FOREWIND

DOGGER BANK
TEESSIDE A & B

October 2013

Draft Environment Statement
Chapter 5
Project Description

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Contents

Table of Tables

Table of Figures

1. Introduction

1.1. Overview

1.1.1. This Chapter of the Environmental Statement (ES) describes the third and fourth offshore wind farm arrays to be applied for in the Dogger Bank Zone; Dogger Bank Teesside A and Dogger Bank Teesside B (collectively known as Dogger Bank Teesside A & B). This Chapter describes onshore and offshore aspects of Dogger Bank Teesside A & B, including the project site, as well as the components, construction, commissioning, operation and maintenance, and decommissioning of the proposed offshore wind farm arrays. Any additional assumptions which have been made to input into the detailed environmental impact assessments are stated within the relevant chapter of the Environmental Statement. Any applied mitigation, intended to reduce or avoid adverse environmental effects, is also discussed in the relevant chapter of the Environmental Statement.

1.1.2. The offshore wind turbine array areas of Dogger Bank Teesside A and Dogger Bank Teesside B are geographically separated. The export cable routes and onshore infrastructure are aligned and adjacent to one another, but are expected to be constructed, operated and decommissioned separately where practicable.

1.1.3. This information has been used to inform the technical Chapters contained within the ES and is considered to represent the 'development envelope' of Dogger Bank Teesside A & B for use within the Environmental Impact Assessment (EIA). In **Chapter 4 Environmental Impact Assessment Process**, the approach to assessment involving the Rochdale Envelope approach is explained in detail, and this explanation should be read with this chapter.

1.1.4. This Chapter also incorporates three appendices: **Appendix 5.A Underwater Noise Technical Report**, **Appendix 5.B Foundation Characterisation Study** and **Appendix 5.C Health Impact Assessment**.

1.2. Project Development Envelope - Flexibility

1.2.1. Large scale offshore wind farm developments are relatively new, and technology is advancing rapidly to address the associated challenges. In addition, component suppliers have not yet been selected and products fulfilling the same function can vary markedly between suppliers. Factors such as on-going stakeholder consultations, identification of new environmental constraints and onshore landowner negotiations may also all potentially impact upon the final project design. Given the anticipated future changes in the design and availability of wind farm components, continual improvements in installation techniques, the uncertainty regarding future costs, and the need for flexibility to reduce health, safety, and environmental risks where they are identified, it is therefore not feasible to predict the optimum design solution for Dogger Bank Teesside A & B at this time.

1.2.2. The project description presented here therefore contains flexibility that will allow the adoption of the best available technology and methodologies as part of an optimised solution. This is expected to be developed during future detailed design, to be carried out alongside the procurement and placement of contracts for the construction of Dogger Bank Teesside A & B, post consent.

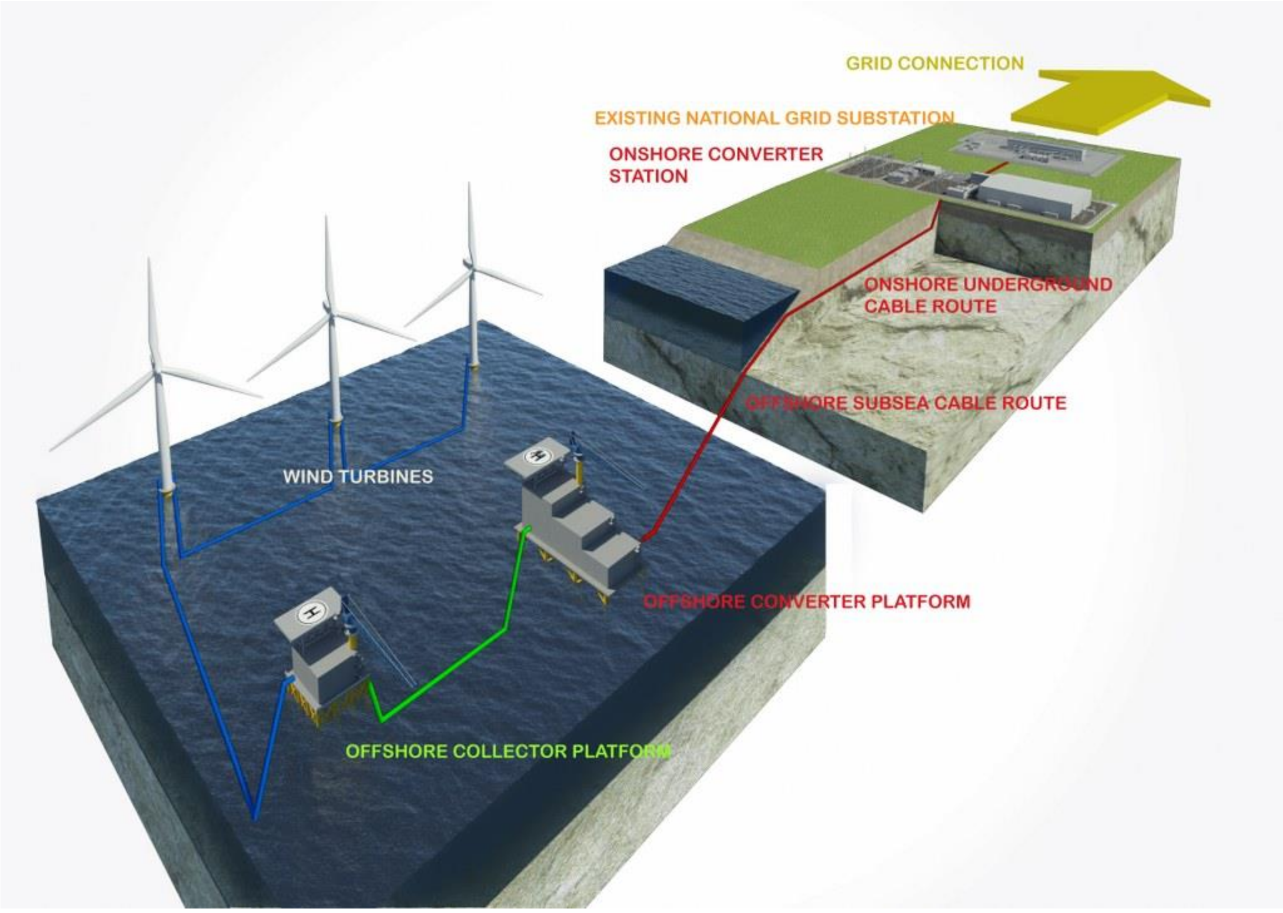
1.2.3. This flexibility to respond to developing engineering and environmental understanding will enable Dogger Bank Teesside A & B to be delivered using approaches which minimise health, safety, and environmental risk, keep pace with rapid technical developments in the field of offshore wind, deliver Government targets for cost reduction, and maximise its potential viability.

1.2.4. This flexible approach to development, and the associated consent, is based upon the use of a 'Rochdale Envelope' methodology. This approach has taken account of The Planning Inspectorate advice note nine on the use of the Rochdale Envelope approach; see **Chapter 4 Approach to Environmental Impact Assessment** for further detailed information.

1.2.5. The limits of flexibility required are described throughout this document, but specific discussions of need for flexibility in the context of the Rochdale Envelope and the assessment of worst realistic cases are included within, for example, **Section 5 Offshore Project Layouts, Section 3.1 Wind Turbines, Section 3.2 Offshore Structure Foundation, and Section 6.3 Construction**.

1.3. Project Description – Summary

Figure 1.1 Schematic diagram of an offshore wind farm project



1.3.1. Each of the two proposed offshore wind farm arrays, forming part of the Dogger Bank Teesside A & B project, will have an installed generating capacity of up to 1,200MW (megawatts). An indicative schematic, showing the significant components of an offshore wind farm can be seen in **Figure 1.1**. Dogger Bank Teesside A and Dogger Bank Teesside B would each primarily comprise the following elements:

- Offshore:
  - Up to 200 wind turbines and supporting tower structures;
  - Wind turbine foundations and associated support and access structures;
  - One offshore converter platform, and associated foundation;
  - Up to four offshore collector platforms, and associated foundations;
  - Up to two offshore accommodation or helicopter platform(s) for operations and maintenance activities, and associated foundations;
  - Subsea inter-array cables:
    - between the wind turbines;

    - between wind turbines and offshore collector platforms;
    - between wind turbines and offshore converter platform;
    - linking to meteorological stations and accommodation platforms;
  - Subsea inter-platform cables:
    - between offshore collector platforms;
    - between offshore collector platforms and High Voltage Direct Current (HVDC) offshore converter platform;
  - Offshore export cable systems, carrying power from the offshore HVDC converter platform to the landfall(s);
  - Crossing structures at the points where project cables cross existing subsea cables and pipelines or other Dogger Bank project cables;
  - Up to five offshore meteorological monitoring stations. This is in addition to the two meteorological stations which were subject to an earlier and separate consent application and installed in 2013;
  - Protection against scour and subsea foundation damage (where necessary);
  - Seabed preparation measures for foundation installation (where necessary)
  - Cable protection measures (where necessary); and
  - Up to ten vessel mooring buoys.
- Onshore:
  - Cable landfall and transition joint bays;
  - Onshore High Voltage Direct Current (HVDC) export cable system carrying power from the landfall to the onshore HVDC converter station;
  - Directional drilling as part of the landfall, as well as under roads, foreshore, railways, watercourses, pipelines, other cables and other obstructions;
  - Onshore converter station with associated road, fencing, landscaping and drainage;
  - Onshore High Voltage Alternating Current (HVAC) cable system carrying power from the onshore HVDC converter station to the existing National Grid substation at Lackenby;
  - Connection bay within the existing National Grid substation at Lackenby containing switchgear and electrical equipment for connection of the export cable system to the transmission network;
  - Temporary works and laydown areas;
  - Permanent and temporary access roads; and

– Service corridors, including telecommunications, water and connection to the local electricity network.

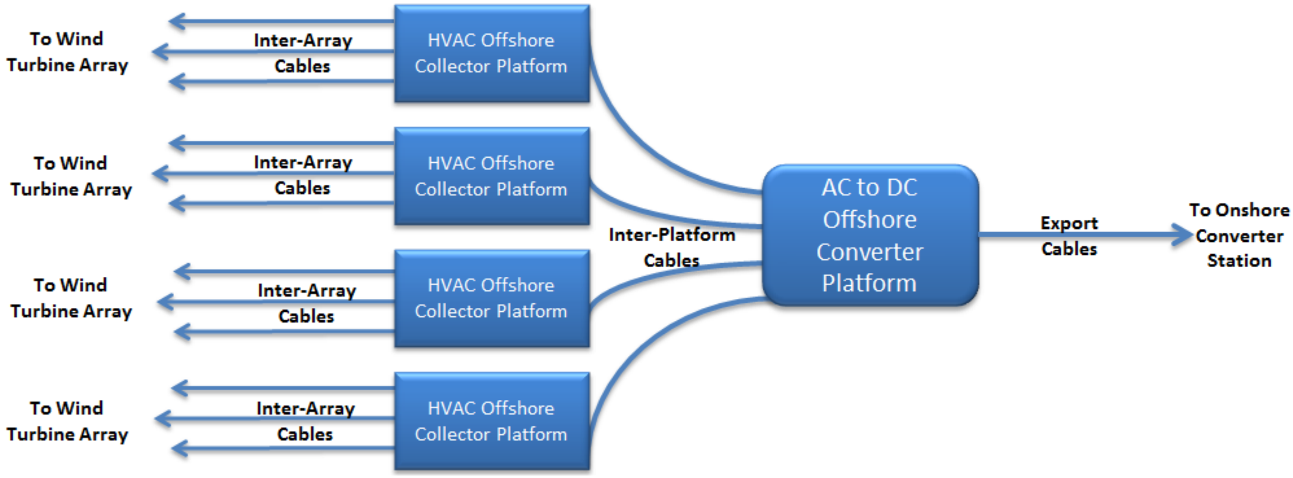
1.3.2. In addition, enabling works will be required at the existing National Grid substation at Lackenby to allow connection of Dogger Bank Teesside A & B. Consent, construction, operation & maintenance, and decommissioning some of these works will be the responsibility of National Grid, with the balance being the responsibility of Forewind. Consultation is currently being undertaken with National Grid to understand the level of works to the substation. These works are referred to as 'works to connect actions' and have been considered in the impact assessment work for Dogger Bank Teesside A & B.

Table 1.1 Summary of key project components

Parameters	Maximum per project	Maximum total for projects A and B
Wind turbines	200	400
Offshore collector substation platforms	4	8
Offshore converter substation platforms	1	2
Offshore accommodation or helicopter platforms	2	4
Offshore meteorological stations	5	10
Length of inter-array cabling (km)	950	1,900
Length of inter-platform cabling (km)	320	640
Number of HVDC export cable pairs	1	2
Onshore converter stations	1	2
Number of onshore HVAC export cables	3	6

1.3.3. An indicative connection schematic for the offshore electrical system components of a single project can be found in **Figure 1.2** and comprises of the following; inter-array cables which connect to the wind turbines, offshore HVAC collector platforms, inter-platform cables, an offshore HVDC converter platform and HVDC export cables which connect to an onshore HVDC converter station. In addition there will be HVAC cables linking the onshore converter into National Grid's network.

Figure 1.2 Indicative connection schematic for the electrical system



The Offshore Transmission Owner

1.3.4. Following first generation, the transmission assets will be transferred to an Offshore Transmission Owner (OFTO), under the revised regulatory regime for licensing offshore electricity transmission.

1.3.5. The OFTO will be appointed through a competitive tender round managed by the Office for Gas and Electricity Markets (Ofgem). The OFTO is expected to take responsibility for the operation and maintenance of the offshore export cables, offshore converter platforms, inter-platform cables, offshore collector platforms, onshore cables, and onshore converter station.

1.4. Project Capacities & Overplanting

1.4.1. Although the wind farms may have an installed generating capacity of up to 1,200MW, the projects have secured 1,000MW of grid connection capacity. Thus, the generation will be curtailed such that the connection point into National Grid's existing onshore substation does not receive more than around 1,000MW at any point in time.

1.4.2. This allows the projects to be optimised for maximum efficiency taking into account electrical losses, availability, and the natural variability of a wind farm's output. This can be described as 'overplanting' (adding additional turbines to offset losses and increase the utilisation of the transmission capacity). Overplanting potentially allows an improved economic optimisation of the project. **Table 1.2** shows both the maximum installed generating capacity and the grid entry capacity for Dogger Bank Teesside A & B.

1.4.3. The maximum installed generating capacity offshore is therefore fixed, and the grid entry capacity caps the power that can be delivered at the onshore point of connection to the grid, but the capacities, dimensions, and detailed design of many of the electrical components of the projects may vary. The values provided throughout the design envelope have been developed to accommodate this approach. The precise design of the wind farm systems will be determined through a process of detailed design and optimisation post-consent.

Table 1.2 Key project capacity figures

Parameter	Teesside Project A	Teesside Project B
Maximum installed generating capacity (MW)	1,200	1,200
Maximum grid entry capacity (MW)	1,000	1,000

1.5. Project Output & Electricity Generation

1.5.1. On the basis that each project has the maximum capacity of 1,200MW, for a total installed capacity of 2,400MW for both projects combined, the annual electricity generation expected from Dogger Bank Teesside A & B is predicted to be approximately 8,410,000,000kWh (one kWh, or kilowatt hour, being one 'unit' on a typical electricity bill), or 8,410GWh (gigawatt hours). This figure is based upon an assumed capacity factor of 40%, (that is, averaged over the year, the wind farms will supply to the grid 40% of the electricity which would have been generated offshore if all turbines were running at maximum output throughout the year). Dogger Bank has a strong wind resource, and Forewind has determined that the capacity factor of these projects should be in excess of 40%, dependent upon the turbine model, wind farm layout, and availability achieved. This takes into account the expected site wind conditions for an average year, and all expected losses and downtime up to the point where Dogger Bank Teesside A & B connects into the onshore electricity network. It also takes into account the effects upon the available wind resources of all eight anticipated Dogger Bank offshore wind projects being fully constructed.

1.5.2. Dogger Bank Teesside A & B has the potential to make a very significant contribution to the reduction of harmful greenhouse gas emissions in the UK as a whole through the generation of nationally significant quantities of electricity from a clean, renewable, and sustainable source. This is electricity that might otherwise need to be generated through alternative forms of electricity generation, such as the burning of coal or gas in thermal power stations. Further detail on this subject is provided in **Chapter 2 Project Need**.

1.5.3. By providing a significant quantity of renewable electricity, Dogger Bank Teesside A & B could also allow a corresponding reduction in the reliance on fossil fuels, such as gas or coal, which the UK has to produce or import to generate electricity.

1.5.4. By displacing electricity generated by burning fossil fuels, Dogger Bank Teesside A & B could also reduce a range of other non-greenhouse gas pollutants and waste products produced by UK fossil fuel electricity generation. These vary dependent upon the design of the power station and the type of fuel burned.

Future Dogger Bank Zone Output

1.5.5. Dogger Bank Teesside A & B is the second stage of the Dogger Bank Zone development. An application for the first stage of Dogger Bank Zone development, Dogger Creyke Beck A and Dogger Bank Creyke Beck B (collectively known as Dogger Bank Creyke Beck) has been made earlier this year. It is anticipated that consent for a further four projects shall be sought. Should the whole of the zone be built out as planned (eight projects in total, or 9,600MW), it could supply a significant portion of total UK generation supplied to the grid. This would make the Dogger Bank Zone the largest source of electricity generation in the UK and amongst one of the largest electricity generators in the world.

1.6. Links to the Development Consent Order

1.6.1. Under sections 14(1)(a) and 15(3) of the Planning Act 2008, both of the Dogger Bank Teesside A & B projects are classed as Nationally Significant Infrastructure Projects. Therefore, in order to gain development consent to construct and operate Dogger Bank Teesside A & B it is necessary to apply to the Major Applications and Plans Directorate of the Planning Inspectorate for a Development Consent Order (DCO) and a deemed Marine Licence. One application will be submitted to encompass the consent for both Dogger Bank Teesside A & B, and one draft DCO will be submitted to the Planning Inspectorate.

1.6.2. The DCO will describe both projects and specify the limits within which the offshore wind farm and its associated infrastructure must be constructed. This description is based upon the range of parameters presented within Chapter 5 and the remainder of the ES, and the extent of this flexibility is in accordance with the principles for the Rochdale Envelope advised by the Planning Inspectorate. Schedule 1, Part 1 of the draft DCO comprises the detailed description of the projects which is further split into Work Numbers for reference purposes.

1.6.3. There will also be a set of requirements set out in Schedule 1, Part 3 of the DCO and a set of conditions attached to the deemed Marine Licences which will secure the mitigation identified throughout the ES and restrict the development in accordance with the relevant minimum and maximum parameters within this chapter (the Rochdale Envelope).

1.6.4. As the DCO maintains some flexibility in the consent, as described above, the final layout and details will be designed post-consent in line with the limits defined in the DCO and submitted to the relevant authority for approval.

1.7. Relevant Guidance

1.7.1. The Dogger Bank Teesside A & B project description has been produced with specific reference to the relevant National Policy Statements (NPS). These are the principal decision making documents for Nationally Significant Infrastructure Projects. Those relevant to Dogger Bank Teesside A & B are:

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

1.7.2. The specific areas of relevance within the NPS are summarised in **Table 1.3**, together with an indication of where each is addressed.

Table 1.3 NPS requirements

NPS requirements	NPS reference	ES reference
Environmental statement In some instances it may not be possible at the time of the application for development consent for all aspects of the proposal to have been settled in precise detail. Where this is the case, the applicant should explain in its application which elements of the proposal have yet to be finalised, and the reasons why this is the case.	Section 4.2.7 of EN-1	Considered throughout Chapter 5 and the ES as a whole. The Project Development Envelope & flexibility is addressed specifically in **Section 1.2**.
Environmental statement Should the IPC determine to grant development consent for an application where details are still to be finalised, it will need to reflect this in appropriate development consent requirements.	Section 4.2.9 of EN-1	See above
Environmental statement Where some details are still to be finalised the ES should set out, to the best of the applicant's knowledge, what the maximum extent of the proposed development may be in terms of site and plant specifications, and assess, on that basis, the effects which the project could have to ensure that the impacts of the project as it may be constructed have been properly assessed.	Section 4.2.8 of EN-1	See above
…some flexibility may be required in the consent. Where	Section	

this is sought and the precise details are not known, then the applicant should assess the effects the project could have (as set out in EN-1 paragraph 4.2.8) to ensure that the project as it may be constructed has been properly assessed (the Rochdale Envelope). In this way the maximum adverse case scenario will be assessed and the IPC should allow for this uncertainty in its consideration of the application and consent.	2.6.43 of EN-3	
Criteria for "good design" for energy infrastructure …the IPC needs to be satisfied that energy infrastructure developments are sustainable and, having regard to regulatory and other constraints, are as attractive, durable and adaptable (including taking account of natural hazards such as flooding) as they can be. In so doing, the IPC should satisfy itself that the applicant has taken into account both functionality (including fitness for purpose and sustainability) and aesthetics (including its contribution to the quality of the area in which it would be located) as far as possible. Whilst the applicant may not have any or very limited choice in the physical appearance of some energy infrastructure, there may be opportunities for the applicant to demonstrate good design in terms of siting relative to existing landscape character, landform and vegetation. Furthermore, the design and sensitive use of materials in any associated development such as electricity substations will assist in ensuring that such development contributes to the quality of the area.	Section 4.5.3 of EN-1	Chapter 5 (the design of the onshore converter station is covered in **Section 4.6**). Landscape considerations are covered in **Chapter 21 Landscape Visual Character**.
Safety HSE is responsible for enforcing a range of occupational health and safety legislation some of which is relevant to the construction, operation and decommissioning of energy infrastructure. Applicants should consult with the Health and Safety Executive (HSE) on matters relating to safety.	Section 4.11.1 of EN-1	Chapter 5 **Section 7**
Hazardous substances All establishments wishing to hold stocks of certain hazardous substances above a threshold need Hazardous Substances consent. Applicants should consult the HSE at pre-application stage if the project is likely to need hazardous substances consent. Where hazardous substances consent is applied for, the IPC	Section 4.12.1 of EN-1	Chapter 5 **Section 7**

will consider whether to make an order directing that hazardous substances consent shall be deemed to be granted alongside making an order granting development consent. The IPC should consult HSE about this.		
Water depth and foundation conditions The onus is on the applicant to ensure that the foundation design is technically suitable for the seabed conditions and that the application caters for any uncertainty regarding the geological conditions.	Section 2.6.31 of EN-3	**Section 2.2** presents site information. **Sections**, **3.2**, **3.3**, **3.5**, and **3.6** present foundations and associated elements. **Sections 6.2** and **6.3** discuss pre-construction and construction
Grid Connection Applicants for consent for offshore wind farms will have to work within the regulatory regime for offshore transmission networks established by Ofgem. Under the regime offshore transmission will be a licensed activity regulated by Ofgem.	Section 2.6.34 of EN-3	Chapter 5 **Section 1.3**
Micrositting Any consent that is granted by the IPC should be flexible to allow for necessary micrositing of elements of the proposed wind farm during its construction where requested at the application stage. This allows for unforeseen events such as the discovery of previously unknown marine archaeology that it would be preferable to leave in situ. Where micrositing tolerance is requested by the applicant in any consent, given that the EIA should assess a maximum adverse case scenario, the assessment should reflect the implications of any micrositing as far as reasonably possible.	Sections 2.6.44 and 2.6.45 of EN-3	Chapter 5 **Sections 5.**1 and **5.4** acknowledge the potential for micrositing. The possible impacts are assessed in the relevant technical assessment chapters e.g. **Chapter 12 Marine and Intertidal Ecology**.
Repowering Where an operational offshore wind farm reaches the	Section 2.6.49 of	Repowering is discussed in

end of its life, subject to obtaining the necessary lease from The Crown Estate or providing an existing lease is still valid, the owner of the wind farm may wish to "repower" the site with new turbines. Given the likely change in technology over the intervening time period, any repowering of sites is likely to involve wind turbines of a different scale and nature. This could result in significantly different impacts as well as a different electricity generating capacity and a new consent application would be required.	EN-3	Chapter 5 **Section 6.6** under the heading "Replanting/ Life Extension".

1.8. Consultation

1.8.1. As part of the development of Dogger Bank Teesside A & B, Forewind has undertaken a thorough pre-application consultation process, which has included the following key stages:

- Scoping Report submitted to the Infrastructure Planning Commission (IPC) (now the Planning Inspectorate) (May 2012);
- Scoping Opinion received from the IPC (July 2012); and
- First stage of statutory consultation (in accordance with sections 42 and 47 of the Planning Act 2008) on Preliminary Environmental Information (PEI) 1 (report published May 2012).

1.8.2. Forewind currently intends to undertake the second stage of statutory consultation (in accordance with sections 42, 47 and 48 of the Planning Act 2008) on the draft ES in October 2013. The second stage of statutory consultation is designed to allow for comments before final application to the Planning Inspectorate.

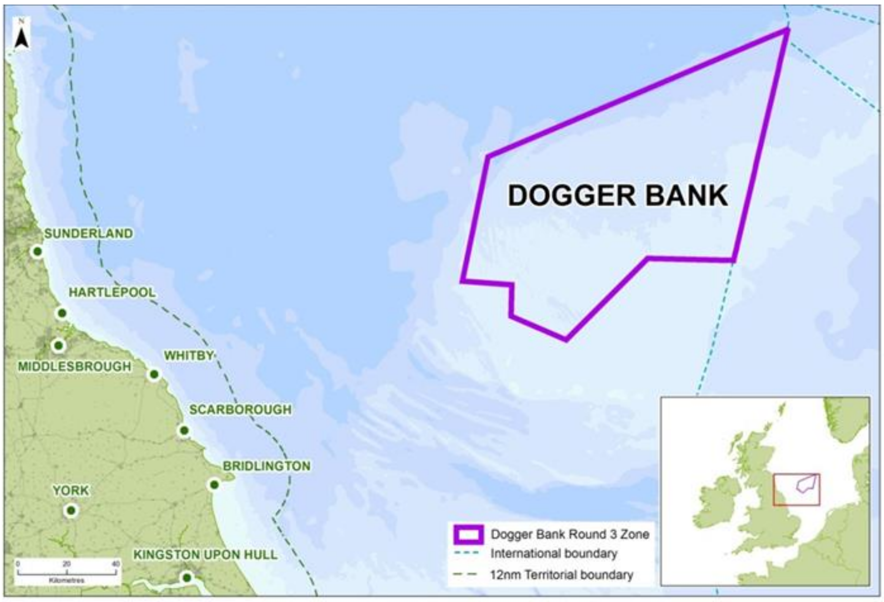
1.8.3. In between the statutory consultation periods, Forewind consulted specific groups of stakeholders on a non-statutory basis to ensure that they had an opportunity to inform and influence the development proposals. Consultation undertaken throughout the pre-application development phase has informed Forewind's design decision making and the information presented in this document. Further information detailing the consultation process is presented in **Chapter 7 Consultation**. A Consultation Report is also provided alongside this ES, as part of the overall planning submission.

2. Site Description

2.1. Site Location

Dogger Bank Zone

Figure 2.1 Dogger Bank Zone



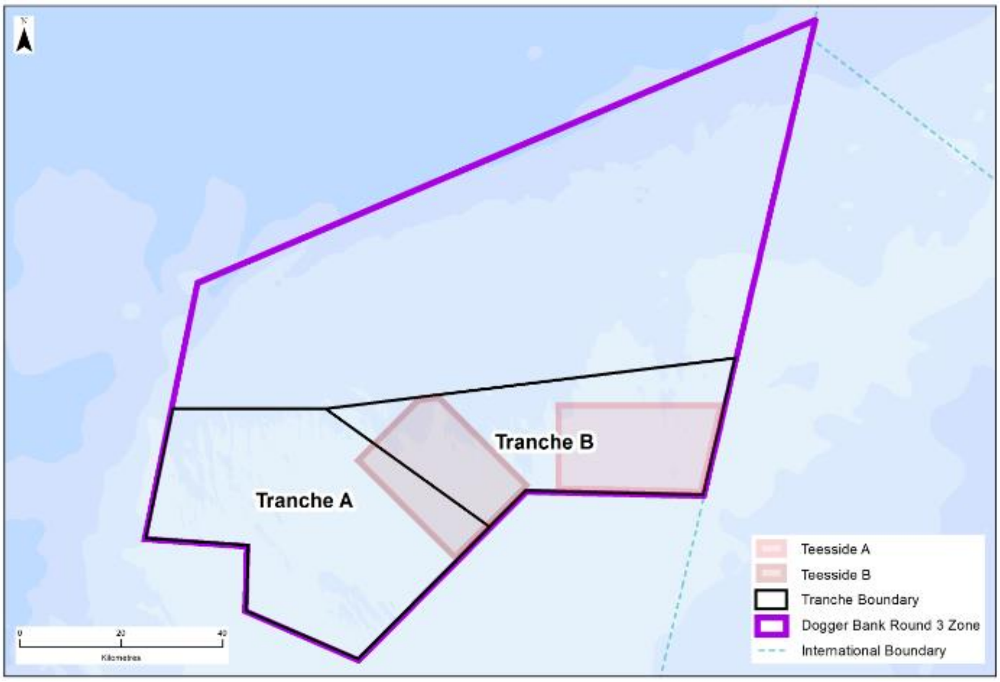
2.1.1. The Dogger Bank Zone is located in the North Sea off the east coast of Teesside, as can be seen in **Figure 2.1**. It is the largest of the UKs Round 3 offshore wind zones, with its outer limit broadly coincident with the UK Continental Shelf limit, as defined by the UK Hydrographic Office. The key zone characteristics are described in **Table 2.1**.

Table 2.1 Dogger Bank Key Zone Characteristics

Parameter	Value
Zone size	8,639km^2 / 3,336 sq. miles
Distance from shore (closest point on UK mainland)	123km
Predominant water depth range	20 to 65m below LAT

Dogger Bank Tranches

Figure 2.2 Dogger Bank tranche boundaries



2.1.2. To manage the development of the Zone, Forewind has divided the Dogger Bank Zone into a number of 'tranches' which will in turn be surveyed, reviewed and taken into a development phase. Each tranche is defined taking into account the following:

- Safety,
- Existing environmental data,
- Planning considerations,
- Minimising disruption to the environment and stakeholders,
- Project viability,
- Commercial viability, and
- Delivering projects according to programme

2.1.3. Each tranche is defined with enough area to ensure there is flexibility in locating the wind farm projects therein. The locations of the individual wind farm projects are defined through a process of detailed survey, data collection, constraint mapping, technical and commercial modelling and then refined through the Environmental Impact Assessment (EIA) and consultation process.

2.1.4. The boundaries of tranches A and B are shown in **Figure 2.2**. These boundaries were defined using information collected in a series of stakeholder workshops and discussions, and considering relevant technical, environmental and commercial factors associated with offshore wind farm project delivery and operation. Please see **Chapter 6 Site Selection and Alternatives**, for further details.

2.1.5. Tranche A is an area in the south west of the Dogger Bank Zone consisting of approximately 2,000km^2. Tranche B is located in the south east of the Dogger Bank Zone and has an area of approximately 1,500 km^2. The Dogger Bank Teesside A project boundary is located entirely within Tranche B. The Dogger Bank Teesside B project boundary is located primarily within Tranche B with some, an area of approximately 200km^2, extending into the eastern margin of Tranche A.

Dogger Bank Teesside A

2.1.6. Dogger Bank Teesside A is located within the eastern portion of the Dogger Bank Zone. The key project characteristics are listed in **Table 2.2** and the boundary coordinates are identified in **Figure 2.3** and **Table 2.3**. The basis for the selection of the Dogger Bank Teesside A boundary is discussed within **Chapter 6 Site Selection and Alternatives**.

Table 2.2 Dogger Bank Teesside A key project characteristics

Parameter	Value
Project size	560km^2 / 216 sq. miles
Distance from shore (closest point on UK mainland)	196km
Predominant water depth range	20 to 35m below LAT

Figure 2.3 Dogger Bank Teesside A boundary

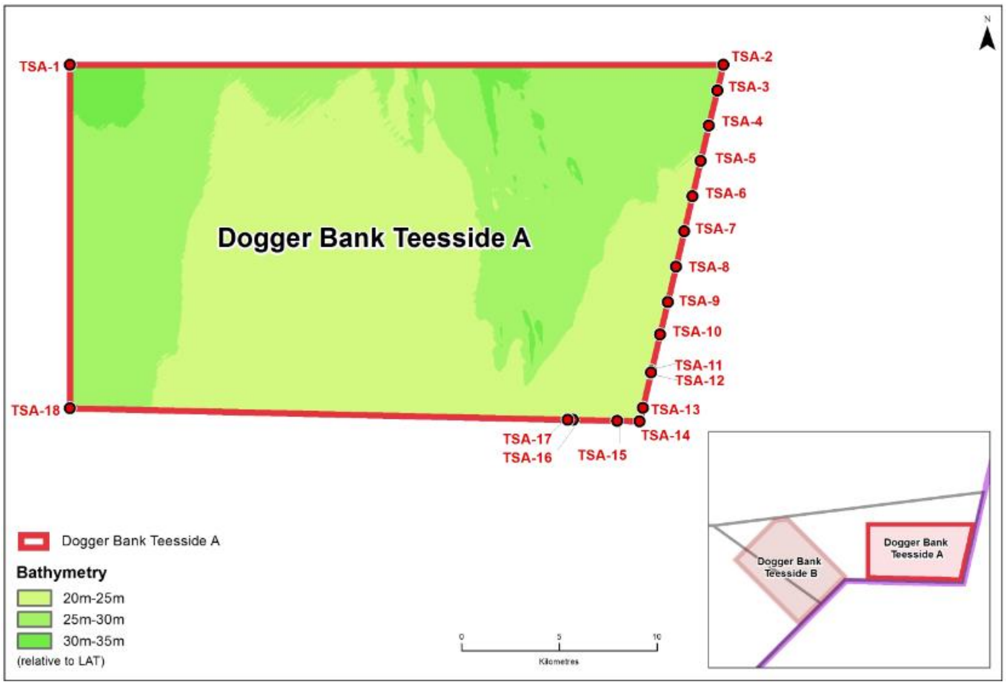


Table 2.3 Dogger Bank Teesside A boundary co-ordinates

WGS 84/UTM ZONE 31 N (3°E)				
Point	Easting (m)	Northing (m)	Latitude	Longitude
TSA-1	472908	6107993	55° 7.074' N	2° 34.514' E
TSA-2	506308	6107993	55° 7.116' N	3° 5.934' E
TSA-3	506003	6106692	55° 6.414' N	3° 5.645' E
TSA-4	505581	6104889	55° 5.443' N	3° 5.246' E
TSA-5	505159	6103087	55° 4.471' N	3° 4.848' E
TSA-6	504737	6101284	55° 3.499' N	3° 4.449' E
TSA-7	504315	6099482	55° 2.528' N	3° 4.051' E
TSA-8	503893	6097679	55° 1.556' N	3° 3.654' E
TSA-9	503471	6095877	55° 0.584' N	3° 3.256' E
TSA-10	503084	6094222	54° 59.692' N	3° 2.892' E
TSA-11	502645	6092347	54° 58.682' N	3° 2.479' E
TSA-12	502627	6092272	54° 58.641' N	3° 2.463' E
TSA-13	502205	6090469	54° 57.669' N	3° 2.066' E
TSA-14	502041	6089767	54° 57.291' N	3° 1.912' E
TSA-15	500892	6089795	54° 57.306' N	3° 0.836' E
TSA-16	498624	6089847	54° 57.334' N	2° 58.711' E
TSA-17	498367	6089853	54° 57.337' N	2° 58.470' E
TSA-18	472908	6090435	54° 57.607' N	2° 34.614' E

Dogger Bank Teesside B

2.1.7. Dogger Bank Teesside B is located centrally within the lower portion of the Dogger Bank Zone. The project boundaries of Dogger Bank Teesside B are primarily within Tranche B but do extend into the eastern portion of Tranche A. The key project characteristics are listed in **Table 2.4** and the boundary coordinates are identified in **Figure 2.4** and **Table 2.5**. The basis for the selection of the Dogger Bank Teesside A boundary is discussed within **Chapter 6 Site Selection and Alternatives**.

Table 2.4 Dogger Bank Teesside B key project characteristics

Parameter	Value
Project size	593km^2 / 229 sq. miles
Distance from shore (closest point on UK mainland)	165km
Predominant water depth range	20 to 40m below LAT

Figure 2.4 Dogger Bank Teesside B boundary

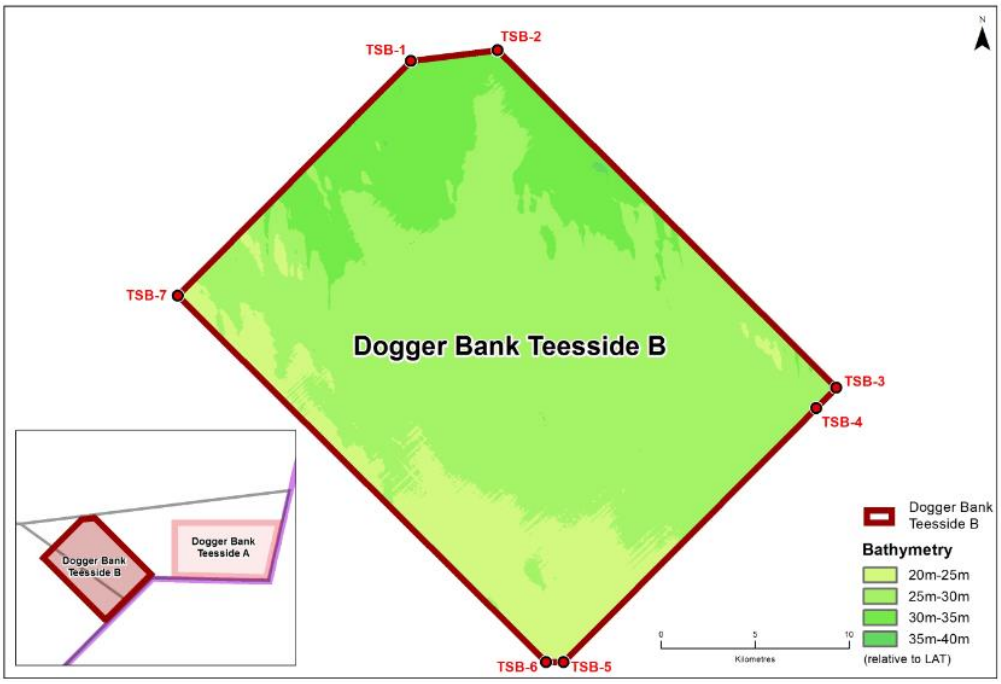


Table 2.5 Dogger Bank Teesside B boundary co-ordinates

WGS 84/UTM ZONE 31 N (3°E)				
Point	Easting (m)	Northing (m)	Latitude	Longitude
TSB-1	445523	6108971	55° 7.466' N	2° 8.743' E
TSB-2	450126	6109539	55° 7.801' N	2° 13.068' E
TSB-3	468113	6091645	54° 58.242' N	2° 30.113' E
TSB-4	467043	6090569	54° 57.658' N	2° 29.117' E
TSB-5	453619	6077075	54° 50.319' N	2° 16.670' E
TSB-6	452689	6077082	54° 50.317' N	2° 15.801' E
TSB-7	433143	6096527	55° 0.666' N	1° 57.272' E

Offshore Export Cable Corridor

2.1.8. The export cables for both the Dogger Bank Teesside A & B projects will be installed within the corridor shown in **Figure 2.5**. The export cables will run from the offshore converter platforms, described in **Section 3.7 Offshore Platforms**, to the cable landfall. The export cable corridor will link the project boundaries, via the zone exit point, to the cable landfall and will predominantly stretch from the north-east to south-west from the development zone. The landfall is an area along the Teesside coastline located between Redcar and Marske-by-the-Sea where the joint transition bay is located and the offshore cables comes ashore. The basis for the selection of the export cable corridor boundaries is discussed within **Chapter 6 Site Selection and Alternatives**.

2.1.9. The point at which the export cables leave their respective project boundaries as they journey to the zone exit points have not yet been finalised. These locations will depend on the final wind farm layout and the location of the converter platforms of each project. As such, several options for the in-zone portions of the export cable corridors are under consideration. These options fall within the areas shown in **Figure 2.5** and have been assessed as part of the EIA process.

2.1.10. From the zone exit point the export cable corridor runs predominately east to west from the south western corner of the Dogger Bank development zone. The export cable corridor is generally 1.5km wide but widens in the vicinity of the zone exit point to approximately 2km. The export cable corridor narrows in proximity to the cable landfall. **Table 2.6** provides a simplified version of the export cable corridor coordinates.

Figure 2.5 Dogger Bank Teesside A and B offshore export cable corridor

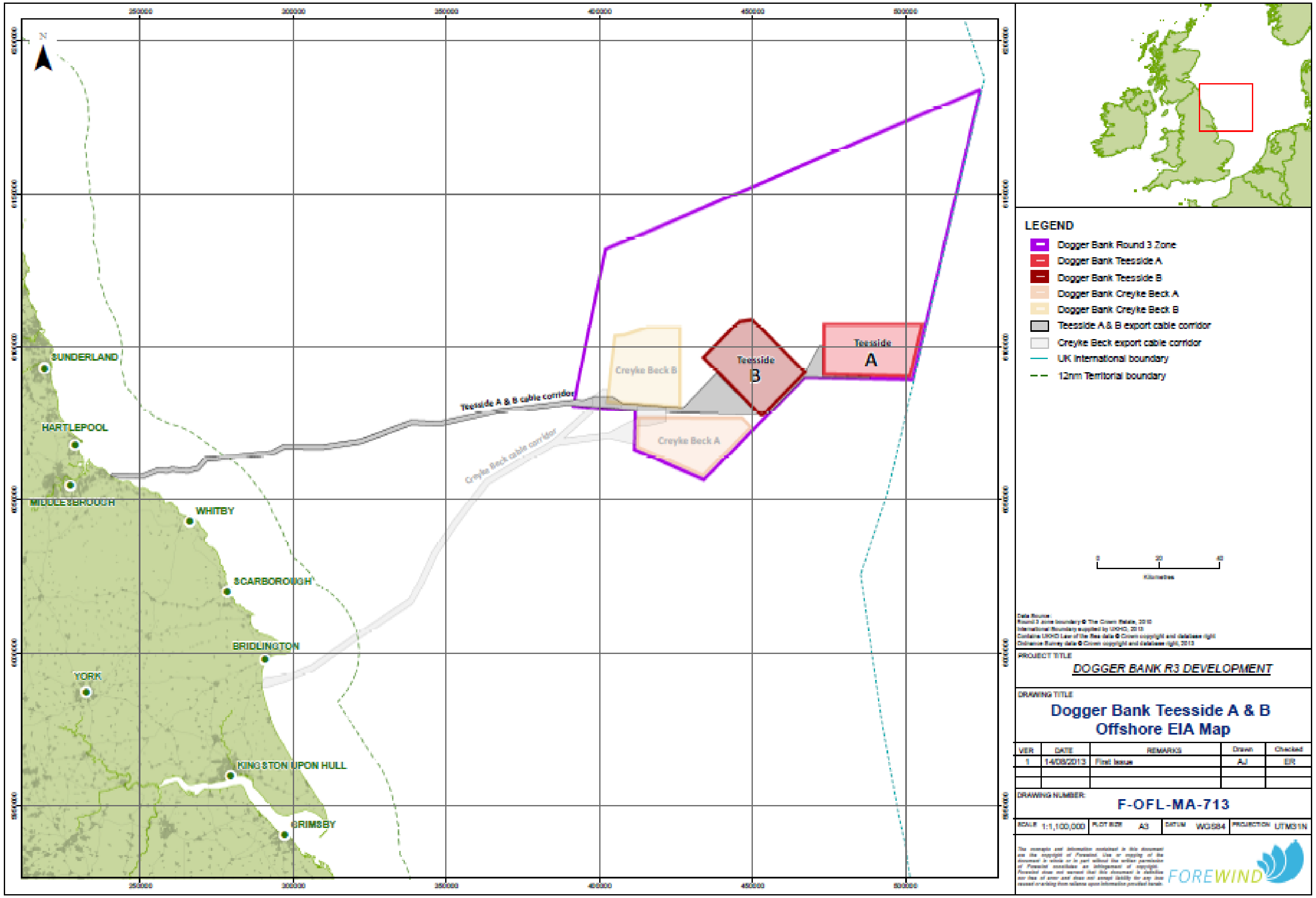


Table 2.6 Dogger Bank Teesside A and B export cable corridor co-ordinates

WGS 84/UTM ZONE 31 N (3°E)				
Point	Easting (m)	Northing (m)	Latitude	Longitude
1	488474	6090079	54° 57.451' N	2° 49.201' E
2	488463	6089579	54° 57.182' N	2° 49.191' E
3	467246	6090064	54° 57.386' N	2° 29.311' E
4	455060	6077815	54° 50.725' N	2° 18.009' E
5	450910	6077844	54° 50.718' N	2° 14.132' E
6	426943	6078217	54° 50.743' N	1° 51.735' E
7	389518	6080893	54° 51.774' N	1° 16.719' E
8	366144	6078113	54° 49.934' N	0° 54.960' E
9	347897	6074058	54° 47.437' N	0° 38.058' E
10	338535	6074372	54° 47.431' N	0° 29.320' E
11	322094	6068365	54° 43.862' N	0° 14.216' E
12	309260	6066440	54° 42.543' N	0° 2.350' E
13	296847	6066614	54° 42.346' N	0° 9.200' W
14	293022	6064595	54° 41.165' N	0° 12.670' W
15	271520	6062481	54° 39.470' N	0° 32.546' W
16	269043	6059665	54° 37.887' N	0° 34.711' W
17	265205	6058683	54° 37.252' N	0° 38.225' W
18	260204	6059200	54° 37.389' N	0° 42.887' W
19	258736	6058697	54° 37.077' N	0° 44.224' W
20	255553	6058972	54° 37.133' N	0° 47.189' W
21	250944	6057027	54° 35.952' N	0° 51.363' W
22	242371	6057255	54° 35.817' N	0° 59.318' W
23	240129	6057779	54° 36.029' N	1° 1.422' W
24	239945	6057941	54° 36.111' N	1° 1.601' W
25	240689	6058659	54° 36.520' N	1° 0.950' W

26	250536	6058487	54° 36.725' N	0° 51.814' W
27	255412	6060425	54° 37.911' N	0° 47.392' W
28	258607	6060282	54° 37.926' N	0° 44.421' W
29	259993	6060716	54° 38.199' N	0° 43.157' W
30	265191	6060292	54° 38.118' N	0° 38.315' W
31	268255	6061040	54° 38.605' N	0° 35.508' W
32	270787	6063919	54° 40.224' N	0° 33.294' W
33	292589	6066055	54° 41.941' N	0° 13.134' W
34	296464	6068059	54° 43.114' N	0° 9.616' W
35	309147	6067938	54° 43.347' N	0° 2.186' E
36	321719	6069824	54° 44.640' N	0° 13.814' E
37	338286	6075875	54° 48.235' N	0° 29.037' E
38	347764	6075562	54° 48.245' N	0° 37.887' E
39	365818	6079577	54° 50.718' N	0° 54.615' E
40	392116	6082712	54° 52.789' N	1° 19.106' E
41	394757	6082524	54° 52.721' N	1° 21.578' E
42	398546	6083957	54° 53.540' N	1° 25.090' E
43	404599	6083524	54° 53.379' N	1° 30.759' E
44	407549	6081609	54° 52.379' N	1° 33.554' E
45	427464	6080209	54° 51.822' N	1° 52.192' E
46	438366	6091331	54° 57.905' N	2° 2.239' E
47	450917	6078844	54° 51.257' N	2° 14.128' E
48	453947	6078823	54° 51.263' N	2° 16.959' E
49	467757	6092704	54° 58.812' N	2° 29.772' E
50	471908	6100214	55° 2.876' N	2° 33.620' E
51	472908	6100214	55° 2.879' N	2° 34.559' E
52	472908	6090435	54° 57.607' N	2° 34.614' E

Offshore Temporary Work Areas

2.1.11. During the construction phase temporary work areas may be required for conducting temporary intrusive activities such as deploying anchors or jack-up legs as part of the construction process. These activities could include cable installation vessels working alongside the defined cable corridors, and construction vessels working near or outside the edge of the wind farm array boundaries. Any activities within the temporary work areas would be of a limited extent and temporary nature reducing their environmental impact.

