- Landscaping and reinstatement of the site.

5.6.5 Indicative Onshore Construction Programme Scenario 1

400. This section summarises the main construction activities and sequence associated with installation of the Norfolk Boreas onshore infrastructure under Scenario 1.

5.6.5.1 Pre-construction works

401. Under Scenario 1, the majority of pre-construction works for the onshore cable route would have been completed by Norfolk Vanguard. Some limited surveys may be required prior to the start of the cable pulling works during 2025. Pre-construction activities could take place at and around the onshore project substation (refer to section 5.6.3.4) and the Necton National Grid substation (refer to section 5.6.4.3) these works would take place in advance of the main construction works and are scheduled to commence in 2022.

5.6.5.2 Landfall

402. For a drill length of 1000m, it is anticipated that site establishment, there will be three drills and two ducts (allowing for failure of one drill at 1000m for worst case assessments), and demobilisation will take approximately 20 weeks when considering 12 hour (7am to 7pm), 7 day shifts. 24 hour operation may be employed for drilling activities, subject to planning and environmental restrictions, and could reduce the installation to approximately 14 weeks.

403. Under Scenario 1 there is the potential that the landfall ducts could be installed at the same time as Norfolk Vanguard ducts to minimise the cumulative impacts of the project. Therefore, there are two programme options under Scenario 1 at the landfall:

- Option A – landfall duct installation prior to cable pulling in 2024 and 2025; or
- Option B – landfall duct installation concurrently with Norfolk Vanguard in 2022 and 2023.

404. Cable pulling at the landfall will be undertaken subsequent to the main duct installation to facilitate the commissioning of up to two phases of offshore wind turbine planting (2025 and 2026).

5.6.5.3 Cable pulling

405. For details of the cable pulling and associated works refer to section 5.6.2.1. The cables will be supplied and installed in up to two phases to facilitate two phases of offshore wind turbine planting. The cable pulling is scheduled for 2026 and 2027.

5.6.5.4 Onshore project substation

406. Full details of the onshore project substation construction activities are provided in section 5.6.3. The primary works for the final substation infrastructure, such as drainage, foundations and buildings would be constructed within a 24 to 30 month period (2024 to 2025). Onshore project substation plant (such as transformers and switchgear) will subsequently be supplied and installed in up to two phases of 2026 and 2027 to facilitate two phases of offshore wind turbine planting.

5.6.5.5 National Grid substation extension

407. The National Grid substation extension main construction works would be expected to be constructed in approximately 24 to 30 months. The programme for the works is likely to run in parallel to the onshore project substation works, commencing with pre-construction works in 2022.

5.6.5.6 Indicative construction programme Scenario 1

408. Table 5.39 below presents a high level indicative construction programme associated with the landfall and onshore infrastructure under Scenario 1 with respect to a two phase development programme.

Table 5.39 Scenario 1 onshore indicative project construction programme [5]

Activity	Year					
	2022	2023	2024	2025	2026	2027
Landfall						
Duct installation – Option A			🟦	🟦		
Duct installation – Option B	🟦	🟦				
Cable pulling, jointing and commissioning					🟦	🟦
Phase 1					🟩	
Phase 2						🟩
Onshore cable route						
Cable pulling, jointing and commissioning					🟦	🟦
Phase 1					🟩	
Phase 2						🟩
Onshore project substation and National Grid substation extension						
Pre-construction works	🟦	🟦				
Primary works			🟦	🟦		
Electrical plant installation and commissioning					🟦	🟦
Phase 1					🟩	
Phase 2						🟩

5.7 Onshore under Scenario 2

409. This section describes the onshore construction works and infrastructure required under Scenario 2. Under Scenario 2 Norfolk Vanguard does not proceed to construction and Norfolk Boreas proceeds alone. Under this scenario, Norfolk Boreas would install all onshore infrastructure as an independent project, including duct installation, all enabling works and modification to the existing overhead lines at Necton National Grid substation.

410. Under Scenario 2 the following onshore elements of the project will be constructed by Norfolk Boreas:

- Landfall;
- Onshore cable route, trenchless crossing (e.g. HDD) and mobilisation areas;
- Cable pulling;
- Onshore project substation
- Extension to the Necton National Grid substation;

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[5] The years of work outlined in this programme are indicative and are based on current assumed programmes and may be subject to change.

- Overhead line modifications at Necton National Grid substation; and
- Landscape, drainage and planting schemes.

5.7.1 Landfall

411. The location and construction works required for the landfall are the same as identified for Scenario 1; refer to section 5.6.1 for details.

5.7.2 Onshore Cable Route

412. The onshore cable route is approximately 45m wide and under Scenario 2 the ducts, cable pulling and all associated works will be undertaken by Norfolk Boreas within a 35m working width within the 45m cable route.

413. The location of the onshore cable route is the same as that identified in Scenario 1 and presented in Figure 5.4.

414. Under Scenario 2 all onshore cable route infrastructure will be installed by Norfolk Boreas. The onshore cable route would require trenches (within which ducts would be installed to house the cable circuits); a running track to deliver equipment to the installation site from mobilisation areas; and storage areas for topsoil and subsoil.

415. An indicative working width required to install the ducts and cables for Norfolk Boreas is provided in Plate 5.15 below, which illustrates the:

- total temporary strip (total land requirement to install the ducts);
- permanent strip (total ongoing land requirement of the installed ducts and cables); and
- ongoing right of access strip (temporary area required to be reserved for access for future repair or maintenance activities).

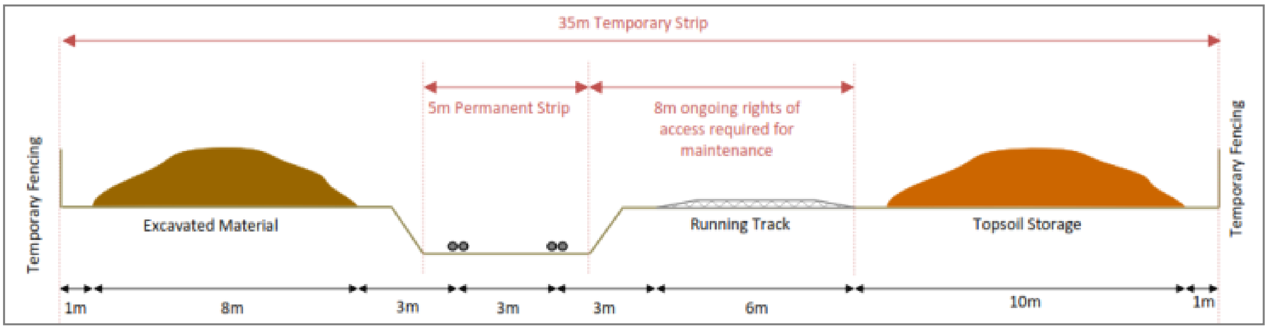

Plate 5.15 Indicative Norfolk Boreas onshore cable route

5.7.2.1 Pre-construction works

416. Prior to the construction works beginning, a number of surveys and studies would be undertaken to inform the final detailed design including ecological surveys (see Chapter 22 Onshore Ecology), archaeological surveys (see Chapter 29 Onshore

Archaeology and Cultural Heritage), geotechnical investigations, noise modelling and mitigation requirements such as landscaping and drainage assessments.

417. Pre-construction works would be conducted to maximise the efficiency of the main construction works, this will include:

- Road Modifications – New junctions off existing highways would be required. Installing these ahead of the main works provides immediate access to the mobilisation areas and provides float should any planning issues arise.
- Hedge and Tree Netting / Removal – Hedge and tree removal is seasonal and can be influenced by ecological factors. Removing these ahead of the main works provides flexibility to account for seasonal restrictions and mitigates potential programme delays.
- Ecological preparations – pre-construction activities and mitigations agreed with Natural England and local authorities.
- Archaeological preparations – pre-construction activities and mitigations agreed with Historic England and local authorities.
- Pre-construction Drainage – Modifications to existing agricultural drainage would be required. This is often complex meaning it is time consuming and difficult to modify. Pre-construction drainage works allow the existing drainage to be understood and provisions installed to allow easy modification during construction. This is best done at least a season before main construction starts in order to let the drainage establish in the landscape. This significantly improves the productivity of construction, especially in fields with significant water management.

5.7.2.2 Cable duct installation method

418. The main cable duct installation method would be through the use of open cut trenching. High Density Polyethylene (HDPE) ducts would be installed within the trenches and the soil backfilled. Cables would then be pulled though the pre-laid ducts at a later stage in the construction programme (refer to section 5.6.2.1).

419. Trenches would be approximately 1m in width and the ducts would be buried to a minimum depth of 1.05m in ‘normal’ agricultural ground (from top of duct to surface). This minimum depth is equivalent to the local electricity distribution providers standard installation (Engineering Construction Standard ECS 02-0019). The cable circuits would be installed in a flat formation (each cable core installed alongside another).

420. Where the onshore cable route crosses transport routes, waterways or other features, the standard open cut trenching installation technique would not be suitable. Further details of alternative crossing methodologies are provided in section 5.7.2.4.

421. To minimise impacts on sensitive features such as hedgerows the working width could be reduced to the running track and trenching areas only (e.g. a maximum reduction to 13m, assuming a perpendicular crossing and 16.5m, assuming an angled crossing) with soil storage areas retained immediately before and after the feature crossing.

422. The onshore cable duct installation strategy is proposed to be conducted in a sectionalised approach in order to minimise impacts. Construction teams would work on a short length (approximately 150m section) and once the cable ducts have been installed, the section would be back filled and the top soil replaced before moving onto the next section. This would minimise the amount of land being worked on at any one time.

423. Work sections are expected to be roughly 150m in length, and each work section will take approximately one to two weeks to complete. This includes all the following activities:

- Marking out and fencing off the new work section;
- Stripping and storing topsoil;
- Extending the running track along the new work section;
- Instating temporary drainage measures;
- Excavating trenches, installing ducts and back-filling; and
- Re-covering work section with topsoil (except for running track and drains).

424. Small welfare facilities would be accommodated within the working corridor to immediately support the construction work front.

5.7.2.2.1 Fencing

425. Fencing will be installed to demarcate the working area. Stock fencing will be used where necessary; post and wire or similar will be used otherwise.

5.7.2.2.2 Topsoil stripping and storage

426. Topsoil would be stripped from sections of the onshore cable route for the length of route to be worked on at any one time and stored and capped to minimise wind and water erosion within the working width as shown in Plate 5.15.

427. The profile of the soil would be carefully maintained during the storage process. The trenches would then be excavated, typically utilising tracked excavators. The excavated subsoil would be stored separately from the topsoil, capped and the profile of the soil maintained during the storage process. For further details please refer to Chapter 19 Ground Conditions and Contamination.

5.7.2.2.3 Running track

428. The running track would provide safe access for construction vehicles along the onshore cable route, from mobilisation areas to cable duct installation sites. The running track could be up to 6m wide and will be built out in stages as the cable duct installation sites advance away from mobilisation zones. At the end of the construction period, the running track may ultimately extend the full length of the onshore cable route. A separation of 2m would be maintained from the edge of the running track and the trench for safety, drainage and duct storage prior to pulling (if this is required). Speed limits on the running track will be limited to 20mph.

429. For the running track it may be possible to operate directly on the subsoil or it would be formed of protective matting, temporary metal road or permeable gravel aggregate dependant on the ground conditions, vehicle requirements and any necessary protection for underground services.

430. At drain crossings the running track will be installed over a pre-installed culvert pipe to allow continued access to the cable route. The pipe will be installed in the drain bed so as to avoid upstream impoundment and will be sized to accommodate reasonable ‘worst-case’ water volumes and flows. See section 5.7.2.3.5 for further details.

431. At larger crossings, temporary bridges may be employed to allow continuation of the running track. At sensitive locations such as some rail and river crossings (Mid-Norfolk railway, North Walsham railway, River Wensum, River Bure, King’s Beck, Wendling Beck (upstream), North Walsham & Dilham Canal and Marriott’s Way (twice)), the running track would terminate and continue on the far side. These locations would be defined as ‘stop ends’ to the construction work fronts to mitigate any direct impacts to the features and therefore divide up the various construction areas.

432. During the duct installation process, each work team will use the running track to travel from the mobilisation area (refer to section 5.7.2.5.1) or appropriate running track access point to the work front. The running track will also be used for transport of plant and materials between the mobilisation area and the work front.

433. When duct installation is completed, the running track would be taken up and the topsoil replaced. All recovered stone and other materials will be removed from site via the mobilisation area. Some areas of running track may need to be retained or reinstalled to facilitate the cable pulling works, see section 5.6.2.1 for details.

5.7.2.2.4 Drainage

434. A Surface Water and Drainage plan would be developed and implemented to minimise water within the trenches and ensure ongoing drainage of surrounding land. Where water enters the trenches during installation, this would be pumped via settling tanks or ponds to remove sediment, before being discharged into local ditches or drains via temporary interceptor drains (further detail is provided in Chapter 20 Water Resources and Flood Risk).

5.7.2.2.5 Trenches and duct installation

435. The cable trenches will be excavated typically utilising tracked excavators. The excavated subsoil would be stored separately from the topsoil, capped and the profile of the soil maintained during the storage process.

436. The trench could require shoring with wooden battens or other edge protection to enhance integrity and mitigate trench collapse risks. This requirement would be dependent on appropriate risk assessments considering the soil, prevailing weather conditions and trench depth.

437. A stabilised backfill such as Cement Bound Sand (CBS) would be installed at the base of the trench. A duct for each cable core and a separate duct for a fibre optic bundle would be laid on the CBS base and backfilled with CBS to a covering depth of 100mm. This approach would ensure a consistent homogeneous medium for the dissipation of heat generated by the cables during operation. The CBS backfill would be covered with high voltage cable warning tiles with integrated warning tape and the trench backfilled with subsoil material excavated from the trench. The stored topsoil would be replaced upon the backfilled subsoil to reinstate the trench to pre-construction condition, so far as reasonably possible.

438. The plant required for trench excavation is summarised in Chapter 25 Noise and Vibration. An indicative trench arrangement is shown in Plate 5.16.