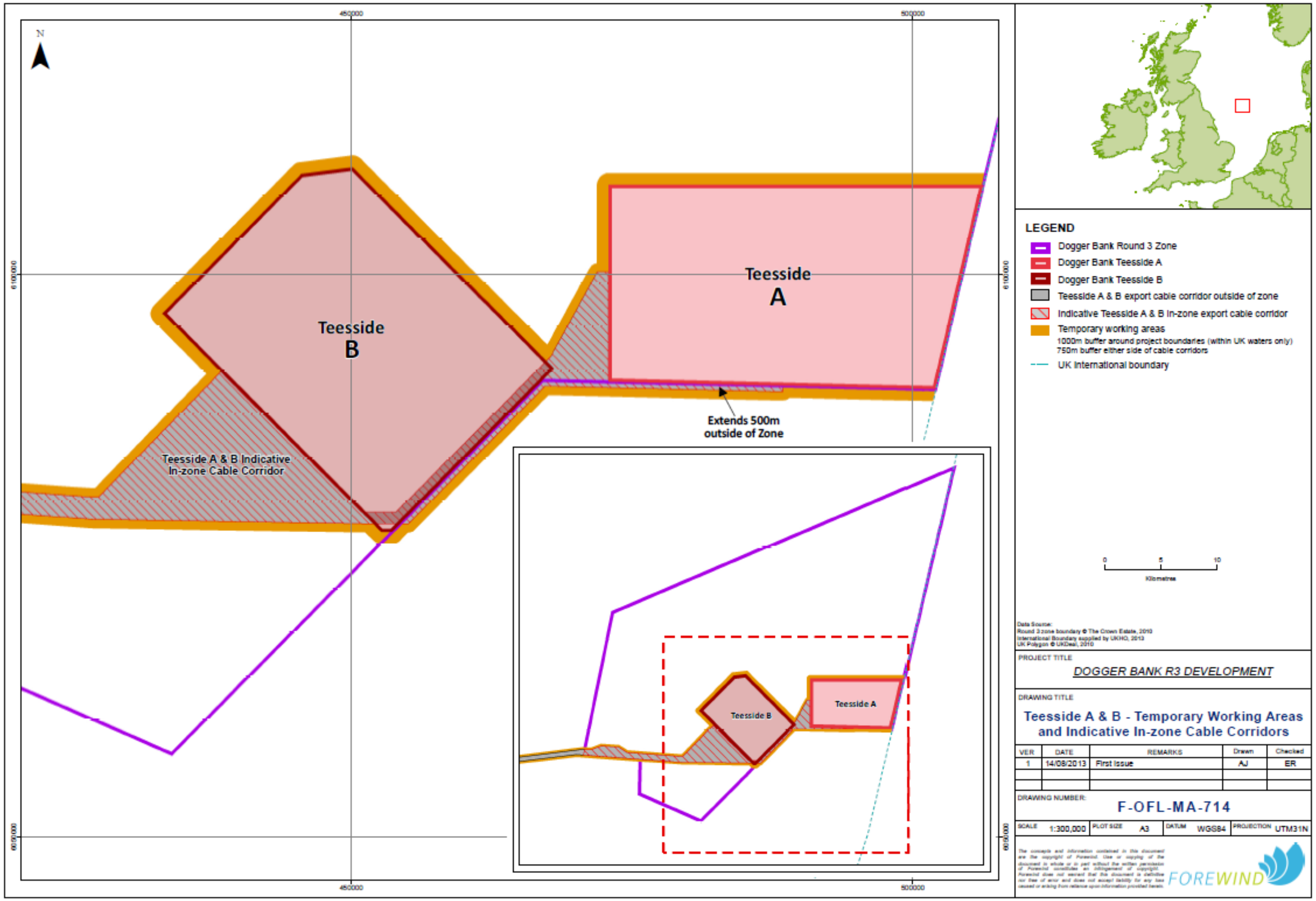
2.1.12. The key characteristics of the temporary work areas are surmised in **Table 2.7** and are shown in **Figure 2.6**.

Table 2.7 Dogger Bank Teesside A & B temporary work area dimensions

Parameter	Value
Width of temporary work area outside export cable corridor (m)	750
Width of temporary work area outside offshore project boundary (m)	1000

2.1.13. It should be noted that the temporary work area on the eastern margin of Dogger Bank Teesside A does not extend for the full distance shown in **Table 2.7** but terminates at the International Boundary. No works, activities, temporary or otherwise will occur beyond the international boundary.

Figure 2.6 Overview of offshore boundaries



Offshore Boundary Overview

2.1.14. **Figure 2.6** shows an overview of the boundaries of the offshore project elements described within this document. Included within this figure are:

- The Dogger Bank Teesside A & B project boundaries,
- The export cable route near the zone boundary,
- The in-zone portions of the offshore export cable route,
- Temporary work areas.

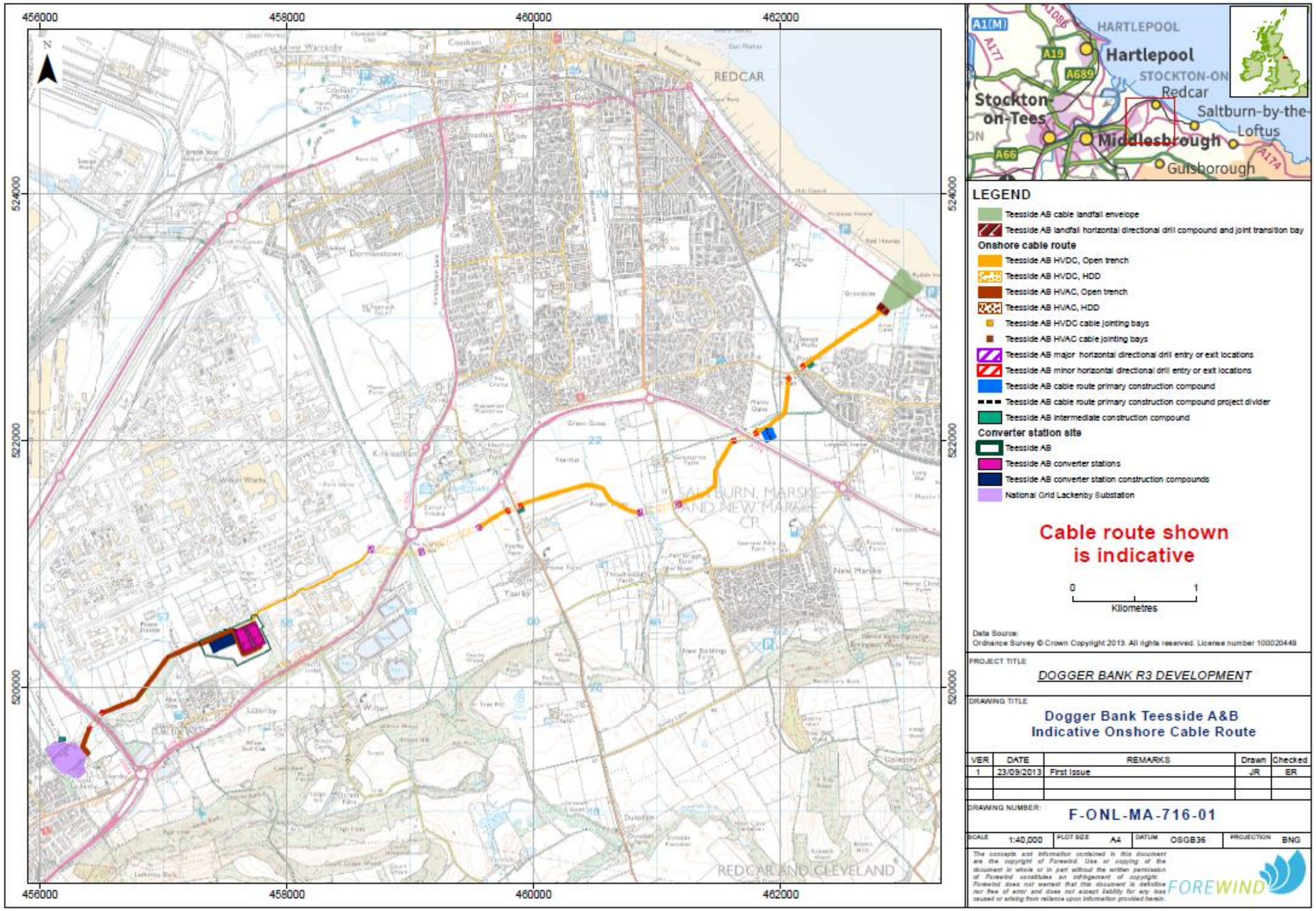
Onshore Cable Landfall, Corridor & Route

2.1.15. The cable landfall is an area along the Teesside coastline located between Redcar and Marske-by-the-Sea, where the joint transition bay is located and the offshore export cables come ashore. From the landfall, the underground HVDC export cable corridor will continue onshore to the proposed Dogger Bank Teesside A & B converter stations. From the converter stations, underground HVAC cables will transmit the electricity to the connection points at the nearby existing National Grid substation at Lackenby. The basis for the selection of the cable corridor boundaries is discussed within **Chapter 6 Site Selection and Alternatives**

2.1.16. The onshore cable corridor can be divided into three sections; Landfall to the A174, the A174 to the Wilton complex and the Wilton Complex to the existing National Grid substation at Lackenby. These sections are described in more detail in **Section 2.3 Onshore Site Description**. The width of the onshore cable corridor varies along its length to take into account local factors and where practical to further minimise environmental impact. The export cable corridor forms the area within which cable route selection and surveys have taken place.

2.1.17. Within the onshore cable corridor, the cable route, and items such as the temporary works compounds, temporary horizontal directional drilling (HDD) compounds, the landfall transition joint bays, and access routes onto the construction working width have all been located. The cable route encompasses the HVDC and HVAC cable systems, and related construction working width. The cable route will consist of an approximately 6km HVDC section and an approximately 2km HVAC section. The cable route is up to 36m wide for the HVDC section, and 39m wide for the HVAC sections. Within the Wilton complex the HVDC section will be approximately 20m. The below-ground sections of the cable route at major HDD operations may be up to 50m wide for single project and up to 250m wide below-ground at the landfall HDD. An overview of the onshore cable route is shown in **Figure 2.7**.

Figure 2.7 Dogger Bank Teesside A & B onshore cable route

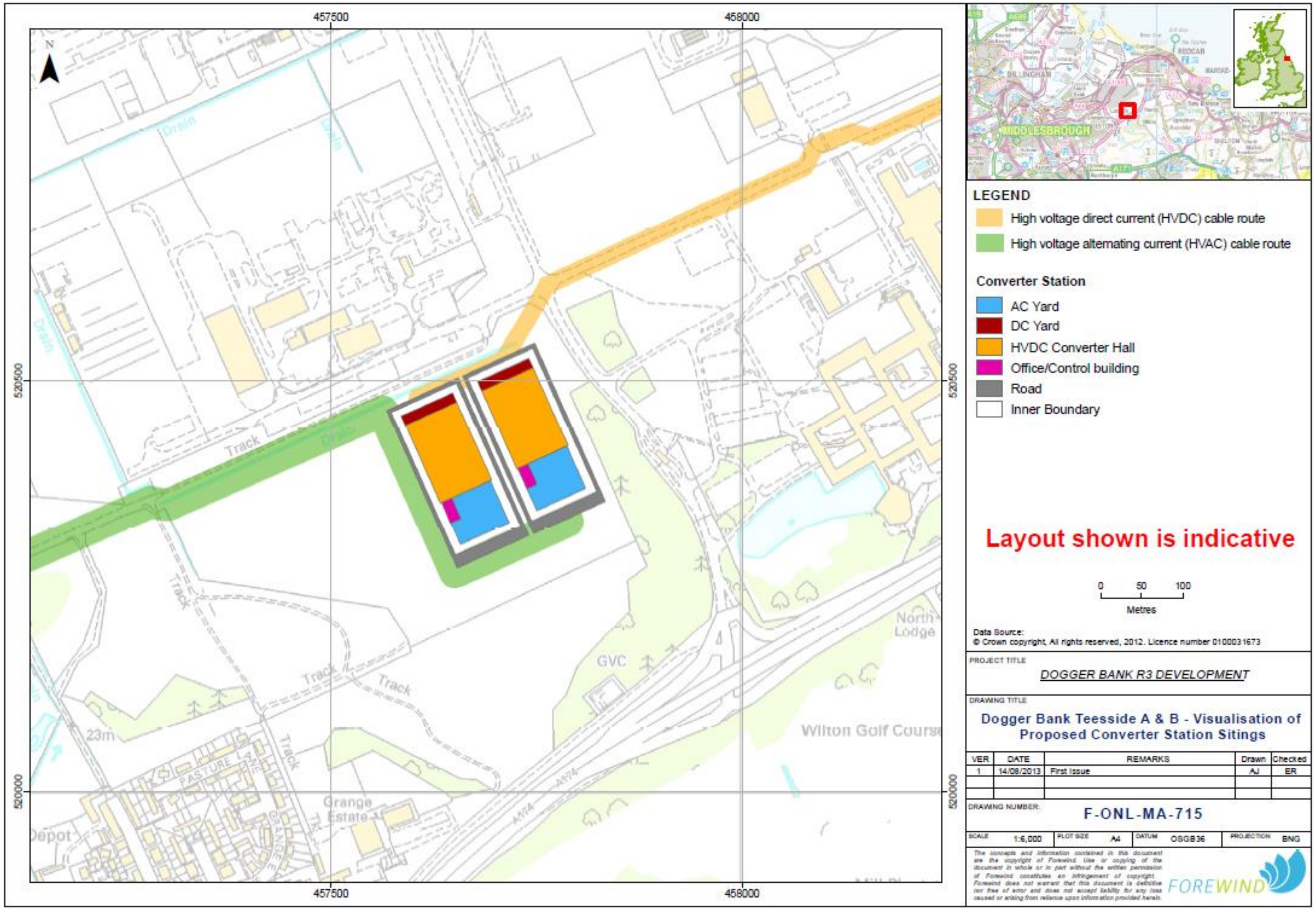


Onshore Converter Station Sites

2.1.18. The new Dogger Bank Teesside A & B converter stations will be constructed within the southern margin of the Wilton Industrial Complex, located approximately 2km to the north-east of the existing National Grid Lackenby substation and approximately 5km to the to the south-west of Redcar Central train station. The converter stations site is located to the north of the A174. An indicative plan of the proposed layout is shown in **Figure 2.8**. The basis for the selection of the converter station site is discussed within **Chapter 6 Site Selection and Alternatives**.

2.1.19. It is proposed that two converter stations will be built, one for each of the Dogger Bank Teesside A & B projects. The two converter stations will be required for the conversion of the electricity transmitted by the HVDC export cable into HVAC before connection to the existing National Grid substation at Lackenby.

Figure 2.8 Proposed Dogger Bank Teesside A & B converter stations location



2.2. Offshore Site Description

Overview

2.2.1. Forewind has gathered a significant amount of information on the physical environment of the Dogger Bank Zone. The survey programme has included detailed geophysical (seabed and sub-seabed) surveys, geotechnical testing (boreholes and cone penetration tests), meteorological and oceanographic data collection via wave buoys and acoustic doppler current profilers (ADCPs), and wind data collection using lidar and a meteorological mast. Data gathering across the Dogger Bank Zone is ongoing but has included approximately:

- 70 boreholes (including sampling and wireline logging);
- 180 cone penetration tests;
- 55,000 line kilometres of seabed and geophysical survey data;
- 100 seabed grab samples;
- 100 seabed camera survey locations;
- 3 wave buoys deployed;
- 2 ADCPs deployed;
- 1 tide gauge deployed;
- 1 wind lidar deployed; and
- 2 meteorological masts deployed

2.2.2. These data have been analysed with help from a number of expert consultants and groups including the British Geological Survey, the Norwegian Geotechnical Institute, RPS Energy and Royal HaskoningDHV.

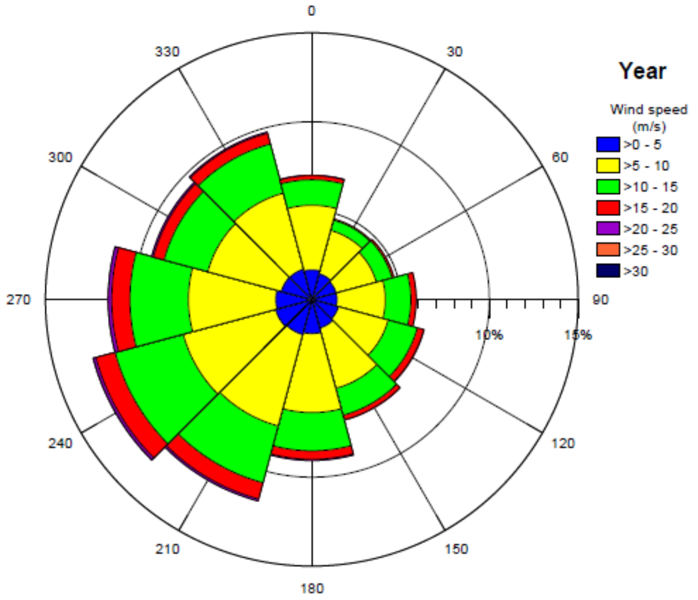
2.2.3. Information on site bathymetry, waves, tidal currents, tidal range, geology and seabed sediments are all contained within **Chapter 9 Marine Physical Processes**.

2.2.4. The current level of information is sufficiently detailed for the purposes of the environmental assessment, however additional high resolution survey data will need to be obtained to enable tasks such as detailed foundation design and cable burial assessment to be undertaken. These surveys will be undertaken post-consent.

Wind Climate

2.2.5. The following indicative annual wind rose, **Figure 2.9**, shows the average wind speed and direction for a representative location within Tranche B. In comparison to the typical wind conditions across the UK as a whole, the Dogger Bank Zone can be characterised as having very high average annual wind speeds.

Figure 2.9 Indicative annual wind rose for Dogger Bank Zone Tranche B



2.3. Onshore Site Description

2.3.1. The land affected by the onshore works can be divided into the following three areas, which are described within **Chapter 26 Land Use and Agriculture**:

- Landfall to A174;
- A174 to Wilton Complex and Main Dike;
- Wilton Complex and Main Dike to the existing Lackenby Substation.

2.3.2. A detailed description of the land affected by the onshore works and its corresponding use can be found in **Chapter 26 Land Use and Agriculture**. Land uses associated with tourism and recreation are considered in **Chapter 23 Tourism and Recreation**.

Landfall to A174

2.3.3. The area is predominantly urban in character with the landfall located between the towns of Redcar to the north and Marske-by-the –Sea to the south. The route crosses the Coast Road (A1085) before passing through arable land and passing south of the Marske Sewage Treatment Works. There are a number of buried services including water mains, foul sewers, gas and telecommunications between settlements.

A174 to Wilton Complex and Main Dike

2.3.4. The proposed cable corridor between the A174 and the Wilton Complex is predominantly rural, comprising mainly of large arable fields. The route passes close to the development of New Marske and the village of Yearby. It crosses two minor roads, Grewgrass Lane and Yearby Bank. The area is flat and relies on a number of drainage channels, the two largest being Rogers Dike and Main Dike. Buried services include telecommunication cables and gas pipes.

Wilton Complex and Main Dike to Existing National Grid Substation at Lackenby

2.3.5. This area is predominantly industrial in character with large areas of hard standing, buildings (including offices, warehouses and industrial units) and areas of bare ground ready for future development, or having recently been cleared of previous land use. To the south of the area there are several arable fields which form part of the Wilton complex but are yet to be developed for industrial uses (including the potential development of Dogger Bank Teesside C & D converter station location). The area has a number of buried services connected to the activities of the Wilton Industrial estate. The proposed location of the converter station is close to the settlement at Lazenby

Land Use

2.3.6. Outside the Wilton complex the area is predominantly characterised by arable agriculture, 52% of the study area is of Grade 2: very good quality agricultural land as classified under the Agricultural Land Classification system, a further 9% is of a lesser grade and the remaining 39% is urban. The agricultural land of South Teesside is dominated by cereal crops (29%), and mixed farms (28%), diary and livestock make up a further 33%.

2.3.7. Within the Wilton Complex (approximately 750ha in total) is an industrial area managed by Sembcorp Utilities. It encompasses a large area of chemical industry related buildings and equipment. Within the site is an extensive road network. There are available brownfield and greenfield sites, earmarked for development within the complex.

3. Offshore Project Components

3.1. Wind Turbines

Figure 3.1 A typical offshore wind turbine

Courtesy of RWE npower renewables

3.1.1. The wind turbines which will be installed at Dogger Bank Teesside A & B will be three bladed, horizontal axis machines, an example of which can be seen in **Figure 3.1**. The rotor will be attached to a nacelle containing the electrical generator and other equipment. The nacelle will sit on top of a tubular support tower. Wind energy causes the blades on a wind turbine to rotate, which turns a generator in order to transform the kinetic energy of the air into electricity.

3.1.2. Modern wind turbines function over a wide range of wind speeds. The wind turbines will operate automatically, self-starting when the wind speed is sufficient, and shutting down automatically to protect themselves from structural damage when the maximum operational wind speed is reached (in 'storm' conditions).

3.1.3. Offshore wind turbine technology is evolving rapidly and it is anticipated that wind turbines of between approximately 6MW and 10MW will be available within the timescales of the projects. Forewind has therefore described a range of wind turbine characteristics so that this range of options can be assessed. Dimensions for these two wind turbine sizes are described in **Table 3.1**.

3.1.4. In addition, fixed caps on the project total rotor swept area and the project total generating capacity are defined. These values are linked to the two wind turbine sizes, such that at the maximum generating capacity the turbines sizes have the same rotor swept area. These additions have been included to define how the wind turbine numbers and dimensions may vary with other capacities of wind turbines. (The defined maximum project capacity allows the maximum number of wind turbines of a given individual capacity to be calculated. Knowing the number of wind turbines and the maximum swept area, then allows the maximum rotor diameter to be calculated). The majority of other values may vary linearly between the two points described. However, the maximum upper blade tip height is an exception to this and is calculated by linearly interpolating the rotor diameter and adding 100m. This ensures that the Rochdale Envelope for the wind turbines is robustly defined, and that future wind turbine selections can be easily verified as falling within the project assessment envelope

Table 3.1 Indicative wind turbine parameters per project

	Indicative wind turbine generating capacity	
Parameter	Up to 6MW	10MW or greater
Maximum project total generating capacity (MW)	1,200	
Maximum project total rotor swept area (km^2)	4.35	
Maximum number of wind turbines per project	200	120
Maximum rotor diameter (m)	167	215
Maximum upper blade tip (m) above HAT (maximum rotor diameter plus 100m)	267	315
Minimum lower blade tip (m) above HAT	26	26

3.1.5. The wind turbine options detailed in **Table 3.1** are defined such that:

- The values in the table define the range of values considered within the environmental impact assessment. For example lower blade tip may vary from the stated minimum of 26m above HAT, up to a height defined by the stated maximum upper tip height and the selected wind turbine rotor diameter;
- The values provided for the up to 6MW wind turbine represent the realistic worst case for wind turbines of any size up to 6MW. 5MW wind turbines could therefore be used, for example, but no more than 200 could be installed (providing for a 1000MW generating capacity);

- The values for the 10MW or greater wind turbine represent the realistic worst case for wind turbines of 10MW or greater generating capacity. 15MW wind turbines could therefore be used, for example, but the dimensions would not be permitted to exceed the values considered within the assessment envelope (e.g. a maximum rotor diameter of 215m), and only 80 units would be required to provide the 1200MW maximum generating capacity;
- Scenarios in which less than the maximum generating capacity is installed introduce the possibility of a specific exception to the options described above. In this circumstance wind turbines with unusually large dimensions could be accommodated as part of the assessment envelope, as long as the installed generating capacity was reduced to match the proportionality of the largest dimensions. For example, if a 6MW wind turbine was produced with a 215m rotor diameter, the rotor would then correspond to the defined 10MW wind turbine limit. This would still be within the assessment envelope as long as only 120 were installed (a maximum installed generating capacity of 720MW) and none of its dimensions exceed the 10MW or greater absolute maximum values.

3.1.6. Shown in **Figure 3.2** and **Figure 3.3** are illustrations of the assessed parameters for the up to 6MW and 10MW or greater wind turbines.

Figure 3.2 Indicative drawing of an up to 6MW turbine

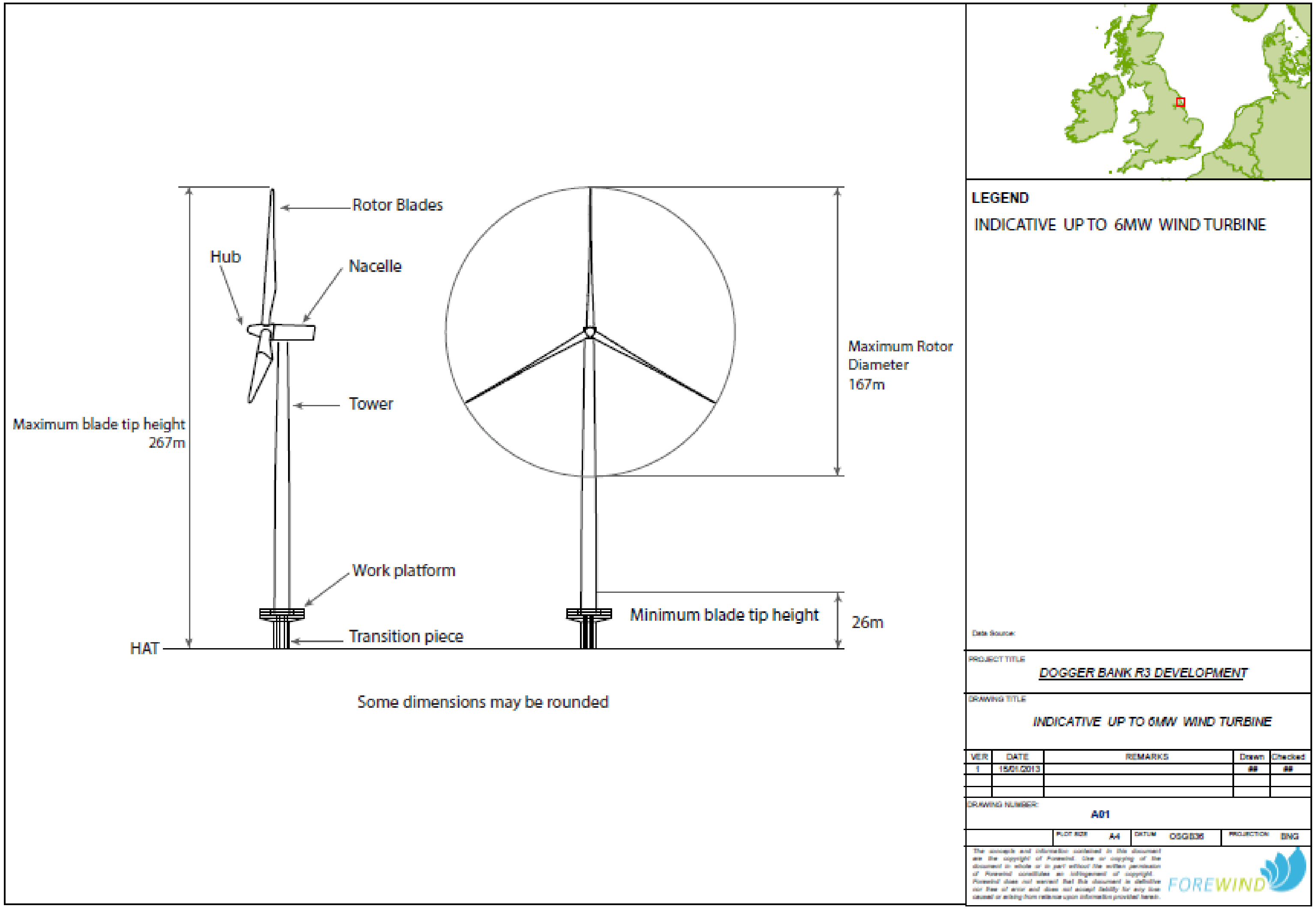
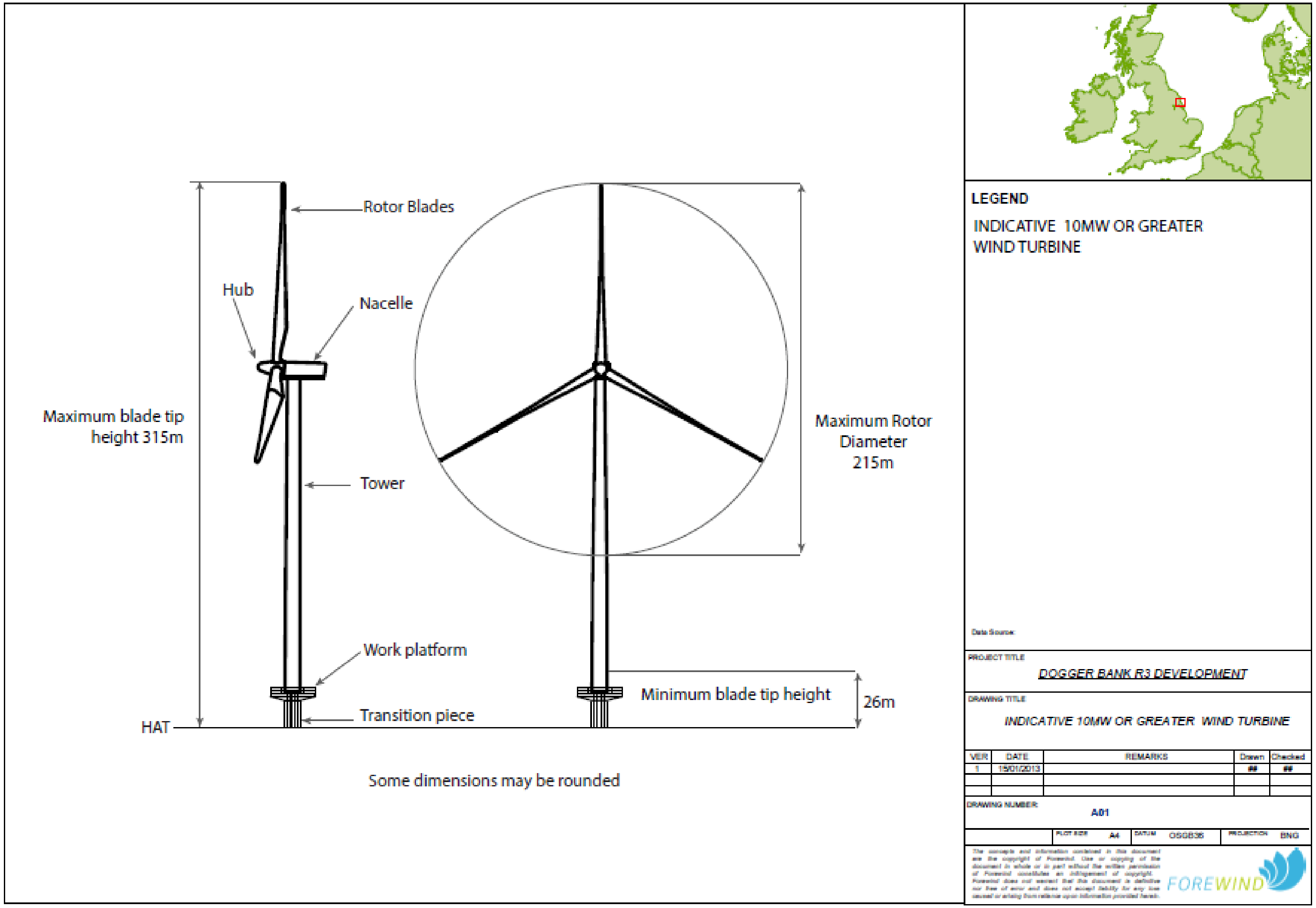


Figure 3.3 Indicative drawing of a 10MW or greater turbine



3.1.7. Based on this approach, the key characteristics for any wind turbine within this range can be identified – for example, for 8MW wind turbines, 150 units would be permitted (1,200MW generating capacity), with a maximum diameter of 192m (giving the maximum swept area of 4.35km^2), and a maximum tip height of 292m (maximum rotor diameter plus 100m), etc.

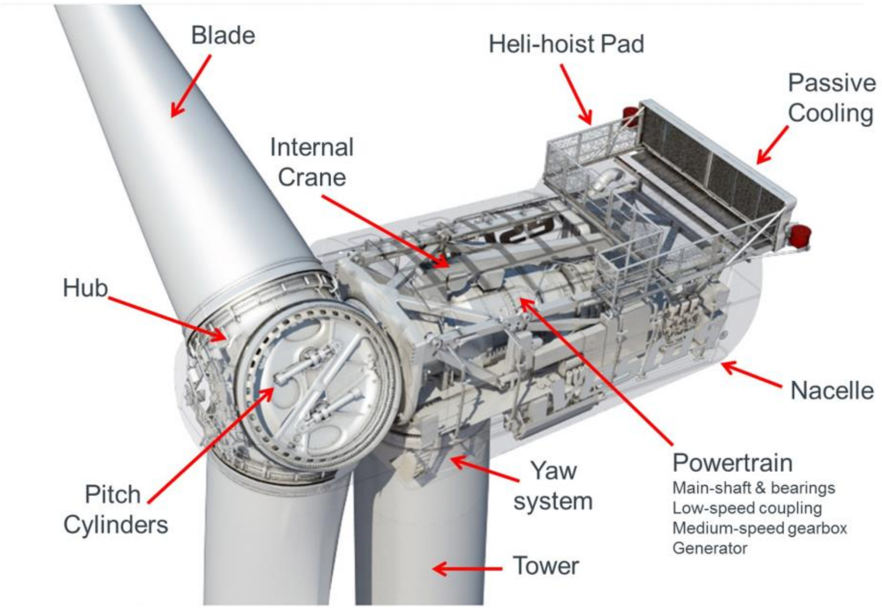
3.1.8. The relevant points within this wind turbine envelope can, therefore, be selected to:

- provide realistic worst case wind turbine parameters for use in environmental assessments;
- confirm whether a commercially available wind turbine is within the envelope of assessments completed by Forewind.

3.1.9. As outlined in **Section 1.2 Project Development Envelope – Flexibility**, a range of wind turbines are being considered for these projects. The final selection of the wind turbines will be made following consent and on the basis of a number of factors including economics, efficiency, reliability, track record and availability.

Wind Turbine Components

Figure 3.4 Illustration of the components of a typical geared wind turbine



Courtesy of Vestas Wind Systems

Wind Turbine Tower

3.1.10. The tower is the component which supports the rotor and nacelle. It provides the necessary height for the wind turbine to efficiently capture the most energy. The tower is likely to be made up of several tapering steel tubular sections which are lifted into place and then secured together by bolting. The bottom tower section sits on top of the transition piece and is bolted to a flanged connection.

It is common industry practice for some control and electrical components to be located within or at the base of the wind turbine tower.

Nacelle

3.1.11. The nacelle houses the electro-mechanical components of the wind turbine. There may also be other equipment in the nacelle such as transformers, yaw systems, and gearboxes. Some wind turbines include a fixed or dismountable crane, which can be used to move components within the nacelle and/or down to the tower base to aid maintenance activities. The nacelle may also be fitted with a helicopter access winching platform to allow technicians and potentially rescue personnel to access the wind turbine directly by helicopter.

Rotor

3.1.12. The rotor, comprising the three blades and the hub, is the device which extracts energy from the wind and converts it into rotational motion. Increasing the blade length allows more energy to be extracted from the passing wind. The pitch of the blades can be adjusted by feathering or angling them, in order to control the rotation speed of the rotor.

Wind Turbine Colouring

3.1.13. Wind turbines are typically supplied in a small range of standard colours. Offshore wind turbines installed in the UK to date are commonly light grey (although they vary in appearance, depending on the lighting conditions, between white and grey), and it is assumed that Dogger Bank Teesside A & B wind turbines would follow this approach and be coloured predominantly either white or light grey. However, the precise colour, tone and degree of paint reflectivity will be identified during the detailed design process after consultation with stakeholders. In addition contrasting colours may be required on areas of the wind turbines and foundations. Some key examples are listed below, but other areas of contrasting colours and alternative higher-visibility colour schemes may be added if required for purposes such as hazard warnings and increasing the visibility of the wind turbines for various aspects of collision avoidance.

3.1.14. Contrasting colours are currently most commonly required in navigation and aviation safety markings; described further in **Section 7.5 Navigation and Aviation Safety Markings**. A selection of key requirements are listed below:

- High-visibility identification numbering will be required on the nacelles.
- Small helicopter hover reference spots will be required on the blades.
- Transition pieces, and potentially areas of the towers, will be coloured high-contrast yellow for vessel navigation and collision avoidance.

Hazardous Materials

3.1.15. Each wind turbine contains oils and greases used for lubrication, cooling, and hydraulic transmission. Some designs of electrical switchgear may incorporate sulphur hexafluoride gas which is non-toxic, but has the potential to cause asphyxia by the displacement of oxygen, and is a greenhouse gas. The precise volumes used will vary depending on the size and type of wind turbine. These materials will have an operational life at the end of which they, or the components which contain them, will be disposed of in accordance with best practice guidelines and in line with the relevant regulatory requirements.

3.1.16. The design of the wind turbine nacelle, tower and rotor are expected to be such that the consequence of leaks of these fluids during construction or operation would be minimised, through bunding and other methods.

Table 3.2 Indicative hazardous materials peak quantities during normal operation

Parameter	Wind Turbine Size	
Material	Up to 6MW	10MW or greater
Grease (litres)	730	1,220
Synthetic Oil /Hydraulic Oil (litres)	11,050	18,420
Nitrogen (litres)	650	1090
Water/Glycerol (litres)	7,800	13,000
Silicone Oil (kg)	2,340	3,900
Sulphur hexafluoride (SF6) gas (kg)	20	40

Wind Turbine Installation

3.1.17. The primary components of a wind turbine are generally fabricated separately and transported to a port location for assembly, and/or final preparation for transport offshore. The method of transport to site will vary depending on the wind turbine chosen, the timing of installation and the vessel used. Components could be transported to site to be installed or pre-assembled onshore followed by shipment to site. Typically, towers are mounted vertically on a dedicated heavy lift installation vessel and one or more blades joined to the rotor hub before shipment, with the final blade installed once the tower and rotor are in place. Wind turbine erection will typically require a large crane vessel such as a jack-up, similar to those used for monopole or jacket foundation installation.

3.1.18. A typical installation sequence is as follows:

i. The wind turbine and tower may be delivered direct to site from the manufacturer or via a staging or lay-down area, and transferred to site by feeder barge or on the installation vessel.
ii. Wind turbine installation is normally undertaken from a jack-up vessel, but alternatives, such as semi-submersibles or heavy lift vessels, may be used.
iii. The wind turbine may be installed pre-assembled (including on a foundation in some concepts), or more commonly in a series of component parts which are lifted into place and bolted together. The selected approach will depend upon the wind turbine, foundation, and methodology selected.

3.1.19. The process is repeated for each wind turbine.

Wind Turbine Commissioning

3.1.20. Once each wind turbine has been installed and the inter-array cabling connected, a process of testing and commissioning is undertaken prior to the wind turbine being put into service. The commissioning process is described in greater detail in **Section 6.4 Commissioning**.

3.2. Offshore Structure Foundations

3.2.1. Foundation structures are required to secure the wind turbines, platforms, and other offshore structures vertically while withstanding loads from the wind and the marine environment. They also provide means of safe access for maintenance crews to access the structures. A wide range of foundation options are available for offshore wind farms. The foundations for Dogger Bank Teesside A & B will be chosen, in line with the assessed development envelope, as part of the detailed design process. This will take into account factors such as the selected wind turbine type or offshore platform size, ground conditions, water depth, metocean conditions (wind, wave, current and tidal regime) and economic factors at the time of design and construction.

3.2.2. The foundation parameters presented within this section have been developed based upon the available site data; including geological and metocean characteristics. The resulting foundation descriptions are intended to provide suitable maximum parameters in order to input into the generation of realistic worst case scenarios. Realistic foundation solutions for all options described are therefore considered to be achievable within the defined limits.

Approach to Flexibility

3.2.3. The requirement to consent a wide range of foundation options is driven by a number of factors. This includes: the variability in water depth and ground conditions across the project areas, the uncertainty in the size of the wind turbines and offshore platforms, the range of detailed design approaches which may be selected by suppliers, and the costs of the materials of the foundation types at the time of project design and build. It is possible that a combination of different foundation types will be used across the two project areas.

3.2.4. In order to allow for the required level of flexibility, offshore foundations are being described using a robust Rochdale Envelope approach. Detailed foundation geometry is inherently variable and it is not realistic to identify a single set of limiting structural dimension parameters to represent the full consent envelope. For example, in multileg foundations, there is often a trade-off between the number of cross-braces and their size. There are also many possible variations in the detailed geometry of conical gravity bases. To encompass all options in one set of maximum dimensions, therefore results in an unrealistic description. In order to define a realistic limiting description of the foundation geometry for use within the EIA, which also allows the necessary flexibility, the key aspects of the foundation geometry from an EIA perspective have been identified:

- The obstruction the wind turbine foundations provide to the passage of waves and tidal currents is the key input to assessment of impacts upon marine physical processes. Following consultation with experts in the field of fluid flow modelling, the “wave reflection coefficient” was identified as a value which describes both these properties of a foundation structure. Appropriate worst-case wave reflection coefficients have therefore been developed, described later within this section, and realistic worst case wave reflection coefficient values are presented for all wind turbine foundations.

- Worst-case seabed footprint areas and maximum overall foundation widths have also been developed through concept design studies, and are specified for all alternatives. These are commonly required in assessments on subjects such as impacts on the seabed and the potential for vessel collisions, and are also useful when visualising the foundations described.

3.2.5. This approach allows the EIA to be progressed based on a relatively simple definition of foundation options, while at the same time ensuring that:

- Future foundation selections can be easily verified as falling within the project assessment envelope.
- The assessment envelope is robustly linked to environmental impact; giving certainty that foundations within the consent envelope will always have environmental impacts within the maximum potential environmental impact.

Foundation Options

Wind Turbine Foundations

3.2.6. The range of wind turbine foundation types is continually growing as new sub-types are developed, but can be considered as grouped within the following categories:

- Wind turbine monopole:
  - i. Steel monopile;
  - ii. Concrete monopile;
  - iii. Suction bucket monopole.
- Wind turbine multileg:
  - i. With driven piles;
  - ii. With suction buckets.
  - iii. With screw piles;
  - iv. With jack-up foundations.
- Wind turbine gravity base:
  - i. Conical gravity base;
  - ii. Flat-base gravity base.

Meteorological Monitoring Stations

3.2.7. The foundation types for meteorological monitoring stations may be fixed structures, similar to those used for wind turbines. These have been represented within the EIA by foundation parameters and methodologies for smaller versions of the wind turbine foundations. To improve consistency the assessed values for meteorological monitoring station foundations have been included alongside their equivalent wind turbine foundation.

3.2.8. Alternatively, meteorological monitoring stations may be floating in which case they could be considered to be represented by the parameters and methodologies provided for the vessel moorings, as discussed in **Section 3.14 Vessel Moorings**.

Offshore Platform Foundations

3.2.9. The range of offshore platform foundation types has been grouped into the following categories:

- Offshore platform multileg:
  - i. Offshore platform jacket foundation (potentially using driven piles, suction buckets, and/or screw piles);
  - ii. Offshore platform jack-up foundation.
- Offshore platform gravity base:
  - i. Offshore platform conical or flat-base gravity base foundation;
  - ii. Offshore platform semi-submersible gravity base foundation.

Wind Turbine Monopole Foundations

3.2.10. The term monopole is used to describe the foundation options based around a single vertical, broadly cylindrical structure. This main support structure may change in diameter via conical tapers or abrupt steps. Several sub types exist, including:

- Monopole with steel monopile footing;
- Monopole with concrete monopile footing;
- Monopole with a single suction-installed bucket footing.

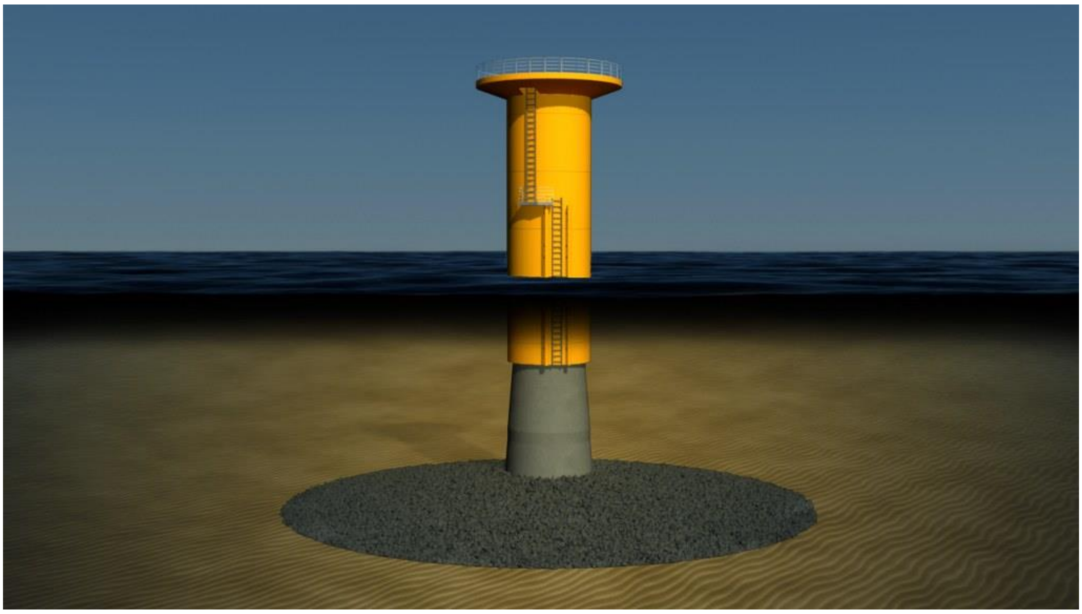
3.2.11. It is noted that 'monopile' is here use to describe the sub-category of monopole foundations, which involves a drilled or driven pile. The assessed parameters covering all sub-types of wind turbine monopole foundation are shown in **Table 3.3**.