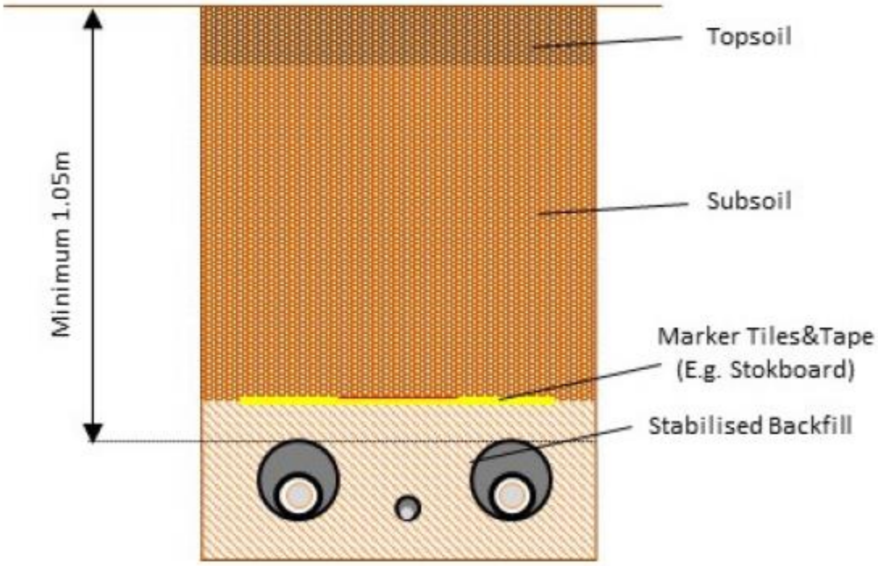

Plate 5.16 Indicative trench arrangement

5.7.2.2.6 Reinstatement of topsoil

439. Once all the trenching is completed and back-filled, the stored topsoil will be re-distributed over the area of the work section, with the exception of the running track and any associated drainage.

440. Long-term storage of topsoil in bunds or heaps is to be avoided where possible. However, some topsoil will have to be reserved for re-covering this final area when the running track is finally removed at the end of the duct installation or cable pulling phase.

5.7.2.3 Crossing installation methods

441. When crossing some features along the onshore cable route, alternative or amended installation approaches would be required to minimise the impact on the feature being crossed as much as reasonably practicable. The following sections detail the crossing installation methods available for each type of crossing.

5.7.2.3.1 Hedgerows

442. When crossing hedgerows, the width of the onshore cable route would be reduced to the running track and cable trenches only (this would result in 13m, assuming a perpendicular crossing and 16.5m, assuming an angled crossing) to minimise the amount of hedgerow removal (see Plate 5.15). Hedgerow removal would be conducted before the nesting season or hedgerows would be netted prior to removal to discourage nesting birds. Any hedgerow removed would be replanted with hedgerow types matching the existing where possible as part of reinstatement works, with the limitations outlined below.

443. After completion of duct installation, ongoing construction access into certain fields along the onshore cable route will be required to facilitate the phased delivery, pulling and jointing of cables. (For the majority of jointing locations, field accesses will be maintained at nearby points where public roads cross the onshore cable route. In a minority of cases, where there are no nearby crossing points or where the roads are unsuitable for construction traffic, it will be necessary to maintain access along the onshore cable route from a suitable road some distance away).

444. To facilitate these access arrangements during the cable pulling phase of the project, it will be necessary to retain suitable openings in a certain number of hedgerows for a further two years after the duct installation phase. These openings would be replanted at the end of this further period, with hedgerow types matching the existing.

445. Only hedge plants such as quick thorn and blackthorn may be planted directly above the onshore cables where a hedge is necessary either for screening purposes or to

indicate a field boundary. For reference, the following trees must not be planted within 6m of the cables and should only be planted as individual specimens or in a single row in the area between 6 to 10m of the cables. Dense mass planting should only be carried out greater than 10m from the cables:

- Ash, cedar, larch, beech, elm, horse chestnut, sweet chestnut, London plane, hornbeam, lime, lime alder, scots pine, black pine, oak, sycamore, apple, plum, cherry, pear, and most conifers.

446. Also, poplar and willow trees must not be planted within 10m of the cables.

447. The number and location of hedgerow openings required for ongoing access during cable pulling will not be known until the detailed design of the cable system is completed. The total number of openings is not expected to exceed 200. No opening would be greater than 6m wide.

5.7.2.3.2 Manual excavation for underground services

448. Information on the type and location of underground services has been collected (see Chapter 21 Land Use and Agriculture) and would be updated and verified as part of the pre-construction activities. Where these services are identified, manual trench excavation would be employed within 1m (or the stipulated distance requirement of the asset owner if applicable) of these locations to uncover the services in a controlled and safe manner.

449. The exposed services would be supported as necessary to prevent damage and the cable ducts installed at a suitable depth below the asset. Crossing of the services would be made at a perpendicular angle where possible to minimise crossing length and any potential interference impacts.

450. The works would be conducted within the onshore cable route with no additional land requirements. The running track could require reinforcement in these locations to minimise services damage. Soil storage and re-instatement of the trench would be conducted in line with the main cable route installation.

5.7.2.3.3 Traffic management

451. Where the onshore cable route crosses roads, tracks and public rights of way, traffic management would be employed to allow construction activities to continue safely. Where appropriate, single lane operation of roads would be utilised during installation with signal controls to allow movements to continue. Where the width of the road (<7.2m kerb to kerb) does not permit single lane operation, alternative methods such as temporary road closure or diversion could be required. To minimise the impact of closures or diversions, night working could be employed. The detailed installation method for each crossing utilising traffic management

would be agreed with the relevant highways authority or landowner prior to works beginning. It should be noted that trenchless crossing methods (refer to section 5.7.2.4) may be required at locations where standard traffic management techniques are not deemed to be suitable.

452. Temporary closures or diversions would be in place for the period of time required for the duct installation (e.g. approximately one to two weeks for 150m). Temporary crossings of the onshore cable route could then be installed to allow public access to continue where the running track is required to remain in service. The crossings would be managed to allow safe operation.

453. For installation, the ducts may be encased in concrete to a minimum depth of 0.9m, under the road surface, equivalent to the local electricity distribution providers standard installation (Engineering Construction Standard ECS 02-0019), to ensure protection of the onshore cables from traffic movements.

454. The works would be conducted within the onshore cable route with no additional land requirements. Soil storage and re-instatement of the trench would be conducted in line with the main cable route installation and the road surface would be reinstated to its pre-excavation condition, so far as reasonably possible.

5.7.2.3.4 Temporary dam and divert

455. Where small scale watercourses such as field drains, which are shallower than 1.5m, are to be crossed, temporary damming and diverting of the watercourse would be employed. The suitability of this method would be approved by the relevant authority at detailed design and in consultation with land owners.

456. The watercourse would be dammed at either side of the onshore cable route using sandbags or straw bales and ditching clay with water flow pumped/piped across the dammed section. The cable trenches would then be excavated within the dammed section and ducts installed to a suitable level below the drainage depth (e.g. 2m of cover below the bed level for Internal Drainage Board (IDB) drains). Reinstatement of the trench would be conducted to the pre-construction depth of the watercourse and the dams removed.

457. The works would be conducted within the onshore cable route with no additional land requirements. The running track could also require culverting or temporary bridging in these locations to allow continued cable route access and removed once cable installation is complete. Soil storage and re-instatement of the trench would be conducted in line with the main cable route installation.

5.7.2.3.5 *Culverting*

458. Where larger watercourses are deeper than 1.5m, culverting could also be implemented; however the suitability of this method would be approved by the relevant authorities at detailed design stage. It is noted that the Environment Agency deem this technique to be least desirable river crossing method due to the potential for adverse effect on the environment.

459. A culvert duct would be installed in the current watercourse, suitably sized for necessary water volumes and flows. The culvert duct would be backfilled or encased in concrete to a depth of 2m, the cable ducts would subsequently be laid perpendicular and backfilled to ground level creating a culverted watercourse.

460. The works would be conducted within the cable route with no additional land requirements. The running track would be included within the culverting exercise in these locations to allow continued cable route access. Excess excavated material from other areas of the cable route could be used for backfill of the trench.

461. Culverting may be required temporarily for a width of 6m to allow the running track to cross watercourses during duct installation works (up to 2 years dependant on location along the route section being worked) and for 'inaccessible' sections of the running track relating to the cable pulling works period (approximately 3 months per location). This method could be employed at all watercourses with exception to those designated as 'stop ends' where the running track will not cross the watercourse.

5.7.2.4 Trenchless crossing methods

462. Trenchless installation methods such as HDD, micro tunnelling or auger boring would be used where open cut trenching is not suitable due to the width and, or type of feature being crossed. The locations where trenchless methods would be employed are listed in Table 5.40 in displayed in Figure 5.4 (trenchless crossing zones).

463. With trenchless methods, the depth at which the ducts are installed depends on the topology and geology at the crossing site. Typically, for a river crossing, HDD ducts would be installed 5m below the floodplain, and at least 2m below the river bed. A Flood Risk Activity permit under the Environmental Permitting Regulations 2010 will be applied for where required.

Table 5.40 Schedule of Trenchless crossings

ID	Name / Feature crossed	Location (Map no. in Figure 5.4)
TC1	A47	8
TC2	Wendling Carr County Wildlife Site (CWS)	8
TC3	Wendling Beck and Little Wood CWS	8
TC4	Mid-Norfolk Railway	8
TC5	River Wensum	7

ID	Name / Feature crossed	Location (Map no. in Figure 5.4)
TC6	Marriotts Way CWS (South)	6
TC7	Marriotts Way CWS (North) & Proposed Kerdiston CWS	6
TC8	Ørsted (Hornsea Project 3)	5
TC9	River Bure	4
TC10	A140	4
TC11	Kings Beck	3
TC12	A149	3
TC13	Norwich to Sheringham Railway	3
TC14	Paston Way and Knapton Cutting CWS and B1145	2
TC15	North Walsham and Dilham Canal	2
TC16	Woodland South of Witton Hall	2

5.7.2.4.1 Horizontal Directional Drilling

464. The methodology for HDD is the same as detailed in section 5.6.1 for the landfall works.

5.7.2.4.2 Auger boring / micro-tunnelling

465. In both cases a circular or rectangular pit (shaft or cofferdam) is constructed each side of the feature to be crossed. These are typically 1m below the invert level of the conduit (pipe or duct) to be installed. The conduit is driven through the side wall from the launch pit to a reception pit. The method of driving varies to suit prevailing ground conditions.

466. Auger boring is suitable in most cases with the exception of sands or obstructions such as cobbles or boulders. First a pilot pipe is jacked through the ground from the launch shaft to the reception shaft. An auger is attached to the end which clears the opening of soil and is itself followed by the permanent lining.

467. Micro-tunnelling involves remote control tunnel boring machines tunnelling themselves from the launch to reception shaft conveying spoil to the launch shaft via conveyors. The permanent conduit immediately follows the machine, installed by jacking from the launch pit. This method can be used in most ground as the drilling head can be configured to prevailing ground conditions.

5.7.2.4.3 Trenchless crossing compounds

468. Where trenchless drilling activities are to be conducted, a temporary compound would be required to store drilling equipment, welfare facilities, ducting and water[6] for the drilling process. The trenchless crossing compounds would typically be of dimensions 100m x 50m for the reception site and 150m x 50m on the launch site and would be located adjacent to the onshore cable route, as displayed in Figure 5.4.

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[6] It is assumed that water is required to be transported and stored on site in water bowsers during the trenchless drilling activities and cannot be sourced from local watercourses.

469. The exact dimensions would be fully determined by site specific constraints and drilling requirements such as cable segregation and drilling depth. A temporary bridge may be included to allow crossing at Wendling Carr to allow continuation of the running track and allow access to both sides of the crossing. At all other locations, a stop end would be employed, requiring the inclusion of a turning area for vehicles within the temporary work area. Plate 5.17 to Plate 5.21 provide indicative plan layouts and example aerial photography of trenchless installation techniques for crossing significant features such as major roads, major rivers and railways.

470. The trenchless installation would occur prior to or parallel to the main cable installation works and the drilling rig would be located within the onshore cable route for duct installation with the temporary compound adjacent. The precise location and sizing of the drilling site can only be derived through detailed analysis of the ground conditions and derivation of proposed drill profile (angle and depth).

471. A series of desk top studies and site visits have been used to identify the likely proposed locations for trenchless installation and these are shown in Figure 5.4.