Table 3.3 Indicative wind turbine and meteorological mast monopile foundation parameters

	Offshore Structure		
Parameter	Wind turbine up to 6MW	Wind turbine 10MW or greater	Meteorological Mast
Maximum wave reflection coefficient per foundation	See **Table 3.6**		
Maximum width of main supporting structure (m)	30	35	27
Maximum seabed footprint area per foundation (excluding scour protection) (m^2)	707	962	573
Piling related characteristics	See **Section 3.6 Piling and Noise Modelling**		

Monopile – Steel Monopile

Figure 3.5 Illustrative example of a steel monopile foundation



3.2.12. To date, the steel monopile has been the most commonly deployed foundation type for offshore wind turbines. Steel monopiles, an example of which can be seen in **Figure 3.5**, are large cylinders, normally constructed from welded steel tubular sections, which are driven vertically into the seabed. The pile supports the weight of the wind turbine primarily using friction between the pile walls and the seabed. The monopile relies on the surrounding geology to provide lateral resistance to the horizontal forces of the wind and the sea. The diameter and length of the monopile depends on water depth, the prevailing metocean conditions and the ground conditions as well as the size of the wind turbine generator chosen. Installed piles will typically extend above the sea surface but it is also possible to terminate below sea surface. A transition piece is used to create the connection between the monopile and the tower sections of the wind turbine.

Installation – Steel Monopiles

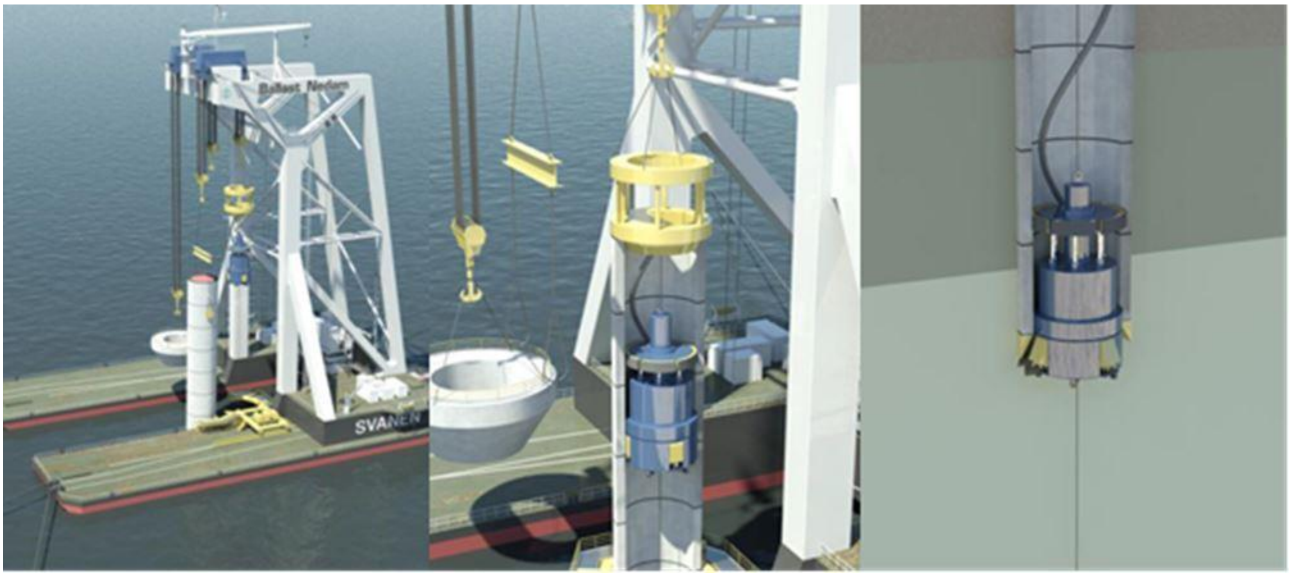
3.2.13. Each foundation will be fabricated at a suitable fabrication yard and transported to site (potentially via a lay-down area at the selected construction port). A typical installation sequence for each foundation is as follows:

i. Transport of foundation to offshore site via vessel, barge, or towed float-out (potentially with detachable buoyancy, or structural elements filled with air to give positive buoyancy).
ii. Seabed preparation is carried out if required as described in **Section 3.5 Seabed Preparation, Drilling & Disposal of Spoil Arisings**.
iii. The installation vessel positions itself at the required location and jacks up, anchors, or otherwise holds its position.
iv. Foundation is up-ended by the installation vessel into a vertical position, with buoyancy assistance if necessary, and lowered onto the seabed.
v. Installation of monopiles progressed by piling (as described within **Section 3.6 Piling & Noise Modelling**), drilling (as described within **Section 3.5 Seabed Preparation, Drilling & Disposal of Spoil Arisings**), or a combination as required by site specific soil conditions and technical and economic viability.
vi. Installation of transition piece and any ancillary equipment, such as cable J-tubes and boat landings, which are not integral to the main structure, including their alignment and fastening (typically grouting, bolting or welding).
vii. Installation of scour protection if required, as described in **Section 3.3 Protection Against Foundation Scour & Subsea Damage** (noting that this can alternatively happen before foundation arrives on site).

3.2.14. The sequence is repeated for each foundation.

Monopole – Concrete Monopile

Figure 3.6 Illustrative visualisation of the installation of a concrete monopile foundation



Courtesy of Ballast Nedam Offshore

3.2.15. An alternative monopile solution currently under development consists of a steel reinforced concrete design. Concrete monopiles, an example of which can be seen in **Figure 3.6**, would typically comprise a number of pre-cast reinforced concrete ring sections which may be partially fitted and grouted together prior to floating out to site. Additional rings are then joined onto the top as installation progresses, gradually lengthening the pile as it penetrates into the seabed, until the top section with access platforms and wind turbine tower connecting flange is attached last. Concrete monopiles are commonly characterised by their large diameters, thick walls, and piling-free installation methodologies.

Installation – Concrete Monopile

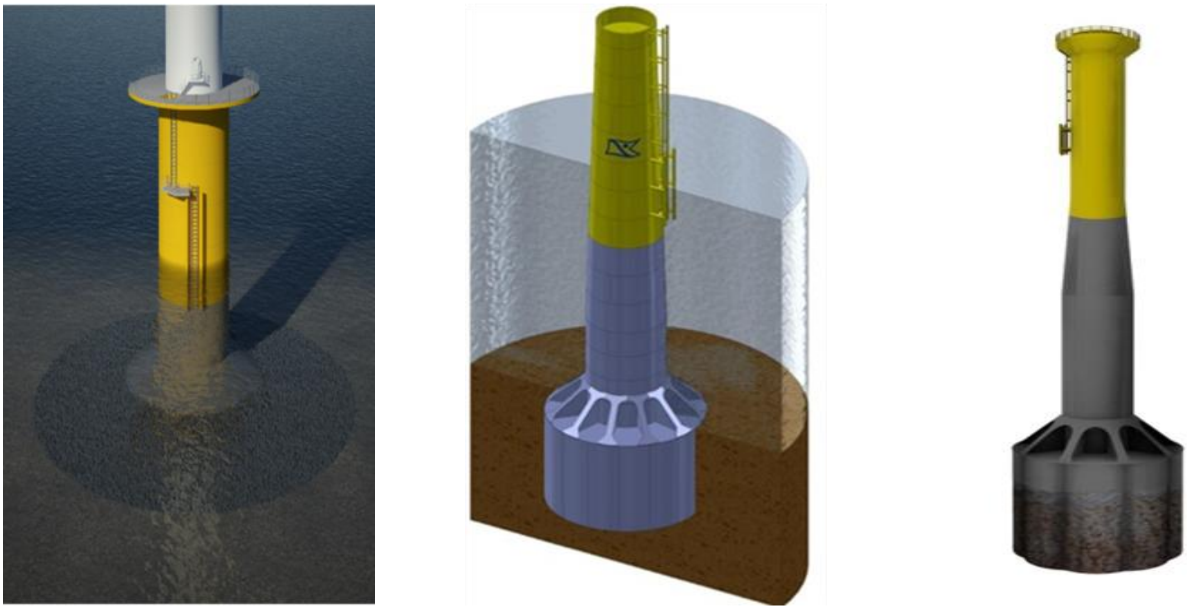
3.2.16. Each concrete monopile will be fabricated at a suitable fabrication yard and transported to site (potentially via a lay-down area at the selected construction port). A typical installation sequence for each foundation can be assumed to be similar to that for a steel monopile, described previously in this section, with the following key differences:

i. Concrete monopiles are lowered onto seabed location, with the large pile weight providing initial seabed penetration.
ii. Installation of concrete monopiles progressed by drilling out the central section or full diameter of the pile (using an 'under-reaming' drill) as required by site specific soil conditions as described in **Section 3.5 Seabed Preparation, Drilling & Disposal of Spoil Arisings**).
iii. Particularly in the event of under-reaming being required, slow-setting grout could be pumped into the gap between the walls of the pile and the drilled socket. This would help to lubricate the pile, and also improve the strength of the foundation once the grout has cured.

iv. Additional ring sections would be assembled and added, lengthening the pile, and the additional weight causing the pile to incrementally penetrate further, until fully installed. The transition piece, potentially including access platforms and ancillary equipment would likely form part of the final section to be added.

Monopole – Suction Bucket

Figure 3.7 Illustrative examples of suction bucket monopole foundations



Courtesy of RWE npower renewables (left) and Fred Olsen United (centre and right)

3.2.17. Suction buckets (also known as suction caissons), an example of which can be seen in **Figure 3.7**, are cylindrical, or near cylindrical-shaped structures, similar to inverted buckets which are attached to the base of the monopole column and partially inserted into the seabed. Supporting brace structures link the bucket to the column and provide strength and stiffness to the bucket itself. The foundation structure is commonly made in steel, but other materials such as concrete could be used as alternatives. The suction bucket can be considered to work as a hybrid between a driven pile and a gravity base foundation; utilising friction between the bucket walls and soil, as well as the mass of the soil contained within the bucket - plus additional suction effects which resist movement of the whole mass below the seabed.

Installation – Monopole Suction Bucket

3.2.18. Each suction bucket monopole will be fabricated at a suitable fabrication yard and transported to site (potentially via a lay-down area at the selected construction port). A typical installation sequence is for each foundation can be assumed to be similar to that for a steel monopile, described previously in this section, with the following key differences:

i. The suction bucket foundation is fitted with a pump and control unit (if detachable) during installation.

ii. Suction bucket lowered to seabed location, with structure weight providing initial seabed penetration.
iii. Negative pressure is then applied within the bucket structure by means of the pumps and it is embedded until the top sits as close as possible to the seabed. Water jets within the bucket structure may be used to assist in penetrating the sediments and controlling the installation process.
iv. A layer of grout may be pumped into the top of the bucket after installation, to provide a uniform bearing surface between the top of the suction bucket and the seabed.

Wind Turbine Multileg Foundations

3.2.19. The term multileg is used to refer to foundations based around structures with multiple legs or footings. This typically includes options with three, four, five or six legs or footings. This includes jackets, tripods, and a variety of other structures which include multiple large tubulars, cross-bracing, or lattices. Several sub-types exist, including:

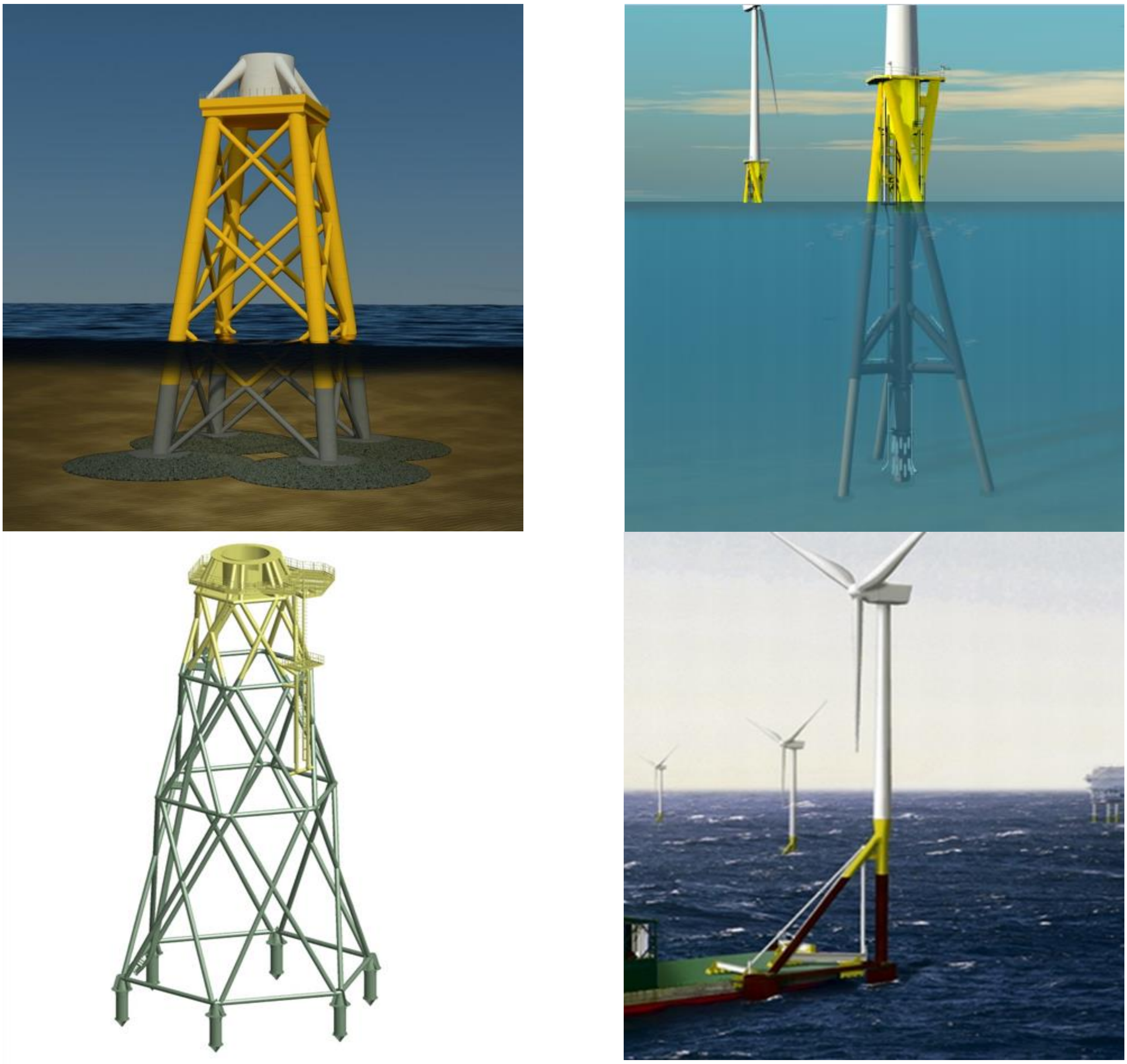
- Multileg with driven pile footings;
- Multileg with suction bucket footings;
- Multileg with screw pile footings;
- Multileg with jackup footings.

3.2.20. The assessed parameters covering all sub-types of wind turbine multileg foundation are shown in **Table 3.4**.

Table 3.4 Indicative wind turbine and meteorological mast multileg foundation parameters

	Offshore Structure		
Parameter	Wind turbine up to 6MW	Wind turbine10MW or greater	Meteorological Mast
Maximum wave reflection coefficient per foundation	See **Table 3.6**		
Maximum overall width of main supporting tower structure excluding footings (m)	55	61	51.5
Maximum seabed footprint area per foundation (excluding scour protection) (m^2)	707	707	707
Piling related characteristics	See **Section 3.6 Piling and Noise Modelling**		

Figure 3.8 Illustrative examples of multileg foundation structures



Courtesy Keystone Engineering (top right), ThyssenKrupp Mannex GmbH (bottom left), and SPT Offshore (bottom right).

3.2.21. The multileg main support structure is based around varying arrangements of tubular legs and cross bracing. Examples of the designs that fall within this category are illustrated in **Figure 3.8**. Key variables within this class of structures include:

- General arrangement of structure. Some key examples include:
  - Classic quatropod jacket with four legs forming a square-based tower(see **Figure 3.8** top left), or similar three-legged equivalent;
  - Classic tripod with centre column plus three supporting legs (see **Figure 3.8** top right);

  - Asymmetric tripod with one main column, plus two supporting legs, such as the SPT 'Self Installing Wind Turbine' suction tripod concept (see **Figure 3.8** bottom right);
  - Hexabase-type, including a supporting frame without distinct "legs", supported by up to six piles in the seabed (see **Figure 3.8** bottom left).
  - Tripod with no central column or cross braces in the water (similar to the Bard Tripile or Titan 200 jack up); and
  - Heavily braced tripod with the ability to be self-buoyant for installation, such as the Ulstein F2F concept.
- Dimensions of the structure and component parts (including leg spacing, seabed footprint, diameters of tubulars, etc.).
- Type, number and arrangement of footings (including driven piles, screw piles, suction-installed buckets and jack-ups).
- Details of the connection arrangements with the footings (including pre-connected, grouted, or swaged).

3.2.22. Some multileg structures are planned to be self-buoyant to assist in transport to site, and may or may not include a wind turbine pre-installed onto the foundation structure.

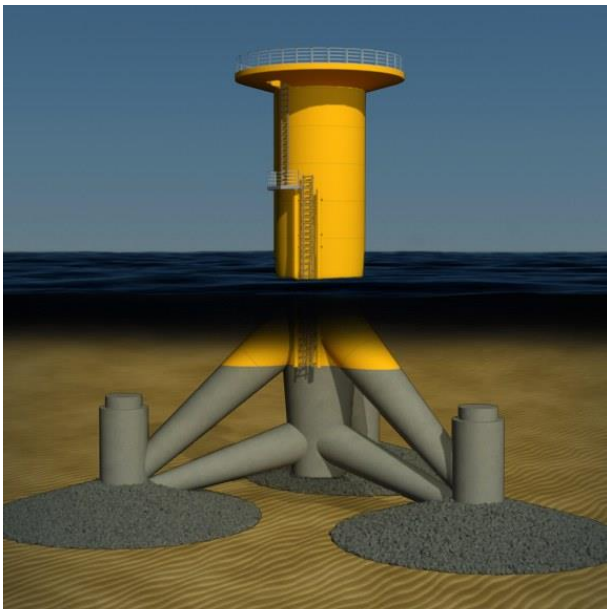
3.2.23. Secondary structures (such as boat landing, access ladder, etc.) are usually pre-mounted on the multileg main supporting structure.

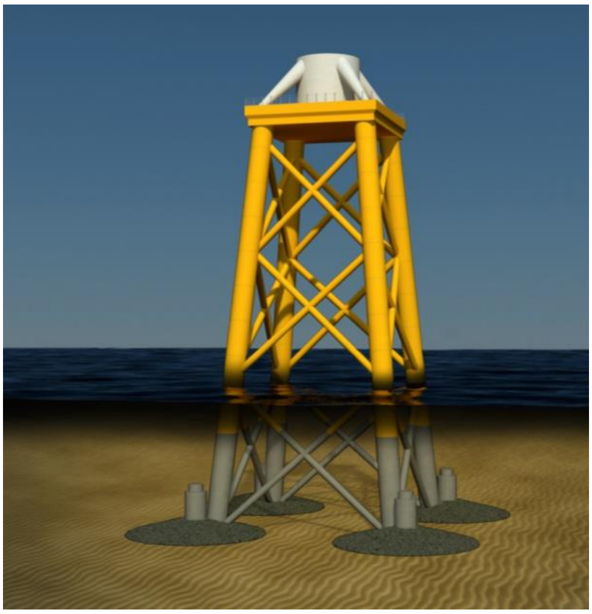
3.2.24. Mud mats are expected to be required as part of many multileg designs. Steel mud mats rest on the seabed to provide temporary vertical support and prevent subsidence of the structure prior to connection of the footings. The footprint of these is considered to be captured in the maximum seabed footprint stated.

3.2.25. There is a limited or no requirement anticipated for seabed preparation to ensure a suitably level seabed surface for placement of multileg foundations.

Multileg – Driven Piles

Figure 3.9 Illustrative examples of driven pile multileg foundation





3.2.26. Driven piles are the most commonly used multileg footing; this includes all of the offshore wind turbine jacket foundations installed to date, plus the vast majority of tripods. As in the steel monopile, the piles themselves are cylindrical structures, normally constructed from welded steel tubular sections. The pile supports the weight of the wind turbine primarily using friction between the pile walls and the seabed. The pile relies on the surrounding geology and the separation of the legs of the multileg tower to provide resistance to the horizontal forces of the wind and the sea. The diameter and length of the piles depend on the tower geometry, water depth, the prevailing metocean conditions and the ground conditions, as well as the size of the wind turbine generator chosen.

3.2.27. Installed piles will typically extend only a short distance above the seabed, and be connected to the multileg support structure using either a grouted or swaged connection. There are also alternative arrangements, such as the Bard tripile, in which the three piles extend around 20m above the sea surface before they connect to the crossbrace structure, and some jacket designs in which the piles are driven inside the legs.

Installation – Multileg with Driven Pile Footings

3.2.28. Each multileg main support structure, plus associated piles and pile templates as required, will be fabricated at a suitable fabrication yard and transported to site (potentially via a lay-down area at the selected construction port). A typical installation sequence for each foundation can be assumed to be similar to that for a steel monopile, described previously in this section, with the following key differences:

i. The multileg main support structure may be lowered onto the seabed location first, with piles driven after. Alternatively piles may be driven first, following the sequence below.
ii. Installation of piles progressed by driving, drilling (both driving and drilling are described within **Section 3.5 Seabed Preparation, Drilling & Disposal of Spoil Arisings**), or a combination as required by site specific soil conditions and technical and economic viability.
iii. If further piles are required at this foundation location, the vessel or equipment may be re-positioned to allow additional piles to be installed using a similar sequence.
iv. When all required piles are in place, installation of main support structure may occur, if not already in position. The main structure is then secured to the piles (typically grouted or swaged into place within pile sleeves).

3.2.29. There is limited or no requirement anticipated for seabed preparation to ensure a suitably level seabed surface for placement of multilegs.

Multileg – Suction Buckets

Figure 3.10 Example of a suction bucket multileg foundation

Courtesy of Statoil

3.2.30. Suction buckets have been used as foundations for jacket structures in the oil and gas industry and are considered a viable future technology for offshore wind jacket foundations. Suction tripod concepts are also under development (such as the 'Self Installing Wind Turbine' concept, developed by the company SPT and the self-buoyant F2F concept by the company Ulstein). Suction foundations have been identified as being potentially well suited to the Dogger Bank site. An example of a previous suction bucket design can be seen in **Figure 3.10**.

3.2.31. As with mono-bucket structures described above, multileg suction buckets are cylindrical, or near cylindrical-shaped structures, similar to inverted buckets, which are inserted into the seabed and attached to the base of the foundation main structure. Supporting brace structures link the bucket to the structure and provide strength and stiffness to the bucket itself. The suction buckets may be made of steel and/or reinforced concrete. Ballast may be required within the main structure to ensure resistance of uplift forces during operation, and potentially to ease installation.

Installation – Multileg Suction Bucket Footings

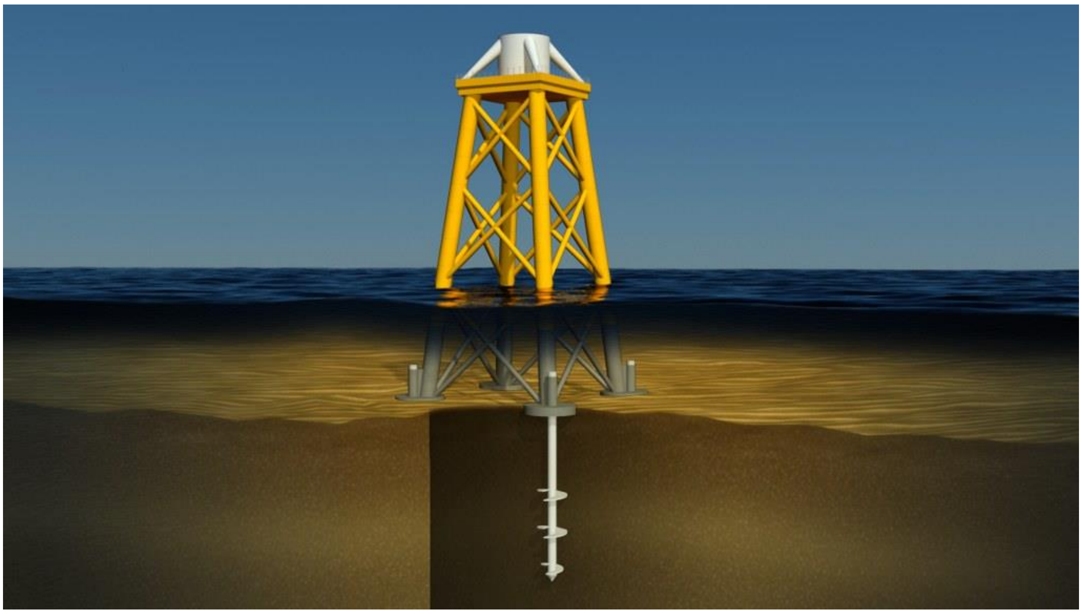
3.2.32. Each suction bucket multileg will be fabricated at a suitable fabrication yard and transported to site (potentially via a lay-down area at the selected construction port). A typical installation sequence for each foundation can be assumed to be similar to that for a steel monopile, described previously in this section, with the following key differences:

i. Buckets are fitted with pumps and control units (if detachable) during installation.

ii. Structure is up-ended or positioned by crane vessel, with buoyancy assistance if necessary.
iii. Suction buckets lowered onto seabed locations, with structure weight providing initial seabed penetration.
iv. Negative pressure is then applied within the suction buckets by means of the pumps, and the bucket embeds itself until the top sits as close as possible to the seabed. Water jets within the bucket structure may be used to assist in penetrating the sediments and controlling the installation process.
v. A layer of grout may be pumped into the top of the suction buckets after installation, to provide a uniform bearing surface between the top of the buckets and the seabed.
vi. If the suction buckets were not pre-connected to the multileg structure and were installed separately, then grouting or swaging may be used to connect the multileg to the buckets, similar to a pre-piled pile connection.

Multileg – Screw Pile Footings

Figure 3.11 Illustrative visualisation of a screw pile multileg foundation



3.2.33. Screw piles have been used extensively as a foundation technique in a wide range of onshore civil engineering applications, but they originated historically as an offshore foundation. Screw pile foundation solutions are under development, and are considered a potentially viable future technology for offshore wind multileg foundations.

3.2.34. Screw piles, an illustration of which can be seen in **Figure 3.11**, consist of a central tubular pile, with a helical 'thread', typically consisting of curved steel plates welded in place, spiralling up the tube similarly to a traditional woodworking screw. The thread can be either continuous up the length of the tube (as in a domestic screw), or in shorter sections with the bare tube in between. Once installed, screw piles work structurally in a similar manner to a traditional driven pile, but with the relatively wide metal plates significantly increasing the capacity of the foundation against vertical loads (which are very significant for multileg footings). Screw piles may be installed vertically or at an angle. It is anticipated that to increase the horizontal capacity of the foundation (i.eits resistance to sliding across the seabed) some screw pile foundations may also incorporate additional elements which may resemble small suction buckets – which would embed into the seabed during the screw pile or main structure installation. More than one screw pile may be used per multileg foot.

Installation – Multileg Screw Pile Footings

3.2.35. Screw piles may be installed similarly to a standard driven pile, but using a 'torque motor' or similar machinery instead of a piling hammer. The torque motor would act in a similar manner to a domestic electric screwdriver, and would be connected to the end of a screw pile in order to rotate it (or screw it) into the seabed. Similar concept torque motors are used in the offshore oil and gas industry for drilling operations. The screw piles would either be pre-installed before the multileg structure is placed into position, using a pile template or similar, or installed once the multileg is in place.

3.2.36. Each screw pile multileg will be fabricated at a suitable fabrication yard and transported to site (potentially via a lay-down area at the selected construction port). A typical installation sequence for each foundation can be assumed to be similar to that for a steel monopile, described previously in this section, with the following key differences:

i. The structure is up-ended or positioned by crane vessel, with buoyancy assistance if necessary and screw piles are fitted with torque motors during installation.
ii. If screw piles are being pre-installed, then piles are positioned on their seabed locations, potentially using a piling template or jig.
iii. The screw piles are then rotated using the torque motors, potentially in counter-rotating pairs to counter the tendency for the structure to be twisted. This rotation, plus vertical pressure potentially applied mechanically or just by the component weights, would embed the screw piles and any associated bucket-type structures into the seabed until fully installed.
iv. If further screw piles are required at this foundation location, vessel or equipment may be re-positioned to allow additional piles to be installed using a similar sequence.
v. In the case of pre-piling, the main structure would now be installed according to the multileg main structure installation section.
vi. When all required elements are in place, the main support structure may be aligned and connected to the piles (typically grouting or swaging piles into place within pile sleeves).

Multileg – Jack-up Foundation

Figure 3.12 Illustrative example of a jack-up foundation

Courtesy of Offshore Wind Power Systems of Texas

3.2.37. Jack-up foundations are widely used in the oil and gas industry on offshore platforms of various types and are considered a viable future technology for offshore wind multileg foundations. An example of a jack-up foundation can be seen in **Figure 3.12**.

3.2.38. Jack-up foundations are based around the concept of a platform structure with legs that can be extended to lift the structure above the sea surface. The legs push into the seabed to a varying depth, depending on the soil conditions at the site and the weight of the structure. The legs can also be fitted with 'spud cans', generally circular or square in shape, and which can be equivalent to suction buckets or feet which spread the load more widely into the seabed.

3.2.39. The amount the structure is raised above the sea surface will generally depend on the expected metocean conditions at the site. If the structure is expected to be deployed for long periods then the main structure will need to stay above expected peak wave crests to survive storm conditions. The leg height can also potentially be adjusted during operation in the event that one leg needs to be further embedded or similar. In some seabed conditions, jack-up foundations may also require scour protection.

Installation – Multileg Jack-up Footings

3.2.40. Each jack-up multileg will be fabricated at a suitable fabrication yard and transported to site (potentially via a lay-down area at the selected construction port). A brief typical installation sequence for each foundation can be assumed to be similar to that for a steel monopile, described previously in this section, with the following key differences:

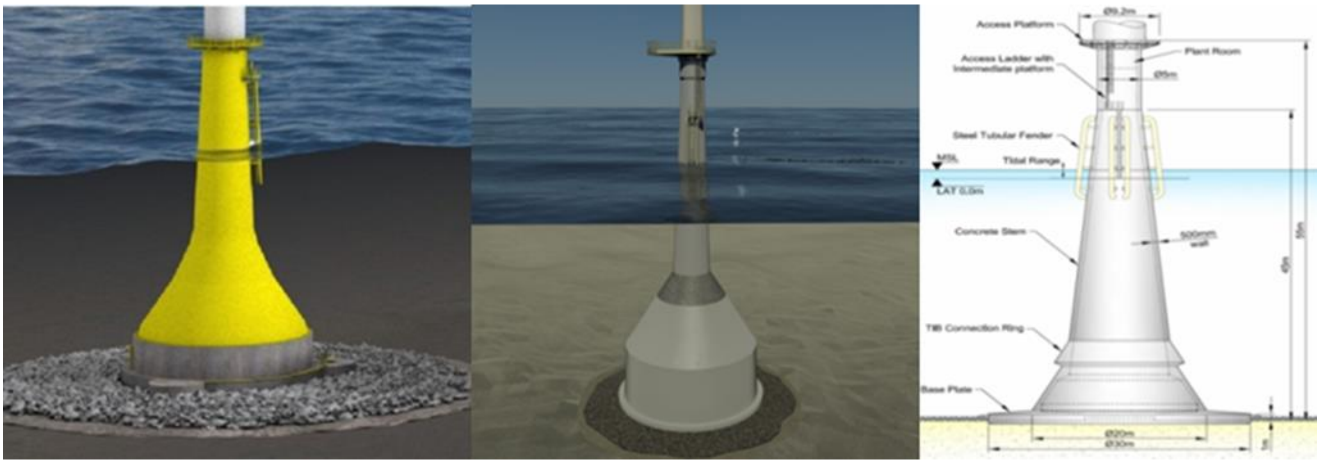
i. Jack-up positioned and legs are extended to the seabed.

ii. Jack-up mechanisms embed legs or spud cans, and structure is lifted to the desired installed height.

iii. If required, suction pumps or water jets may be used in a manner similar to a suction bucket installation, to assist or control the installation of suction bucket-type footings.

Wind Turbine Gravity Base Foundations

Figure 3.13 Illustrative examples of conical gravity base foundations



Courtesy of Seatower (left), Skanska (centre) and GBF (right)

3.2.41. A gravity base structure is a large diameter steel, concrete, or steel and concrete combination base which sits on the seabed. Two sub types have been identified:

- Conical gravity base;
- Flat-based gravity base.

3.2.42. The assessed parameters covering all sub-types of wind turbine gravity base foundation are shown in **Table 3.5**.

Table 3.5 Indicative wind turbine and meteorological mast gravity base foundation parameters

	Offshore Structure		
Parameter	Wind turbine up to 6MW	Wind turbine10MW or greater	Meteorological Mast
Maximum wave reflection coefficient per foundation	See **Table 3.6**		
Maximum overall width of foundation structure (m)	50	55	47
Maximum seabed footprint area per foundation (excluding scour protection) (m^2)	1,963	2,376	1,735

3.2.43. The gravity base solution primarily relies on its size and weight to maintain the stability of the structure. Gravity base foundations can additionally incorporate steel or concrete 'skirts' around the perimeter which could penetrate into the seabed to help resist horizontal movement, reduce the impact of scour, and offer similar foundation benefits to those offered by a suction bucket. The base of the structure can also be grouted to enhance the frictional force between foundation and the seabed and ensure even contact with the base. Gravity base structures are typically filled with ballast such as water, sand, rock, or iron-ore to increase their weight. Some gravity base structures may be wholly or partially self-buoyant for transportation and during installation. The structural connection between the wind turbine tower and the foundation may be made directly by bolted flange or via a transition piece. Ancillary equipment such as boat landings and access platforms may be pre-installed or installed on site. In some cases, gravity bases may require seabed preparation prior to the installation of the foundations, as described in **Section 3.5 Seabed Preparation, Drilling & Disposal of Spoil Arisings**. Gravity bases may also require scour protection, as described in **Section 3.3 Protection Against Foundation Scour & Subsea Damage**.

Figure 3.14 Illustrative examples of flat based gravity foundations

Courtesy of Strabag (left), Seabreeze (centre) and Strabag (right)

3.2.44. The term conical gravity foundation describes the family of gravity base designs with a predominantly conical shape. Within this sub-type there is a wide variability in the detailed geometry and a range of examples, both concept designs and installed structures, are illustrated in **Figure 3.13**. Although the geometry is variable, the essential characteristics of the structures remain similar and the general description and installation methodology for gravity base foundations is still applicable.

3.2.45. The term flat base gravity foundation describes the family of gravity base designs with a main shaft and a predominantly slab base. The base may be cross-shaped, octagonal, circular, hexagonal, or other shaped in plan. Three examples, of flat based gravity foundations are illustrated in **Figure 3.14**. Although the geometry is variable, the essential characteristics of the structures remain similar and the general description and installation methodology for gravity base foundations is still applicable.

Installation – Gravity Base Foundation

3.2.46. Each gravity base will be fabricated at a suitable fabrication yard and transported to site (potentially via a lay-down area at the selected construction port). A typical installation sequence is as follows:

i. Seabed preparation is undertaken if required, as described in **Section 3.5 Seabed Preparation, Drilling & Disposal of Spoil Arisings**.
ii. Transport of gravity base to offshore site via vessel, barge, or towed/floated out if a self-buoyant design is used.
iii. The gravity base is positioned and the foundation is then filled with ballast as required to be lowered to the seabed by controlled buoyancy adjustment.

iv. If required, suction pumps or water jets may be used in a manner similar to a suction bucket installation, to assist in skirt penetration or control the installation of skirted gravity base foundations.
v. Under-base grouting, if required to improve contact between the gravity base and seabed, could be supplied by flexible hose, potentially including pre-installed piping to allow access under the base.
vi. Installation of ancillary equipment, such as J-tubes and boat landings if not integral to the gravity base structure.
vii. Installation of scour protection if required, as described in **Section 3.3 Protection Against Foundation Scour & Subsea Damage** (noting that this can alternatively happen before foundation arrives on site).

3.2.47. The sequence is repeated for each foundation.

Wind Turbine Foundation Wave Reflection Coefficients

3.2.48. The obstruction the foundations of the various offshore wind farm components provide to the passage of waves and tidal currents is the key input to assessment of impacts upon marine physical processes. Following consultation with Royal HaskoningDHV and the Danish Hydraulic Institute, who are experts in the field of fluid flow modelling around marine foundation structures, the "wave reflection coefficient" was identified as the value which describes best both these properties of a foundation structure. The basis for this is discussed within **Appendix 5.B Dogger Bank Teesside A & B Foundation Characterisation Study**.

3.2.49. An appropriate methodology has therefore been developed by Royal HaskoningDHV and the Danish Hydraulic Institute, to calculate a foundation's wave reflection coefficient, and this is described in detail within **Appendix 5.B Dogger Bank Teesside A & B Foundation Characterisation Study**.

3.2.50. Based on this design and methodology, a set of realistic worst case wave reflection coefficient values have been produced for the range of wind turbine foundation sizes and the meteorological mast foundations. These realistic worst case values are presented in **Table 3.6**.

Table 3.6 Worst case foundation wave reflection coefficients

Parameter	Teesside Project A	Teesside Project B
Up to 6MW wind turbine foundation (750m spacing)	2.84	2.75
10MW or greater wind turbine foundation (1080m spacing)	3.61	3.50
Metrological mast foundation	2.42	2.34

3.2.51. The assessment envelope, when evaluated in accordance with **Appendix 5.B Dogger Bank Teesside A & B Foundation Characterisation Study** covers all foundations with a wave reflection coefficient less than or equal to those shown in **Table 3.6**. If the wind turbine foundations are spaced closer than 1080m (the spacing assessed for 10MW sized wind turbine foundations), then the assessment envelope covers these foundations by using the wave reflection coefficients of the 6MW sized wind turbine foundations (assessed with a spacing of 750m).

3.2.52. Conical gravity base foundations were identified as overwhelmingly the worst-case foundation solution with respect to this issue for wind turbines and meteorological mast foundations. The defined methodology therefore states that all foundations within the project envelope other than gravity base structure designs are deemed to comply with this test automatically.

3.2.53. Full details of the methodology and reasoning which supports this approach, plus the criteria for determining the wave reflection coefficient and whether this lies within the assessed envelope for any given foundation design, are provided in **Appendix 5.B Dogger Bank Teesside A & B Foundation Characterisation Study**.

Offshore Platform Multileg Foundations

3.2.54. The term multileg is used to refer to offshore platform foundation options based around several supporting legs. This includes jackets, jack-ups and a variety of other structures which include multiple large tubular structural members, with variable degrees of cross-bracing. Offshore platform multileg foundations may employ a wide range of footings, including driven piles, suction buckets, and screw piles.

3.2.55. Two example sub-types of offshore platform multileg foundations are described below:

- Offshore platform jacket foundations;
- Offshore platform jack-up foundations.

3.2.56. The assessed parameters covering all sub-types of offshore platform multileg foundation are shown in **Table 3.7**.

Table 3.7 Indicative offshore platform multileg foundation parameters

	Offshore Platform Type		
Parameter	Collector	Converter	Accommodation
Maximum overall length of structure (m)	75	100	100
Maximum overall width of structure (m)	75	125	125
Maximum seabed footprint area per foundation (excluding scour protection) (m^2)	5,625	12,500	12,500
Piling related characteristics	See **Section 3.6 Piling and Noise Modelling**		

Offshore Platform Jacket Foundations

3.2.57. Jackets have been the standard offshore substation platform foundation to date, consisting of a number of legs connected by a lattice support structure, as outlined in the wind turbine multileg section. Offshore platform jacket structures may commonly have driven pile and/or suction bucket footings, but screw piles may also become an option in the future. Jacket foundations are commonly pre-installed separately to the offshore platform topsides. In some cases, jacket structures may require seabed preparation prior to the installation of the foundations, as described in **Section 3.5 Seabed Preparation, Drilling &**

Disposal of Spoil Arisings. Jackets may also require scour protection, as described in **Section 3.3 Protection Against Foundation Scour & Subsea Damage**.

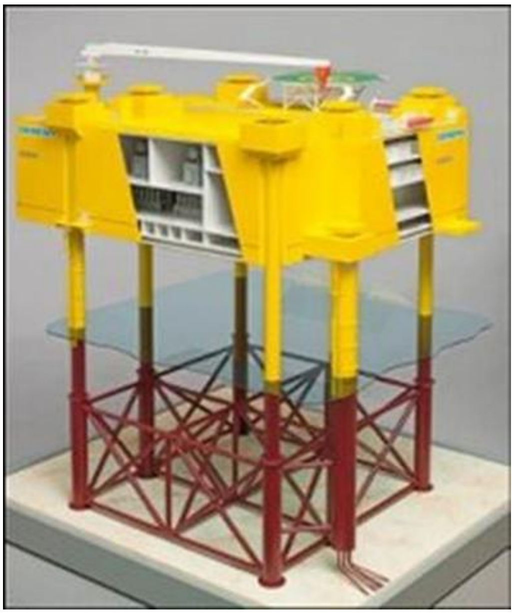
Installation – Offshore Platform Jacket Foundations

3.2.58. Each jacket structure will be fabricated at a suitable fabrication yard and transported to site (potentially via a lay-down area at the selected construction port). A typical installation sequence for each foundation can be assumed to be similar to that for a steel monopile, described previously in this section, with the following key differences:

i. Driven piles/suction buckets/screw piles may have been pre-installed, in which case the multileg structure is connected to the footings (potentially using grouting or swaging) and levelled if required;
ii. Alternatively, installation of footings are progressed at this point (as described for the relevant wind turbine foundations);
iii. Installation of topsides in one or more sections if required, via heavy lift vessel or using a jack-up, or alternative self-installing option.

Offshore Platform Jack-Up Foundations

Figure 3.15 Illustrative example of a hybrid jacket/jack up platform foundation



WIPOS 800MW HVDC Offshore Converter Station. Courtesy of Siemens

3.2.59. Jack-up foundations are under consideration for future substation concepts. Jack-up foundations consist of a number of extendable legs built into the main substation topside structure. The topside is floated into position (either using a barge, or with a self-buoyant topside design), at which point the jack-up legs extend, lifting the topside clear of the sea surface and fixing it in place. The legs push into the seabed to a varying depth, depending on the soil conditions at the site and the weight of the structure. The legs can also be fitted with ‘spud cans’, generally circular or square in shape, and which can be equivalent to suction buckets or 'feet' which spread the load more widely into the seabed.

3.2.60. This foundation type is particularly suited to self-installing (or self-lifting) platform concepts, which eliminate heavy lift vessels and are potentially viable options for the larger platforms under consideration for the Dogger Bank projects.

3.2.61. Pre-installed jacket or gravity foundations may be combined with jack-up installation solutions. In this case, the initial jacket or gravity foundation structure is fully submerged once installed. The platform topside is floated over the top and jacks up; fitting its legs into sockets in the submerged foundation structure.

3.2.62. In some cases, jack-up structures may require seabed preparation prior to the installation of the foundations, as described in **Section 3.5 Seabed Preparation, Drilling & Disposal of Spoil Arisings**. Jack-ups may also require scour protection, as described in **Section 3.3 Protection Against Foundation Scour & Subsea Damage**.

Installation – Offshore Platform Jack-up Foundations

3.2.63. Each jack-up will be fabricated at a suitable fabrication yard and transported to site (potentially via a lay-down area at the selected construction port). A brief typical installation sequence is for each foundation can be assumed to be similar to that for a steel monopile, described previously in this section, with the following key differences:

i. Jack-up positioned and legs are extended to the seabed;
ii. Jack-up mechanisms embed legs or spud cans, and structure is lifted to the desired installed height;
iii. If required, suction pumps or water jets may be used in a manner similar to a suction bucket installation, to assist or control the installation of suction bucket-type footings;
iv. If a footing has been pre-installed (see the sections on offshore platform jacket and gravity base foundations for descriptions and methodologies) then the jack-up legs may connect with sockets in the submerged foundation structure;
v. It is assumed that topsides are typically integral to these solutions, but additional sections may be lifted into place at this point by suitable crane vessels or self-installing options.

3.2.64. The sequence is repeated for each foundation.

Offshore Platform Gravity Base Foundations

3.2.65. A gravity base foundation is a large, typically steel, concrete, or steel and concrete combination, structure which sits on the seabed, supporting the platform topside primarily using its size and mass.

3.2.66. The gravity base structure can additionally incorporate steel or concrete 'skirts' around the perimeter which penetrate into the seabed to help to resist horizontal movement, reduce the impact of scour, and offer similar foundation benefits to those offered by a suction bucket. The base of the structure can also be grouted to enhance the frictional force between the foundation and the seabed and ensure even contact with the base. Gravity base structures are typically hollow and filled with ballast such as water, sand, rock, or iron-ore to increase their weight. If constructed from concrete, the structure would typically be heavier, reducing the mass of additional ballast required. In some cases, gravity bases may require seabed preparation prior to the installation of the foundations, as described in **Section 3.5 Seabed Preparation, Drilling & Disposal of Spoil Arisings**. Gravity bases may also require scour protection, as described in **Section 3.3 Protection Against Foundation Scour & Subsea Damage**.

3.2.67. Two key gravity base foundation sub-types have been identified:

- Offshore Platform Conical or Flat-Base Gravity Base Foundations.
- Offshore Platform Semi-Submersible Gravity Base Foundations.

3.2.68. The assessed parameters covering all sub-types of offshore platform gravity base foundation are shown in **Table 3.8**.

Table 3.8 Indicative offshore platform gravity base foundation parameters

	Offshore Platform Type		
Parameter	Collector	Converter	Accommodation
Maximum overall length of structure (m)	75	100	100
Maximum overall width of structure (m)	75	125	125
Maximum seabed footprint area per foundation (excluding scour protection) (m^2)	5,625	12,500	12,500

Installation – Offshore Platform Gravity Base Foundations

3.2.69. Each gravity base will be fabricated at a suitable fabrication yard and transported to site (potentially via a lay-down area at the selected construction port). A typical installation sequence for each foundation can be assumed to be similar to that for a steel monopile, described previously in this section, with the following key differences:

i. Gravity base is positioned and the foundation is then filled with ballast to be lowered to the seabed by controlled buoyancy adjustment;
ii. If required, suction pumps or water jets may be used in a manner similar to a suction bucket installation, to assist in skirt penetration or control the installation of skirted gravity base foundations;
iii. Under-base grouting, if required to improve contact between the gravity base and seabed, could be supplied by flexible hose, potentially including pre-installed piping to allow access under the base;
iv. Installation of ancillary equipment, such as J-tubes and boat landings if not integral to the gravity base structure;
v. Installation of scour protection if required, as described in **Section 3.3 Protection Against Foundation Scour & Subsea Damage** (noting that this can alternatively happen before foundation arrives on site);
vi. Installation of topsides if required, via heavy lift vessel or using a jack-up or other self-installing option; and
vii. Cable installation and platform commissioning then follow.