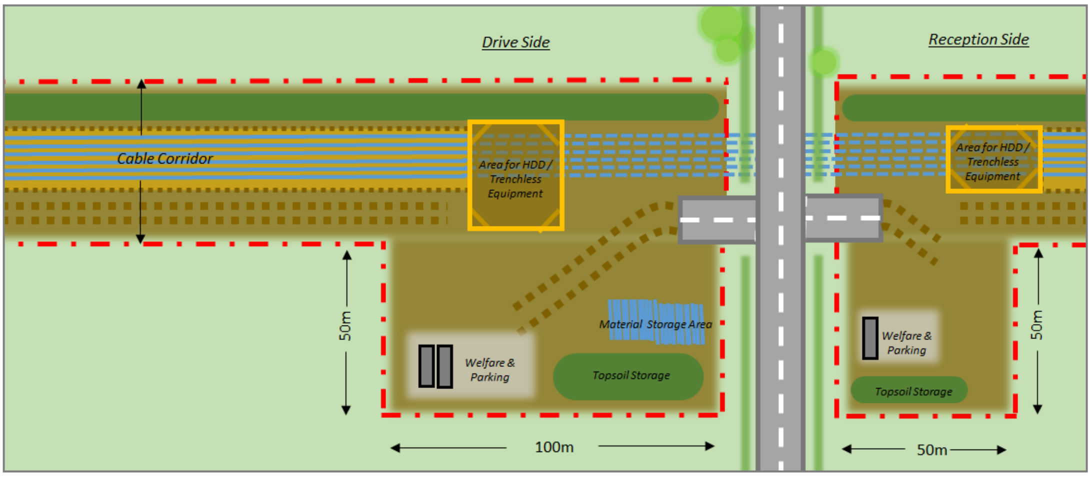

Plate 5.17 Indicative trenchless road crossing

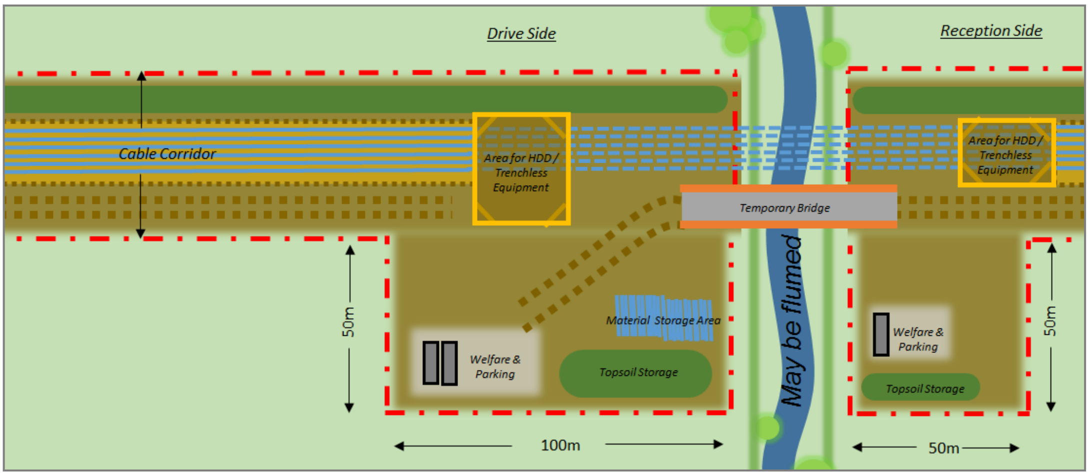

Plate 5.18 Indicative trenchless river crossing with temporary bridge

Plate 5.19 Aerial image of example trenchless river crossing with temporary bridge (Source: Courtesy of J Murphy & Sons Ltd)

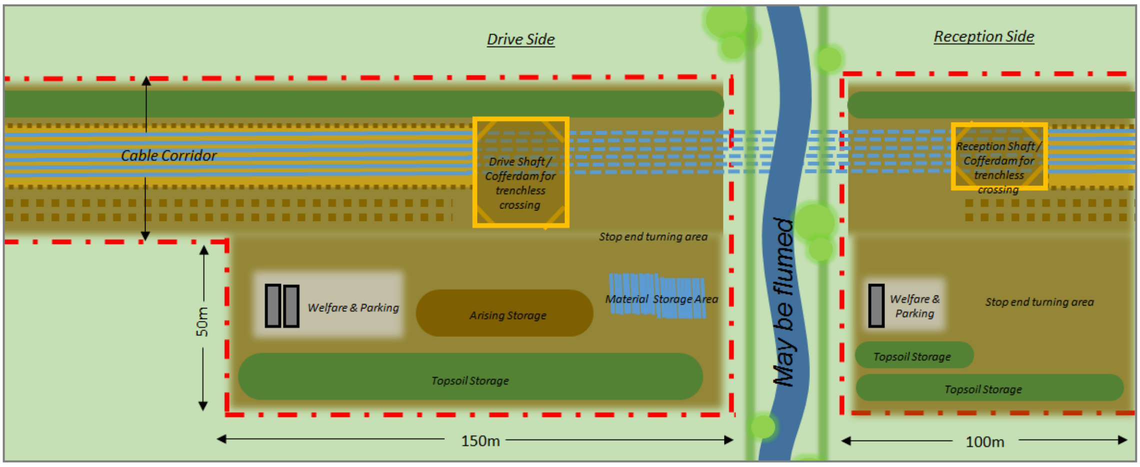

Plate 5.20 Indicative trenchless river crossing with stop end

Plate 5.21 Aerial image of example trenchless river crossing with stop end (Source: Courtesy of J Murphy & Sons Ltd)

5.7.2.5 Temporary Works Areas

5.7.2.5.1 Mobilisation areas

472. To enable onshore duct installation, mobilisation areas would be required to store equipment and provide welfare facilities. These mobilisation areas would be located adjacent to the onshore cable route, accessible from the local highways network and suitable for the delivery of materials and equipment. Each mobilisation area would serve one or two work fronts and are evenly distributed along the onshore cable route length as far as possible. A series of desk based studies and site visits have been used to identify the likely locations for mobilisation areas and these are shown in Figure 5.4, and termed ‘mobilisation zones’.

473. The mobilisation areas would be a maximum of 100m x 100m dimensions (or 150m x 100m if combined with a trenchless crossing compound) with specific sizing and dimensions for each location based on site constraints and land boundaries.

474. Hardstanding would comprise of permeable gravel aggregate to a depth of 0.3m underlain by geotextile or other suitable material and would be laid to allow safe storage and movement of vehicles within the area and maintain required drainage. Site lighting and secure fencing around the perimeter of the mobilisation area would be utilised for safety and security purposes. Where possible, the mobilisation areas would be supplied by existing water, sewerage and electrical services although the use of bowsers, septic tanks and generators could be employed if necessary.

475. The mobilisation areas will remain in place for the duration of the onshore duct installation activities, proposed as two years (see section 5.7.5). Following installation of the ducts, the mobilisation areas would be removed and the land reinstated. During cable pulling, materials will be delivered directly to the jointing locations or via the use of a cable logistics area (existing hardstanding near Oulton) (Figure 5.4 map 5) (see section 5.6.2.4).

476. A mobilisation area (100m x 100m) would also be established at the Spicers Corner junction of the A47 to facilitate the junction improvement and construction of the access road to the onshore project substation.

5.7.2.5.2 Trenchless crossing compounds

477. Full details of trenchless crossings compounds and associated temporary works are provided in section 5.6.2.4.

5.7.2.5.3 Onshore cable route access

478. Small temporary works areas could be required to facilitate the safe ingress and egress from the public highways to the onshore cable route or mobilisation areas through temporary slip roads. Traffic and transport assessments have identified where these additional accesses may be required and further assessment will be undertaken post consent based on the final design of the project. Accesses are expected to be located at each mobilisation area and intersections between the public highway and cable route, where suitable, to facilitate side access to the onshore cable route.

5.7.2.6 Cable pulling

479. The construction works required for cable pulling are the same as identified for Scenario 1 (refer to section 5.6.2.1 for details), as are the works for the associated jointing pits (refer to section 5.6.2.2) and link boxes (refer to section 5.6.2.3).

5.7.2.7 Key onshore cable route parameters for Scenario 2

480. Table 5.41 summarises the onshore cable route key parameters for Scenario 2.

Table 5.41 Summary of onshore cable route key parameters for Scenario 2

Element	Minimum	Maximum	Additional information
Number of cable trenches	1	2	
Width of cable trench (m)	1	5	Maximum considers two adjacent trenches are excavated as a single trench rather than as two separate trenches of 1m
Length of cable Route (km)		60	Approximate
Cable Diameter (mm)	100	150	
Type of cable	XLPE or MIND electrical cables, plus communications cables		

Element	Minimum	Maximum	Additional information
Voltage (kV)	320	500	
Temporary strip width (m)	35	35	
Permanent strip width (m)	13	13	
Burial depth (m)	1.05	-	1.05m ‘normal’ agricultural, 1.2m ‘deep ploughing’ agricultural to top of duct target. Up to 20m at trenchless crossings.

5.7.2.8 Operations and Maintenance

481. The operations and maintenance requirements for the cable route would be the same as under Scenario 1 (refer to section 5.6.2.6).

5.7.2.9 Decommissioning

482. The decommissioning requirements for the cable route would be the same as under Scenario 1 (refer to section 5.6.2.7).

5.7.3 Onshore Project Substation

5.7.3.1 General Specification

483. The general specification of the onshore project substation would be the same as under Scenario 1 (refer to section 5.6.3.1).

5.7.3.2 Location

484. Under Scenario 2 the onshore project substation is proposed to be located within the footprint illustrated in Figure 5.6. The site selection process for identifying this search area is described in Chapter 4 Site Selection and Assessment of Alternatives. Siting of the onshore project substation has been subject to due consideration to avoid existing watercourses, hedgerows and other known infrastructure/ constraints to minimise impacts where possible.

485. Under Scenario 2 the onshore 400kV cable route for cables from the onshore project substation to the Necton National Grid substation would connect to a western extension of the existing site (see section 5.7.4) and as such would take a different route than under Scenario 1, as presented in Figure 5.6.

5.7.3.3 Onshore project substation temporary construction compound

486. The specification of the onshore project substation temporary construction compound would be the same as under Scenario 1 (refer to section 5.6.3.3).

487. A temporary mobilisation area (see section 5.7.2.5.1), 100m x 100m, would also be established at the Spicers Corner junction of the A47 to facilitate the junction improvement works. The area would also be used to construct the new access road to the onshore project substation, prior to construction at that location and be retained during the construction of the onshore project substation.

5.7.3.4 Pre-construction works

488. The pre-construction works as detailed under Scenario 1 (refer to section 5.6.3.4) would be undertaken. However, in addition under Scenario 2 they would also include carriageway works at the Spicers Corner junction of the A47 to install a right turn filter and new exit from the A47 (see Chapter 24 Traffic and Transport) and installation of access road to the onshore project substation.

5.7.3.5 Screening

489. The onshore project substation site benefits from existing hedgerows and woodland blocks within the local area. However, Norfolk Boreas Limited has committed to planting to further screening the onshore project substation. The location of this proposed additional planting is provided in Figure 5.6. Further information on the proposed screening is provided in Chapter 29 Landscape and Visual Impact Assessment.

5.7.3.6 Construction

490. The construction works for the onshore project substation would be the same as under Scenario 1 (refer to section 5.6.3.6).

5.7.3.7 Operations and maintenance

491. The operations and maintenance of the onshore project substation would be the same as under Scenario 1 (refer to section 5.6.3.7).

5.7.3.8 Decommissioning

492. The decommissioning of the onshore project substation would be the same as under Scenario 1 (refer to section 5.6.3.8).

5.7.4 National Grid Substation Extension and Overhead Line Modifications

493. The existing Necton National Grid substation would require to be extended to accommodate the Norfolk Boreas connection points. The Necton National Grid substation accommodates the circuit breakers which are the connection points for Norfolk Boreas with associated busbar structures which allow connection onto the existing 400kV overhead line for generation to be transmitted onto the wider National Grid system.

494. In addition to the Necton National Grid substation itself, modifications to the existing overhead lines in parallel to the substation will be required to provide a double turn-in arrangement.[7]

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[7] Each overhead line tower carries two 400kV circuits. In this arrangement, both circuits are turned into the substation busbar structure.

5.7.4.1 General Specification

495. Under Scenario 2 the Necton National Grid substation outdoor busbar will be extended in a westerly direction to a total length of 340m (inclusive of the existing Necton National Grid substation), with seven new AIS bays installed along the busbar extension. The maximum height of the outdoor busbar and bays at the substation is estimated to be 15m.

496. Table 5.42 summarises the National Grid substation extension key parameters.

Table 5.42 Scenario 2 National Grid substation extension key parameters summary

Element	Maximum	Additional Information
Length of extension site (m)	200	Norfolk Boreas easterly extension site.
Width of extension site (m)	150	Norfolk Boreas easterly extension site.
Total Length of extended site (m)	340	Including existing operational site and Norfolk Boreas extension
Tallest structure (m)	15	Outdoor AIS busbar and landing gantries

497. The National Grid substation extension and overhead line modification works will be conducted within the areas identified within Figure 5.6.

498. Two new overhead line towers will be required in close proximity to the existing corner tower (to the north of the existing Necton National Grid substation). The towers will be sited within the overhead line search areas (one west and one east) as identified on Figure 5.6 and will be a maximum height of 55m, to allow for a double turn in arrangement. The existing corner tower would be removed such that the net new number of towers is one.

5.7.4.2 National Grid temporary works area

499. During construction of the National Grid substation extension, a temporary works area will be established to support the works. Under Scenario 2, the location of the temporary works area would be sited within the zone identified in Figure 5.6, in proximity to the extension site to the west of the existing Necton National Grid substation.

500. The specification of the National Grid temporary works area would be the same as described under Scenario 1 (refer to section 5.6.4.2).

5.7.4.3 Pre-construction works

501. The pre-construction works required for the National Grid substation extension would be the same as under Scenario 1 (refer to section 5.6.4.3) with the exception of the location of the attenuation pond.

502. The drainage strategy for the extension would be the same as Scenario 1, however under Scenario 2 the existing attenuation pond at the Necton National Grid substation will be extended to accommodate additional impermeable ground associated with the substation extension for Norfolk Boreas. A total volume of 4,200m^3 is to be assumed, which considers both the existing Necton National Grid substation and the extension for Norfolk Boreas under Scenario 2.

5.7.4.4 Screening

503. Under Scenario 2, Norfolk Boreas Limited has committed to planting to screen the National Grid substation extension; further details are presented in Chapter 29 Landscape and Visual Impact Assessment. The location of the screening will reflect the extension of the substation in a westerly direction under this scenario and the location of the proposed planting is provided in Figure 5.6.

5.7.4.5 Construction

504. The construction works required for the National Grid substation extension would be the same as under Scenario 1 (refer to section 5.6.4.5).

505. For the National Grid overhead line modification works, temporary towers (maximum height 45m) will be constructed in close proximity to the existing towers and the existing circuits transferred over to the temporary towers. The existing tower will be removed and two new towers will be constructed and the circuits transferred from the temporary towers. The temporary towers and foundations will then be removed. The new tower foundations may be piled or excavated and cast, dependant on the ground conditions and structural requirements. These works will be undertaken within overhead line temporary works areas presented on Figure 5.6.

5.7.4.6 Operations and maintenance

506. The operations and maintenance would be the same as under Scenario 1 (refer to section 5.6.4.6).

5.7.4.7 Decommissioning

507. The decommissioning would be the same as under Scenario 1 (refer to section 5.6.4.7).

5.7.5 Indicative Onshore Construction Programme Scenario 2

508. This section summarises the main construction activities and sequence associated with installation of the Norfolk Boreas onshore infrastructure under Scenario 2.