3.2.70. The sequence is repeated for each foundation.

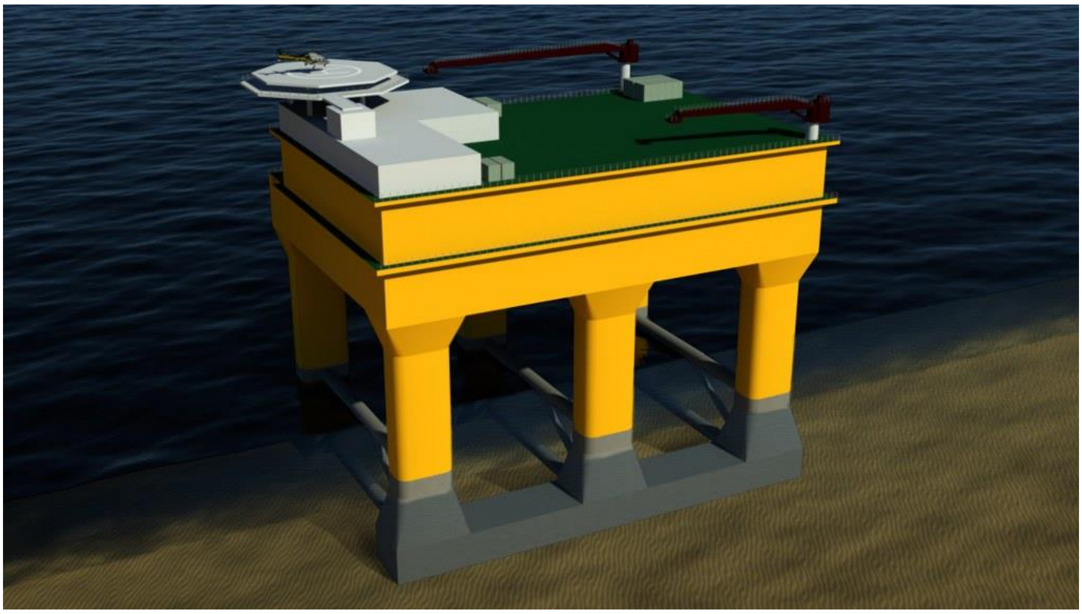
Offshore Platform Conical or Flat-Base Gravity Base Foundations

3.2.71. This category describes a range of gravity bases with varying geometry; from flat base solutions, with a main shaft and a predominantly slab base, to conical solutions, characterised by a predominantly conical base tapering to a central shaft. For both these foundation types the platform topsides are typically installed via bolted connections or similar.

3.2.72. Although the geometry is variable, the essential characteristics of the structures remain similar and the general description and installation methodology for gravity base foundations is still applicable.

Offshore Platform Semi-Submersible Gravity Base Foundations

Figure 3.16 Illustrative example of a semi-submersible gravity base foundation



3.2.73. Semi-submersible gravity base solutions are a floating, self-installing platform concept, where the buoyancy is predominantly provided by submerged portions of the foundation structure. The typical structural arrangement comprises two large submerged pontoons, linked to the topside by a number of large-diameter legs, as shown in **Figure 3.16**.

3.2.74. Although the structural arrangements are unlike conical or flat-base gravity structures, the general description and installation methodology for gravity base foundations is still applicable. Similarly to other gravity base concepts, the platform is towed to site and ballasted down onto the seabed. When in place, this concept then acts as a standard gravity base foundation, with the pontoons resting directly on the seafloor.

Other Foundation Options

3.2.75. There are many foundation solutions being developed and proposed for wind turbines and offshore platforms as the offshore wind industry grows and extends further from shore and into deeper waters. It is anticipated that any other foundation design that is developed, and that fits within the foundation design envelope, would be considered by Forewind for these projects. Technological advances in installation methods for foundations are also anticipated and those that fit within the development envelope would also be considered for these projects.

Additional Foundation Components

3.2.76. Foundation structures include a range of additional components, some or all of which may be required on a specific foundation design. A selection of key components is described below.

Transition Piece

Figure 3.17 Typical wind turbine transition pieces

Transition pieces ready for installation (left) and transition piece being installed (right).
By CHPV, courtesy of Scira Offshore Energy

3.2.77. The transition piece, as shown in **Figure 3.17**, is used as part of some wind turbine foundations to form the interface between the wind turbine tower and the foundation. It also serves other purposes, including housing electrical and communication equipment, and mounting various ancillary components such as boat access facilities, main access platforms, and J-tubes if required.

3.2.78. Transition pieces may be integrated at fabrication stage with the foundation, but are typically craned into position and connected to the foundation structure after installation via grouted or bolted (flange) connections and include means to ensure the verticality of the wind turbine tower. Connection to the wind turbine tower is typically by bolted (flange) connections.

J-tubes

3.2.79. J-tubes are metal tubes that route and protect cables as they travel up the foundation to the base of the wind turbine tower or offshore platform topside. The metal tubes are generally curved at the bottom of the foundation structure as it supports the cable from travelling horizontally along the seabed to vertically up the foundation. J-tubes may be housed internally or externally to the structure. The use of J-tubes is optional and designs exist for which they are not required.

Corrosion Protection Systems

3.2.80. Structures will be protected appropriately against corrosion. Methods for the control of corrosion include a corrosion allowance in the built structure, cathodic protection, protective coating systems, and the use of corrosion resistant materials. The methods used will be dependent on what is appropriate in each situation and location.

3.2.81. It is anticipated that steel structures will primarily be protected by a combination of cathodic protection and coating systems that are appropriate for seawater exposure.

3.2.82. Steelwork which is permanently submerged is commonly protected by a cathodic protection system of a sacrificial anode type.

3.2.83. In addition, protective coating systems (such as paint systems, or galvanisation) are commonly applied for protection in the splash zone and above. Areas of steelwork in the submerged and splash zones may also be coated in order to reduce the load on the cathodic protection system.

3.2.84. The selection of the appropriate corrosion protection method shall be made during the detail design of the structures.

Boat Access System

3.2.85. The design of boat landing facilities, access ladders, and personnel access and rest platforms is driven by the type and largest size of boat or personnel transfer system anticipated to be used in the maintenance programme. Access systems may also be used by third parties in emergency situations. Wind turbines commonly have either one or two boat landings giving access to the structure. Foundations may include advanced devices to improve access, such as lifts, movement compensating platforms, or lock-on points, and offshore platforms may have more elaborate systems, potentially including vessel retrieval systems (based on cranes or a dock system, for example).

3.2.86. To date, systems have included some combination of the following:

- Access ladders enabling maintenance crew to access the wind turbine or offshore platform from a vessel. On some foundation types, stairways may replace ladders for parts of the climb.
- A permanent fender system located on either side of the lower section of the ladders which provides for safe access by personnel from a small vessel.
- Safety equipment, such as fixed inertia reel fall arrest systems are fitted to address safety issues such as working at heights during the climb up the foundation.
- Intermediate access or rest platforms are often included to assist personnel climbing the foundation.

Main Access Platform

3.2.87. The main access platform is a key element of a wind turbine structure, commonly located at the top of the foundation and the base of the wind turbine tower. The platform forms the main working area at the base of the wind turbine tower and often includes an integral laydown area for parts and equipment to be lifted up to the nacelle of the wind turbine. The platform is also often the area used to mount the various ancillary systems, described below.

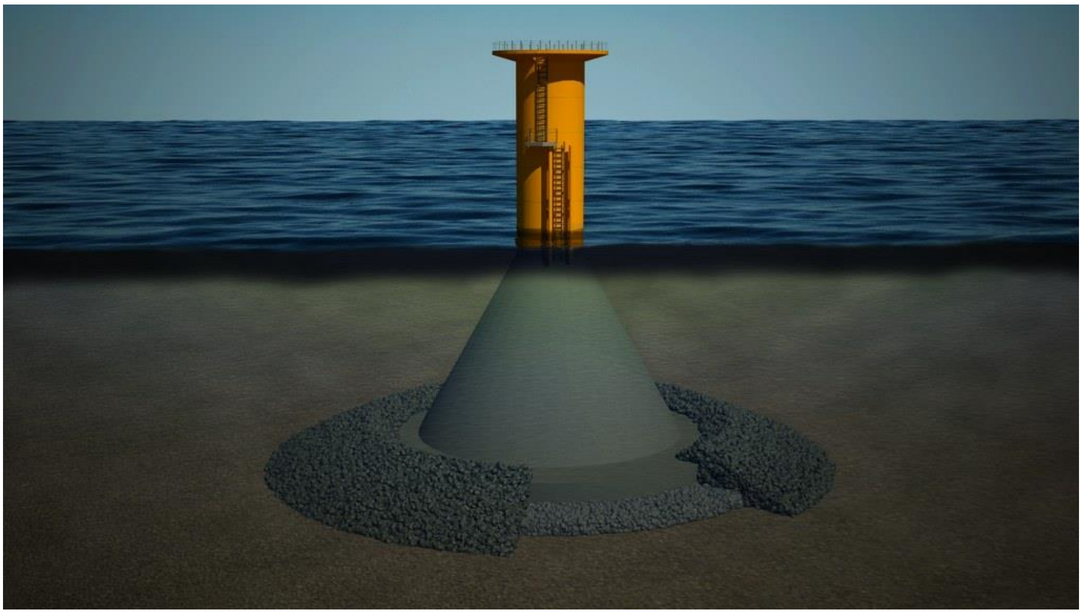
Ancillary Systems

3.2.88. In addition to the components listed above, the structure may also be outfitted with a number of ancillary systems where deemed appropriate. This list includes, but is not limited to:

- navigation lighting;
- fog horns;
- identification symbols;
- workplace lighting for operations at night or in low light;
- cranes, davits, or hoists;
- cooling or air conditioning systems;
- security alarm system;
- fire protection systems; and
- back-up power systems.

3.3. Protection Against Foundation Scour & Subsea Damage

Figure 3.18 Example of gravity base structure with scour protection



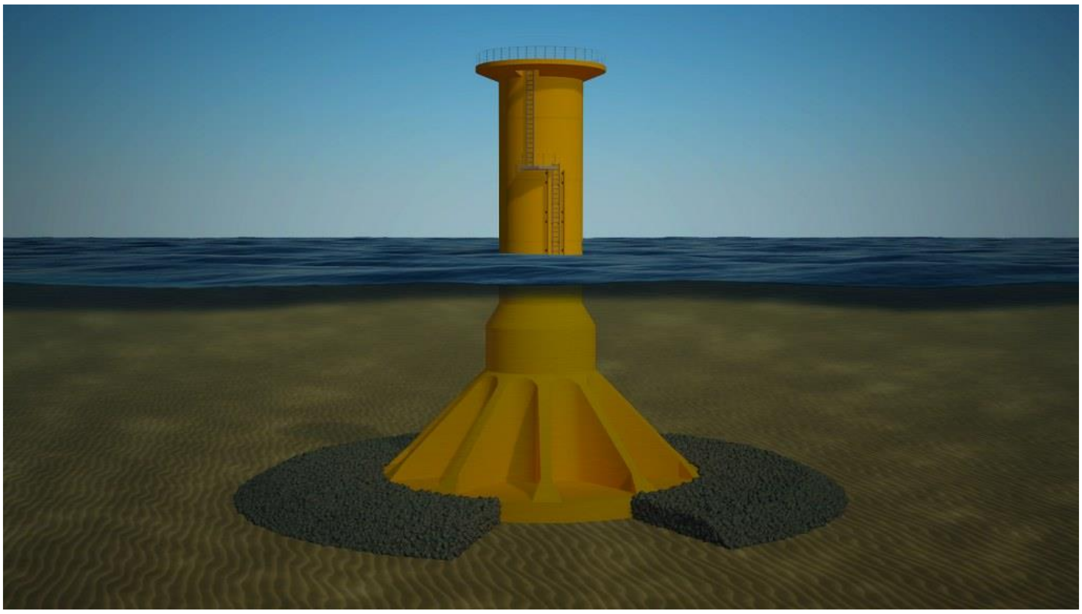
3.3.1. Scour can occur around the base of a foundation when seabed sediment is flushed away as a result of the flow of water around the structure. Scour may result in pits being created at the base of a structure, potentially weakening or undermining a foundation. In addition, the more vulnerable elements of foundation structures, such as J-tubes and the vicinity of the cable exit, can be damaged by waves and tidal currents, or maritime activities such as trawling.

3.3.2. Protection against scour and subsea damage may be required around any and all of the offshore structures installed. There are a number of protection options currently available, as listed below, and examples are shown illustratively in **Figure 3.18** to **Figure 3.20**. Should such protection be required, the design chosen will depend on the final foundation or structural design, ground conditions, as well as the scour and environmental assessment. Vulnerable areas, such as the vicinity of the cable exit from the J-tubes, may receive additional protection, such as localised rock or frond mat placement and/or concrete aprons or coverings extending out onto the cables themselves. Cable protection itself is discussed in detail within **Section 3.10 Remedial Cable Protection**.

3.3.3. Monitoring of the seabed around offshore structures may also be conducted post-installation, and scour protection could be installed retrospectively should scour issues subsequently occur.

3.3.4. As with the design of foundations, there is the potential for technological advances in the field of scour protection which may create additional options at the time of project construction. It is anticipated that other scour protection designs will be considered for use in these projects should the characteristics of the technology fall within the envelope assessed.

Figure 3.19 Example of suction bucket monopole foundation with scour protection



3.3.5. Typical options include one, or a combination of the following examples:

- Rock or gravel placement;
- Concrete mattresses;
- Flow energy dissipation devices (used to describe various solutions that dissipate flow energy and entrap sediment, and including options such as frond mats, mats of large linked hoops, and structures covered with long spikes). It is noted that these technologies are often only appropriate for use in areas with significant mobile seabed sediments, and examples such as the spiked designs are only appropriate for use in areas which are not trawled;
- Protective aprons or coverings (solid structures of varying shapes, typically prefabricated in concrete or high-density plastics), and;
- Bagged solutions, (including geotextile sand containers, rock-filled gabion bags or nets, and grout bags, filled with material sourced from the site or elsewhere).

3.3.6. Protection measures may be placed alone or in combination, and may be secured to the seabed where appropriate. The technologies used to protect against foundation scour and subsea damage are similar to those used for remedial cable protection. These technologies are therefore discussed in more detail, including example illustrations, within **Section 3.10 Remedial Cable Protection**.

3.3.7. A site-specific assessment will be carried out for all foundation structures as part of the final project design process to understand where scour would be anticipated and to what extent, which technologies are suitable for deployment in the local conditions, and what measures should therefore be taken to protect the offshore structures. Preliminary design work suggests that protection could be needed, and having considered a full range of foundation types and designs, the maximum requirements are outlined in **Table 3.9** and **Table 3.10**. In all cases it has been conservatively assumed that 100% of foundations require protection and that it is based on the use of rock placement, to provide a worst case volume. However, it is noted that protection against scour or subsea damage may not be required for some foundation designs, in some locations.

3.3.8. For comparison purposes, if a total area of 2 km^2 were affected (which is more than predicted), this would be equivalent to 0.36% of the Dogger Bank Teesside A area or 0.34% of the Dogger Bank Teesside B area.

Table 3.9 Indicative wind turbine and meteorological mast foundation subsea/scour parameters

	Offshore Structure		
Parameter	Wind turbine up to 6MW	Wind turbine 10MW or greater	Meteorological Mast
Maximum seabed footprint area of subsea/scour protection per foundation (including foundation structure footprint) (m^2)	5027	5675	4657
Maximum seabed footprint area of subsea/scour protection per project (including foundation structure footprint) (km^2)	0.681	1.005	0.023
Maximum volume of subsea/scour protection material per project (m^3)	667,500	1,030,800	24,500

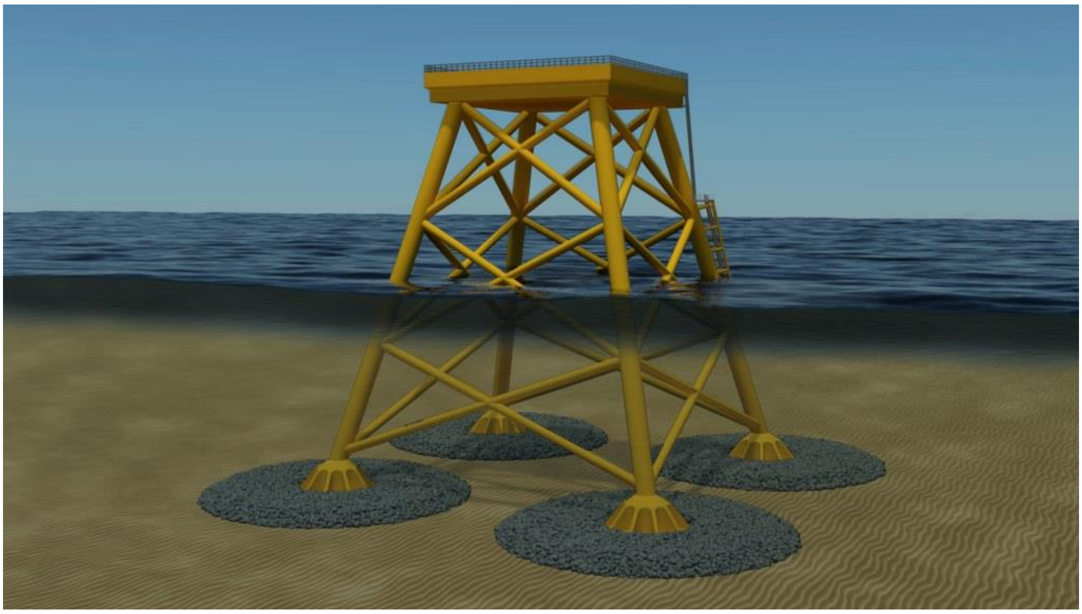
Table 3.10 Indicative offshore platform foundation subsea/scour protection parameters

	Offshore Platform Type		
Parameter	Collector	Converter	Accommodation
Maximum seabed footprint area of subsea/scour protection per foundation (including foundation structure footprint) (m^2)	9,025	17,400	17,400
Maximum seabed footprint area of subsea/scour protection per project (including foundation structure footprint) (km^2)	0.036	0.017	0.035
Maximum volume of subsea/scour protection material for platforms per project (m^3)	36,100	17,400	34,800

Installation of Foundation Protection

3.3.9. The installation of foundation protection shall be assumed to be similar to the approaches described within **Section 3.10 Remedial Cable Protection**. The technologies and techniques employed for remedial cable protection are very similar to those employed for foundation protection.

Figure 3.20 Example of multileg suction bucket foundation with scour protection



3.4. Offshore Grout

3.4.1. Grout is commonly used to bond joints between wind farm components including, but not limited to, the joints between: piles and pile sleeves, piles and transition pieces, and concrete monopiles and the surrounding seabed. Grout may also be used in other applications such as under-base grouting, where grout is used to ensure even contact between the base of a suction bucket or gravity base and the seabed.

3.4.2. Offshore grout primarily consists of a mixture of water, cement and sand plus specialist additives, to form a bonding material. Variants are available for different tasks, with high-performance low-shrinkage types for bonding piles to foundation structures, and low-strength types available for under-base use. Grout is typically mixed on offshore construction vessels, and pumped via pipes into the areas required. Where grouting is used, systems of seals, mechanical separation, or other operational means would be employed to manage the risk of accidental releases into the environment.

3.4.3. Foundations that use techniques such as pre-piling may require the piles to be cleaned prior to any grouting being conducted. The cleaning will remove marine growth, arising in the period between the pile installation and the transition piece installation, or any other materials that may inhibit an optimum connection between the pile and transition piece.

3.4.4. The maximum grout volumes assessed for use are presented in **Table 3.11** and **Table 3.12**.

Table 3.11 Indicative grout volumes for wind turbines

	Offshore Structure		
Parameter	Wind turbine up to 6MW	Wind turbine 10MW or greater	Meteorological Mast
Maximum volume of grout material for per project (m^3)	196,350	142,550	4,350

Table 3.12 Indicative grout volumes for offshore platforms

	Offshore Platform Type		
Parameter	Collector	Converter	Accommodation
Maximum volume of grout material for platforms per project (m^3)	8,850	2,250	4,450

3.5. Seabed Preparation, Drilling & Disposal of Spoil Arisings

3.5.1. The installation of piles using drilling, and some forms of seabed preparation as part of foundation installation, could generate spoil material. With the exception of these activities the installation of foundation structures and scour protection is not expected to include any activities which could produce comparable quantities of spoil.

Seabed Preparation

3.5.2. In some conditions, and for some foundation types (most commonly gravity base solutions), the seabed may need to be prepared before foundation installation. This is to ensure every foundation is laid on a surface capable of supporting the structure adequately, and that the wind turbine stands vertical. The need for seabed preparation will be assessed during the detailed design stage, after consent. Seabed preparation can include one or all of the following options:

- Removal of soft, mobile, or uneven sediments.
- The levelling of the seabed without removal of sediments.
- Installation of a stone or aggregate foundation bed as an alternative levelling strategy or to ensure full baseplate contact with the seabed.

3.5.3. Examples of foundations using stone or aggregate beds are shown in **Figure 3.21** and **Figure 3.22**.

Figure 3.21 Indicative diagram showing gravity base with bedding material

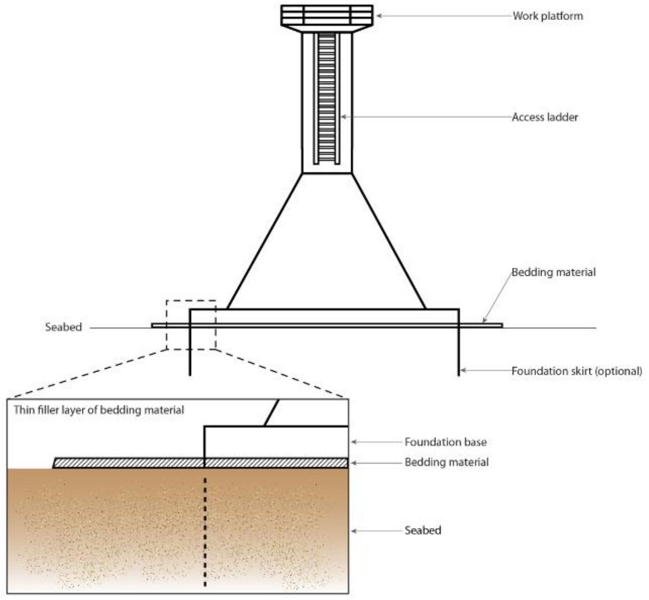
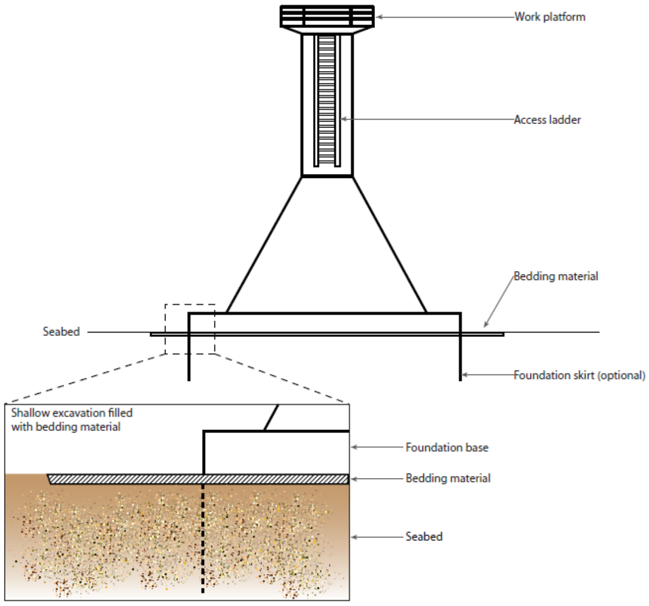


Figure 3.22 Indicative diagram showing gravity base with shallow excavation filled with bedding material



3.5.4. Seabed preparation would typically take place over an area slightly larger than the base footprint of the foundation and could take a range of shapes depending on the equipment used and the geometry of the foundation to be laid, for example rectangular or circular. Seabed preparation involves mechanical levelling, typically using suction dredging where sediments are to be moved or removed.

3.5.5. Other similar aggregate or subsea construction vessels are typically used for installation of rock or gravel layers. The technology for preparing the seabed prior to installation has been used previously for gravity base structures (for example at Thornton Bank offshore wind farm, Belgium). The techniques used to install stone or aggregate foundation beds are similar to those described in **Section 3.10 Remedial Cable Protection** and **Section 3.3 Protection Against Scour & Subsea Damage**.

3.5.6. Seabed conditions for Dogger Bank Teesside A & B are such that only limited seabed preparation is anticipated. Spoil volumes have therefore been developed on this basis, with parameters shown in **Table 3.13** and **Table 3.14**.

3.5.7. Disposal of arisings is discussed in the association with the following section on drilling

Table 3.13 Indicative wind turbine & meteorological mast foundation seabed preparation parameters

	Offshore Structure		
Parameter	Wind turbine up to 6MW	Wind turbine 10MW or greater	Meteorological Mast
Maximum prepared seabed area per foundation (m^2)	4,225	4,900	3,844
Maximum foundation prepared seabed area per project (km^2)	0.845	0.588	0.019
Maximum excavated volume (spoil) foundation (m^3)	3,169	3,675	2,883
Maximum foundation excavated volume (spoil) per project (m^3)	633,750	441,000	14,415
Maximum filler material volume per foundation (m^3)	3,169	3,675	2,883
Maximum foundation filler material volume per project (m^3)	633,750	441,000	14,415

Table 3.14 Indicative offshore platform foundation seabed preparation parameters

	Offshore Platform Type		
Parameter	Collector	Converter	Accommodation
Maximum prepared seabed area per platform foundation (m^2)	8,100	16,100	16,100
Maximum platform foundation prepared seabed area per project (km^2)	0.032	0.016	0.032
Maximum excavated volume (spoil) per platform foundation (m^3)	6,075	12,075	12,075
Maximum platform foundation excavated volume (spoil) per project (m^3)	24,300	12,075	24,150
Maximum filler material volume per platform foundation (m^3)	6,075	12,075	12,075
Maximum platform foundation filler material volume per project (m^3)	24,300	12,075	24,150

Pile Drilling

3.5.8. Steel piles are driven by a large crane mounted hammer and are typically designed to be hammered to the desired penetration depth. However, in some cases the pile may reach a point of refusal and cannot be driven to the required penetration depth due to difficult ground conditions. In this event it is possible to drill out some or all of the volume of sediment inside the pile to reduce the driving resistance and allow the pile installation to be completed.

3.5.9. In the case of concrete monopiles it is fundamental to the foundation concept that drilling must be carried out, since driving concrete piles with a hammer is not appropriate.

3.5.10. Various drilling methodologies are possible, but drills are typically lifted by crane into a part-installed pile, ride inside the pile during drilling, and are removed in the event driving recommences. Drills may only bore out to a diameter equal to the internal diameter of the pile, or they may be capable of expanding their cutting disk below the tip of the pile and boring out to the piles maximum outer diameter or greater (under-reaming). Drilling systems are available in sizes ranging from those required for small jacket pin piles, to large diameter concrete monopiles. Water is continuously pumped into the drill area and any drill arisings generated are flushed out and allowed to disperse naturally at the sea surface.

3.5.11. Soil conditions for Dogger Bank Teesside A & B are such that for steel monopiles and multileg driven piles, only limited need for drilling is anticipated. In the case of concrete monopile wind turbine foundations it is assumed that all piles would have to be fully drilled. **Table 3.15** shows relevant realistic worst-case values, conservatively based on concrete monopile foundation requirements. Pile drilling has not been considered for offshore platform foundations.

Table 3.15 Indicative drill arising parameters

	Offshore Structure		
Parameter	Wind turbine up to 6MW	Wind turbine 10MW or greater	Meteorological Mast
Foundations potentially using drilling	Monopole foundations Multileg foundations		
Maximum percentage of foundations potentially using drilling (%)	100		
Conservative average drill arising volume per foundation (m^3)	4,752	6,220	3,691
Maximum drill arising volume for foundations per project (m^3)	950,350	746,450	1,850

Disposal of Seabed Preparation and Drilling Spoil Arisings

3.5.12. It is proposed that any spoil arisings generated by seabed preparation or drilling would be disposed of within the project area; near the location the material was derived. The spoil materials will then be winnowed away by the natural wave and tide driven processes. Some of the excavated volume may be re-used to meet some or all of the requirements for ballast material required for structures such as gravity bases, or filler material required for protection against scour and subsea damage (such as geotextile sand containers).

3.5.13. It should be noted that the maximum project spoil volume presented in the table above would be generated over the entire period of foundation installation. Spoil generated would therefore be subject to constant erosion and dispersal over time rather than representing one single large dispersal event.

3.6. Piling & Noise Modelling

Foundation Piling

3.6.1. Piling (also known as pile driving, or impact piling) involves a large hammer being dropped, or typically driven, onto the top of a foundation pile, thereby driving it into the ground. Piles may be held in place during piling by the foundation structure itself, or by frames and pile grippers mounted on a vessel, or the seabed. In these cases the piling frames maintain the pile orientation until it has been installed to a sufficient depth to maintain its stability unaided.

3.6.2. Piling is commonly used to install steel monopiles and driven piles associated with multileg foundations.

Soft Start

3.6.3. In line with Joint Nature Conservation Committee (JNCC) guidance, the piling sequence will begin with a 'soft start' period, where the hammer energy and blow rate are less than used during the main piling stage. Hammer energy is typically started at around 10% of rated hammer energy and then ramped up over the duration of the soft start to full power and blow rate.

Typical Piling Sequence

3.6.4. A typical piling sequence progresses as follows:

i. Notices to local diving groups, mariners and other relevant sea users are issued informing them of piling times, locations, expected durations, exclusion zones, etc.
ii. Guard vessels may be deployed around the piling area to restrict access of sea users into the piling safety zone;
iii. Deterrent devices (such as pingers and seal scarers) may be deployed to allow marine mammals an opportunity to move away from the area of noise. This is discussed in greater detail within **Chapter 14 Marine Mammals**;
iv. Pile is lifted into position, typically within a pile gripper on the vessel and is positioned on the seabed (using a pile template or similar if required for multileg foundations) with pile weight providing initial seabed penetration;
v. Piling soft start commences, and ramps up to rated hammer energy and blow rate;
vi. Main piling stage is reached, with hammering at maximum energy and blow rate;
vii. Depending on local geology and technical and economic considerations, drilling may be required, in which case piling would stop to allow this to be undertaken;
viii. Piling would then continue until the desired penetration has been achieved and pile installation is complete;
ix. Vessel either installs transition pieces or foundation structure onto the installed pile, or moves to the next piling location to begin again.

3.6.5. Driving a single pile could take less than an hour if soil conditions are favourable, but significantly longer if the ground conditions are more challenging. Piling may take place at any time of day or night, assuming appropriate procedures are in place, and may not be continuous for a single pile; the active piling time may be split across a longer period, particularly in the event of mechanical breakdown, or drilling being required. The key parameters considered for piling (across all foundation types) are listed in **Table 3.16**, **Table 3.17** and **Table 3.18**.

Table 3.16 Monopole foundation indicative piling parameters

	Offshore Structure		
Parameter	Wind turbine up to 6MW	Wind turbine 10MW or greater	Meteorological Mast
Maximum driven pile diameter (m)	11	12	10
Maximum hammer driving energy (kJ)	3,000	3,000	2,300
Maximum blows per minute	40	40	40
Indicative soft start duration (hr)	0.5	0.5	0.5
Indicative active piling time per pile excluding soft start (hr)	3	3	3
Indicative total blows per pile – including soft start	8,400	8,400	8,400

Table 3.17 Multileg foundation indicative piling parameters

	Offshore Structure		
Parameter	Wind turbine up to 6MW	Wind turbine 10MW or greater	Meteorological Mast
Maximum number of driven piles per foundation	6	6	4
Maximum driven pile diameter (m)	3.5	3.5	3.5
Maximum hammer driving energy (kJ)	2,300	2,300	1,900
Maximum blows per minute	40	40	40
Indicative soft start per pile duration (hr)	0.5	0.5	0.5
Indicative active piling time per foundation excluding soft start (hr)	18	18	12
Indicative total blows per pile – including soft start	8,400	8,400	8,400

Table 3.18 Offshore platform foundation indicative piling parameter

	Offshore Platform Types		
Parameter	Collector	Converter	Accommodation
Maximum number of driven piles per foundation	24	24	24
Maximum driven pile diameter (m)	2.75	2.75	2.75
Maximum hammer driving energy (kJ)	1,900	1,900	1,900
Indicative soft start duration (hr)	0.5	0.5	0.5
Maximum blows per minute	40	40	40
Indicative active piling time per foundation excluding soft start (hr)	72	72	72
Maximum total blows per pile – including soft start	8,400	8,400	8,400

3.6.6. It is noted that although the stated pile diameters do not vary between wind turbine sizes, other characteristics may vary (such as the water depth feasible for deployment, the maximum feasible wind turbine loads, and the pile depth). The potential for variation in pile depth, in particular, is a driver for the variation in maximum hammer driving energy.

Vibration Piling

3.6.7. An alternative methodology to standard impact piling involves using vibrodriver devices in place of impact hammers, to both drive and extract piles. A typical vibrodriver contains one or more pairs of eccentrically-rotating weights which spin in opposite directions to generate ‘up and down’ forces (vertical vibrations), while cancelling out unwanted vibrations in other directions. Vibration piling is then based on the principle of reducing the friction between the soil and the pile using this vibration.

3.6.8. Vibration piling is not yet a proven technique for offshore wind foundations, it is not yet considered viable in all soil conditions and for all foundation types, and can normally only be used for part of the installation of a pile – with impact piling typically required to complete the final installation of each pile.

3.6.9. Vibration piling may be considered for use where the local geological conditions and selected foundation technologies allow.

Non-Piled Foundation Installation

3.6.10. Noise generated by other foundation types and installation techniques will be significantly less than that caused by driven piling. Installation of suction, gravity, jack-up, and screw pile foundations requires only relatively quiet machinery (pumps and motors), and inherently include no activities which generate levels of noise comparable with impact piling.

Noise Modelling

3.6.11. Underwater noise, including construction and operational noise, has been assessed as part of the environmental impact assessment. Full details and results of the noise modelling undertaken are contained within **Appendix 5.A Dogger Bank Teesside A & B Underwater Noise Modelling Report**.

Background to Underwater Acoustics

3.6.12. Underwater sound can be described as a pressure wave travelling through water. The low absorption properties of water allow sound to travel large distances in the ocean, particularly evident for lower frequency sounds (Kinsler *et al*. 1982, Kaye and Laby 2004). This low absorption of pressure waves also results in a greater sound transmission speed of 1,500m/s in water compared to 340m/s in air.

3.6.13. The amplitude of the sound can be described in terms of the sound pressure, where the unit of pressure is the Pascal (Pa) or newton per square metre (N/m2). However, by convention, sound levels are expressed in decibels (dB) relative to a reference pressure, which is 1 µPa for underwater sound.

3.6.14. Metrics most commonly used to describe the underwater sound in impact piling in the UK include Sound Exposure Level (SEL) and peak-to-peak pressure level. The Sound Exposure Level is a measure of the pulse energy content and is calculated from the integral of the squared sound pressure over the duration of the pulse. The SEL can also be expressed in dB notation referenced to 1 $\mu Pa^2 \cdot s$. For a specific pulse or waveform, the peak pressure level, PPL, is defined as the zero to peak pressure of the pulse and can be expressed as the zero-to-peak pressure level (or peak pressure level, PPL) in units of dB re 1 µPa.

3.6.15. Sound Pressure Level (SPL) is another metric used in underwater acoustics, typically for describing the level of continuous type noise sources, such as from shipping or turbine operation.

3.6.16. Propagation Loss (PL) or Transmission Loss (TL) is the reduction of the sound level as a function of distance from an acoustic source. This is primarily due to geometrical spreading, sound absorption in the water and losses into the seabed or other boundaries.

3.6.17. The received level (RL) is the acoustic pressure measured by a hydrophone at some distance away from a sound source. It is also considered to be the sound pressure which arrives at any acoustic receptor which is exposed to a sound. The received level might be expressed in a number of ways, for example as a sound pressure level (dB re 1 μPa) or a sound exposure level (dB re 1 $\mu Pa^2 \cdot s$).

Ambient Noise

3.6.18. There are numerous ambient noise sources in the Dogger Bank Teesside A & B area, both natural and anthropogenic. Natural noise sources will likely be from the wind (sea-state), rain and biological noise, dominated by the interaction of wind with the sea surface. Noise generated by the interaction of wind with the sea surface is likely to be the dominant natural contributor to ambient noise at the Dogger Bank Zone, and will range from a few hertz to a few tens of kilohertz. Biological contribution to ambient noise (such as marine mammal vocalisations and sounds made by fish) may also be significant.

3.6.19. Anthropogenic contributors to ambient noise levels in the North Sea include shipping (e.g. fishing, cargo, cruise ship, ferries and aggregate extraction/dredging) and the oil and gas industry. Dredging vessels may be noisier and produce noise at higher frequencies than other commercial vessel types transiting nearby (Robinson *et al*. 2011).

3.6.20. Tidal changes in shallower areas (<20m) of Dogger Bank Teesside A and Dogger Bank Teesside B may result in ambient noise variations due to changes in the propagation environment, which changes with depth. Sand banks at low tide can elevate propagation loss of lower frequency sounds in particular, resulting in a reduction in ambient noise levels detected in the surrounding area.

3.6.21. The potential impact of noise on marine receptors (namely marine mammals and fish) during each phase of the wind farm development (i.e. construction, operation and decommissioning) has been assessed as part of this EIA. The effects of noise transmission in water and ambient noise levels on these receptors are discussed in further detail in **Chapter 13 Fish and Shellfish Ecology and Chapter 14 Marine Mammals**.

Construction Noise (Foundation Installation)

3.6.22. The installation of foundation systems, namely those which rely on impact piling are considered a major source of noise, resulting in significant noise levels.

3.6.23. Impact piling is considered a transient activity which is only likely to occur concurrently at a small number of locations within the wind farm area. Assuming the concurrent construction of Dogger Bank Teesside A & B with four other projects (The two Creyke Beck projects already in the application process and the two Teesside C & D projects), it is anticipated that a maximum of twelve piling vessels could be in operation at the same time across the Dogger Bank Zone. During this phase, it is assumed a maximum of two piling vessels will be operating in each of the six projects. It is assumed that the piling vessels operating within the same project will have a separation distance of 1500m. Piling vessels operating in different projects are likely to have much larger separation (tens of km). The key parameters considered for piling are listed in **Table 3.16** and **Table 3.18**.

3.6.24. During the piling process, airborne noise is created by the hammer, partly as a result of the impact of the hammer with the pile. The energy imposed on the pile by the hammer also creates significant underwater noise as the pile distorts due to the compressive, flexural and other complex waves travelling down the pile during each 'blow'. Due to the low absorption of pressure waves in the surrounding water column, these waterborne waves are the principle contributor to underwater noise during foundation installation (Subacoustech 2011).

3.6.25. Larger monopile foundations require higher energy hammers than alternative foundation designs, such as jackets, which utilise smaller diameter pin piles. Due to this greater hammer energy, larger monopiles are likely to result in higher noise levels during installation (Nehls *et al*. 2007). The peak noise levels generated by the installation of jacket foundations are thus generally lower than monopile foundations due to the smaller hammer energy. However, the total time required for installation can be longer. Therefore, although the zone of impact may be smaller during pin pile installation, the disturbance may be present for a longer time period. The use of jacket foundations that require lower hammer blow energies, assuming that the total time to construct the wind farm is not increased significantly compared to the use of monopile foundations could be considered to have a reduced impact on hearing sensitive marine life.

3.6.26. The dimensions of the pile are not considered to have a significant effect on the noise energy generated during installation. The noise resulting from a monopile using a given hammer energy would be expected to be the same as that from a smaller diameter pin-pile using the same hammer energy.

3.6.27. The underwater noise due to impact piling is known to result in significant peak pressure levels and sound exposure levels and is distinguishable above ambient noise over distances of several tens of kilometres from the source (Thomsen *et al*. 2006, Nedwell *et al*. 2007).

3.6.28. The use of soft-start systems (involving a gradual ramping up of the hammer strike energy) is widely adopted as a mitigation measure as it enables animals to move away from the sound source before it reaches the maximum noise levels. The use of embedded mitigation such as this is now considered a prerequisite for offshore impact piling activities in the North Sea.

Operational Noise

3.6.29. During the operational phase of a wind farm development, the principle underwater noise source is mechanically generated vibration from the motion of the wind turbine, transmitted through the support structure and foundation into the surrounding water (Nedwell *et al*. 2003).

3.6.30. Underwater noise from an operational turbine mainly originates from the gearbox and the generator and has particular tonal characteristics (Madsen *et al*. 2005, Tougaard and Henriksen 2009). Operational noise from the wind turbines would be present for the operational life of the wind farm and will contribute to the ambient noise in the region. Noise from the operational wind turbines is not expected to noticeably increase ambient noise beyond a few kilometres from the boundary of the wind farm.

3.6.31. Considering the operational wind turbine noise of the wind farm and any associated service vessels, the ambient noise levels within the site would be expected to be lower than those present in the vicinity of the shipping lanes both to the north and south.

Modelling approach

3.6.32. For this noise assessment, a propagation model was developed based on an energy flux approach, providing SEL and peak pressure received level outputs as a function of range away from each modelled location, whilst accounting for seabed properties and varying bathymetry. This approach was used to model noise propagation during both the foundation installation phase and wind farm operation.

3.6.33. A range of hammer energies were modelled from soft-start up to the maximum hammer energy expected for each turbine size and foundation type. The maximum hammer energy and respective initial soft-start energy assumed in each case are summarised in **Table 3.16** and **Table 3.18**. An initial 300kJ hammer blow energy was used to represent the highest expected soft-start hammer energy at the onset of piling.

3.6.34. To illustrate the total spatial extent of the potential impact ranges resulting from the underwater noise during the construction phase, the sound propagation was modelled at various locations along the project boundaries of Dogger Bank Teesside A & B. The maximum noise level received at every location around each project was then calculated to show the construction noise footprint associated with each project.

3.6.35. For each individually modelled piling event, a sound propagation map was obtained showing the noise level as a two-dimensional function of range. The impact piling underwater noise modelling was carried out using an energy source level which scales linearly with the hammer energy.

3.6.36. Injury and behaviour criteria were applied to the outputs of the underwater noise modelling to predict the potential impact ranges for Dogger Bank Teesside A and Dogger Bank Teesside B. These are described in detail in **Chapter 13 Fish and Shellfish Ecology** and **Chapter 14 Marine Mammals**.

Outline Results of the Study

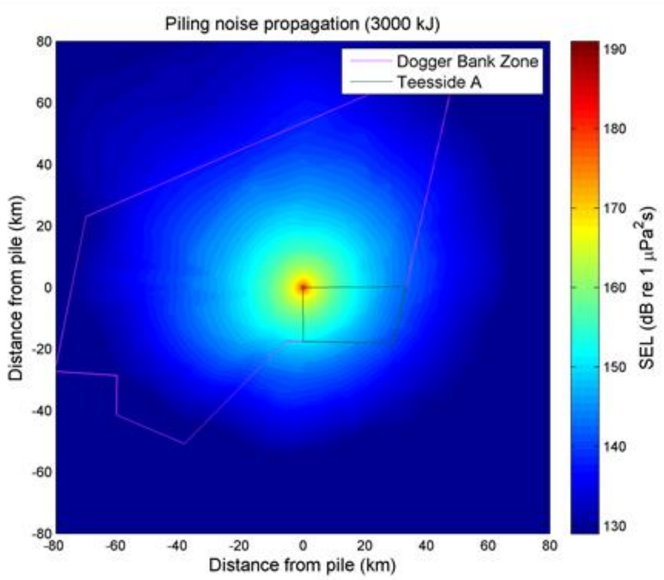
3.6.37. The noise assessment predicts the likely underwater noise levels generated during construction and operation at Dogger Bank Teesside A & B. Based on the modelling conducted it was observed that:

- The estimated maximum sound exposure level (unweighted pulse SEL) during impact piling activities is in the range of 145 – 155 dB re 1μPa^2•s, 20km from the source;

- The estimated maximum sound pressure level (SPL (RMS)) for a single wind turbine during the operational phase of the wind farm is in the range of 110 – 120 dB re 1µPa, 1km from the source. The highest broadband noise levels will occur at ranges close to the sound source and may be expected to be about 130dB re 1 µPa at around 50 m distance from the wind turbine;
- Generally, noise levels observed across Dogger Bank Teesside A and Dogger Bank Teesside B projects are comparable, largely because the general propagation environment is similar. For both projects, the largest propagation distances were observed in a northerly direction, from the northerly pile locations contained within each project. The primary reason for this is the generally down-sloping bathymetry to the north of both Dogger Bank Teesside A & B;
- A piling noise propagation map, based on a representative location within Dogger Bank Teesside A, is shown in **Figure 3.23**, and a noise map for operational noise at Dogger Bank Teesside A & B is shown in **Figure 3.24**.

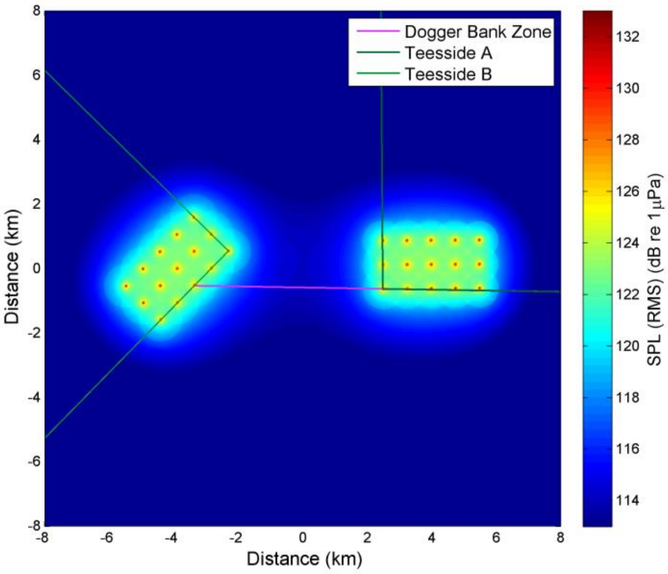
3.6.38. Full results are contained within **Appendix 5.A Dogger Bank Teesside A & B Underwater Noise Modelling Report**, and the impact assessments associated with these results are primarily discussed within **Chapter 13 Fish and Shellfish Ecology** and **Chapter 14 Marine Mammals**.

Figure 3.23 Teesside A impact piling noise propagation map



Impact piling noise propagation map at Dogger Bank Teesside A for 3,000kJ hammer blow

Figure 3.24 Modelling noise map for operational noise



Modelled noise map for a sample of operational turbines at Dogger Bank Teesside A & B, assuming a 750m turbine spacing

3.7. Offshore Platforms

Figure 3.25 Illustration example of an offshore platform

Global Tech 1 MOAB self-installing platform. Courtesy of Overdick GmBH

3.7.1. Each of the Dogger Bank Teesside A & B projects will include up to seven offshore platforms. Depending on the final project design, each project may include:

- Up to four HVAC collector platforms;
- One HVDC converter platform;
- Up to two accommodation or helicopter platforms.

3.7.2. Platforms may be entirely separate, but if built in close proximity they may be connected by short bridge links. Some of these platforms may alternatively be co-located on single foundations, in which case the size of the merged platform will not exceed the combined size assessed for the platforms involved.

Offshore Collector Platforms

Figure 3.26 Typical offshore collector platform design

Courtesy of Seagreen Wind Energy

3.7.3. Offshore collector platforms (also known as offshore collector substations) will receive power from the wind turbines via the inter-array cable systems. Transformers will be located on the collector platforms to increase the voltage of the power received from the wind turbine generators so that the electricity can be efficiently transmitted to the offshore converter platform.

3.7.4. For a single project there may be up to four collector platforms, although the final number of collector platforms for each project will be determined during the detailed design phase.

3.7.5. A collector platform typically consists of two main structural parts: a topside and a foundation. The topside is the structure that is placed on top of the foundation and houses the electrical equipment and supporting functions. It may be configured in either a single or multiple deck arrangement. Decks will either be open, with modular equipment housings, or the structure may be fully or partially enclosed by means of weather-proof cladding. All weather sensitive equipment, such as the control system, will be placed in environmentally controlled areas. An example of an offshore collector platform can be seen in **Figure 3.26**

3.7.6. A collector platform may indicatively accommodate the following:

- Medium voltage (MV) to high voltage (HV) step-up power transformers;
- MV and/or HV switchgear;
- Instrumentation, metering equipment and control systems;
- Standby generators;

- Large-scale power storage systems (batteries, etc.), plus associated systems:
- Auxiliary and uninterruptible power supply systems;
- Navigation, aviation and safety marking and lighting;
- Helicopter landing facilities;
- Systems for vessel access and/or retrieval;
- Vessel and helicopter refuelling facilities;
- Potable water;
- Black water separation;
- Storage (including stores, fuel, and spares);
- Offshore accommodation and mess facilities
- Cranes; and
- Communication systems and control hub facilities.

3.7.7. The final capacity and dimensions for collector platforms of the projects will be determined through detailed design. In order to allow for future designs with large capacities on a single platform, larger dimensions than seen previously have been included into the design envelope. Indicative collector platform dimensions are summarised in **Table 3.19**.

Table 3.19 Indicative collector platform parameters

Parameter	Offshore Collector Platform
Number of platforms per project	Up to 4
Collector system side nominal voltage range (kV)	33 to 72.5
Inter-platform side nominal voltage range (kV)	132 to 400
Indicative width (m)	75
Indicative length (m)	75
Indicative height above HAT (m)	85
Indicative topside weight (t)	3,500 - 5,500

3.7.8. Foundations considered for offshore collector platforms include gravity and multileg options. The preferred platform and foundation concept will be confirmed following detailed design work. Offshore platform foundations are detailed in **Section 3.2 Offshore Structure Foundations**.

Offshore Converter Platforms

3.7.9. Given the large project capacities and considerable distance involved, the electricity generated will be transmitted to shore using High Voltage Direct Current (HVDC) technology. Over long distances this technology provides significant technical advantages over High Voltage Alternating Current (HVAC) technology, including lower power losses.

3.7.10. An offshore converter platform is, therefore, required for each project to convert the power generated by the wind farm from Alternating Current (AC) to Direct Current (DC), for efficient transmission to shore. The offshore ends of the HVDC export cables for each project terminate at the offshore converter platform.

3.7.11. An offshore converter platform may indicatively accommodate the following:

- Converter hall housing the power electronic converter modules;
- High voltage (HV) power transformers;
- HV switchgear and busbars;
- Instrumentation, metering equipment and control systems;
- Standby generators;
- Large-scale power storage systems (batteries, etc.), plus associated systems;
- Auxiliary and uninterruptible power supply systems;
- Navigation, aviation and safety marking and lighting;
- Helicopter landing facilities;
- Systems for vessel access and/or retrieval;
- Vessel and helicopter refuelling facilities;
- Potable water;
- Black water separation;
- Storage (including stores, fuel, and spares);
- Offshore accommodation and mess facilities
- Cranes; and
- Communication systems and control hub facilities.

3.7.12. For a single project, there will be a single offshore converter platform and this may be either standalone or associated with collector substations and/or accommodation platforms. The dimensions assessed are shown in **Table 3.20**, but the final capacity and dimensions of offshore converter substation platforms will be determined through detailed design.

Table 3.20 Indicative offshore converter platform parameters

Parameter	Offshore Converter Platform
Number of converter platforms per project	1
HVAC side nominal voltage range (kV)	72.5 to 400
HVDC side nominal voltage range (kV)	Up to ±550
Indicative width (m)	100
Indicative length (m)	125
Indicative height above HAT (m)	105
Indicative topside weight (t)	15,000 – 20,000

3.7.13. A converter platform typically consists of two main structural parts: a topside and a foundation. The topside is the structure that is placed on top of the foundation and houses the electrical equipment and supporting functions. The topside may be configured in either a single or multiple deck arrangement. Decks will either be open with modular equipment housings or the structure may be fully or partially enclosed by means of weather-proof cladding. All weather sensitive equipment will be placed in environmentally controlled areas.

3.7.14. Foundation types considered for offshore converter platforms include gravity base and multileg options. The preferred platform and foundation concept will be confirmed following detailed design work. Offshore platform foundations are detailed in **Section 3.2 Offshore Structure Foundations**.

Offshore Accommodation or Helicopter Platforms

3.7.15. Offshore accommodation or helicopter platforms are intended to form base locations for offshore construction, operation and maintenance, and decommissioning activities. Up to two may be required per project. These platforms may vary in capabilities, and options considered include: a major offshore base with large-scale accommodation and significant logistics capabilities, relatively small platforms primarily intended as a local staging post with helicopter landing capabilities, or a mix of platform capabilities across a project area. The accommodation will be used by offshore operation and maintenance staff typically working shifts lasting around two weeks on, two weeks off rather than as a long-term residence. An example of an accommodation platform is shown in **Figure 3.27**.

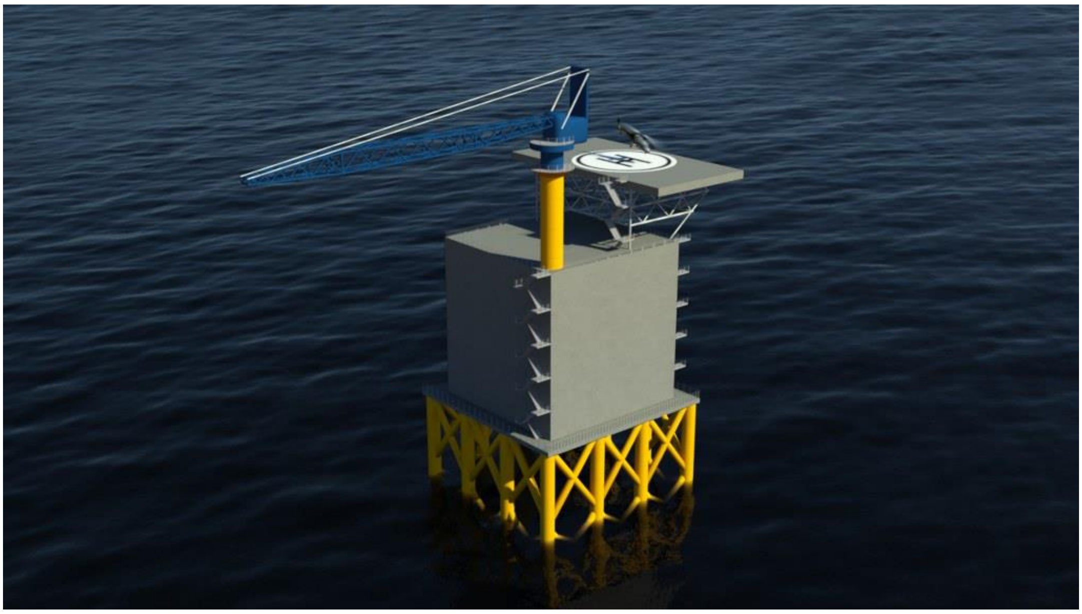
3.7.16. An accommodation or helicopter platform may indicatively accommodate the following:

- Communication systems and control hub facilities;
- Offshore accommodation and mess facilities

- Helicopter landing facilities;
- Systems for vessel access and/or retrieval;
- Standby generators;
- Large-scale power storage systems (batteries, etc.), plus associated systems;
- Power electrical systems and auxiliary and uninterruptible power supply systems;
- Navigation, aviation and safety marking and lighting;
- Vessel and helicopter refuelling facilities;
- Potable water;
- Black water separation;
- Storage (including stores, fuel, and spares); and
- Cranes.

3.7.17. Foundation types considered for offshore accommodation or helicopter platforms include gravity base and multileg options. The preferred platform and foundation concept will be confirmed following detailed design work. Offshore platform foundations are detailed in **Section 3.2 Offshore Structure Foundations**.

Figure 3.27 Example of an offshore accommodation platform



3.7.18. In order to robustly allow for the range of options anticipated, offshore accommodation or helicopter platforms are assumed to be equivalent to offshore converter platforms in terms of dimensions, topside and foundation structures, and installation, operation, and decommissioning methodologies. Assumptions are, therefore, identical in all relevant assessments.

Table 3.21 Indicative offshore accommodation or helicopter platform parameters

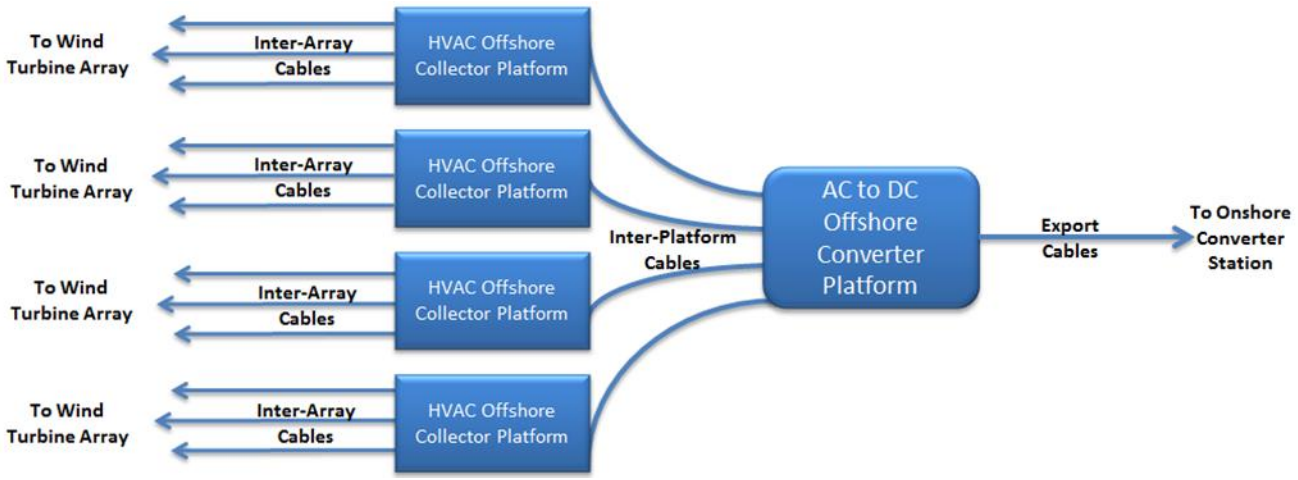
Parameter	Offshore Accommodation or Helicopter Platforms
Number of platforms per project	Up to 2
Dimensions, structures, and methodologies	As for converter platforms (see **Table 3.20**)

3.8. Offshore Cables

3.8.1. Offshore cables are the conduits by which the electricity generated by the offshore wind turbines is transmitted to shore via the offshore collector and converter platforms. Fibre-optic cables, serving the wind farm control systems, will be integrated within offshore power cables to provide data transmission capability. Offshore cables will also provide power to the ancillary systems of the offshore structures. A schematic of the anticipated offshore cables is shown in **Figure 3.28**. The offshore cables can be grouped into the following categories:

- Inter-array cables, connecting wind turbines to wind turbines and collector platforms. Inter-array cables also includes any cables connecting accommodation platforms and met masts to the main wind farm electrical system;
- Inter-platform cables, connecting the collector platforms to the converter platforms;
- Offshore export cables, connecting the offshore converter platforms to the transition bays onshore, where they are jointed to the onshore HVDC export cables.

Figure 3.28 Illustrative schematic of offshore cable layout



Inter-Array Cables

3.8.2. Inter-array cables will connect the wind turbines to the offshore collector platforms. The inter-array cabling will collect the AC electricity generated by the wind turbines, and transfer the electricity to the offshore collector platforms. In addition, the inter-array cables connect the turbines to the wind farm control system via embedded data cables. Inter-array cables also include the cables laid to provide power and data connections to accommodation platforms and meteorological stations.

3.8.3. Inter-array cables are typically three-core, copper conductor cables suitable for subsea installation. Fibre-optic cables are integrated into the cable bundle to transmit data for the wind farm control systems. Submarine three-core cables are protected by one or more armouring layers, typically made of steel wires, to reduce the risk of damage due to accidental impacts. It is estimated that the inter-array cables will have an overall external diameter of up to 250mm, depending on the final electrical design. Aluminium cables, which are being developed for offshore installation, could also be considered if available.

3.8.4. The nominal operating voltage of the AC inter-array cable system will be in the range of 33kV to 72.5kV. 33kV is the standard offshore wind distribution voltage across Europe today, but higher distribution voltages are under investigation, and may bring lifetime cost savings. The higher voltage and resultant lower current can lead to smaller cable cross-sections and enable the connection of more wind turbines per cable. The inter-array cables will not contain oil or other toxic materials which may be released into the environment. The cables will be designed to emit only negligible electric and magnetic fields.

3.8.5. It is noted that met masts and accommodation platforms may also be powered by cables connected to the wind farm main electrical system. These cables will be similar to the inter-array cables although they may be physically smaller, and will likely operate at lower nominal voltages then the stated limits for the inter-array cabling. Since the inter-array cable envelope is therefore conservative in this instance, and these cables are expected to represent only a very small percentage of the total length of inter-array cables, all met mast and accommodation platform cables have been considered to have the characteristics of ordinary inter-array cables for simplicity, and are included within the stated inter-array cable envelope.

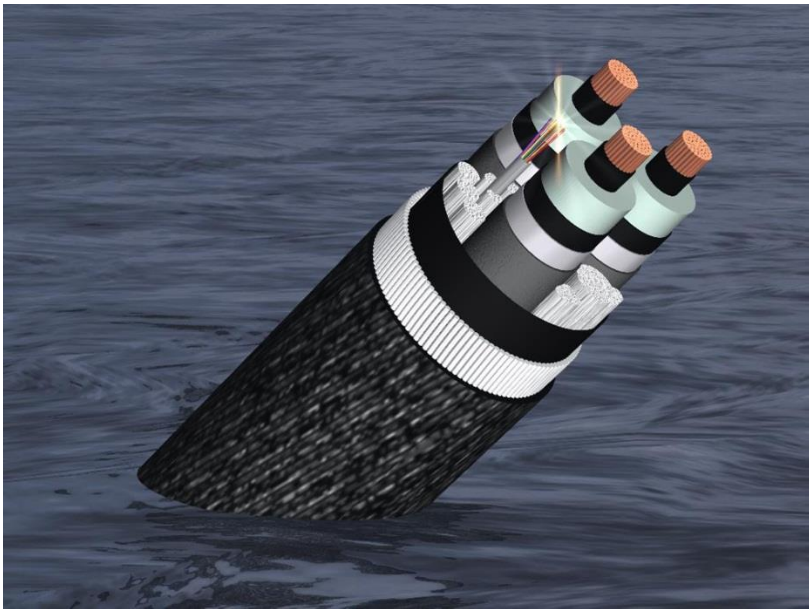
3.8.6. The cable layout is likely to consist of radial networks, ring networks or loops, branched cable systems or a combination of these. The final design and layout of the inter-array cable system will depend on a range of factors, including: the wind turbine array layout, environmental considerations, detailed electrical design, seabed conditions and detailed micro-routing requirements, and the number of collector substation platforms.

Table 3.22 Indicative inter-array cable information per project

Parameter	Inter-Array Cabling
Cable type	HVAC
Indicative cable external diameter (mm)	Up to 250
Nominal cable voltage range (kV)	33 to 72.5 (noting that met mast and accommodation platform cabling may use lower voltages)
Maximum total inter-array cable length per project (km)	950
Maximum seabed area affected during installation per project (km^2)	9.5
Indicative target burial depth range (m)	0 to 3m (dependent upon risk assessment and local conditions)

Inter-Platform Cables

Figure 3.29 Indicative illustration of a typical inter-platform cable.



Typical 3-core HVAC submarine cable design. Courtesy of Nexans

3.8.7. Inter-platform cables will primarily connect the collector platforms to the converter platform of each project. In order to minimise transmission losses, the inter-platform cables will operate at a higher voltage than the inter-array cables. The voltage will be increased by way of the step-up transformers located on the collector platforms.

3.8.8. The inter-platform cables will likely be three-core HVAC cables, with a similar structure to the inter-array cables. A typical three-core HVAC cable that may be used for inter-platform connections is shown in **Figure 3.29**. However, three single-core cable systems could be used if technically and economically preferable. The inter-platform cables will not contain oil or similar toxic materials which may be released into the environment. The cables will be designed to emit only negligible electric and magnetic fields.

3.8.9. The number of cables required from each of the collector substations to the converter substation will vary depending on the nominal voltage, the capacity of the collector substation and the cable electrical design.

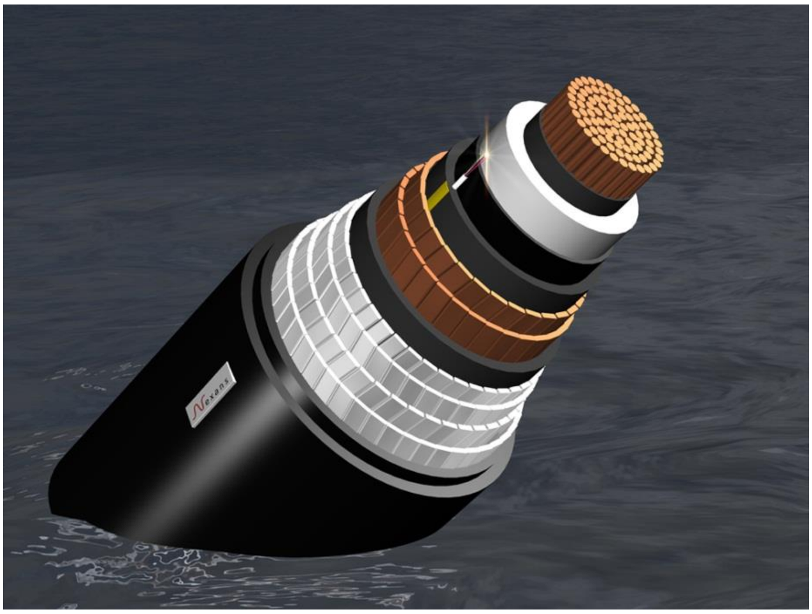
3.8.10. The final lengths and routes followed by these cables will depend on a number of factors, including the ground conditions, and the number and locations of the platforms that are being connected. All inter-platform cables will remain within the assessed project boundaries and more detailed routing decisions will be made as part of detailed design.

Table 3.23 Indicative inter-platform cable information per project

Parameter	Inter-Platform Cabling
Cable type	HVAC
Indicative cable external diameter (mm)	Up to 300
Nominal cable voltage range (kV)	132 to 400
Maximum total inter-platform cable length per project (km)	320
Maximum seabed area affected during installation per project (km^2)	3.2
Indicative target burial depth range (m)	0 to 3m (dependent upon risk assessment and local conditions)

Offshore Export Cables

Figure 3.30 A cutaway of a typical HVDC offshore cable.



Courtesy of Nexans

3.8.11. The offshore HVDC export cables transmit the power generated by the wind farm between the offshore converter stations and the transition bays at the onshore landfall point. At the transition bays the offshore HVDC export cables connect to the onshore HVDC cables, which continue onshore to connect into the onshore converter substations.

3.8.12. The base case offshore export cable design assumption is a pair of single core HVDC cables for each converter platform, one with a high positive voltage, and one with a high negative voltage relative to the earth. The cable nominal voltage will vary depending on the power to be transmitted, available cable technology, and connection distance. HVDC systems, including HVDC cables, are a developing technology. Current designs consist of a metal conducting core surrounded by insulation and water blocking barriers, and protected against mechanical damage by one or more armouring layers. Fibre optic data cables will be included as part of the export cable system, typically bundled as part of one or both of the primary cables, but potentially separated. An indicative cable design is shown in **Figure 3.30**. The cables will not contain oil or other toxic materials which may be released into the environment. The final design of the export cable type and size will be determined during the detailed design phase.

3.8.13. Because of the distance to shore, the HVDC export cables may require one or more joints, since installation vessel cable capacity and/or severe weather events may mean that the cables cannot be installed in a single campaign.

3.8.14. The two cables of each HVDC circuit and associated fibre optic cable may be bundled together and buried in the same trench until they approach the landfall location. Here they are separated for HDD installation, through to the onshore cable transition bays. It may also be necessary to install the two HVDC cables, and associated fibre optic cables, separately in separate trenches, dependent upon the cable and installation strategy used, and the local seabed conditions. The values stated in **Table 3.24** were therefore generated using the conservative assumption that the cables for each project would be installed in two separate trenches. Should alternative installation strategies be adopted, they would remain within the maximum parameters defined within **Table 3.24**.

Table 3.24 Indicative export cable parameter

Parameter	Teesside Project A	Teesside Project B
Cable type	HVDC	
Indicative cable external diameter (mm)	Up to 300	
Nominal cable voltage range (kV)	Up to ±550	
Number of HVDC export cables per converter substation (per project)	Up to 1 pair (plus associated fibre optic cables)	
Indicative offshore export cable route length (from offshore platform to landfall) (km)	260.5	220.4
Maximum total offshore export cable length (from offshore platform to landfall) per project (km)	573.2	484.4
Maximum seabed area affected during installation per project (km^2)	5.73	4.84
Indicative target burial depth range (m)	0 to 3m (dependent upon risk assessment and local conditions)	

3.8.15. The spacing between the two HVDC cable pairs within the export cable corridor has yet to be determined. The final cable routes will typically be as widely spaced as possible to minimise the likelihood of both project's cables being damaged in a single accident, but will also be driven by a number of other considerations, including installation spacing requirements, environmental considerations, seabed conditions, and interactions with other marine users such as fishing activities and existing cables and pipelines. The final cable routes will be determined during detailed design.

3.9. Offshore Cable Installation and Removal

Offshore Cable Installation

3.9.1. The typical key stages of offshore cable installation have been defined as:

- Pre-installation survey;
- Route clearance;
- Cable lay and burial;
- Remedial cable protection (if required);
- Cable and pipeline crossings (if required);
- Post-installation survey.

3.9.2. Details of the activities undertaken during these stages are provided below.

Pre-Installation Surveys

3.9.3. A pre-installation geophysical and/or geotechnical route survey will be conducted approximately 3-6 months prior to the marine installation works. In addition, immediately prior to the installation a visual inspection and confirmation of the route may be carried out using an ROV.

Route Clearance

3.9.4. Prior to the installation of a submarine cable, the precise route along which the cable burial is planned may be cleared of decommissioned cables and any seabed debris that may delay or endanger the progress of burial operations. This should ensure that the selected route is free from seabed and sub-surface debris or any artificial hazards.

3.9.5. Various route clearance techniques may be employed, depending on the nature of any obstacles identified. One method of route clearance is the use of a pre-lay grapnel run. This consists of a grapnel (hooked) device being towed along the precise line of the cable installation to sweep the route clear of obstacles. Alternative techniques include the use of boulder ploughs (devices similar to snowploughs) in a similar manner, and preparing areas with seabed conditions such as sand waves by using suitable equipment to smooth the identified route.

3.9.6. For specific known issues, alternative approaches exist depending on the nature of the obstacles: potentially including the use of ROVs or grabs to cut and/or remove obstacles at the seabed. This could for instance include the removal of larger boulders or other debris identified along a route. In the case of out-of-service cables, these may be able to be removed or cut as opposed to requiring a full cable crossing, as discussed later within this section.

Cable Lay and Burial

3.9.7. Offshore cables are typically installed from a cable laying vessel, **Figure 3.31**, or barge, **Figure 3.32** and **Figure 3.33**, using either a multi-point anchoring or dynamic positioning system. The cable installation vessels will be equipped with specialist cable handling equipment and will have support vessels in attendance as necessary. The cables will be stored on carousels or drums mounted on the deck of the vessels, and the cables then deployed onto the seabed using the cable handling equipment.

3.9.8. Cable lay and burial alternatives include one or a combination of the following:

- Direct burial during the laying campaign (cables laid and buried as part of a single activity);
- Pre-trenching (trenches created separately in advance, cables then subsequently laid into the trenches as a separate activity), and;
- Post-lay burial (cables laid separately in advance, cables then subsequently buried as a separate activity).

3.9.9. The two latter options have the advantage that the cable lay can be completed more rapidly with the slower task of cable trenching being performed independently. A typical cable installation methodology, based upon direct burial during the burial campaign, is summarised as follows:

i. The cable laying vessel approaches the first structure and the cable end is floated off from the vessel to the structure;
ii. The cable is carefully pulled through the J-tube on the structure via a line on the cable end, fed through the J-tube and back to a winch on the vessel;
iii. The cable in the vicinity of the J-tube may be protected, for example by high density polyethylene (HDPE) half-shell castings or equivalent protective measures installed onto the cable, during deployment from the vessel;
iv. When the cable reaches the cable termination point, the pulling operation ceases and the end of the cable is terminated into an electrical equipment enclosure;
v. On the cable laying vessel, the cable is loaded through the plough or trenching unit, which is then deployed onto the seabed. This allows simultaneous lay and burial of the cable along its route;
vi. For cables which terminate at an offshore structure, as the vessel approaches the end structure the cable burial equipment is recovered onto the vessel; and
vii. The end of the cable is then passed off the vessel and floated towards the endpoint structure. Connection to the second structure is completed through the J-tube, as described above.

3.9.10. In the case of pre-trenching a cable trench would be created shortly before cable lay, and then either filled during the cable lay process, or allowed to re-fill naturally. In the case of post-lay burial, cables are temporarily laid onto the seabed surface, either waiting alternative protection or post-lay burial. In these cases the cables are simply laid without the use of a burial plough or trenching unit, as described in point (v) in the methodology above, but by controlling the position and speed of the installation vessel and the speed of the carousel.

3.9.11. Depending on the cable type it may be possible to lay the majority of cables as single lengths without cable joints being necessary. However, this may not be possible in all cases. Because of the distance to shore the HVDC export cables may, for example, require one or more joints.

Figure 3.31 Team Oman cable installation vessel

Courtesy of Scira Offshore Energy

3.9.12. Near shore, where water depths of less than 10m prohibit the use of a cable installation vessel, a shallow draft barge may be employed. Such barges are typically positioned using a multipoint anchor spread and moved incrementally along the route by winches hauling against the anchors.

Figure 3.32 Illustrative example of a shallow draft work barge

Stemat Spirit multi-purpose barge courtesy of Stemat Marine Services

Figure 3.33 Example of a grounded cable lay barge during installation of a near-shore cable section

Pontra Maris multi-purpose barge, courtesy of Stemet Marine Services

Offshore Cable Burial

3.9.13. The Dogger Bank Teesside A & B offshore cables will be buried or protected appropriately along their full length. Cable burial is the preferred protection technique, since it typically provides the best protection, at the lowest cost, in the shortest time. The offshore cables will therefore be buried wherever it is feasible and economic to do so, with additional or alternative protection measures only applied if necessary. A detailed cable burial and protection risk assessment will be carried out to identify the most suitable target burial depth and level of protection in each area. The assessment will include consideration of operating characteristics, sediment type, and risk of damage to the cable from mobile sediments or external activities such as fishing or vessel anchors.

3.9.14. Burial methodologies include for example ploughing, mechanical trenching/cutting and/or jetting techniques, as appropriate to the location. The use of different cable burial techniques will vary depending on the site conditions and the technology available at the time.

3.9.15. Cable burial is expected to be possible in the majority of seabed conditions identified. This also includes many of the more challenging areas such as the very stiff clay of the 'Bolders Bank Formation', hard clay of the 'Swarte Bank Formation', and much of the soft rock (Cretaceous Chalk). These more challenging areas would however be expected to require specialised tools, such as mechanical trenchers, potentially required to be constructed bespoke for the project. The most problematic conditions, for which burial may not be feasible, includes hard rock and also smaller or isolated areas of challenging conditions and which thus present unacceptable economic and logistical issues.

3.9.16. Potential offshore cable burial options include one or a combination of those described below.

Ploughing

3.9.17. Ploughing techniques are suitable for a large range of seabed conditions. Some plough systems, such as rock cutter or vibrating share ploughs, have potential to be deployed in soils up to weak rock. Ploughs may be combined with a jetting facility to improve performance in sand.

3.9.18. Ploughing techniques typically cause minimal disturbance of the seabed. The cable plough commonly lifts a wedge of sediments, typically less than two meters wide, places the cable beneath the wedge, and then lowers the sediments back into their original position, ensuring simultaneous reinstatement of the seabed.

3.9.19. An example of a cable plough is shown in **Figure 3.35**.

Figure 3.34 Illustrative example of an offshore cable plough

By Xero Energy courtesy of Seagreen Wind Energy

Jetting

3.9.20. Jetting (or jet trenching) techniques involve the injection of pressurised water jets into the seabed to fluidise a trench, enabling the cables to sink safely into the seabed. The fluidised material subsequently resettles, giving a degree of backfill. Cable jetting devices include tracked and thruster-propelled ROV trenchers, and other towed jetting devices that are commonly used in shallower water.

3.9.21. An example of a jet trencher is shown in **Figure 3.35**.

Figure 3.35 Example of an ROV equipped with a jetting system

Atlas 1 ROV, courtesy of Global Marine Systems

Mechanical Trenching

3.9.22. For hard materials mechanical trenchers can be used to cut a trench using a chain cutter or a wheel cutter fitted with picks. Mechanical trenching tools are typically used for more onerous soil conditions.

3.9.23. Mechanical trenchers are normally configured for post-lay burial. The cable is picked up by grabs fitted to the vehicle and placed in the cable pathway. The chain cutter is started and lowered into the seabed. The cable is laid or placed into the cut trench. Due to the weight of the chain tool the trenchers are normally tracked, although for shallow water operations some sled mounted devices exist.

3.9.24. An example of a mechanical trencher may be seen in **Figure 3.36**.

Figure 3.36 Illustrative example of a mechanical trenching system

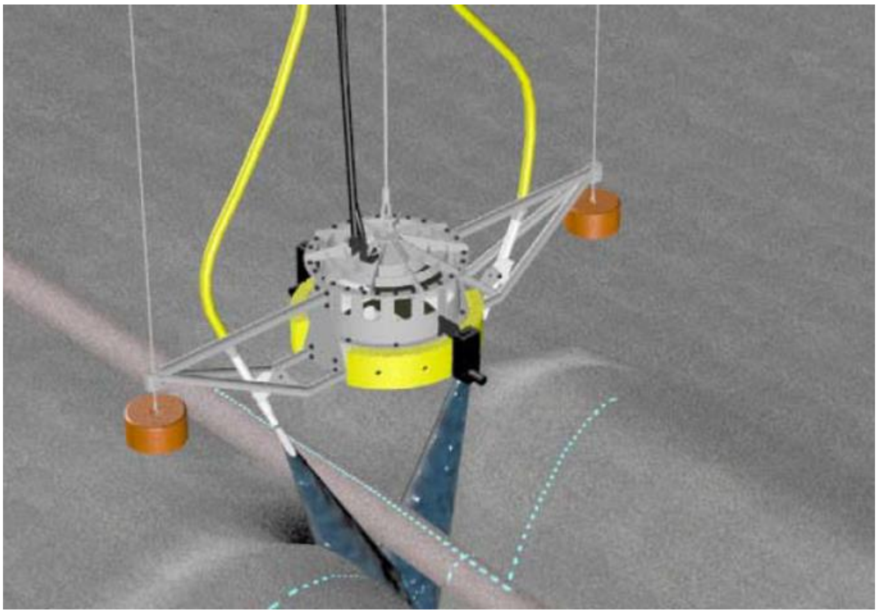
Rocksaw trencher, courtesy of Global Marine Systems

Mass Flow Excavation

3.9.25. Mass flow excavation is sometimes used for remedial burial, particularly in coarse, non-cohesive soils where jet trenchers have been unable to achieve sufficient burial. Mass flow excavation utilises an impeller and duct system suspended from a vessel a short distance above the cable to direct a very high volume low pressure flow at the seabed. Material is fluidised and entrained in the flow causing excavation of a trench which can five or more meters wide and around 2 to 3m deep, depending on seabed conditions. The advantage of this technique is that burial can be achieved where jet trenchers have under-performed.

3.9.26. An example of a mass flow excavation system can be seen in **Figure 3.37**.

Figure 3.37 Illustrative visualisation of a mass flow excavation system in operation



SeaVator™ plus V-Jets mass flow excavation system, courtesy of AGR Seabed Intervention Ltd

Post-Installation Surveys

3.9.27. A post-installation route survey will be conducted after the completion of the cable installation works. This will confirm the as-built condition of the cabling and the actual levels of burial achieved and potentially identify any needs for remedial cable protection.

Removal of Offshore Cables

3.9.28. During the construction of the project there may be a requirement to remove or relocate portions of existing cables in proximity to the project wind turbine array areas or export cable routes. Examples may include works taking place in the vicinity of decommissioned telecommunication cables. Although in these circumstances existing cables will generally be left in-situ, in some cases removal may be judged to be preferable.

3.9.29. A typical methodology used for the removal of cables may include:

i. Use of grapnels, and/or ROVs (potentially including jetting systems to uncover buried sections) to find, physically contact and retrieve cables;
ii. The required section of cable is cut, pulled out of the seabed, and retrieved onto a vessel for disposal onshore as appropriate;
iii. Any remaining cut ends of cable will be weighted as required and returned to the seabed;
iv. This could potentially be followed by re-installation, in a new location if required, using techniques as described in the cable installation section; and
v. Admiralty charts will be updated to reflect the new situation.

3.9.30. As discussed in **Section 5.5 Proximity to Existing Infrastructure**, the necessary agreements would always be sought from the cable owners. The lifting and re-laying of cables may be subject to additional consents, and the necessary permissions would be sought should this be required.

3.9.31. For the purposes of assessment, the environmental impact of cable removal will be considered to be equivalent to cable installation. This is judged to be a conservative assumption as the installation methodologies within the development envelope, including jetting, ploughing and cutting tools, are judged to generate greater footprint impacts and sediment volumes than the potential methods of cable removal. This assumption is also in line with the common assumption that the impact of decommissioning is equivalent to construction.

3.9.32. The total length of cables both installed and removed will therefore be required to fall within our total development envelope limit for installed length of cable, as described within **Section 3.8 Offshore Cables**. Therefore, for example, if 2km of cables were removed, then the maximum length of cables which could be installed should be reduced by a corresponding 2km.

3.10. Remedial Cable Protection

3.10.1. The Dogger Bank Teesside A & B offshore cables will be buried or alternatively protected appropriately along their full length. Cable burial is the preferred protection technique, since in the seabed conditions identified, it typically provides the best protection, at the lowest cost, in the shortest time. The offshore cables will therefore be buried wherever it is feasible and economic to do so, with additional or alternative protection measures only applied if necessary

3.10.2. Where burial is impractical, or sufficient burial depth is not achievable at a particular location, additional or alternative cable protection methods will be required. In the event that remedial cable protection is required in areas where trawling takes place, Forewind will endeavour to make the installed systems over-trawlable by fishing vessels.

3.10.3. There are two common drivers for the installation of remedial protective measures: the presence of hard rock or other challenging seabed conditions for cable burial, and the proximity of other structures, such as the wind turbines, which mean that the cable installation equipment cannot operate safely and burial is unfeasible. The protection method and detailed design chosen will reflect the level of risk to which the cable is exposed, i.e. the expected levels of scouring, seabed mobility, fishing activity, and anchoring.

3.10.4. The range of remedial cable protection parameters and technology options described encompass the likely worst case scenarios identified for the delivery of the project. The different technologies have been identified to address a range of potential requirements, hence this suite of options addresses a range of risks to project delivery. The parameters and quantities defined have been developed based upon assessments of the likely worst case construction and operational scenarios.

3.10.5. Typical cable remedial protection measures include one or a combination of the following options (described in detail below):

- Rock or gravel burial;
- Concrete mattresses;
- Flow energy dissipation devices (used to describe various solutions that dissipate flow energy and entrap sediment, and including options such as frond mats, and mats of large linked hoops);
- Protective aprons or coverings (solid structures of varying shapes, typically prefabricated in concrete or high-density plastics), and;
- Bagged solutions, (including geotextile sand containers, rock-filled gabion bags or nets, and grout bags, filled with material sourced from the site or elsewhere).

3.10.6. Protection measures may be placed alone or in combination, and may be secured to the seabed where appropriate. Where appropriate, cable clips (also known as cable anchors, or anchor clamps) may also be utilised to secure cables to the seabed.

3.10.7. The parameters assessed for the offshore cables requiring remedial protection are reported in **Table 3.25**. The final methods, quantities and designs used will be determined as part of detailed design. The figures in **Table 3.25** do not include crossings of existing assets, which are addressed separately in **Section 3.11 Offshore Cable & Pipeline Crossings**

Table 3.25 Indicative offshore cable remedial protection parameters

Parameter	Teesside Project A	Teesside Project B
Maximum inter-array cable protection footprint per project (km^2)	1.00	1.00
Maximum inter-array cable protection volume per project (m^3)	390,250	390,250
Maximum inter-platform cable protection footprint per project (km^2)	1.00	1.00
Maximum inter-platform cable protection volume per project (m^3)	972,192	972,192
Maximum export cable protection footprint area per project (km^2)	2.57	2.31
Maximum export cable protection volume per project (m^3)	2,496,785	2,242,473

Rock Burial

3.10.8. Protection by rock burial (also known as rock placement or rock dumping) involves installation of a rock 'berm' over the cable. Rock burial is one of most technically robust and commonly used techniques. Rock berm design, and rock grade and density, will be specified to ensure stability in the local environment. Rock protection can be deployed from specialist ships or barges using techniques such as side casting, where rocks are pushed overboard with lateral hydraulic slides and discharged onto the seabed. Alternatives include fall-pipe systems; where rocks are fed into a funnel at the top of a fall-pipe and discharged at a controlled rate as guided by sensors at the base of the pipe – which can also be remotely steerable. An illustrative example of the installation of cable rock protection can be seen in **Figure 3.38**. The correct berm dimensions can be confirmed by bathymetric surveys before and after rock placement.

Figure 3.38 Illustrative visualisation of rock placement for cable protection

Courtesy of RWE npower renewables

Figure 3.39 Illustrative example of rock berm protection for unburied inter-array cables

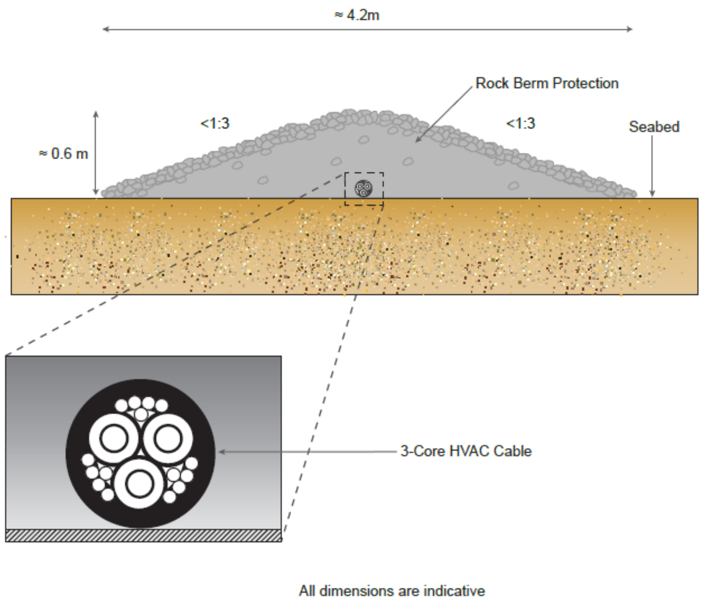
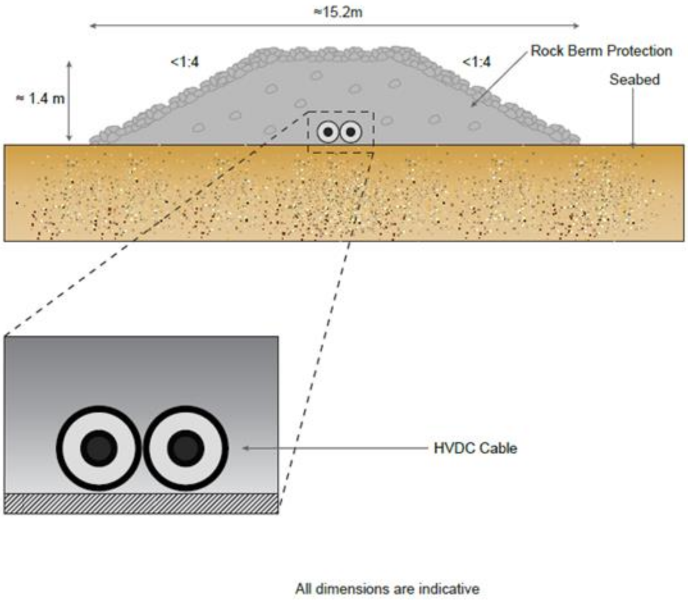


Figure 3.40 Illustrative example of rock berm protection for unburied export cables



Concrete Mattresses

3.10.9. Concrete mattresses consist of a number of concrete blocks linked together by flexible cables. There are various designs of concrete mattresses available. The most suited concrete mattress will depend on a number of factors including application, function and environmental conditions. Designs include options with smoothly tapered edge sections intended to have reduced impact upon trawling, and mattresses with integrated frond mats (described below). Some local factors, such as heavy trawling activity, may however make mattressing inappropriate. For installation the concrete mattresses are lowered down by crane over the cables in a pre-determined pattern to hold the cables in place and provide protection against fishing gear and vessel anchors.

3.10.10. An illustrative example of a concrete mattress is shown in **Figure 3.41**.

Figure 3.41 Illustrative example of concrete mattress cable protection

Pipeshield Bi-Flex Concrete Mattress. Courtesy of Pipeshield

Flow Energy Dissipation Devices

3.10.11. Flow energy dissipation devices are typically designed to trap local and mobile sediments in order to generate a protective covering. A common example includes frond mats, which use flexible buoyant strips (fronds) to gently reduce the water velocity above the mats and are similar in appearance to a sea grass bed. The mats allow mobile sediments to become deposited and trapped around the fronds and gradually build a sand layer on the mats, protecting any cables below. Frond mats, similar to those shown in **Figure 3.42**, can be installed on their own and positioned and secured to the seabed by ROV or similar, or integrated with concrete mattresses. They can also be used to protect cables installed in areas of high seabed mobility. Alternative flow energy dissipation devices exist, including designs where large hoops (such as car tyres) are linked together into a mat and act similarly to a frond mat, and designs which are covered with long rigid spikes to slow the water flow.

3.10.12. It is noted that these technologies are often only appropriate for use in areas with specific local conditions, including significant levels of mobile seabed sediments, and examples such as the spiked designs would only be appropriate in areas without trawling.

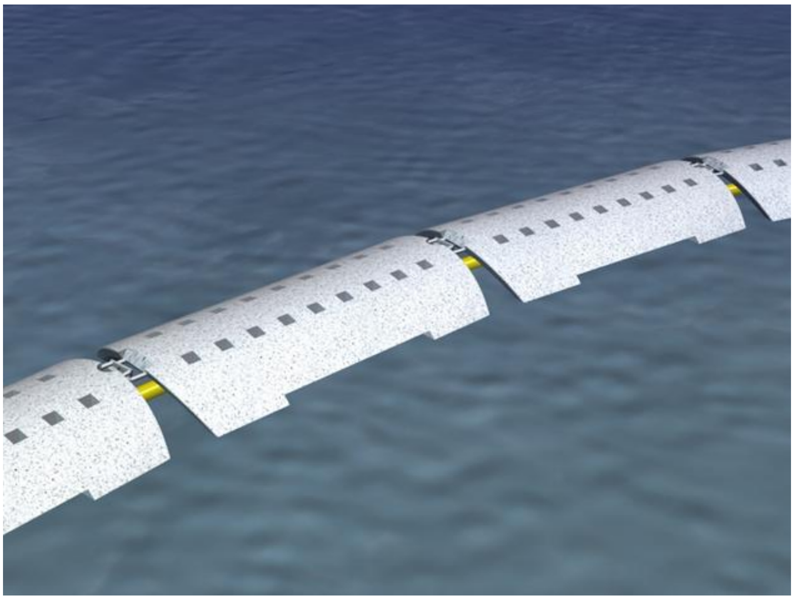
Figure 3.42 Illustrative example of a frond mat, and operational effects

The fronds can allow self-burial in favourable conditions, by trapping sediments. Courtesy of Pipeshield

Protective Aprons or Coverings

3.10.13. This includes solid structures of varying shapes, typically prefabricated in concrete or high density plastics, which can be installed at the same time as the cable, or retrospectively by crane or otherwise. Examples include plastic casings installed to provide additional cable protection around the J-tube at the base of a turbine foundation. Novel technology options also include prefabricated concrete 'half-pipe' structures which fit over the cable to provide robust, over-trawlable protection, potentially with no need for burial. In some cases protective aprons may be equipped with flow energy dissipation devices.

Figure 3.43 Illustrative example of cable protective covering



Courtesy of SeaCult (patented concept)

Bagged Solutions

3.10.14. These include geotextile sand containers, rock-filled gabion bags or nets, and grout bags. Bags are typically lowered into position by crane from a surface vessel, individually or in groups. These options are often used in proximity to a foundation base and around J-tubes, since precise placement is possible.

3.10.15. Examples of gabion bags and grout bags can be seen in **Figure 3.44** and **Figure 3.45** respectively.

Figure 3.44 Illustrative example of a rock-filled bag for cable protection

Subsea rated 1Te bulk-bags. Courtesy of Pipeshield

Figure 3.45 Illustrative example of a grout bag

Courtesy of Pipeshield

Remedial Burial

3.10.16. In the event that cable burial is unsatisfactory, remedial burial may be an option. Jetting or Mass Flow Excavation for example, discussed in **Section 3.9 Offshore Cable Installation and Removal**, is often used for remedial burial, particularly in coarse sandy soils. It is also often possible for burial to be re-attempted using the other cable burial methods discussed, potentially using an alternative technique, or a more powerful or capable machine.

3.11. Offshore Cable & Pipeline Crossings

3.11.1. There are a number of existing pipelines and telecom cables installed within the Dogger Bank Zone and along the offshore export cable corridor. Although the number of crossings may be able to be minimised, some crossings will be required. It may also be necessary to cross other Dogger Bank wind farm power cables. The values assessed for cable crossings are summarised in **Table 3.26**.

3.11.2. In cases where crossing a subsea asset is necessary, a site-specific crossing design will be required. Details of the crossing design will be determined in collaboration with the owners of the infrastructure to be crossed. Crossings will be designed to provide adequate separation between assets, and maintain protection and stability through the lifetime of the wind farm. It may not be feasible to make cable crossings overtrawlable in all cases. Illustrative sketches of cable crossing designs can be seen in **Figure 3.46** to **Figure 3.49**.

3.11.3. Any of the techniques described for remedial cable protection in **Section 3.10 Remedial Cable Protection** may be used to achieve cable or pipeline crossings, but the common options include one or a combination of:

- Pre-lay and post lay concrete mattresses;
- Pre-lay and post lay rock dumping;
- Pre-lay steel or concrete structures; or
- Pre-constructed HDPE castings or other innovative approaches.

3.11.4. The installation techniques described for remedial cable protection in **Section 3.10** can be similarly applied in the context of cable and pipeline crossings. A typical sequence for an installation based on concrete mattresses would be as follows:

i. The proposed crossing locations are surveyed to confirm the precise location and burial depth of the existing assets, and the crossing designed accordingly;
ii. An installation vessel places concrete mattresses perpendicular to the orientation of the existing asset;
iii. The cable installation vessel lays the cables over the mattresses. Burial would terminate a short distance from the existing asset, and the cables may have HDPE half-shell castings installed onto the cable as they are deployed from the laying vessel for additional protection in the region of the crossing;
iv. The mattress installation vessel places additional concrete mattresses, aligned with the orientation of the newly installed cable, for top protection;
v. Rock burial is carried out on the mattress edges, to stabilise them.