5.7.5.1 Pre-construction works

509. Under Scenario 2, pre-construction works would be required for the onshore cable route (refer to section 5.7.2.1). Pre-construction works would also be required at the onshore project substation (refer to section 5.7.3.4) and the National Grid

substation (refer to section 5.7.4.3). These works would take place in advance of the main construction works and are scheduled to commence in 2021.

5.7.5.2 Landfall

510. For a drill length of 1000m, it is anticipated that site establishment, there will be three drills and two ducts (allowing for failure of one drill at 1000m for worst case assessments) and demobilisation will take approximately 20 weeks when considering 12 hour (7am to 7pm), 7 day shifts. 24 hour operation can be employed for drilling activities, subject to planning and environmental restrictions, and could reduce the installation to approximately 14 weeks. The duct installation works at the landfall are scheduled for 2023 to 2024. Cable pulling at the landfall will be undertaken subsequent to the main duct installation (2025 to 2026).

5.7.5.3 Duct installation

511. The main duct installation works would be undertaken in 2023 to 2024 and can be broadly broken into the following work packages:

- Enabling works;
- Duct installation and
- Reinstatement works.

512. Plate 5.22 provides an indicative overview of the duct installation works programme (approximately two years. Full details of the processes involved in these installation works is provided in section 5.7.2.2.

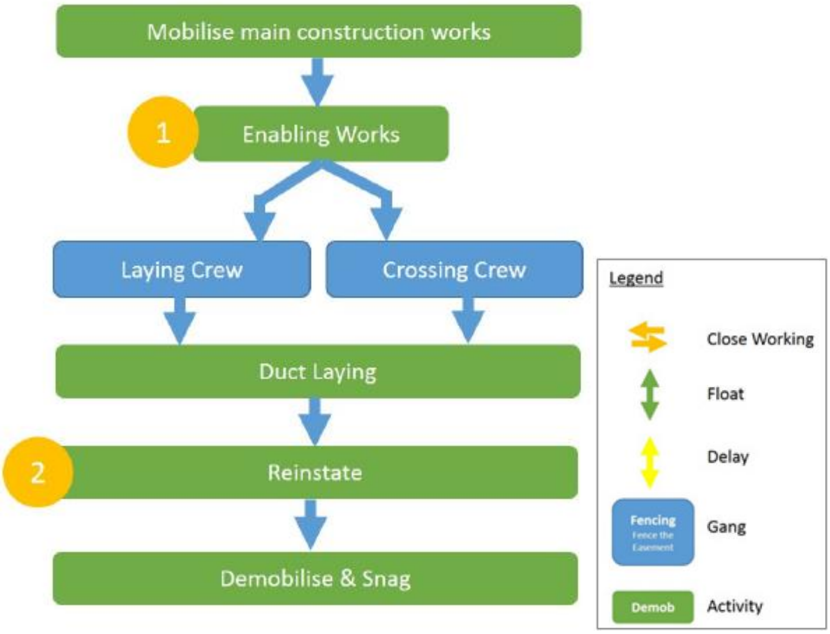

Plate 5.22 Overview of main duct installation works process

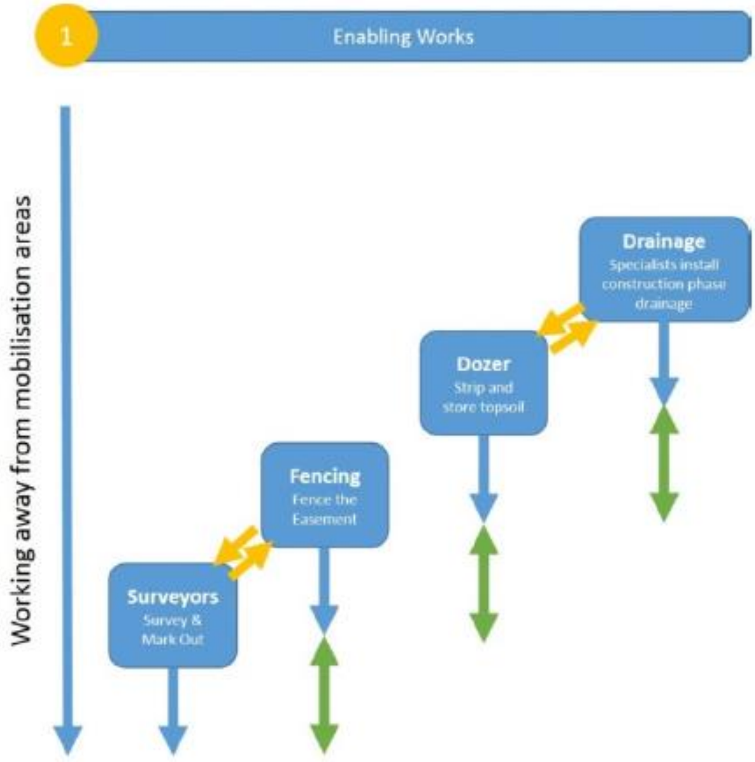

Plate 5.23 Enabling works details

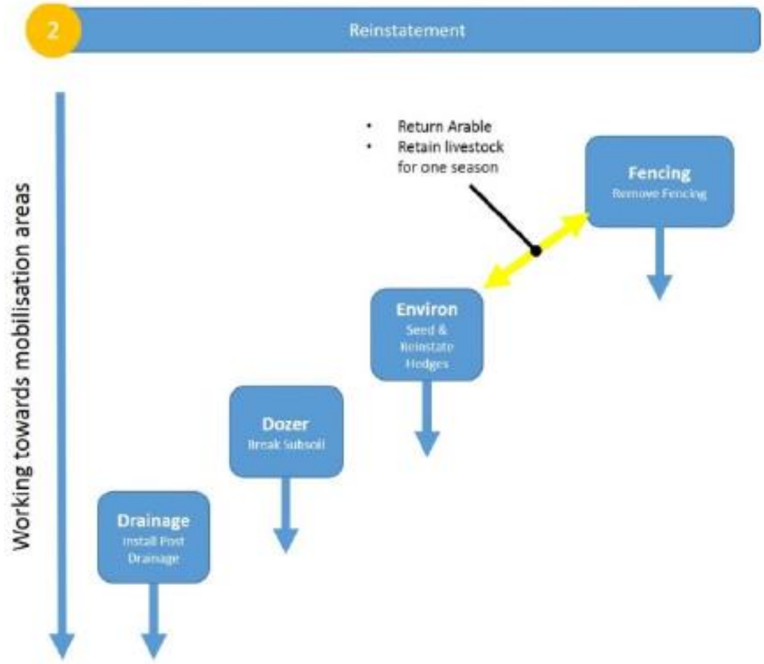

Plate 5.24 Reinstatement works detail

513. It is estimated that the required resource, across the route length, would peak to 300 to 350 operatives during the two year duct installation works. It is proposed that a five day working week limited to the hours of 7am to 7pm would be employed with an average installation productivity of approximately 150m per week.