Figure 3.46 Illustrative example of crossing design for inter-array cables (cross sectional view)

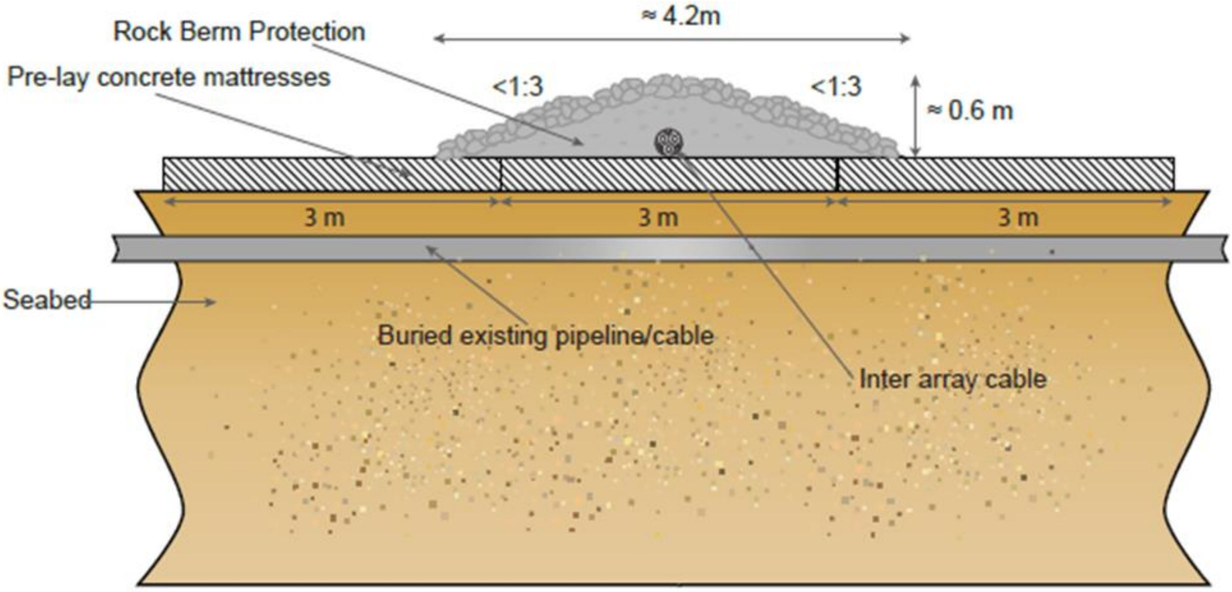


Figure 3.47 Illustrative example of crossing design for inter-array cables (plan view)

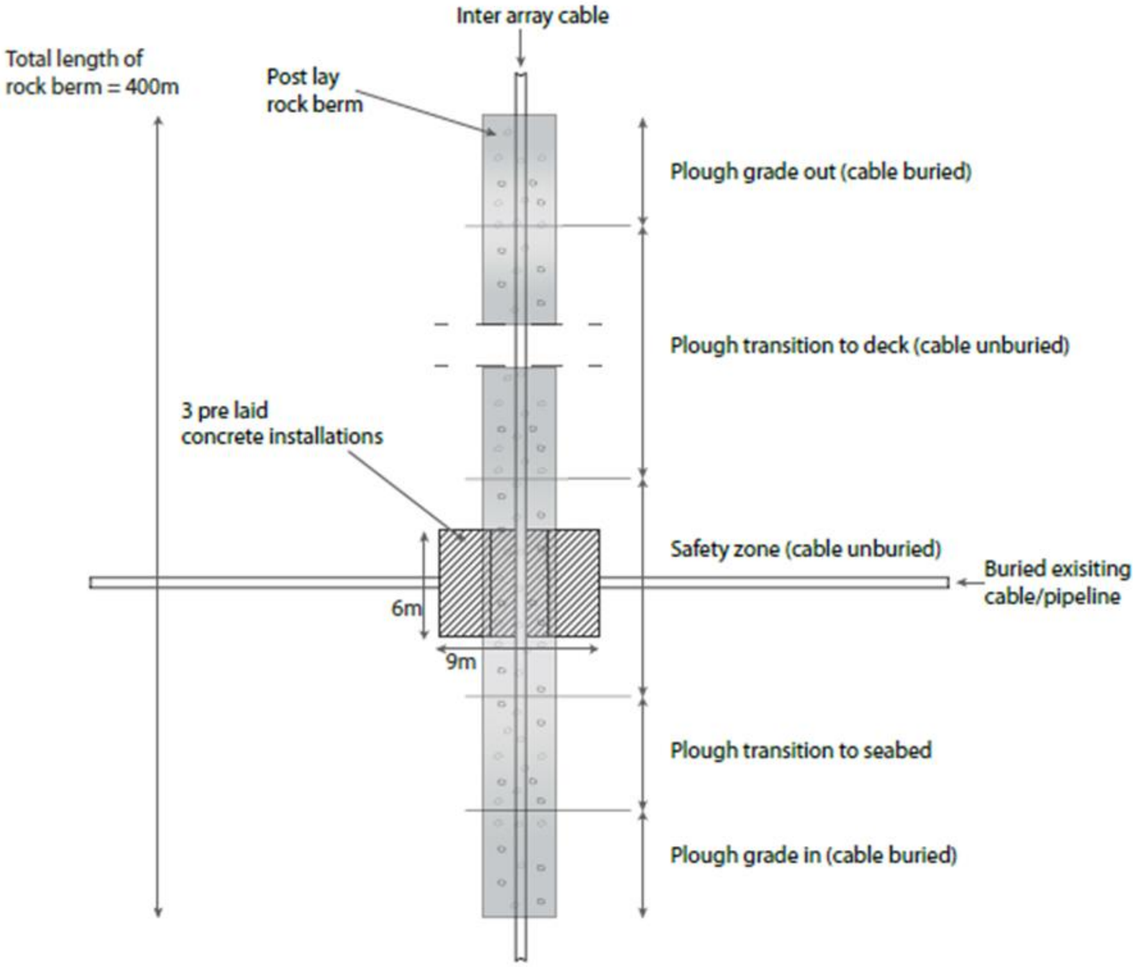


Figure 3.48 Illustrative example of crossing design for export cables (cross section)

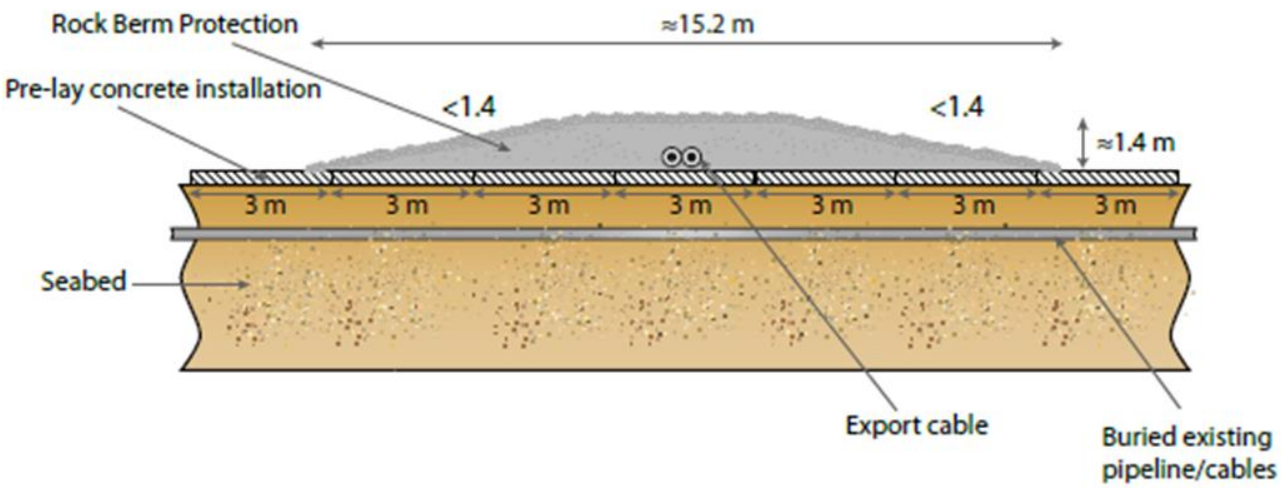


Figure 3.49 Illustrative example of crossing design for export cables (plan view)

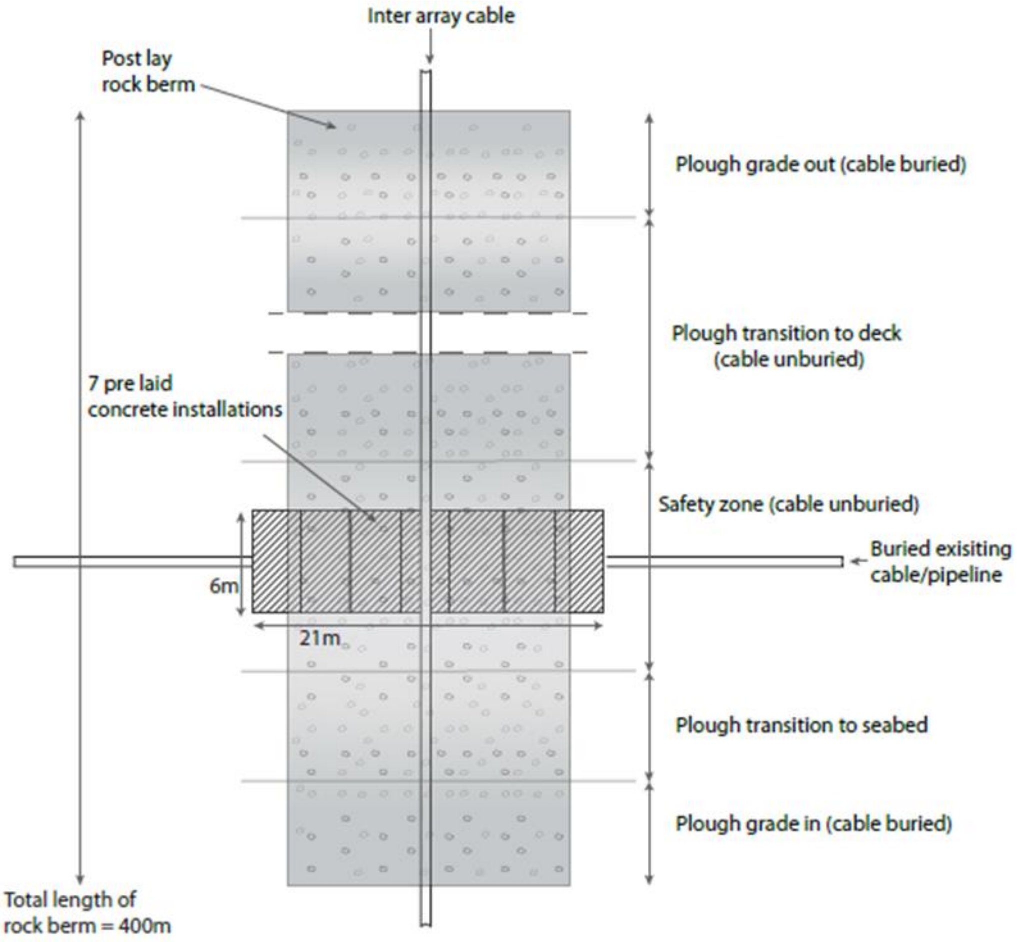


Table 3.26 Indicative crossing protection parameters

Parameter	Teesside Project A	Teesside Project B
Inter-Array and Inter-Platform Cables		
Maximum number of inter-array and inter-platform cable crossings (including crossings of both third party and other Dogger Bank assets)	24	24
Maximum volume of inter-array and inter-platform cable crossing material per project (m^3)	132,745	132,745
Maximum total footprint of inter-array and inter-platform cable crossings per project (km^2)	0.147	0.147
Export Cables		
Maximum number of export cable crossings	16	16
Maximum total volume of export cable crossings protection material per project (m^3)	88,497	88,497
Maximum total footprint of export cable crossing protection material per project (km^2)	0.098	0.098

3.12. Offshore Electromagnetic Fields

3.12.1. This section summarises the results of the assessment carried out on the expected magnitude and potential effects of the electric and electro-magnetic fields (EMF) that would be generated by the offshore cables for Dogger Bank Teesside.

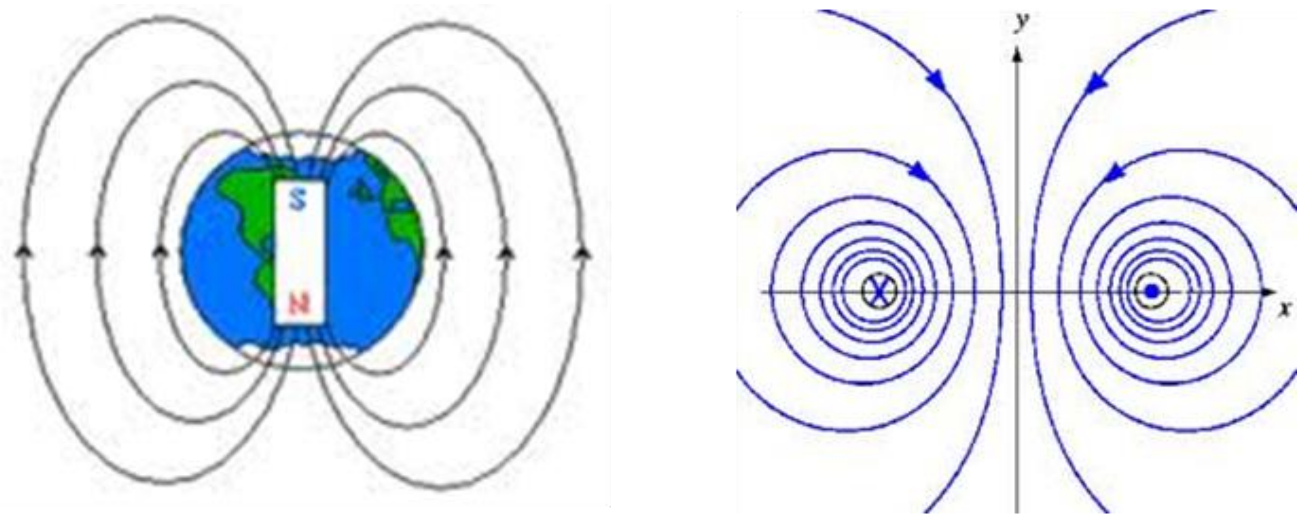
3.12.2. The offshore AC cables (including inter-array and inter-platform) will be designed to emit only negligible magnetic fields and consequently negligible induced electric fields. AC cables are therefore not discussed further in the context of EMF assessment and the following assessments refer to DC cables only.

Summary of Assessment Methodology

3.12.3. EMFs detected within the marine environment are generated by both natural sources, such as the Earth's magnetic field and anthropogenic sources, such as power cables.

3.12.4. Earth is surrounded by a magnetic field, which is used for compass navigation. Earth's magnetic field originates in the Earth's core and can be represented by the field of an ordinary bar magnet, as shown in **Figure 3.50**. On the surface, Earth's magnetic field is oriented predominantly north-south. HVDC cables also produce an external magnetic field whose intensity and orientation depends on the current intensity, distance from the cables, and the cable separation and orientation.

Figure 3.50 Illustrative representation of EMF field



Illustrative representations of the Earth's magnetic field (left), and the magnetic field around a pair of DC cables (right)

3.12.5. If two cables of the same HVDC bipolar or balanced monopole circuit, such as the ones the will be used for Dogger Bank Teesside A & B, are bundled together i.e. installed in close proximity, the external magnetic field becomes negligible since the currents flowing in the two cables are equal in value and opposite in direction and their fields tend to cancel each other out.

3.12.6. Conversely, for unbundled cables the resulting field, also shown in **Figure 3.50**, is reinforced in the space between the cables and reduced in the space external to the conductors. A measure of the magnetic interaction is the magnetic flux density (B). This can be calculated in value and direction by applying the Biot-Savart law, which can be reduced, in the most simple case, to the following expression:

$$B = \frac{\mu I}{2\pi R}$$

3.12.7. Where I is the current, μ the magnetic permeability of the medium, and R is the radial distance from the current (cable) axis.

3.12.8. The magnetic field produced by cables sums up geometrically with Earth's magnetic field, resulting in a modified overall magnetic field, causing compass deviation. The compass deviation caused by a pair of HVDC cables in a bipolar system can therefore be assessed by applying the equations above and superposing the effects of the two cables.

Offshore EMF Assessment Results (DC Cables Only)

3.12.9. The compass deviation potentially generated by a pair of Dogger Bank Teesside A & B cables therefore varies with several key variables, including:

- Orientation – the interaction with the Earth's magnetic field means that orientation has a substantial influence, (for example cables laid east-west should not affect compass navigation);
- Cable spacing – the spacing of the two cables will influence the magnitude, extent and shape of the affected areas. In particular, the area affected will reduce as cable spacing is reduced, and bundled cables will have no expected affect at all upon compasses;
- Electric current – the magnetic field strength varies with the square of the current, so during periods when the wind farm is operating below maximum output, the effect upon compasses may be substantially reduced;
- Proximity to cables – the effects upon magnetic compasses are highly localised, and even in severe cases typically drop to negligible levels within a few tens of metres.

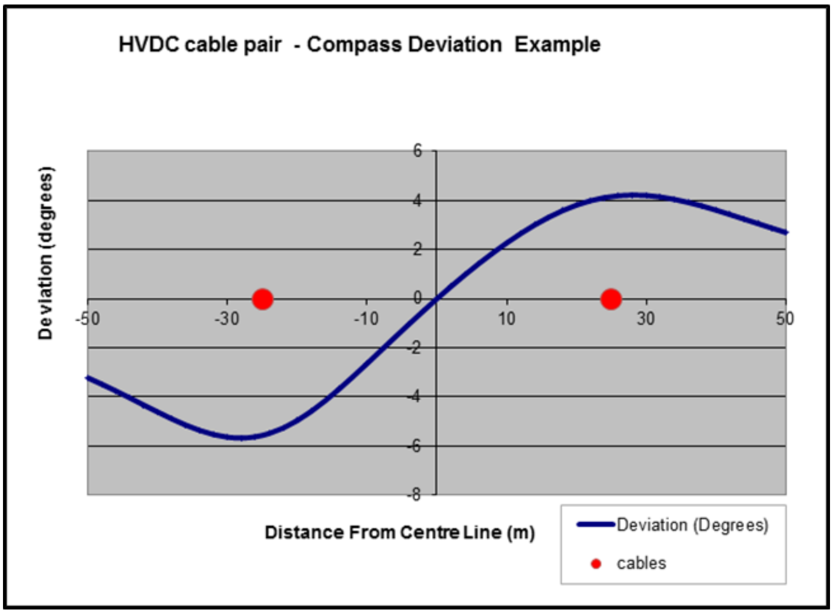
3.12.10. **Table 3.27** shows compass deviation values for a set of example cases. These assume a conservative cable orientation, and the maximum peak current through the cables.

Table 3.27 Example of compass deviation assessment results - conservative example assuming a pair of HVDC cables oriented at 120 degrees to magnetic north, carrying 1700A (the maximum possible), buried 1m into the seabed

		Compass deviation at sea surface (Degrees)		
Parameter	Water depth	Peak	Peak at 25m from cables	Peak at 50m from cables
Bundled cables	Any	Negligible	Negligible	Negligible
30m cable separation	50m	1.5	1.3	0.8
	30m	4.0	2.1	0.9
50m cable separation	50m	2.3	2.0	1.1
	30m	5.6	3.2	1.1

3.12.11. The most conservative case from **Table 3.27** is illustrated in **Figure 3.51**, where it can be seen that in the shallower 30m water depth, for 50m cable separation, the compass deviation peaks at 5.6 degrees for the left-hand cable in a localised band, with compass deviations dropping substantially once you move around 25m from the cables.

Figure 3.51 Example of compass deviation from a pair of HVDC cables at 50m separation



Example assumes a 30m water depth, and plus the conservative assumptions of a maximum current flow of 1700A and orientation of 120 degrees to magnetic north.

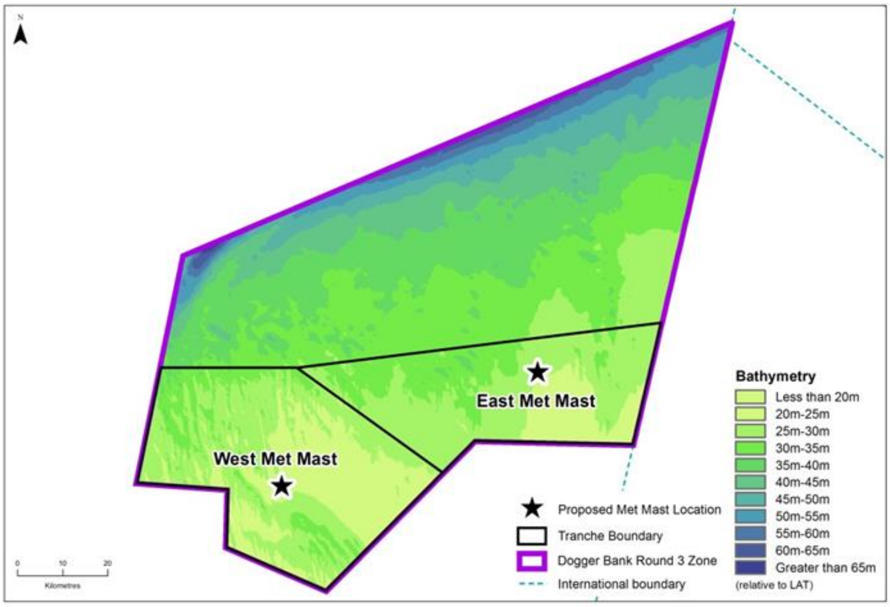
3.12.12. The offshore DC cables from the Dogger Bank Zone to the landfall located between the towns of Redcar to the north and Marske-by-the –Sea to the south will generate magnetic fields, but no external electric fields.

3.12.13. As shown above, under some circumstances, EMFs produced by DC cables can interfere with vessel navigation systems by causing magnetic compass deviation in their immediate vicinity. These effects have been shown to be highly localised and may occur only in shallower waters (less than around 30m water depth) and for restricted zones on the surface (indicatively less than 100m wide) immediately above any unbundled cables. Bundling the cables will address this effect by reducing the EMFs produced by the cables such that compass deviation is reduced to negligible levels.

3.12.14. Significant compass deviations may therefore occur only with unbundled cables buried in shallower waters, and thus are only possible in the vicinity of the landfall, where the cables will be split for HDD installation, and any other areas where waters are shallow and unbundling the cables is also necessary. The magnitude of any compass deviation is also significantly affected by the spacing of cable pairs, and the orientation of cables, and will only reach the values stated within the examples above when the wind farm is at peak output. The results of this assessment are considered further within **Chapter 16 Shipping and Navigation**.

3.13. Meteorological Monitoring Stations

Figure 3.52 Locations of development-phase meteorological masts installed in 2013



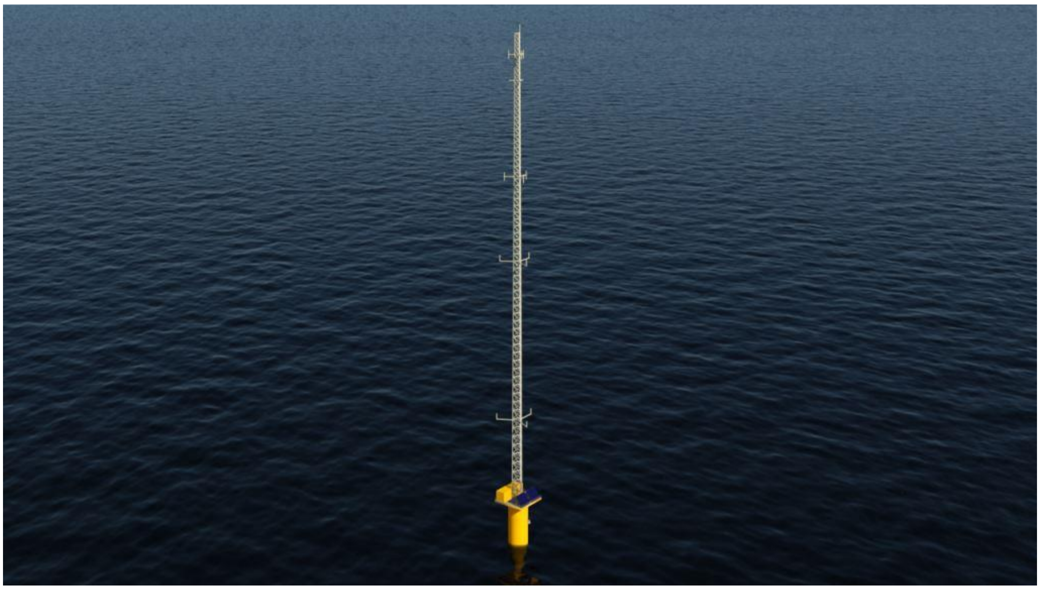
3.13.1. Each of the Dogger Bank Teesside A & B projects will each have up to five meteorological monitoring stations (also referred to as meteorological monitoring masts, or met masts) in addition to the two development-phase meteorological stations installed in 2013. Meteorological monitoring stations are essential to provide meteorological and oceanographic (metocean) data. The data will be used for optimising the wind farm design prior to installation and subsequently for monitoring wind farm performance, and input into project control and management systems. The final number and locations of the proposed meteorological stations will be determined as part of the final project design process.

3.13.2. A separate consent has been received for two meteorological monitoring stations at the coordinates shown in **Figure 3.52**. Stations installed ahead of the main project provide valuable site information to assist the final project design.

3.13.3. The meteorological monitoring stations typically comprise a foundation, ordinarily fitted with a tall lattice tower and mounting anemometers for measuring wind data, plus a wide variety of other instrumentation, both mounted on the station and deployed around it. An example illustration of a meteorological monitoring station can be seen in **Figure 3.53**.

3.13.4. The foundations for the meteorological monitoring stations may be fixed structures, and these are considered to be represented by the foundation parameters and methodologies provided for the wind turbines. These have been represented within the EIA by foundation parameters and methodologies for smaller versions of the wind turbine foundations. Alternatively, meteorological monitoring stations may be floating, like the example shown in **Figure 3.54**, in which case they could be considered to be represented by the parameters and methodologies provided for the vessel moorings, although alternative anchoring arrangements (including tension moorings, which fix the buoy into position more rigidly) are also possible.

Figure 3.53 Illustrative example of a fixed meteorological monitoring station



3.13.5. The meteorological monitoring stations may typically include a range of the following elements:

- Lattice tower (up to the maximum tip height of the wind turbines) although this is not always necessary, for instance in stations based around wind lidar remote sensing systems;
- Anemometers and other meteorological sensors, potentially including wind lidar systems;
- Oceanographic sensors, on the structure or potentially deployed on the seabed in the immediate proximity of the station;
- Power supply and generation equipment including photovoltaic cells, small wind generators, battery banks, diesel generators, fuel cells, and associated fuel;
- Control, data recording, and communication equipment;
- Cables for connection to the wind farm power and control systems network, discussed further within **Section 3.8 Offshore Cables**; and
- Navigation, aviation, and safety marking and lighting.

Figure 3.54 Example of a floating meteorological monitoring station, including wind lidar

Courtesy of RWE npower renewables

3.14. Vessel Moorings

Figure 3.55 Illustrative example of a single buoy mooring

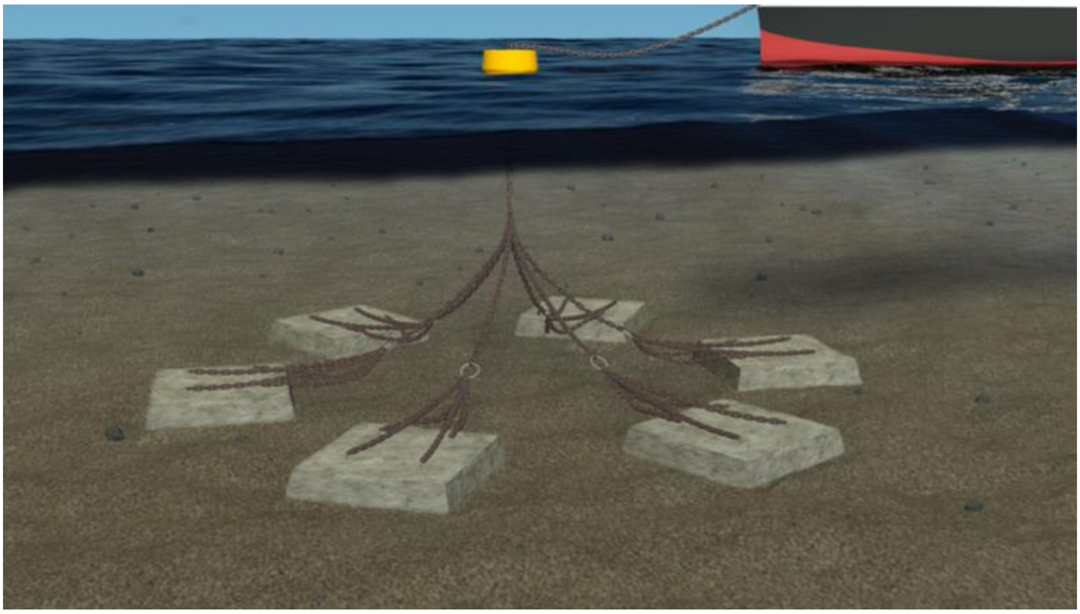
Courtesy of Det Norske Veritas

3.14.1. It is expected that as part of the operations and maintenance activities of the wind farm, a variety of vessels may be used continually to support offshore activities. As part of their operation it may be necessary to have a number of pre-installed permanent moorings at intervals around the project area to allow vessels to moor at the project site. Moorings may be used in a variety of situations, including at night, during lulls in work, to save fuel while station keeping, or in the event of machinery failures.

3.14.2. The mooring technology considered for use at Dogger Bank Teesside A & B is the single buoy mooring. These consist of a single floating buoy, fixed to the seabed by a system of one or more anchors, and including lengths of floating line to allow vessels to initially contact and secure the buoy, and mooring loops, hooks, or other systems as appropriate for a wind farm vessel to moor onto. An example of a single buoy mooring can be seen in **Figure 3.55**.

3.14.3. Dependent upon the scale, type, and location of buoys installed, it may be deemed appropriate to include aids to navigation, or adopt other suitable navigational safety measures. These could include for example: high visibility yellow colour schemes, navigational lighting, or appropriate charting. This would be determined as part of the detailed design of the project.

Figure 3.56 Illustrative example of a single buoy mooring with six gravity anchors



3.14.4. The buoys themselves would typically be constructed of steel or plastic. Various shapes are possible, including cylindrical or spherical. The buoys would be secured to the seabed using a variety of anchor systems, potentially including drag anchors ('traditional' anchors), plate anchors, suction pile anchors, or gravity anchors. The chains securing the buoy to the anchors will contact the seabed. **Figure 3.56** shows an example of a possible anchor and chain arrangement for a single buoy mooring.

3.14.5. The parameters considered for mooring buoys are listed in **Table 3.28**.

Table 3.28 Indicative mooring buoy parameters

Parameter	Teesside Project A	Teesside Project B
Maximum number of vessel moorings per project	10	10
Indicative buoy diameter (m)	6	6
Maximum number of anchors per vessel mooring	6	6
Maximum seabed impact footprint of all buoys during operation, per project (km^2)	0.472	0.472

3.14.6. Each mooring buoy will be fabricated and assembled and transported to site (potentially via a lay-down area at a selected construction port). A brief typical installation sequence is as follows:

i. Transport of buoys to offshore site using a vessel such as an anchor handler;
ii. Installation of the mooring's anchors into the seabed in predefined positions. For drag or pull anchors this is typically by dragging or pulling until they are fully embedded into the seabed; suction piles are typically embedded in a manner similar to that used for wind turbine suction bucket foundations; and gravity anchors are craned into position on the seabed.
iii. Deployment of the mooring buoy and associated components, and connection onto the pre-installed anchors.

3.14.7. The sequence is repeated for each buoy

4. Onshore Project Components

4.1. Cable Landfall

4.1.1. The offshore export cables will come ashore at landfall to connect to the onshore export cable systems. The cable landfall works, including the methods of installation, will depend on the geology of the landfall point, width of the beach, the height of the cliffs under which the landfall cable has to pass and any local environmental considerations.

4.1.2. There are a number of techniques which may be utilised to bring the project offshore export cables ashore. In order to minimise the disruption on the shoreline caused by open trenching the assessed construction method is to use the horizontal directional drilling (HDD) technique. Landfall HDD operations are anticipated to be undertaken starting from the transition bay location, drilling under the cliffs and beach, then exiting in the seabed. In some cases it may be necessary for the HDD to exit on the beach in the inter-tidal area, and the additional works potentially required for this option are described below.

4.1.3. HDD techniques are also used for onshore installation and details of HDD operations are therefore given in **Section 4.4 Cable Installation**. Other cable installation techniques are also described in **Section 4.4 Cable Installation**.

Cable Transition Bay

4.1.4. The offshore cables will be connected to the onshore cables in one or more specifically designed underground joint bays or pits, referred to as transition bays. The transition bay location will be carefully chosen, on dry land, and buried below ground. The selection of the position of the transition bay(s), and the landfall works in general, must also take into account local coastal erosion which is a feature of the Dogger Bank Teesside A & B landfall area.

4.1.5. Typical transition bay dimensions are approximately 1.5m depth, 4m width and 12m length. Dimensions may vary depending on the final electrical design

4.1.6. After installation and jointing of the cables at the transition bay it will be backfilled and the top surface reinstated. There will be no above ground structures and the ground can be returned to previous use.

Landfall Works Compound

Figure 4.1 Example of typical HDD equipment

Courtesy of JP Kenny

4.1.7. During the landfall works a temporary construction compound of approximately 0.5ha will be required to contain the drilling equipment for the cable installation and HDD works. An example of typical HDD equipment is shown in **Figure 4.1**. The compound will be located on dry land and typically comprised of the following elements:

- Compound fencing;
- Cable laydown area;
- Portacabin with offices and comfort rooms;
- Lock-up storage area;
- Car park;
- Wheel wash
- Machinery and lifting equipment area;
- HDD rig;
- Portable generator;
- Temporary lighting.

4.1.8. It is envisaged that the construction compound will be lit during the works. The lighting will be switched off during periods where the natural lighting levels are adequate. It is envisaged that the lighting will be left on overnight for security purposes. Any lighting will be directed into the compound and designed to minimise light spillage.

4.1.9. It is anticipated that, if necessary, the construction compound will be provided with a temporary access track. This access track will be removed after the completion of the works.

Cable Beach Exit

4.1.10. It may be that it is not possible to drill directly from the transition bay area to the seabed in the sub-tidal area, for geotechnical reasons or otherwise. This would result in the exit point for the HDD being located in the inter-tidal zone, between low water mark and mean high water mark. In this case it may be necessary to carry out works such as the installation of cofferdams and open cut trenching, to reach the sub-tidal zone.

Figure 4.2 Example of a sheet piled cofferdam being installed on a beach

Courtesy of Intertek METOC

4.1.11. Cofferdams may therefore be required at the HDD exit points. These could contain the drill workings produced during the drilling operations and provide an area to install cable joints. The maximum assessed dimensions of each cofferdam are 10m wide, 15m long and 3m deep. Shown in **Figure 4.2** is an example of a cofferdam. There may be up to two cofferdams per HVDC cable. The material excavated to create the cofferdam may be stored on a barge for later backfill, or alternatively stockpiled elsewhere away from the influence of tides or waves.

4.1.12. After the drilling slurry has been pumped out and securely contained, the cofferdam may be opened on the seaward side to allow cable burial to commence using the techniques outlined for offshore cable installation. The cofferdam does not need to be in place once the trenching operation has started and the burial tool is clear of the cofferdam. The cofferdam will then be backfilled with the original material. It is envisaged that the cofferdams will need to be in place for no more than 2 months per cable per project.

4.1.13. In the case of the seaward HDD exit hole being located on the beach within the inter-tidal zone, the cable installation may also be carried out using techniques such as open cut trenching to a point where installation can continue using the techniques outlined for the offshore cable installation.

4.2. Onshore Cables

4.2.1. It has been determined that for the Dogger Bank Teesside A & B projects all the onshore cables will be buried and the use of electric overhead lines shall be excluded.

4.2.2. The cable parameters provided are based upon open trench installation of cables at a depth of approximately 1.2m. The cables will be mainly laid in open cut trenches either directly buried or in ducts. The trenches will be backfilled with material of adequate thermal resistivity, to dissipate the heat generated in the cables made of either native soil or stabilised material such as CBS (Cement Bound Sand). For parts of the cable route the cables will be installed through HDD (Horizontal Directional Drilling), which is the standard method used for obstacle crossing. Therefore the cable parameters provided below are indicative only and information such as cable weight and conductor material will be subject to change depending on the method of installation, ground conditions, manufacturer, and the detailed electrical design.

4.2.3. The size of the onshore underground cables used for Dogger Bank Teesside A & B will be subject to detailed electrical and thermal design analysis. This will be carried out as part of the detailed design in consultation with specialist cable manufacturers. However, Forewind has estimated the expected cable dimensions based on information currently available.

Onshore HVDC Cables

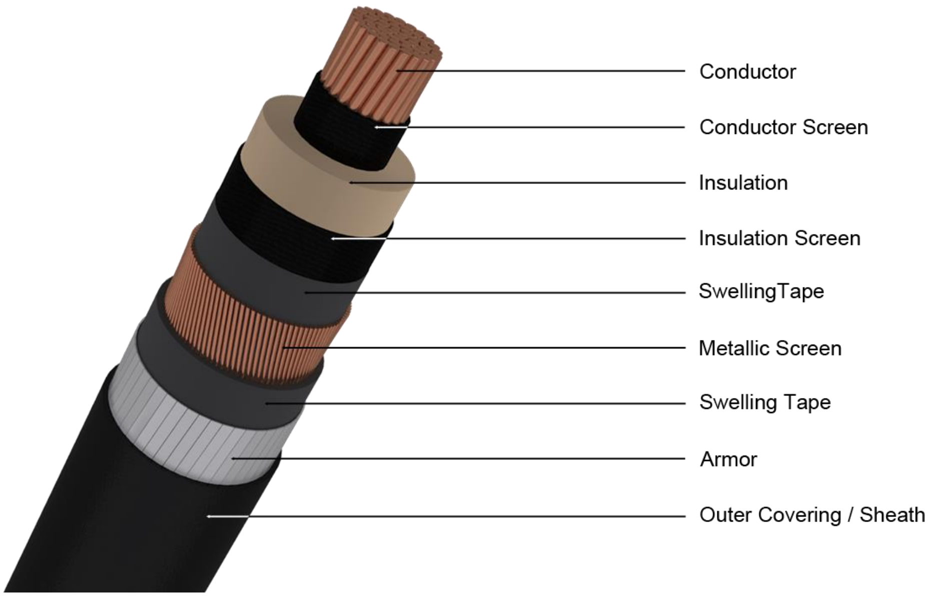
4.2.4. It is envisioned that the onshore HVDC cables will likely be single core, unarmoured, aluminium or copper conductor cables, suitable for underground installation. The nominal voltage is currently envisaged to be ±320kV, however higher voltages up to ±550kV may be used, following cable technology developments. **Table 4.1** shows indicative parameters for the HVDC cables that may be used for each project.

Table 4.1 Indicative onshore HVDC cable parameters

Parameter	Quantity per project
HVDC export system electrical description	1 x approximately 1000MW HVDC circuits, each comprising 2 x approximately 500MW HVDC cables.
Total number of single core cables	2
Indicative nominal voltage (kV)	±320 (±550kV maximum)
Indicative HVDC cable route length (km)	6
Indicative cable linear weight (kg/m)	17
Indicative overall external cable diameter (mm)	120

4.2.5. An example of a typical cross-linked polyethylene (XLPE) insulated HVDC cable is shown in **Figure 4.3**. An HVDC cable is very similar in construction to an HVAC cable of equivalent size and rating, the main difference being the size and properties of the insulation layer of cross-linked polymer. For higher nominal voltages alternative cable designs are available, such as mass impregnated cables.

Figure 4.3 A cutaway view of a typical onshore HVDC cable



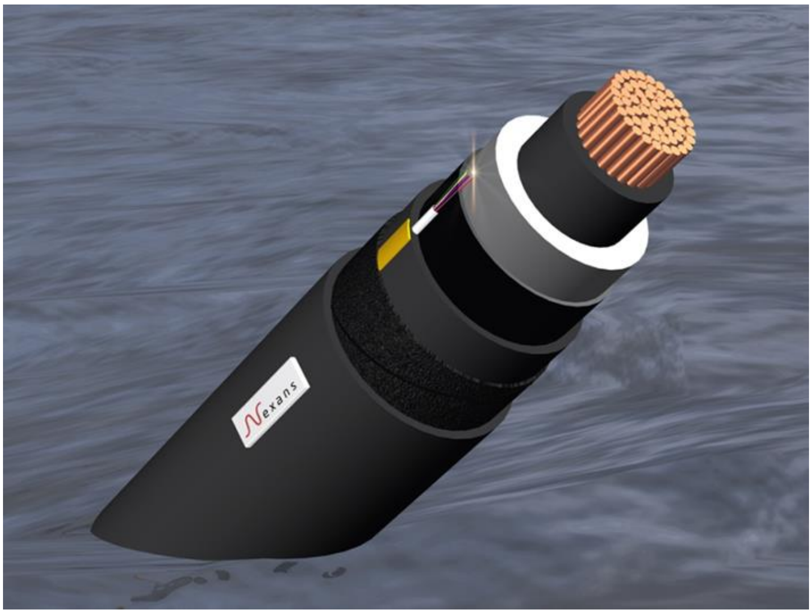
Onshore HVAC Cables

4.2.6. The HVAC cables will likely be XLPE insulated, single core, unarmoured, aluminium or copper conductor cables suitable for underground installation. The cable nominal voltage will correspond to the connection point nominal voltage. **Table 4.2** shows indicative parameters for the HVAC cables that may be used for each project, and the typical structure of an HVAC cable is illustrated in **Figure 4.4**.

Table 4.2 Indicative onshore HVAC cable parameters

Parameter	Quantity per project
HVAC export system electrical description	1 x approximately 1000MW HVAC three-phase circuits, each comprising 3 single core HVAC cables
Maximum total number of single core cables	3
Indicative cable nominal voltage (kV)	400
Indicative HVAC cable route length (km)	2
Indicative cable linear weight (kg/m)	40
Indicative overall external diameter (mm)	150

Figure 4.4 A typical 400kV HVAC cable



Courtesy of Nexans

Onshore Electromagnetic Fields

4.2.7. This section summarises the impact of EMFs that would be generated by the onshore assets of Dogger Bank Teesside. These comprise as a maximum two HVDC converter stations and HVAC connection equipment, two sets of underground HVAC cables and two sets of underground HVDC cables, as described within this Chapter.

4.2.8. The assessment of the impact of any EMFs generated by the projects follows the National Policy Statement guidance on decision making for Electric and Magnetic Fields. Also see the Health Impact Assessment, contained in **Appendix 5.C**

4.2.9. As there will be no overhead lines connecting to the converter stations, only underground cables, there will be no electric fields generated as cable screening eliminates external electric fields. The cables will produce magnetic fields, but these will be within Health Protection Agency, and other relevant regulatory guidelines.

4.2.10. The converter stations will generate electric fields from the above ground conductors but these are small in comparison to overhead lines and are contained within the perimeter of the station or at most fall away to zero within the first few metres of the perimeter fence.

4.3. Onshore Cable Routes

Onshore Cable Routes Overview

4.3.1. The onshore cable systems will be buried underground for the entire length of their routes. Forewind has ruled out the use of overhead line connections for a number of reasons, which include the associated landscape and visual impact

4.3.2. The installation will be made through a range of topographies including rural and industrial landscapes. Installation shall be undertaken using conventional trench installation, either direct buried or in ducts. However, the cables will cross a number of obstacles such as minor and major roads, railways, hedges, etc., for which alternative installation methods will be considered. Depending on the length and features of the crossing trenchless installation techniques will be considered, such as horizontal directional drilling (HDD). These will be identified in the final detailed design process. Cable installation methods are discussed in **Section 4.4 Cable Installation**.

4.3.3. The topography of the route is discussed within **Section 2.1 Site Location**. The cable route crosses major roads three times and a number of minor and unclassified roads as well. In addition there are a number of small watercourses such as Roger Dyke and numerous field drains of varying widths and depths both named and un-named. There is also a Network Rail line, two high pressure gas pipeline, including the Trans Pennine Ethylene Pipeline and the other utility service providers such as electricity both overhead and underground, water, sewage, gas and telecommunications.

4.3.4. **Table 4.3** summarises key elements of the onshore export cable route, including length and expected width of the relevant cable route sections. These are estimated for the worst case scenario of parallel, contemporary installation of the two projects and include cable trench, haul roads, fencing, and temporary topsoil and subsoil storage areas.

Table 4.3 Indicative onshore route summary, per project

Parameter	Teesside Project A	Teesside Project B
Indicative HVDC cable route length (km)	6	6
Indicative HVAC cable route length (km)	2	2
HVDC cable route width (m)	36	36
HVAC cable route width (m)	39	39
Cable route width at HDD locations (for below-ground drilled sections)	Up to 50m (major HDD) Up to 250m (landfall)	Up to 50m (major HDD) Up to 250m (landfall)
Indicative number of features crossed (HVDC and HVAC)	36	36
Indicative number of onshore HDD sections (HVDC and HVAC) (note one HDD may cross multiple features)	7	7

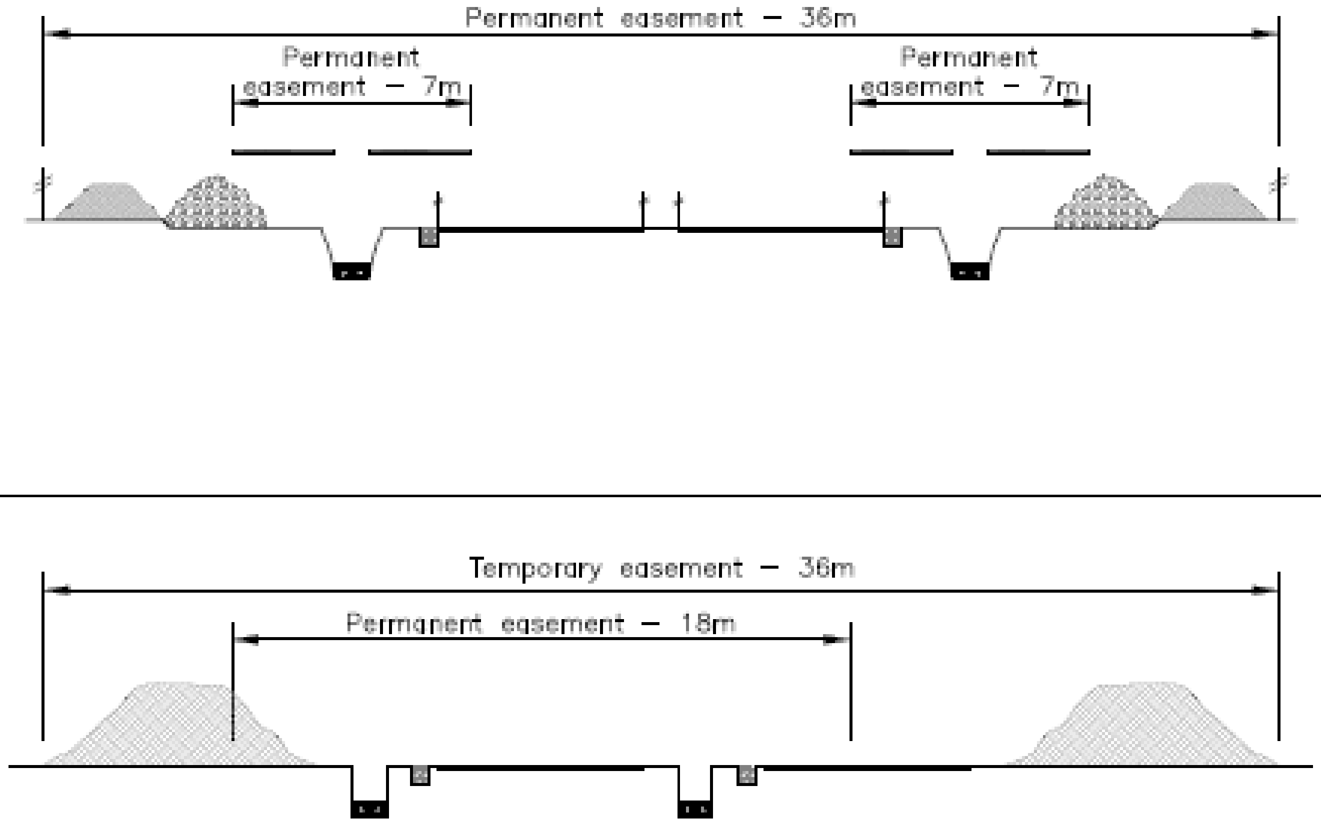
HVDC Cable Route

4.3.5. The proposed cable route passes through a range of topographies including rural and industrial landscapes.

4.3.6. **Table 4.4** provides a breakdown of the areas required by the construction works. The overall HVDC cable route width is provided to allow for the two projects being built at the same time. Two indicative cable route cross sections for two projects are illustrated in **Figure 4.5**. The precise breakdown of the working widths within the overall maximum cable route width may vary dependent upon project and location specific detail design considerations.

4.3.7. Due to the nature of the ground conditions along the length of the cable route and the potential issues surrounding surface water run-off and groundwater, it is envisaged that a temporary haul road will be required for a significant portion of the cable route. The haul road will be constructed using appropriate materials for the local conditions, such as hardcore material or proprietary bog mats.

Figure 4.5 Indicative onshore cable route working widths



4.3.8. The exact requirements for the temporary haul road will be dependent on a number of factors such as the time of year that the works are being undertaken and the detailed knowledge of subsoil and groundwater regime obtained from the ground investigation.

4.3.9. After the termination of the installation works the construction material and haul roads will be removed and the original surface will be reinstated.

Table 4.4 Indicative breakdown of working widths for typical HVDC cable corridor

Parameter	Quantity
Indicative topsoil and subsoil storage width per project (m)	7
Indicative separation distance between trench and soil storage area (m)	2
Indicative separation distance between drain and cable trench	1
Indicative drain width on the side of the haul road (m)	0.5
Indicative haul roads width per road (m)	6
Indicative separation between haul roads (m)	0.5
Maximum overall HVDC cable route width (two projects – contemporary construction) (m)	36

HVAC Cable Route

4.3.10. For the HVAC cable sections a 39m overall cable route has been assessed as being a realistic width to enable two HVAC cable circuits to be installed. The HVAC route is 3m wider than the HVDC cable route to take into account the larger number of cables to be installed and related excavation material. Each HVAC circuit comprises three cables laid in flat formation and requires a larger trench around 1.5m wide at the base to accommodate the three cables plus a slightly larger spoil area to accommodate the related extra spoil from this trench.

4.4. Cable Installation

4.4.1. The onshore project cable systems may be installed using a variety of techniques dependent on situation. Key options identified include:

- Laid directly into the ground via open trenches and backfilled;
- Laid into ducts in the ground and backfilled;
- Laid into ducts in roads or directly in trenches in roads
- Laid into ducts over culverts and;
- Laid by trenchless installation.

4.4.2. Where practicable the standard cable installation methodology will be open trenching, either directly into the ground or using ducts or conduits.

4.4.3. Minor crossings, such as minor roads, paths, ditches, and utilities, which will be encountered on the cable route, are addressed by trenching the cables underneath the obstacle.

4.4.4. For both the HVDC and HVAC cable sections, major obstacles such as large watercourses, major utilities, railways or major roads, where open trenching is not practical, the preferred method of cable installation will be by trenchless installation. Horizontal Directional Drilling, HDD, is the preferred method of trenchless installation as it typically allows the greatest steerability and longer installation distances. Other trenchless installation techniques, such as thrust boring, may be considered where it is not feasible or economic to use HDD. The use of any other trenchless installation technique would be committed to operating within the limits assessed by the Dogger Bank Teesside A & B EIA . The procedures and equipment required for onshore HDD installation are similar to the landfall HDD installation.

Open Trench Cable Installation

Direct Burial in Agricultural Land

4.4.5. Where the route traverses agricultural land, cables will be laid directly into the ground via an open trench, unless an installation using ducts is chosen. Typical dimensions for an ordinary trench, capable of containing two cables, are given in **Table 4.5**. Each project would require a cable trench.

4.4.6. For arable land installation it is standard practice to install the cables at a sufficient depth, as shown in **Table 4.5**, to prevent damage from agricultural activities such as deep ploughing and drain excavation. Installation depths may vary in other locations, as determined during detailed design.

Table 4.5 Typical direct burial cable trench dimensions

Parameter	Quantity
Indicative overall trench depth (m)	1.5

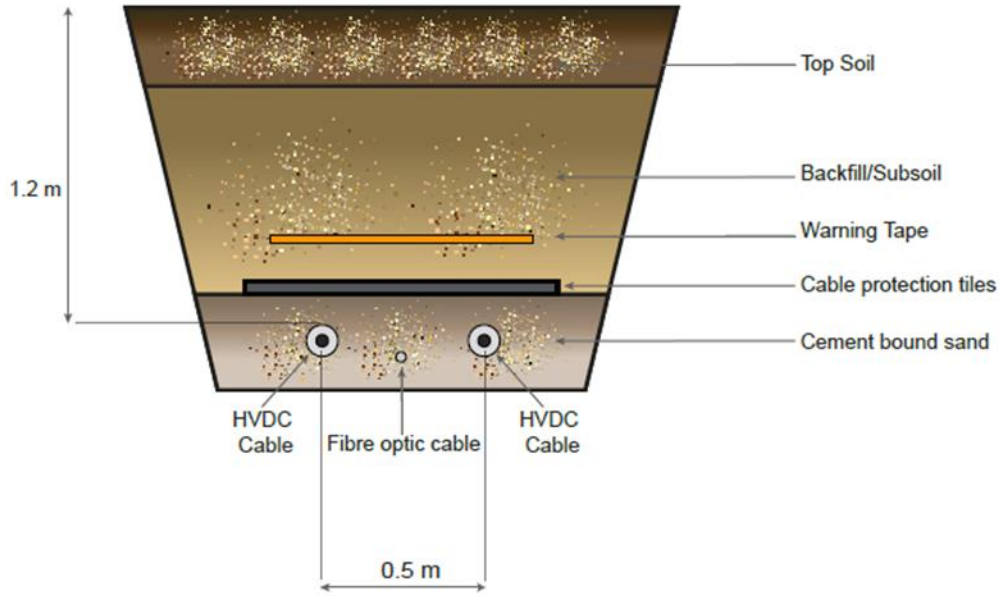
Indicative HVDC trench width (at base of trench) (m)	1.0
Indicative HVAC trench width (at base of trench) (m)	1.5
Typical minimum cable installation depth (arable land) (m)	1.2
Indicative warning tape depth (m)	0.8 to 0.9
Indicative thickness of trench top soil backfilled material (m)	0.2

4.4.7. The cable trench bottom must be smooth and rocks, boulders and any other item that may mechanically damage the cables are removed.

4.4.8. Power cable trenches will be backfilled with stabilised material, such as cement bound sand (CBS) to provide the layers surrounding the cables with a material with adequate thermal conductivity and drainage. The trench top layer will then be backfilled with native material and the original surface reinstated.

4.4.9. Warning tapes and protective tiles will be placed above the cables to clearly demarcate their location and reduce the risk of damage during future excavation works. A typical trench cross section is shown in **Figure 4.6**.

Figure 4.6 Indicative cross section of a direct burial trench



Direct Burial in Roads

4.4.10. Where the route follows the line of roads the cables may be installed directly into the road via an open trench or more usually installed in ducts placed in trenches in the road. Typical dimensions for an ordinary trench in a road, capable of containing two cables, are given in **Table 4.6**. Each project would require a cable trench.

Table 4.6 Typical direct burial cable trench dimensions in road

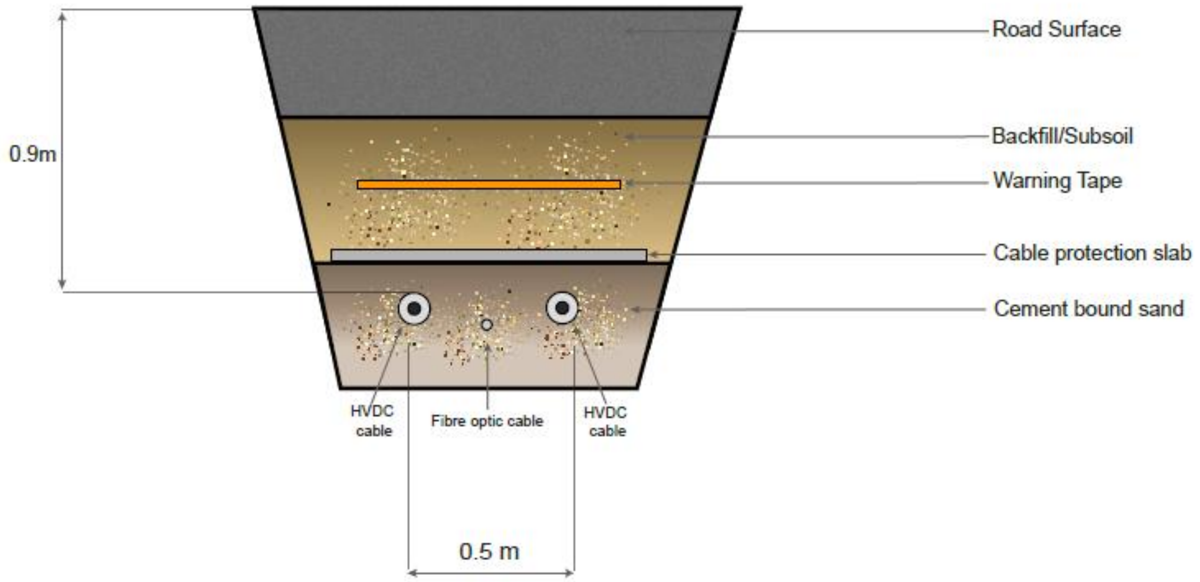
Parameter	Quantity
Indicative overall trench depth (m)	1.2
Indicative trench width (at base of trench) (m)	1.0
Typical minimum cable installation depth (road) (m)	0.9
Indicative warning tape depth (m)	0.5 to 0.6
Indicative thickness of finished road surface (m)	0.35

4.4.11. The cable trench bottom must be smooth and rocks, boulders and any other item that may mechanically damage the cables are removed.

4.4.12. Power cable trenches will be backfilled with stabilised material, such as cement bound sand (CBS) to provide the layers surrounding the cables with a material with adequate thermal conductivity and drainage. The trench top layer will then be backfilled with native material and the original surface reinstated.

4.4.13. Warning tapes and protective tiles will be placed above the cables to clearly demark their location and reduce the risk of damage during future excavation works. A typical trench cross section is shown in **Figure 4.7**.

Figure 4.7 Indicative cross section of a cable buried direct in road



Cable Installation Procedure

4.4.14. Following the setting out of the trench location lines, the area would be scanned with a Cable Avoidance Tool (CAT) to identify any services present. The CAT survey may be combined with hand excavation, where necessary. Once services have been located, they will be clearly demarcated at ground level. In certain areas, the presence of contaminated material may be encountered during the excavation works. These shall be dealt with as outlined in **Section 7.2 Waste Management**.

4.4.15. The contractor will use all the appropriate measures to prevent collapse of the trench side walls while the cable trenches remain open. This may comprise options such as shuttering of the trench side walls or installing temporary support. **Figure 4.8** shows an example of timber frame reinforcement. A clear separation distance will be provided between the edge of the cable trench and adjacent vehicles or stockpiles.

Figure 4.8 Example of close timbered trench

Courtesy Prysmian Cables and Systems

4.4.16. It is envisaged that the majority of the agricultural fields in which the cable route passes will contain land drainage systems. Archive drainage records have been made available for a localised area of the cable route and these indicate that the drains in these locations are set out at regular centres (circa 10m). The depth of the drains is unknown and is likely to vary between fields, however, it is expected that the drains will commonly be buried at an approximate depth of 1m, to avoid damage when the fields are ploughed. The drains may therefore need to be removed locally, to accommodate the trenches, and subsequently reinstated.

4.4.17. It may be necessary to drain the cable trenches during the excavation works and this will depend on the groundwater level, the volume of surface water run-off and also the amount of water flowing within any intersected/severed land drains. A suitable location for discharging water will be agreed by the contractor prior to commencing works, with all necessary licences and permits obtained, and pollution prevention measures in place. It is envisaged that the water will likely be pumped to drainage ditches in the vicinity of the works; however, this will be subject to achieving an acceptable standard of water quality and sedimentation level. Settlement lagoons may be required, and it is anticipated that these lagoons, where required, will be able to fit within the 36m and 39m route widths as applicable

4.4.18. The likely items of plant and equipment that would be used for this element of the works are presented in **Table 4.7**.

Table 4.7 Plant and Vehicles indicatively required for trench excavation

Likely items of plant/vehicles to be used for activity	Specific Use
Personnel Vehicles	Site staff arriving / leaving site
CAT scanner	Scanning for buried services
360^0 Tracked/wheeled excavators	Excavating trenches and stockpiling materials
Dumper (5t)	Distributing subsoil
Water pumps	Draining water from within cable trenches
Generators	Power for water pumps
Wheel wash	Cleaning outgoing vehicles
Road sweeper	Cleaning local roads

Ducted Cable Installation

4.4.19. For sections of the cable route, such as roads, the cables may be installed using ducts. Ducts can increase the cable mechanical protection and provide greater installation flexibility. Furthermore, ducts are always used for HDD installation, and commonly used when crossing culverts.

4.4.20. The use of ducts for increased installation flexibility will be dependent on the construction scenario used, as described in **Section 6.3 Construction**, and whether enabling actions are being undertaken for the second project.

4.4.21. In order to reduce the footprint and length of time required for cable installation, ducts and all associated civil works, could be installed prior to the installation of the cables, which will be pulled through the pre-installed ducts at a later stage. However, cable ducting increases the thermal resistivity, therefore reducing the cable actual rating. CBS or another stabilised material can be used in duct installation in order to increase the rate of heat dissipation and increase the cable rating. Shown in **Figure 4.7** and **Figure 4.8** are indicative cross sections for ducted cable installation under arable land and roads respectively.

Figure 4.9 Indicative cross section of ducted trench installation

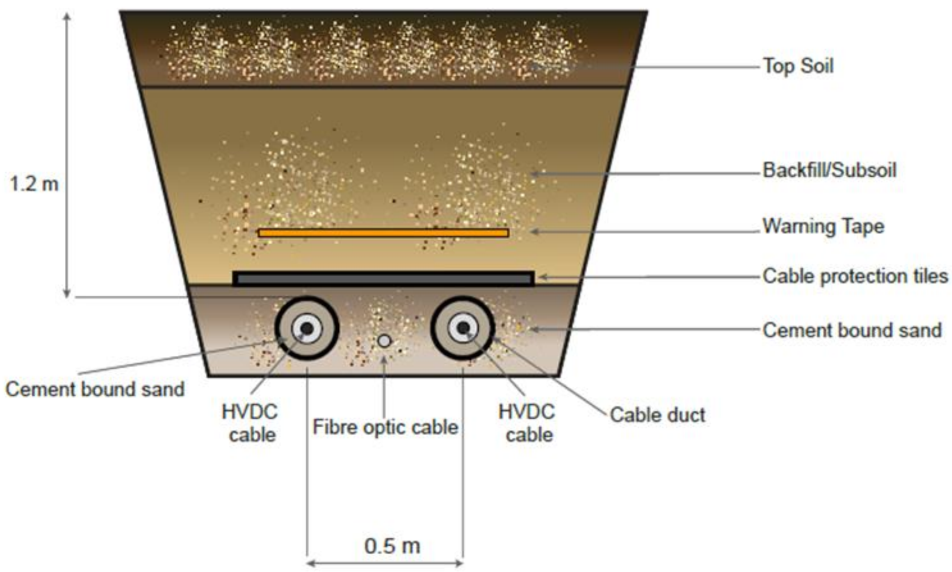
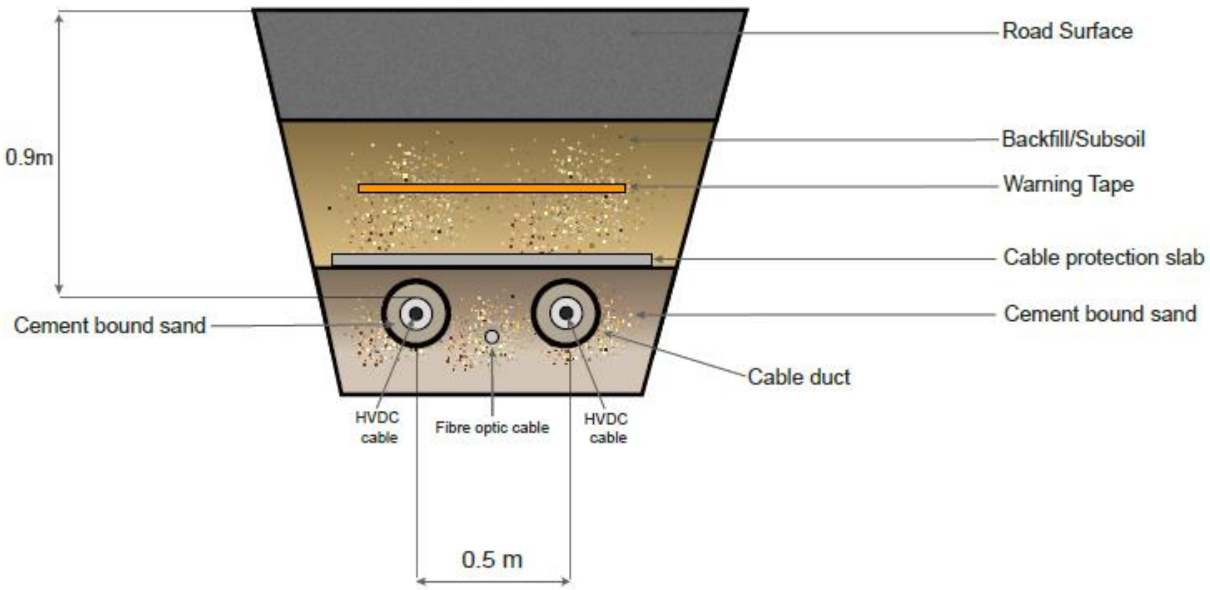


Figure 4.10 Indicative cross section of ducted trench installation in road



4.4.22. Where the cable route crosses roads and some watercourses and utilities, ducting is often the preferred method of installation in order to decrease the disruption to these features during construction and for maintenance during the operational phase.

4.4.23. The cable trench excavation will be checked for line and level by the contractor's engineers/foreman. Once satisfied, the base of the cable trench will receive a layer of CBS or subsoil. The use of CBS will be dependent upon the subsoil's thermal resistivity properties. This will be tested along the length of the cable route to assess suitability as part of the ground investigation. It is envisaged that the requirements for CBS will vary along the length of the cable route.

4.4.24. If ducts are installed, two ducts and a small fibre optic duct for the HVDC cables, and three ducts and a small fibre optic cable for the HVAC cables are expected to be laid in each trench.

4.4.25. The cable ducts will be delivered to site on a low loader with HIAB and will be distributed to the trench locations using a dumper. The ducts are typically supplied in 6m lengths and are typically jointed using push-fit systems.

4.4.26. Once the ducts are in place, the trench will be backfilled with CBS or subsoil (where soil properties permit). The backfill will be installed to a level around 100mm above the top of the duct. Once the backfill is levelled, protective cable tiles and warning marker tape will be put in place.

4.4.27. In the case of agricultural land the reinstatement of the cable trench above the marker tape (up to topsoil level) will utilise the subsoil that was previously excavated from the trench.

4.4.28. Excess subsoil spoil (not topsoil) will be removed from site in a tipper wagon to an appropriately certified disposal site. The material will be deposited in the wagon using an excavator.

4.4.29. In areas where existing land drainage pipes have had to be severed to accommodate the cable trenches, the pipework will be made good in accordance with the land drainage specialist's drawings.

4.4.30. For installation in roads the reinstatement of the roads will be to the Highway Authority standards and will normally comprise a tarmacadam finish. Excess spoil will be removed from site in a tipper wagon to an appropriately certified disposal site.

4.4.31. Ducted installation is often employed when crossing culverts. A culvert is a drain or pipe, for instance spanning a small watercourse or ditch, which allows water to flow. Where culverts are already installed the cables will often be laid in ducts across the culvert and the top reinstated to allow continuation of the haul road. It may be required to install a new culvert across a watercourse instead of a bridge in which case a precast concrete pipe would typically be installed in the watercourse, and cable ducts and road installed on top. An example of a culvert is shown in **Figure 4.11**.

Figure 4.11 An example of a typical culvert

Courtesy of LMNO Engineering, Research and Software Ltd.

Table 4.8 Plant and Vehicles indicatively required for installation of ducts

Likely items of plant/vehicles to be used for activity	Specific Use
Personnel Vehicles	Site staff arriving / leaving site
Low loader / HIAB wagon	Delivery of ducts
360^{0} Tracked excavators	Trench backfilling
Dumper (5t)	Distributing ducts, pipes, warning tiles, marker tape
Eight wheel Tipper wagon	Disposal of surplus material
Wheel wash	Cleaning outgoing vehicles
Road sweeper	Cleaning local roads

Horizontal Directional Drilling

4.4.32. Horizontal Directional Drilling, HDD, is a steerable trenchless method of installing underground pipes, ducts and cables in a shallow arc along a prescribed bore path by using a surface launched drilling rig. HDD is a well-established method for cable installation where the more conventional trench installation is either unfeasible, or undesirable for environmental reasons.

4.4.33. Pipe diameters which can be installed range from approximately 50mm to 1,000mm. For HV cable installations using HDD, it is normal to install ducts of multiples of the cable diameter to be pulled through the pipe or duct. This could result in bore diameters up to around 450 to 600mm, although smaller diameters could be possible, depending on the cable external diameter and length of duct.

4.4.34. The typical activities required by an HDD operation are summarised below:

- Site survey and bore planning;
- Preparation of site for HDD operation;
- HDD Drilling operation;
- Demobilisation from site.

4.4.35. Prior to the commencement of HDD operations a site survey will be conducted. A survey team will attend the site and map out the bore paths. Borehole surveys may be undertaken to establish structural conditions for the drill path. The survey team will create an accurate plan and elevations of the proposed duct route. During the survey any buried services which are in close proximity to the route will be clearly marked and documented on the survey drawings and where possible also on site.

4.4.36. A bore plan and profile will be created from the results of the survey. The plan will provide final information on the proposed bore arc including entrance and exit points, radius of curvature and the bore diameter required to accommodate the duct. The plan will be used to determine the actual length of the bore. Information on all buried services close to the bore path will also be contained within the bore plan and, where necessary, the bore plan will be amended to avoid these services.

4.4.37. The likely items of plant and equipment that be used for this survey element of the works are outlined in **Table 4.9**.

Table 4.9 Plant and vehicles indicatively required for site survey and bore planning

Likely items of plant/vehicles to be used for activity	Specific Use
Personnel Vehicles	Site manager and assistants
Transport vehicle and Percussion/rotary core borehole rig on trailer	Transport and drilling staff.

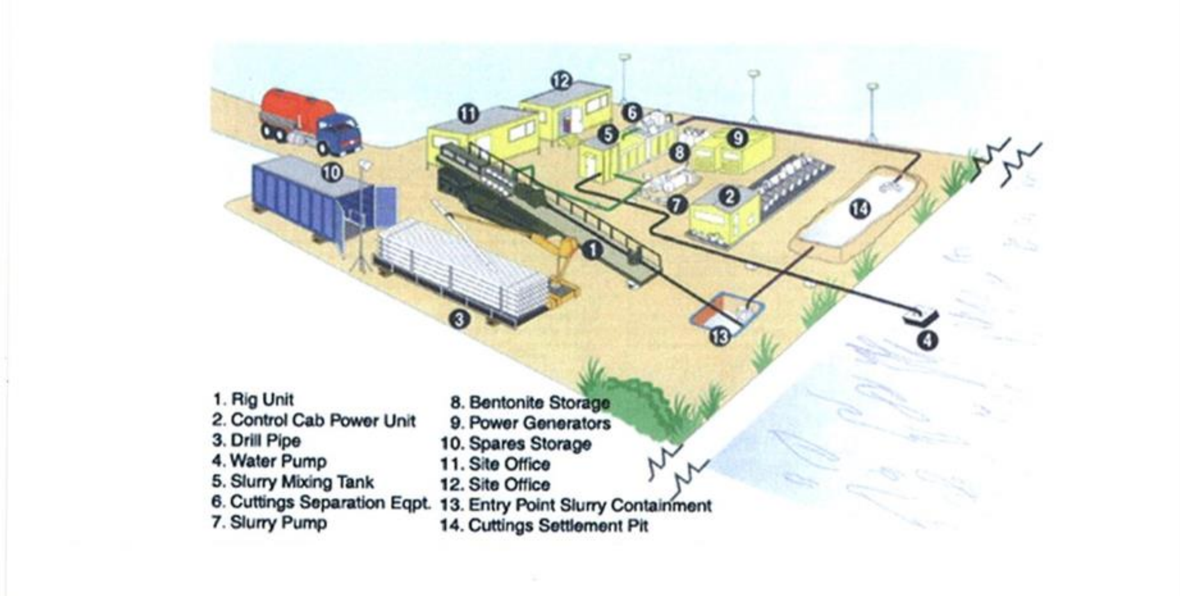
Preparation of Site for HDD Operation

4.4.38. The surveyors will set out the launch and reception pits to be used for the HDD operations. The dimensions and location of the launch and reception pits are carefully planned.

4.4.39. A suitable access road and working platform at the launch and reception sites are constructed to allow the set-up of the drilling equipment and easy access by support vehicles. The requirements of both the launch site, where the drills are launched into the ground, and the reception sites where the drills exit the ground, are outlined below.

Launch Site

Figure 4.12 Typical arrangement of a major HDD launch site



Courtesy of Rambøll

4.4.40. For the launch pit a rectangular area would be prepared, sized to suit the scale of the HDD operation being undertaken.

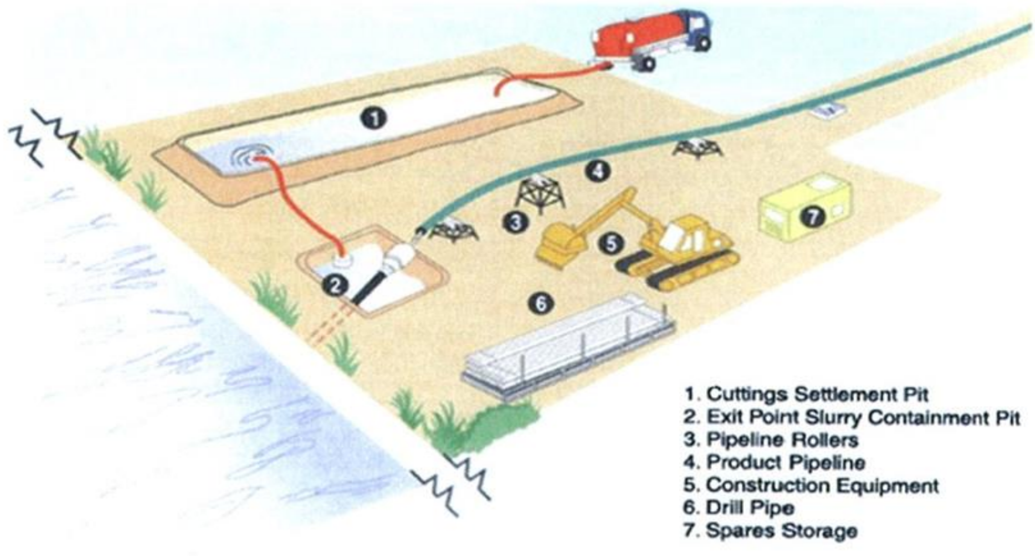
4.4.41. Access to the site would be via an access road designed to accommodate heavily loaded vehicles and heavy plant. Generally this will be the access road installed alongside the trench for the majority of the route, and including watercourse crossings via temporary vehicle bridges or similar.

4.4.42. A regular supply of fresh water will be required on site at all times either via a reliable pumped source or frequent water tankers. If a continuous supply of water cannot be provided then storage tanks may be required on site for water and adequate space may be required for these.

4.4.43. Storage of slurry in a settling pond or disposal of excess slurry from site may be required. Therefore, a pit/settling pond will be excavated at the launch site to contain the slurry arisings from the HDD bore. This excavation pit/settling pond must have a sufficient capacity to accommodate the drill arisings/slurry from the HDD operation being undertaken. Tankers may be required during the operation to control the levels of slurry and where necessary remove the slurry from the working area. **Figure 4.12** shows the arrangement of a typical HDD launch site.

Reception Site

Figure 4.13 Typical arrangement of major HDD reception site



Courtesy of Rambøll

4.4.44. For an onshore reception pit, a site access and working platform would be constructed in a similar manner to the launch area. A slurry pit/settling pond would also be required to collect any slurry discharged from the drill hole. **Figure 4.13** shows the arrangement of a typical HDD reception pit site.

4.4.45. The likely items of plant and equipment to be used for setting out the launch and receive pits are outlined in **Table 4.10**.

Table 4.10 Plant and vehicles indicatively required for setting out pits

Likely items of plant/vehicles to be used for activity	Specific Use
Personnel Vehicles	Site staff arriving / leaving site
Low loader / HIAB wagon	Delivery of geotextiles/geogrid/pipes for access and working area hardstanding construction
Eight wheel Tipper wagon	Delivery of hardcore for hardstanding construction / removal of slurry pit material from working area.
360^{0} Tracked/wheeled excavators	Distributing hardcore material and topsoil strip/excavation of slurry pits
Bulldozer	Distributing hardcore material and topsoil strip

Roller	Compacting hardcore
Dumper (5t)	Distributing ancillary items

4.4.46. Surface space requirements during operation need to be sufficient to allow access by tankers to remove liquid slurry. Little working area is required for the drilling rig itself during operation; however storage for materials and equipment will be necessary. Should additives need to be introduced to the bore then area for a batching plant will be required. Likewise, should recycling of the waste slurry be required then an area should also be allowed for a recycling plant and/or a settlement lagoon. A suitable working area will need to be allowed for excavators to remove slurry from the ground surface.

4.4.47. At the receiving trench, working space will be required to construct the proposed receiving duct. This needs to be constructed prior to the HDD operation commencing.

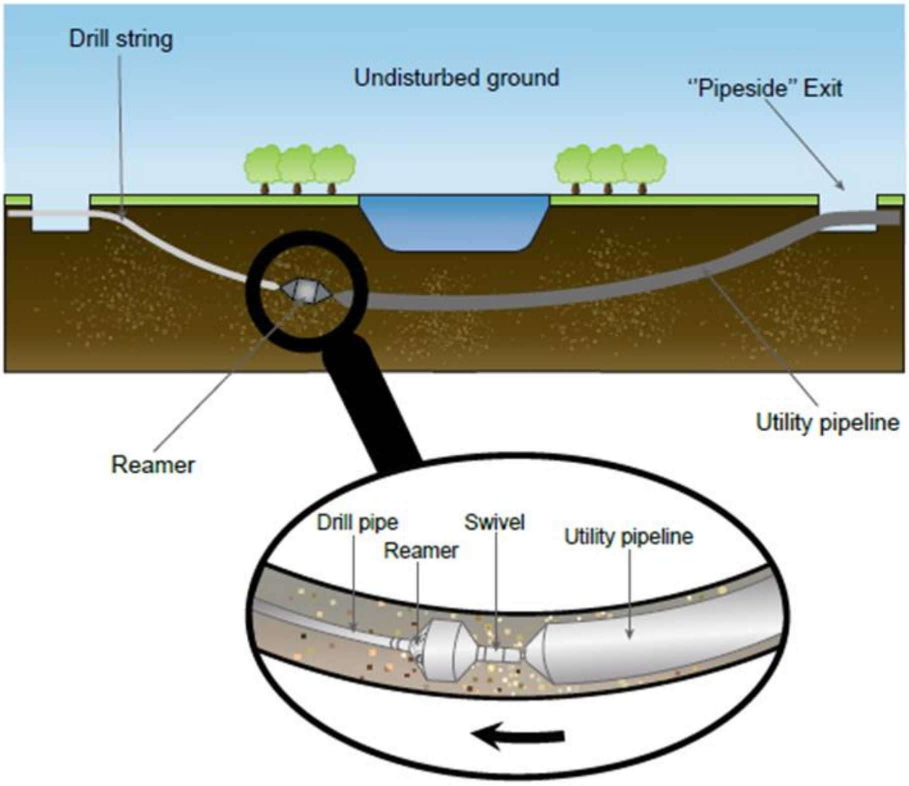
HDD Drilling operation

4.4.48. Prior to drilling, the HDD rig will be elevated to the correct entry angle which will conform to the angle on the bore plan. Once the correct angle is achieved the rig will be anchored into position.

4.4.49. The HDD rig will first undertake a pilot bore using the drill head and involving the injection of drilling fluid. The bore is then carried out in intervals which will be determined by the contractor based on the specific HDD rig in use and the length of the bore to be installed.

4.4.50. The depth and direction of the pilot bore will be closely monitored by the operator to ensure that the bore follows the prescribed bore path. At each drill interval a locator operator will keep the drill operator informed of the location, pitch and roll of the drill head. If there is a major divergence from the drill path, the operator will draw back the drill head to the point where the correct path was lost and re-drill in the correct direction.

Figure 4.14 Illustrative visualisation of an HDD Installation



4.4.51. When the pilot bore emerges from the ground in the reception pit, the drill head is removed and a reaming bit will be attached to the drill string. The reamer will be pulled back through the pilot hole, widening the bore. Dependent on the size of duct to be installed, several passes with the reamer may be necessary to gradually widen the bore. The reamed hole is pumped with drilling fluid down the stem of the drill string during reaming to maintain the integrity of the bore and prevent significant settlement or collapse.

4.4.52. When the bore hole has been reamed out to the correct diameter the back reamer is passed through the bore once or twice again to ensure that the hole is clear of any large objects and that the slurry in the hole is well mixed.

4.4.53. Prior to its installation in the hole, the duct itself must be constructed in a single length at the same length or longer than the bore and where necessary, hydrostatically tested.

4.4.54. When the driller is satisfied that the bore is ready for the duct installation a pull head is attached to the drill string at the reception pit via a swivel to prevent rotation of the duct. The duct is then attached to the pull head.

4.4.55. The duct is then pulled back through the bore toward the launch area by the drill rig. Once installed the cable can be pulled through the constructed duct. **Figure 4.14** provides a visualisation of the HDD drilling operation.

4.4.56. The likely items of plant and equipment that are required for this element of the works are listed in **Table 4.11**.

Table 4.11 Plant and vehicles indicatively required for HDD operations

Likely items of plant/vehicles to be used for activity	Specific Use
Personnel Vehicles	Site staff arriving / leaving site
HDD drilling rig	Progression of the HDD bore
Heavy Goods Vehicle (HGV) Low loader	Delivery of cable drums/ Delivery of duct work / Delivery of HDD rig
Mobile crane	Lifting cable drums
360^0 Tracked excavators	Construction of drilling launch and reception pits/Removal of excess drill arisings tidying work area
Slurry tanker	Removal of arising generated by HDD bore
Water Tankers	Provide water to progress the HDD bore
Eight wheel Tipper wagon	Importation of materials for access roads and working platforms and the disposal of surplus solid material
Tractor & cable drum trailer	Moving cable drums
Forklift	Cable drums lifting
Sludge handling plant;	Excavation results treatment
Diesel generator	Providing power
Excavator/back actor	Earthworks

4.4.57. The working area and plant requirements associated with each specific HDD operation are linked to the size and length of the HDD bore being undertaken. The HDD size depends on the features of the crossing and different HDD rigs could be used for different obstacles. These details should be discussed at the detailed design stage with the HDD contractor as early as possible, to determine their requirements

4.4.58. It is estimated that seven HDDs sections will be required, resulting in an overall length of around 2km. The longest potential HDD section is estimated to be around 500m although a typical HDD is expected to be in the order of 150-200m.

4.4.59. Staffing requirements will also depend on the size and length of the HDD and are estimated to be 5 – 10 people at the launch site and 2 - 5 people at the receiving pit.

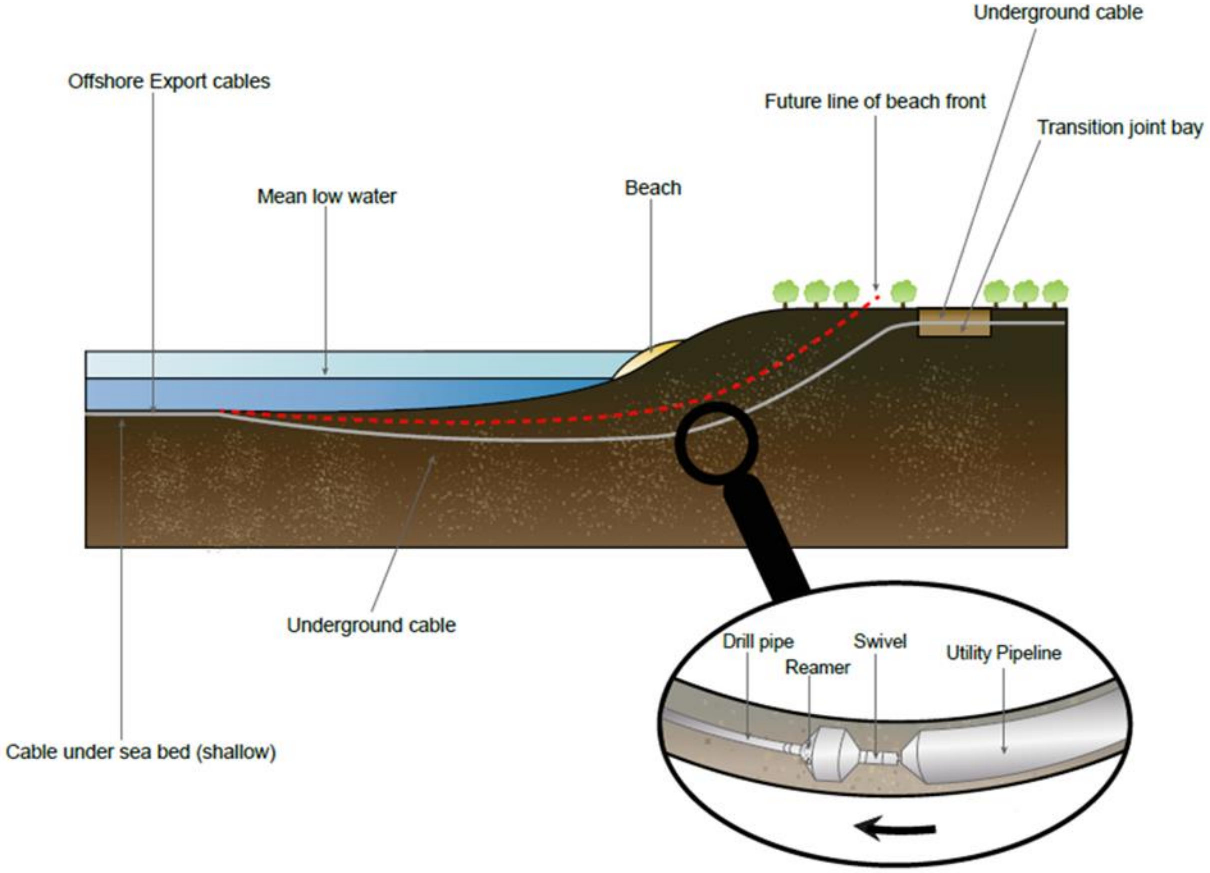
Landfall HDD

4.4.60. Where HDD is being used for a landfall cable system, HDDs are expected to be drilled from the launch pit to exit points in the sea bed. A reception pit would not be expected to be used as the HDD exit point is typically in the sub-tidal zone, although in some circumstances the exit point may be in the inter-tidal zone, or beach.

4.4.61. A typical cable landfall HDD installation involves drilling a pilot hole from behind the low lying cliff face at the shoreline down to the sub-tidal zone, reaming (to make the hole bigger), pulling a conduit pipe through the reamed hole, then pulling the landfall cable through the conduit. A separate HDD will be required for each export cable.

4.4.62. **Figure 4.15** shows a schematic representation of an HDD which is long enough to reach the sub-tidal zone also taking into account coastal erosion.

Figure 4.15 Schematic Diagram to show a typical HDD through an eroding coastline



HDD Demobilisation

4.4.63. All the HDD working platforms will be removed and reinstated to a similar condition as prior to the works.

4.4.64. The likely items of plant and equipment that will be used for this element of the works are outlined in **Table 4.12**.

Table 4.12 Plant and Vehicles indicatively required for removal of HDD Sites

Likely items of plant/vehicles to be used for activity	Specific Use
Personnel Vehicles	Site staff arriving / leaving site
HGV Low loader	Removal of plant and equipment
Mobile crane	Lifting surplus cable drums
360^0 Tracked excavators	Reinstating working areas/ Clearance of surplus spoil / removal of hardstanding / redistribution of removed topsoil and subsoil.
Eight wheel Tipper wagon	Disposal of surplus material / transportation of re-useable material to designated locations

4.5. Onshore Construction

Cable Construction Works Areas and Site Compounds

4.5.1. The contractor responsible for the installation of the onshore cable systems will establish temporary construction compounds for the location of offices, storage areas, welfare facilities and lay-down areas at several points along the route.

4.5.2. It is intended that there will be two cable construction compound types (in addition to the converter station construction compound) and these are categorised as primary and intermediate compounds, which will be strategically placed along the route. On the basis that each circuit will be installed by its own contractor, the compound areas and traffic numbers presented are considered a reasonable estimate for each contractor's requirements, i.e. when considering parallel concurrent working each contractor would require their own compound areas and would generate their own traffic movements.

4.5.3. The larger primary compounds will form the main construction compounds in which the site based construction team will be located. The primary compounds will where possible be positioned adjacent to the public highway to allow for ease of access for material deliveries and site based personnel. To accommodate a phased approach to the installation of the cabling, it is envisaged that there will be one primary compound and three intermediate compounds per project (in addition to the converter station construction compound).

4.5.4. The smaller intermediate compounds will be located approximately every 1 to 2km along the cable route to provide localised office provision, welfare facilities, provisional machinery parking and material/debris storage for each circuit. **Table 4.13** reports the indicative areas for the two compound types.

4.5.5. For sections of the onshore cable route that require HDD activities, as described in **Section 4.4 Cable Installation**, there shall be a requirement for launch and reception sites for the HDD unit. Similarly to the cable construction compounds the HDD sites can be divided into two size categories, larger major compounds and smaller minor compounds. The size of HDD compounds is dependent on the amount of equipment which is required, which is in turn primarily governed by the distance that the HDD must travel. It is estimated that the number of major and minor HDD compounds that will be required is about equal.

Table 4.13 Indicative cable construction and HDD compound sizes

Parameter	Indicative areas (Single project)
Primary construction compounds area (m^2)	5000
Intermediate compounds area (m^2)	784
Major HDD compound area (m^2)	2000
Minor HDD compound area (m^2)	1200

4.5.6. For compounds located adjacent to the public highway, the access arrangements into the site will be designed by a highways engineer to ensure appropriate sight lines, turning radii, including swept path analysis where necessary. Highways engineers will also provide for adequate signage, lighting and traffic management.

4.5.7. The cable construction compounds will be provided with suitable hardcore surfacing. Typically this would be constructed from stone in a similar way to the haul roads for the main cable laying activities. The compound will be surrounded by security fencing and provided with lockable gates to control access to the compound. Where necessary, suitable site drainage will be provided to deal with surface water run-off from the compound.

4.5.8. For both practicality and health and safety reasons it is envisaged that both primary and intermediate cable compounds will be lit during the works. The lighting will be switched off during periods where the natural lighting levels are adequate. It is envisaged that the lighting will be left on overnight for security purposes. Any compound lighting will be designed to minimise light spillage.

4.5.9. The cable construction compounds will indicatively contain the following elements:

- Site offices;
- Welfare facilities;
- A compound for storage of items like cable drums, ducting and other construction materials (primary compound only);
- General storage area;
- Car parking area;
- Plant storage area – Note: it is assumed that items of plant will be removed from site when they require major maintenance work to be undertaken;
- Storage containers;
- Waste management area; and
- A compound with bunded generator and fuel storage.

4.5.10. Indicative cable compound layout plans are provided for the primary and intermediate compounds in **Figure 4.16** and **Figure 4.17** respectively.