514. Seven day working could be required during specific periods of the installation, such as following periods of poor weather, but would be reserved where programme acceleration is required. Seven day and 24 hour working could be employed for any trenchless crossings, subject to specific requirements.

5.7.5.4 Cable Pulling

515. For details of the cable pulling and associated works refer to section 5.7.2.6. The cables will be supplied and installed in up to two phases to facilitate the commissioning of up to two phases of offshore wind turbine planting. The cable pulling is scheduled for 2025 to 2026.

5.7.5.5 Onshore project substation

516. Full details of the onshore substation construction activities refer to section 5.7.3. The primary works for the final substation infrastructure, such as drainage, foundations and buildings would be constructed within a 24 to 30 month period (2023 to 2024). Onshore project substation plant (such as transformers and switchgear) will subsequently be supplied and installed in up to two phases of 2025 and 2026 to facilitate the commissioning of up to two phases of offshore wind turbine planting.

5.7.5.6 National Grid substation extension and overhead line modifications

517. The National Grid substation extension main construction works and the overhead line modifications would be expected to be constructed in approximately 24 to 30 months. The programme for the works is likely to run in parallel to the onshore project substation works, commencing with pre-construction works in 2021.

5.7.5.7 Indicative construction programme Scenario 2

518. Table 5.43 below presents a high level indicative construction programme associated with the landfall and onshore infrastructure under Scenario 2 with respect to a two phase development programme.

Table 5.43 Scenario 2 onshore indicative project construction programme [8]

Activity	**Year**					
	2021	**2022**	**2023**	**2024**	**2025**	**2026**
Landfall						
Duct Installation			🟦	🟦		
Cable pulling, jointing and commissioning					🟦	🟦
Phase 1					🟩	
Phase 2						🟩
Onshore cable route						
Pre-construction works	🟦	🟦				
Duct installation works			🟦	🟦		
Cable pulling, jointing and commissioning					🟦	🟦
Phase 1					🟩	
Phase 2						🟩
Onshore project substation and Necton National Grid Substation						
Pre-construction works	🟦	🟦				
Primary works			🟦	🟦		
Electrical plant installation and commissioning					🟦	🟦
Phase 1					🟩	
Phase 2						🟩

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[8] The years of work outlined in this programme are indicative and are based on current assumed programmes and may be subject to change.

5.8 Use of Natural Resources

519. Norfolk Boreas Limited has sought to minimise the use of, and effect on natural resources through its careful site selection process (outlined in Chapter 4 Site Selection and Assessment of Alternatives) as well as its choice of technology and the specific installation methods proposed. Early site surveys, including water resources, ecology and archaeology have enabled a good understanding of the natural resources of the area to ensure that significant effects on key features can be avoided where possible. Where the project has the potential to directly affect a resource, installation methods such as the use of trenchless techniques have either removed or considerably reduced any impacts.

520. The decision to adopt HVDC technology has provided a much reduced project footprint as a cable relay station is no longer required and the number of cables, and therefore the width of the cable corridors on and offshore, is significantly reduced. This reduces direct impacts on the natural environment and the additional resources to build the project.

521. Further information on natural resources and the avoidance of key features can be found in Chapter 4 Site Selection and Assessment of Alternatives, Chapter 21 Land Use and Agriculture, Chapter 22 Onshore Ecology, Chapter 23 Onshore Ornithology and Chapter 28 Onshore Archaeology and Cultural Heritage.

5.9 Response to Potential Major Accidents and Disasters

522. The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 (the EIA Regulations 2017) require significant risks to the receiving communities and environment, for example through major accidents or disasters, to be considered. Similarly, significant effects arising from the vulnerability of the proposed development to major accidents or disasters should be considered. Relevant risks are covered in the topic chapters within this ES.

523. A major accident, as defined in the Control of Major Accident Hazards (COMAH) Regulations 2015 (as amended), means "an occurrence (including in particular, a major emission, fire or explosion) resulting from uncontrolled developments in the course of the operation of any establishment and leading to serious danger to human health or the environment, immediate or delayed, inside or outside the establishment and involving one or more dangerous substances".

524. Offshore wind developments have an intrinsically low risk of causing major accidents. The turbines, blades, towers and foundation bases of offshore wind farms have an excellent safety record with a very low failure rate and are positioned many kilometres offshore away from populated areas and the public. On the rare occasion that offshore turbine blades have been lost into the sea or damage has been caused

to a turbine by a fire within the nacelle, this has resulted without injury. The performance of each turbine is constantly monitored through the SCADA system sending performance data through to a central, partly automated monitoring and control centre. As a result, a problem can be quickly detected and pre-prepared safety management action plans rapidly enacted.

525. Whilst exposed power cables on the seabed can pose a snagging risk to shipping and fishing vessels, the projects export and array cables will be buried where possible to protect the cables and remove the snagging risk. This is discussed in detail in Chapter 15 Shipping and Navigation, which also discusses the risk that the increased vessel movement to and from the site may pose to navigational safety during construction and operational phases.

526. The buried cables onshore and offshore pose very little risk to the public as the HVDC system is designed to detect faults and 'trip out' the DC circuit automatically should any failure in insulation along the cable be detected.

527. The risk of substation fires is historically low. The highest appropriate levels of fire protection and resilience will be specified for the onshore project substation to minimise the existing low fire risk. The onshore project substation is located sufficiently distant from populated areas to further minimise the risk of fire hazard.

528. The lubricants, fuel and cleaning equipment required within the project will be stored in suitable facilities designed to the relevant regulations and policy design guidance.

529. The offshore wind industry strives for the highest possible health and safety standards across the supply chain. However there have been incidents including a small number of worker fatalities during the construction and operation of offshore wind farms. Risks to the public onshore and other sea users offshore during construction are minimised through the use of controlled construction sites onshore and vessel safety zones offshore.

530. Safety zones are temporary exclusions enacted during construction, allowing Norfolk Boreas Limited and its contractors to control vessel movement to enable safe construction works to proceed.

531. Onshore, controlled or closed construction sites will be operated where construction works are undertaken in sections where access is strictly controlled during periods when the works are ongoing.

532. Norfolk Boreas Limited recognises the importance of the highest performance levels of health and safety to be incorporated into the project. There is a commitment to adhere to a high level of process safety, from design to operations and for all staff,

contractors and suppliers to have a high level of safety awareness and knowledge of safety and safe behaviour. Norfolk Boreas Limited will enact a Code of Conduct for suppliers, contractors and subcontractors. They must all comply with the Code as well as health and safety legislation. Norfolk Boreas Limited will ensure that employees that are going to work for Norfolk Boreas Limited have undergone necessary health and safety training.

533. With a commitment to the highest health and safety standards in design and working practises enacted, none of the anticipated construction works or operational procedures is expected to pose an appreciable risk of major accidents or disasters.

534. In conclusion, the risk of ‘major accidents and/or disasters’ occurring associated with any aspect of the project, during the construction, operation and decommissioning phases is considered to be negligible.

5.10 References

AECOM (2012). Kelling to Lowestoft Ness Shoreline Management Plan.
Fugro (2016) (Unpublished). Norfolk Vanguard Offshore Wind Farm Geophysical Investigation.
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