Figure 4.16 Indicative arrangement of a typical primary site compound

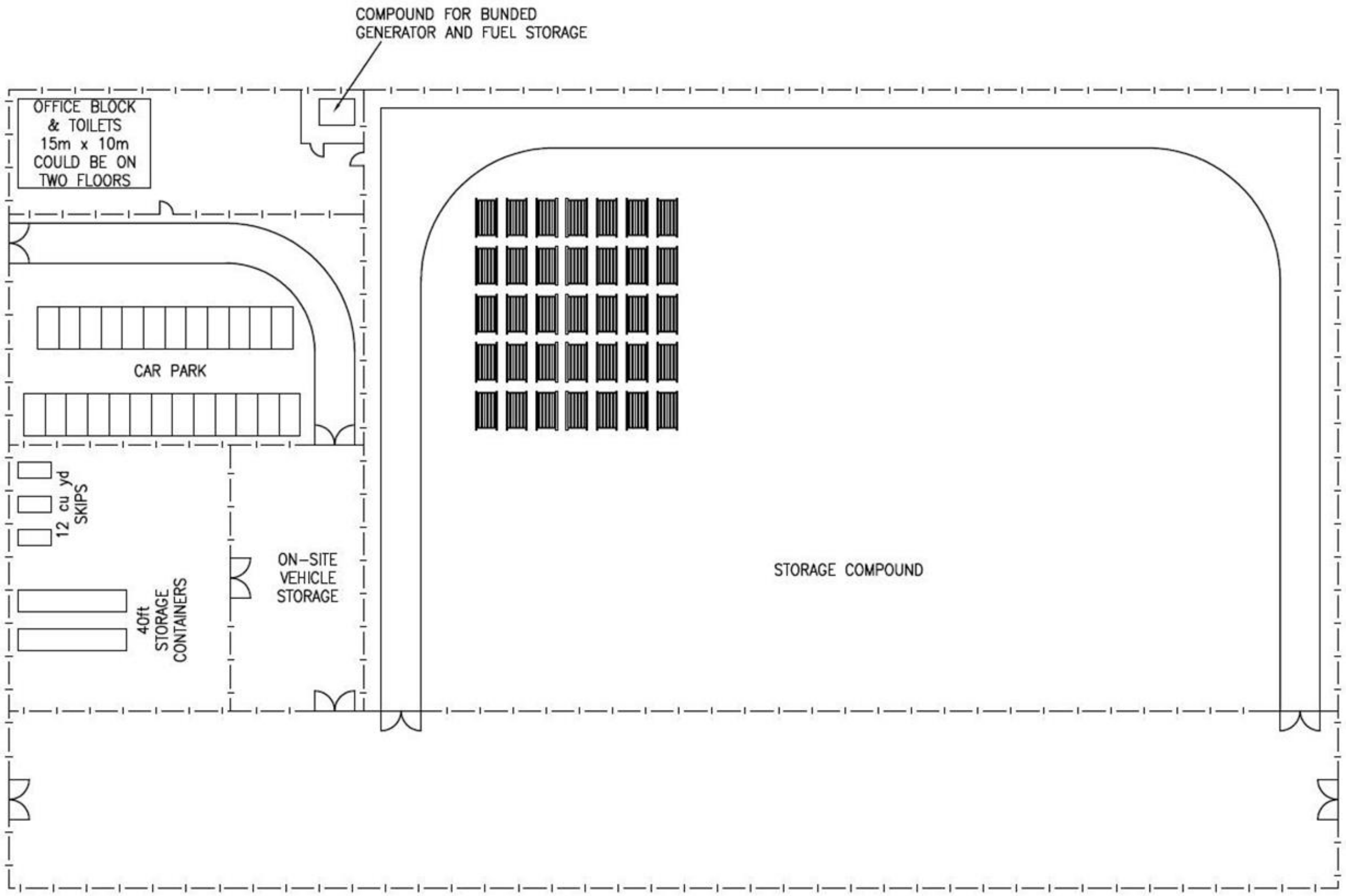
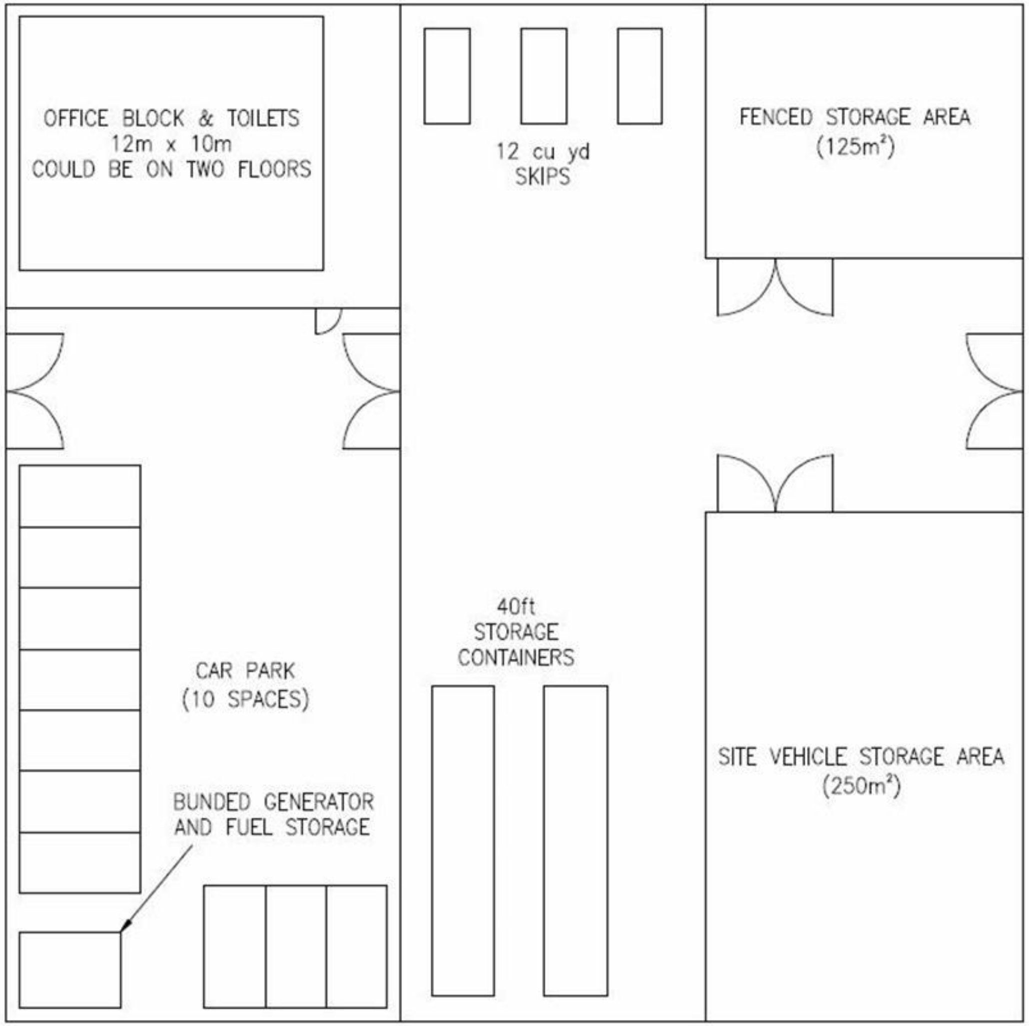


Figure 4.17 Indicative arrangement of a typical intermediate site compound



Setting Out of Works and Erection of Fencing

4.5.11. Prior to commencing works, the boundary of the cable route will be set out by a survey team. The surveyors will walk the course of the cable route, marking out the boundary of the cable route at regular intervals by knocking in wooden stakes.

4.5.12. The cable route will be fenced off to segregate the construction activities from the adjacent parcels of land and clearly define the extent of the works.

4.5.13. It is envisaged that the landowners and occupiers may request designated crossing points across the cable route to facilitate access to the surrounding parcels of land. This will be determined through consultation with the landowner and measures will be put in place to facilitate this.

4.5.14. The likely items of plant and equipment that would be used for this phase of the works are presented in **Table 4.14**.

Table 4.14 Plant and vehicles indicatively required for setting out and fencing

Likely plant/vehicles to be used for activity	Requirement
Personnel Vehicles	Site staff arriving / leaving site
Surveying Equipment	Setting out of cable trench
Tractor and trailer	Delivery of timber stakes / fencing materials
Low loader / HIAB wagon	Delivery of timber stakes and fencing components to compound locations
Tractor with post driver & auger equipment	Fencing installation

Haul Road Construction & Topsoil Strip

4.5.15. It is assumed that the haul road construction will require imported material over a significant portion of the cable route. This takes account of the alluvial subsoil that characterises most of the onshore route and includes an allowance for localised areas of poor ground conditions. The exact requirements for the haul road will be related to a number of factors, which will include:

- Subgrade materials;
- Nature and frequency of construction traffic;
- Weather conditions.

4.5.16. The haul road will typically comprise imported granular material with geogrid reinforcement layers and geotextile separation layers, as required. Where possible, the materials for the haul road will be recycled and/or sourced from local providers.

4.5.17. For the purposes of this method statement, it is assumed that the haul road will be indicatively 350mm thick. This figure is provided as a guide only and may change depending on the local conditions.

4.5.18. It is assumed that the imported material will typically be brought to site in eight-wheeled tipper wagons, with the material deposited at the required locations. Once deposited, the material will be spread using an excavator and bulldozer, and compacted using a roller. The latter could be either self-propelled or towed by the bulldozer.

4.5.19. To provide a continuous access route along the length of the cable route, it will be necessary to install temporary crossing points, typically temporary vehicle bridges, where the cable route intersects existing ditches and small to medium watercourses. The use of temporary vehicle bridges at these locations will minimise disturbance to both the watercourse channel and the top of the watercourse banks, thus reducing ecological impacts. Where necessary additional consent shall be sought from the Environmental Agency for the use of temporary crossing points.

4.5.20. Temporary vehicle bridges vary in size depending on the width of watercourse to be crossed. Typical lengths are 6, 8 or 13 m long. They are quick to install and arrive on an articulated lorry. When installed typical widths are 3 to 4m. An example of a temporary vehicle bridge is shown in **Figure 4.18**.

Figure 4.18 Example of a temporary vehicle bridge

Courtesy of Mitchell Bridges Limited

4.5.21. Settlement lagoons are expected to be required prior to discharge of surface water into the watercourses along the route, to ensure that excess silt is not discharged from the site. Given that the construction works are of short duration, and that the haul road itself will have a degree of permeability, these are anticipated to be temporary in nature and would only need to accommodate small return period storms. These would be located prior to any watercourse into which discharge is proposed, and would be sized based on the length of haul road and area of compounds that are being served. In some cases such as sections of the route where space is limited alternative silt management measures may be more appropriate. It is anticipated that these lagoons, where required, will be able to fit within the width 36 or 39m of the cable route described in **Section 4.3 Onshore Cable Routes**. It is assumed that topsoil and subsoil storage areas can be locally adjusted to accommodate the lagoons. The topsoil strip will be undertaken as part of the haul road preparation using tracked excavators, dumpers and dozers. The topsoil will not be stripped from beneath the topsoil storage areas.

4.5.22. During the preparation phase of the works, appropriate protection measures will be put in place where overhead lines cross the cable route. The protection measures will be in accordance with the Health & Safety Executive Guidance Note GS6 ‘Avoidance of danger from overhead electric power lines’.

4.5.23. Furthermore, as part of the preparation phase, it will be necessary to remove hedgerows/trees from within the cable route. There may be ecological requirements that need to be addressed in association with this process and these will be incorporated into the working method. See **Chapter 25 Terrestrial Ecology** for further discussion.

4.5.24. To control dust during the summer months, it may be necessary to dampen down the subsoil haul roads. This would be carried out using a water bowser. Further discussion of dust control methods can be found within **Chapter 30 Air Quality** and **Chapter 23 Tourism and Recreation**.

4.5.25. Where the cable route intersects with a public right of way (PRoW), it will be necessary to apply for either a temporary closure, use of traffic management, or diversion through Redcar and Cleveland Borough Council. Diversions and closure works will need to be placed prior to construction works commencing.

4.5.26. Mud and debris affecting local highways will be controlled by means of a wheel wash and/or road sweeper. See also **Chapter 23 Tourism and Recreation** for further details.

4.5.27. The likely items of plant and equipment that would be used for this element of the works are presented in **Table 4.15**.

Table 4.15 Plant and vehicles indicatively required for haul road construction and top-soil strip

Likely items of plant/vehicles to be used for activity	Specific Use
Personnel Vehicles	Site staff arriving / leaving site
Low loader / HIAB wagon	Delivery of geotextiles/geogrid/pipes for haul road construction

Eight wheel Tipper wagon	Delivery of hardcore for haul road construction
360° Tracked/wheeled excavators	Distributing hardcore material and topsoil strip
Bulldozer	Distributing hardcore material and topsoil strip
Roller	Compacting haul road
Dumper (5t)	Distributing ancillary items
Wheel wash	Cleaning outgoing vehicles
Road sweeper	Cleaning local roads

Cable Delivery, Storage and Installation

4.5.28. The cable drums, similar to the one shown in **Figure 4.19**, will be initially delivered to the primary or intermediate compound locations on a HGV low loader and will be lifted off the low loader and deposited within the cable storage area, using a mobile crane.

4.5.29. From the laydown areas of the construction compounds the cable drums will be brought to the joint bay locations. Individual cable drums will be lifted onto a cable drum trailer which will be towed by a tractor unit to the intended joint bay. A cable winch will be set up at the following joint bay position.

4.5.30. The joint bay will be located along the route at intervals compatible with the cable section length. Where present the duct ends will be exposed within the joint-bays.

4.5.31. The joint bays are expected to be approximately 10m long x 4m wide and will require temporary earthwork support, in a similar fashion to the trenches. The joint bays will require a concrete base with drainage canals and will need to be kept free of water and debris during the cable installation works.

Figure 4.19 Example of a cable drum delivery to cable storage area

Courtesy of Scira Offshore Energy

4.5.32. A bond (for instance, a rope or cable) will be blown through the ducts using compressed air and will be connected to the cable winch. The bond will be attached to the nose of the cable and the cable will be pulled through the duct using the winch and powered drum trailer. Once pulled to the correct location, the bond will be cut.

4.5.33. Once adjacent cables lengths are in place, the cables will be jointed together and an appropriate airtight casing applied. A layer of CBS will placed around the jointed cables, similar to the main duct runs. Shown in **Figure 4.20** is an example of CBS delivery.

Figure 4.20 Example of a cement bound sand delivery

Courtesy of Prysmian Cables and Systems

4.5.34. On completion of the cable installation and jointing, the joint pits and trenches will be reinstated using the excavated soil.

4.5.35. Although future access to the joint bays may be needed for repairs, it is not envisaged that regular maintenance will be required and hence the joint pits will not require any inspection chambers or access covers.

4.5.36. The likely items of plant and equipment that would be used for this element of the works are presented in **Table 4.16**.

Table 4.16 Plant and vehicles indicatively required for cable delivery, storage and installation works

Likely items of plant/vehicles to be used for activity	Specific Use
Personnel Vehicles	Site staff arriving / leaving site
HGV Low loader	Delivery of cable drums
Mobile crane	Lifting cable drums
360^0 Tracked excavators	Excavating and reinstating joint bay pits
Eight wheel Tipper wagon	Disposal of surplus material
Concrete wagon	Importing concrete for joint bay bases
Tractor & cable drum trailer	Moving cable drums, installing cables
Cable winch	Cable pulling
Wheel wash	Cleaning outgoing vehicles
Road sweeper	Cleaning local roads

Demobilisation from Site

4.5.37. On completion of the works, it will be necessary for the contractor to reinstate the cable route to an acceptable standard. It is envisaged that this will comprise the following activities:

- Removal and disposal of construction haul road, as appropriate;
- Removal and disposal of temporary crossing facilities;
- Removal and disposal of temporary drain/watercourse crossings;
- Appropriate disposal of waste materials
- Reinstatement of drainage systems (where existing);
- Reinstatement of stored topsoil;

- Re-seeding of topsoil (where necessary);
- Reinstatement of hedgerows and vegetation removed to accommodate the work;
- Removal of boundary fencing.

4.5.38. The likely items of plant and equipment that would be used for this element of the works are presented in **Table 4.17**.

Table 4.17 Plant and vehicles indicatively required for site demobilisation works

Likely items of plant/vehicles to be used for activity	Specific Use
Personnel Vehicles	Site staff arriving / leaving site
360^{0} Tracked excavators	Removal of hardcore, moving topsoil
Eight wheel Tipper wagon	Removal of hardcore used for haul road construction
Dozer	Distributing hardcore material and topsoil strip
Tractor	Ripping of topsoil
Wheel wash	Cleaning outgoing vehicles
Road sweeper	Cleaning local roads

4.5.39. Once all the above activities are completed it is expected that the vegetation will return after a reasonable time to a state as prior to the construction activities. **Figure 4.21** shows a typical HV cable route after topsoil reinstatement (left) and the same location 18 months after (right).

Figure 4.21 Example of cable installation swathe after topsoil reinstatement

Courtesy of Prysmian Cables and Systems

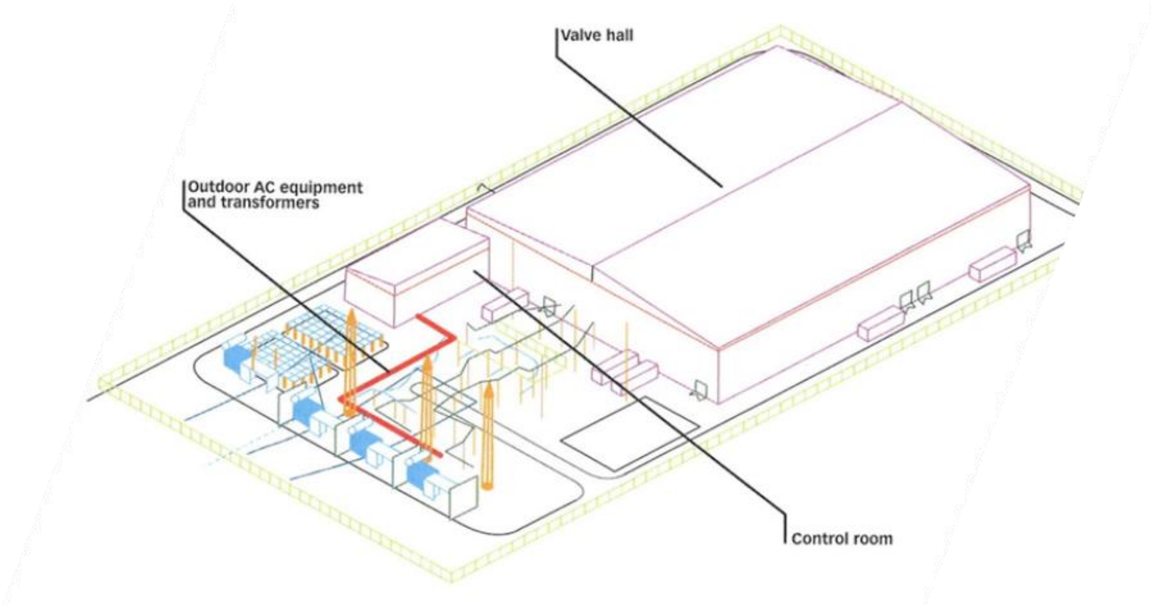
4.6. Onshore Converter Station

4.6.1. Two converter stations will be built, one for each of the Dogger Bank Teesside A & B projects. Each converter station will be rated at up to around 1,000MW nominal power.

4.6.2. The two converter stations will be built on industrial land contained within the Wilton Industrial Complex located to the south-west of Redcar. The location of the converter stations is discussed in more detail in **Section 2.1 Site Location**.

Converter Station Details

Figure 4.22 Typical converter station layout



Courtesy of Siemens

4.6.3. Access to the site for construction traffic will be via the existing road network within the Wilton Industrial Complex. This will be closed once the site is operational and only opened to allow access to heavy loads if large equipment has to be replaced. This should be a very infrequent requirement and in the operational phase of the substation, traffic will access and egress the site via local roads.

4.6.4. Each converter station will include:

- A valve hall, which is a large building that houses electronic devices that convert the power from DC to AC.
- Ancillary buildings which may containing:
  - A control room and operator facilities;
  - Communication equipment and an interface with the National Grid Control Centre;
  - An auxiliary transformer to provide low voltage electrical power for the converter station;

- Ancillary equipment such as measurement, protection and metering equipment; and
- Equipment storerooms.

- Outdoor equipment areas containing rigid aluminium DC and AC current connectors, transformers, cable sealing ends and air-conditioning equipment.
- Permanent lighting, designed to minimise glare and light spillage off-site, to the sky and to adjacent areas (particularly residential properties close to the site);
- Areas for car parking and internal roads.

4.6.5. An illustrative example of a typical converter substation similar to those proposed for Dogger Bank Teesside A & B is shown in **Figure 4.22**.

4.6.6. The valve halls are expected to be steel framed buildings with cladding. The colour and external materials will be agreed with the local authority. The onshore converter stations will be provided with lightning protection systems (LPS).

Table 4.18 Indicative converter substation parameters per project

Parameter	Indicative converter substation parameter
Maximum valve hall height (m)	20
Maximum lightning protection height (m)	30
Maximum access road width (m)	6
Indicative valve hall dimensions (m)	110 (L) x 75 (W) x 20 (H)
Indicative footprint of construction and laydown areas (ha)	1
Indicative footprint of site (including roads and drainage) (ha)	3
Indicative footprint of landscaping (ha)	2
Indicative total converter substation footprint (ha)	5

4.6.7. The footprint of such a design has been developed based on data from the major suppliers, and allowing for roads and drainage. Areas have also been developed for construction and laydown areas, and landscaping. The final footprint will be determined in the detailed design process and will be in part determined by the equipment, connections, safety clearances and access requirements. Indicative parameters for the converter substation footprint are shown in **Table 4.18**.

4.6.8. The construction methods employed would be those typical of a large steel framed building with cladding. The access roads would be constructed first followed by the base and then the buildings which will be designed along with the rest of the site in consultation with stakeholders, particularly with regard to water drainage and flooding.

General Surface Water Strategy

4.6.9. The National Planning Policy Framework promotes sustainable management of surface water run-off from any new development and the use of Sustainable Drainage Systems (SuDS) is recommended.

4.6.10. The flood risk assessment (see **Chapter 24 Geology, Water Resources and Land Quality,** and **Appendix 24.B Flood Risk Assessment**) which covers the area of the converter stations site states that surface water runoff from brownfield sites should be reduced by 30% and that discharge from Greenfield sites should not exceed the Greenfield runoff rates. The converter stations will be located upon Greenfield land allocated for industrial use within the Wilton Complex.

4.6.11. Initial ground investigation information indicates that the ground conditions are not conducive to the use of infiltration techniques due to the site history and potential for contaminated soils. There is also a secondary aquifer under the site. Therefore it is expected that the discharge of surface water runoff from the site will need to be controlled so as not to exceed the calculated Greenfield runoff rates. Consultation with RCBC, Sembcorp Utilities UK Ltd., Northumbrian Water and the Environment Agency will be required to agree the location for discharge.

4.6.12. The Water Framework Directive and planning policy guidance requires that water quality is assessed in the design. Further consultation will be required regarding water quality discharge with the Environment Agency; however, it is likely that water from external hardstanding areas will be required to pass through a water quality treatment system. This will need to remove silt, debris and other possible sources of contamination from the water prior to it leaving site for discharge.

4.6.13. Due to the industrial nature of the converter stations site location, there is an extensive network of existing drains and sewers available. Forewind are planning the use the existing site drainage system (comprising of a combination of open ditches and piped surface water drains) as the receptor for the surface water runoff, as it has the required additional capacity to cope with the predicted levels of runoff from the converter station site.

4.6.14. Different forms of sustainable drainage techniques (SuDS) can be used to treat runoff, including permeable paving, swales and detention basins. If required, Foul water waste will be disposed of using the existing sewer system, avoiding the need to use swales or a packaged treatment plant.

4.6.15. The proposed approach to drainage will be sustainable and support biodiversity enhancement/ ecological mitigation efforts.

4.6.16. During detailed design, the Environment Agency, Northumbrian Water, Sembcorp Utilities UK Ltd. and RCBC will be fully consulted to ensure their approval of the final design. This is discussed further in **Chapter 24 Geology, Water Resources and Land Quality**.

4.7. Expected Construction Traffic

4.7.1. The construction activities will generate HGV construction traffic that will add to the existing ordinary traffic affecting the access roads in the proximity of the works. Construction traffic access options have been selected to avoid smaller local roads and built up areas, as discussed in detail within **Chapter 28 Traffic and Access**.

4.7.2. For the cable routes a worst case scenario based on parallel, independent installation of the two projects has been considered. Deliveries for the cable route include the following elements:

- Haul road hard core material;
- Cable drums and cable joints;
- Tiles, ducts and fibre-optic ducts;
- Trench excavation material.

4.7.3. It is assumed that the deliveries will be carried out with 20t dumper trucks. One HGV delivery corresponds to a two way HGV movement along the affected road.

4.7.4. **Table 4.19** reports the key results of the traffic assessment carried out. The figures are given in terms of total number of deliveries per project.

Table 4.19 Indicative number of deliveries expected for the onshore works

Construction activity	Indicative HGV number of deliveries per project
HVDC cable route per project (independent installation)	3,528
HVAC cable route per project (independent installation)	437
Primary compounds (per project)	364
Intermediate compounds (per project)	181
Converter station (per project)	12,107

4.7.5. **Chapter 28 Traffic and Access** contains more detailed information on the traffic and access requirements for the onshore converter station.

5. Offshore Project Layouts

5.1. Wind Farm Layouts

5.1.1. The final chosen layout of the wind turbines, and other wind farm components, will depend on a number of factors including: stakeholder feedback, seabed obstructions, ground conditions, water depth, economic factors, and the chosen wind turbine.

5.1.2. Areas where flexibility is required include, but are not limited to, the following:

- Total number of wind turbines (subject to the maximum 1,200MW installed generating capacity limit);
- Location and pattern of wind turbines within the array areas;
- Capacity and type of wind turbines (in line with the options defined within the wind turbine envelope) and their mix in the development;
- Extent to which the consented areas are developed – in part or in full;
- Mix of, and areas used for, different foundation types within the array areas;
- Variation of detailed design within any of the identified foundation types;
- Numbers and positions of offshore platforms, met masts, and mooring buoys;
- Number and routing of subsea cables (and thus number of onshore cables and transition bays);
- The points where cables and pipelines (including existing infrastructure and other wind farm components) are crossed; and
- The need to microsite the location of any structures by up to 50m during construction.

5.1.3. To ensure sufficient flexibility of the scheme design can be maintained, all wind turbine layouts included in the body of this ES or its Appendices are purely illustrative and are solely for the purpose of informing the reader as to the fundamental flexibility permitted. No layout provided represents a final project layout, over and above other potential permutations. The final layout will be designed within the parameters assessed and will comply with the relevant limitations, requirements and conditions in the draft Development Consent Order (DCO).

5.2. Wind Turbine Array Layout Rules

5.2.1. During the development of the project, rules have been developed in consultation with stakeholders that will apply to the final proposed array layout, and which restrict the array patterns employed in order to address particular issues or environmental sensitivities. These are considered further within **Chapter 16 Navigation and Shipping**:

i. Layout Pattern and Regularity - The position of all wind turbines, collector substation platforms, converter substation platforms and accommodation platforms (except those covered by rule ii below) shall, so far as is practicable, be arranged in straight (to a tolerance of ±150m) in an easily understandable pattern within individual wind farm site layouts, avoiding structures which break this pattern and without any dangerously projecting peripheral structures.
   - Reason: To facilitate safe navigation, aid location of casualties or incidents during emergency response, and to avoid creating an isolated hazard in or around the wind farm, while allowing the flexibility to optimise wind turbine arrays allowing for issues such as local geology, seabed obstacles, and energy capture.

ii. Perimeter-Type Layouts - The position of all wind turbines, collector substation platforms, converter substation platforms and accommodation platforms forming a line of perimeter structures around a wind farm area shall, so far as is practicable, be arranged in straight or curved lines (to a tolerance of ±150m) in an easily understandable pattern, avoiding structures which break this pattern and without any dangerously projecting peripheral structures.
   - Reason: To facilitate safe navigation, aid location of casualties or incidents during emergency response, and to avoid creating an isolated hazard in or around the wind farm, while allowing the flexibility to optimise wind turbine arrays allowing for issues such as local geology, seabed obstacles, and energy capture.

iii. Layout Clarity - Any changes in wind turbine size and separation distance within a wind farm project will be introduced so as to minimise potential visual confusion for any vessel navigating through the wind farm.
   - Reason: To facilitate safe navigation for vessels which are working within the Dogger Bank Zone, (noting an assumption of no significant levels of passing traffic within the zone).

iv. Boundary Clarity - Opposing site boundaries which approach closer than 5km to each other shall be aligned broadly parallel with one another and marked to distinguish between separate wind farms.
   - Reason: To facilitate safe navigation for vessels which are working within the Dogger Bank Zone, (noting an assumption of no significant levels of passing traffic within the zone).

v. Existing Infrastructure - Space will be left for maintenance vessels to access existing active telecommunication cables within the projects (details to be agreed on a case-by-case basis).

- Reason: To enable safe operation of existing infrastructure.

vi. Proximity to Project Boundaries – All wind farm surface and sub-surface structures, including rotor swept areas, will be located wholly within the relevant wind farm or cable corridor work area boundaries (see **DCO Offshore Works Plan**). No permanent surface infrastructure will be located in the export cable corridor. All temporary construction works will be within the order limit boundaries (also see **DCO Offshore Works Plan**).

- Reason: To ensure all aspects of the development are within the assessed areas.

5.2.2. A number of example project layouts have been developed in accordance with these rules. These are not options from which a final project layout could be selected, but are instead included to provide clear examples of layouts which are compatible with the layout rules, and illustrative the types of layouts which could be implemented within final project designs. These layouts, (**Figure 5.1** to **Figure 5.7**) are all shown illustratively within the boundary of Dogger Bank Teesside A & B.

Figure 5.1 Dogger Bank Teesside A illustrative layout 1 - Perimeter plus regular grid

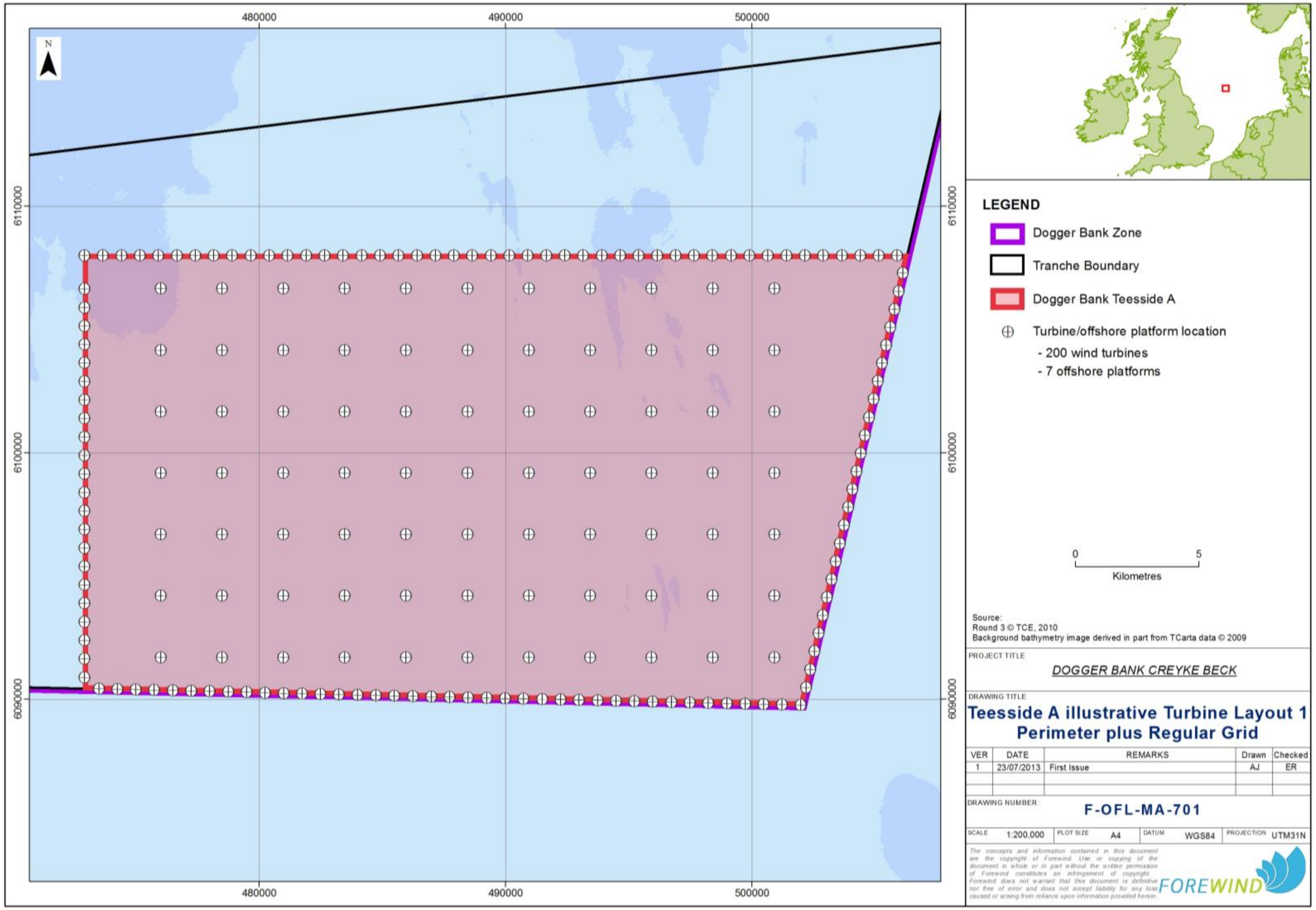


Figure 5.2 Dogger Bank Teesside A illustrative layout 2 - perimeter plus stripes

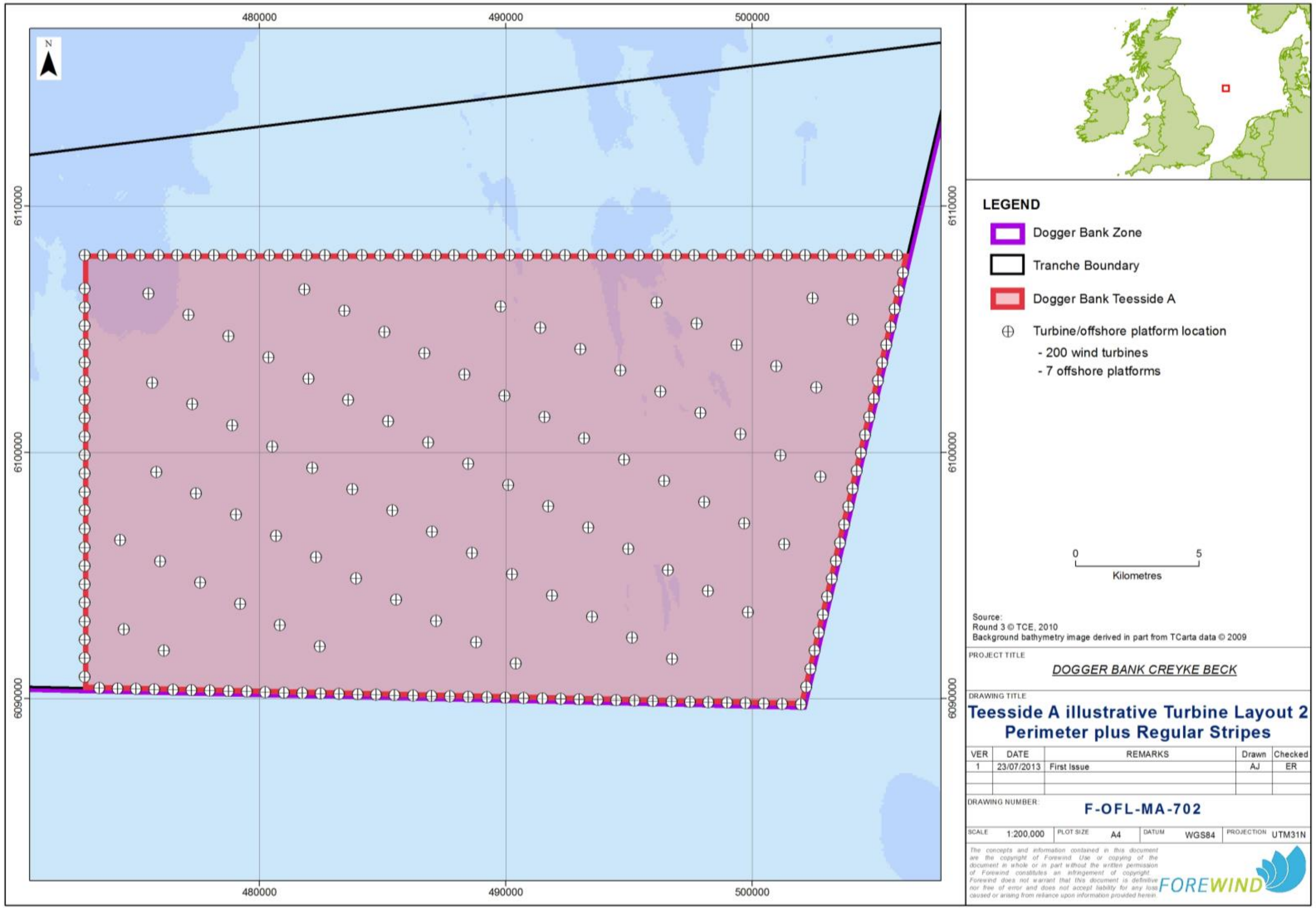


Figure 5.3 Dogger Bank Teesside A illustrative layout 3 – regular grid

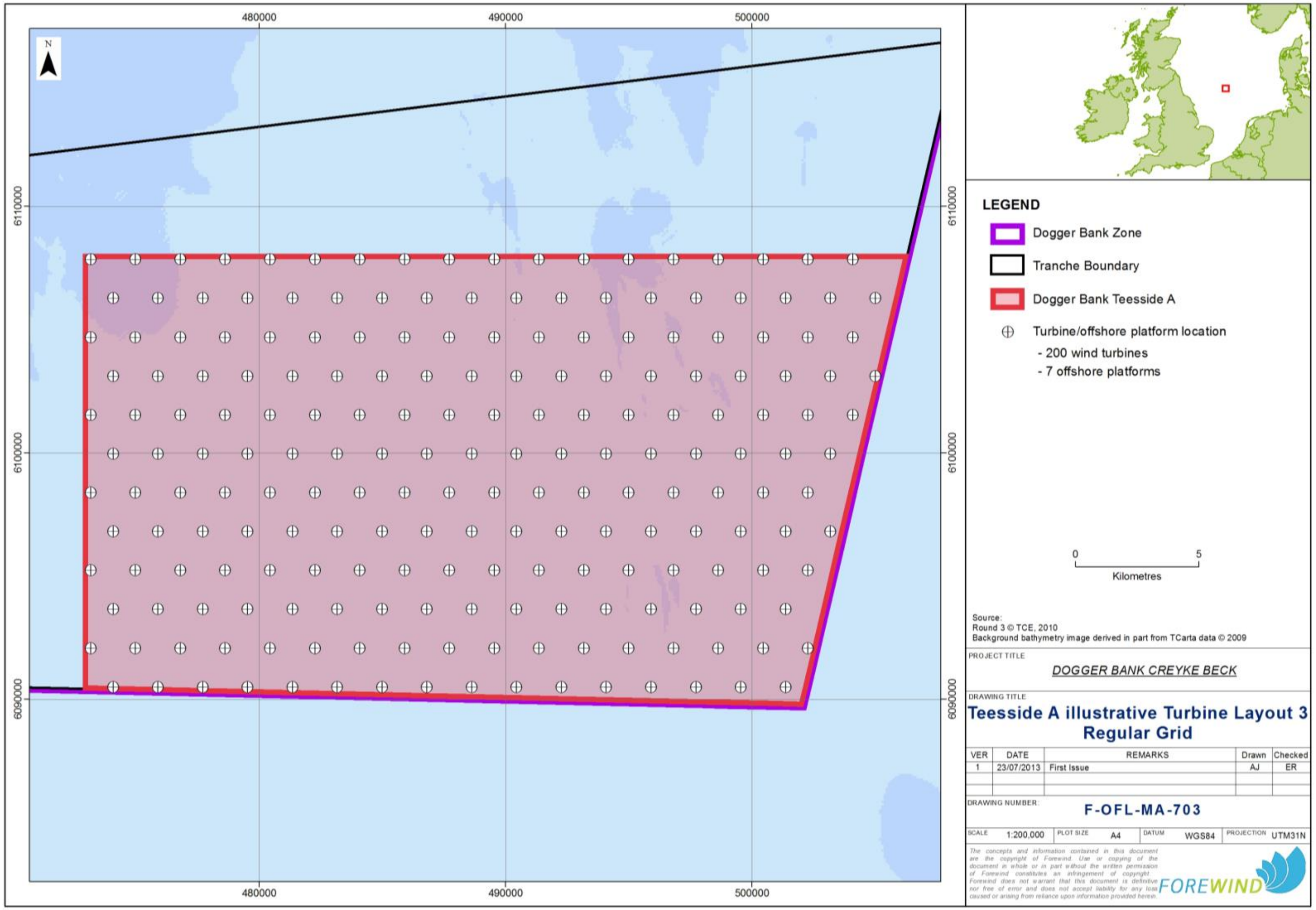


Figure 5.4 Dogger Bank Teesside A illustrative layout 4 – reduced area regular grid

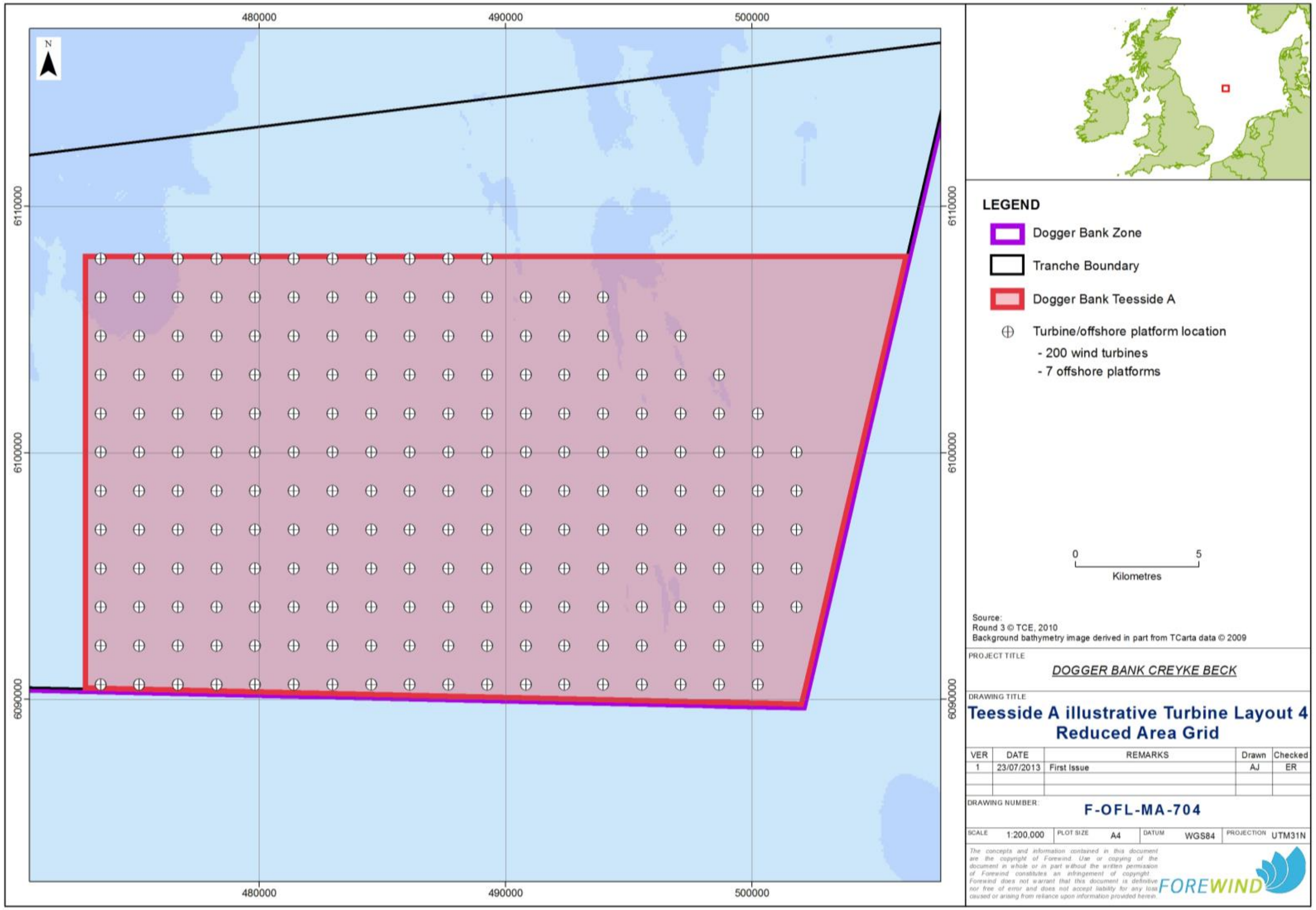


Figure 5.5 Dogger Bank Teesside A illustrative layout 5 – curved perimeter plus grid

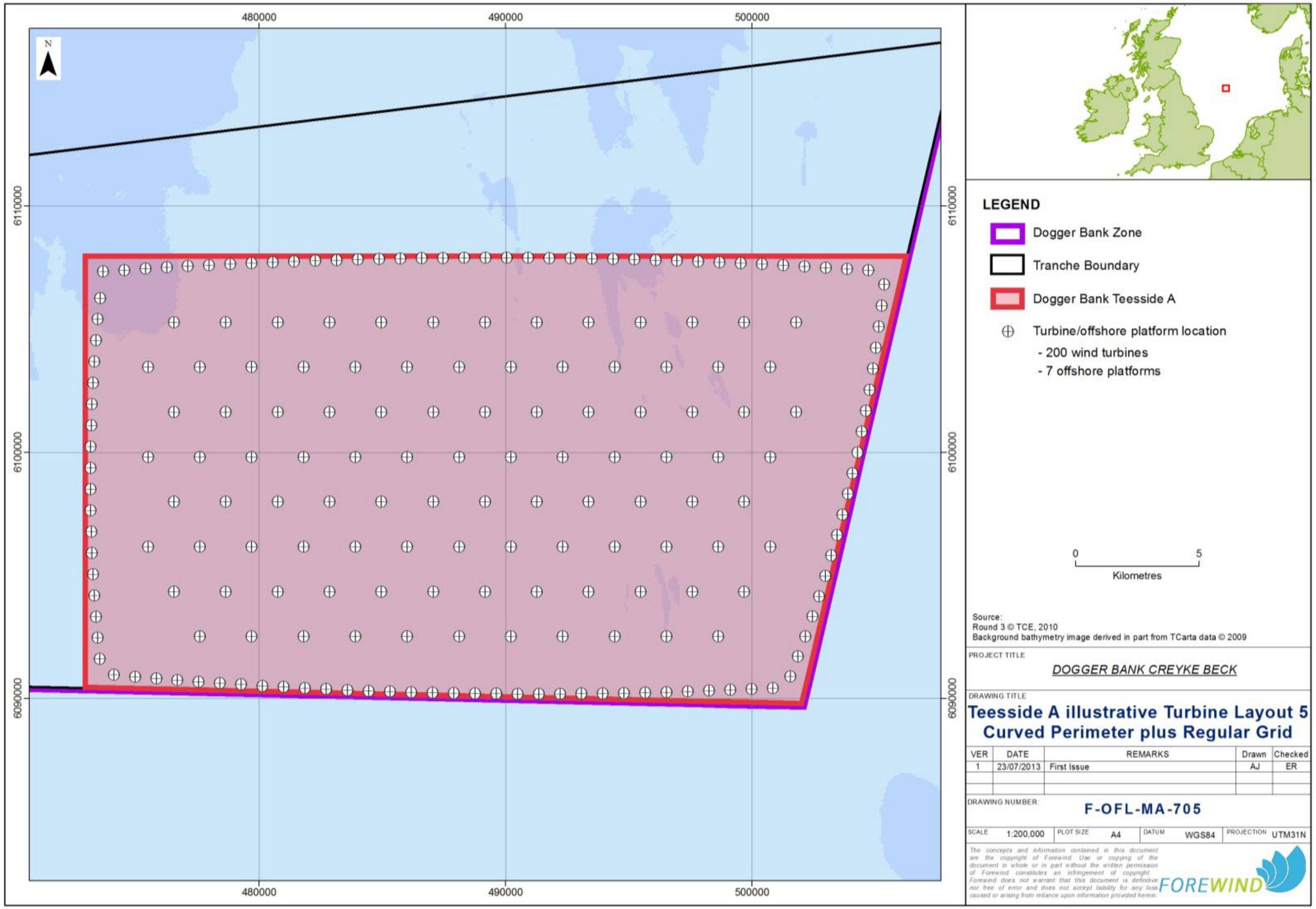


Figure 5.6 Dogger Bank Teesside A & B illustrative layout 1 – perimeter plus regular grid

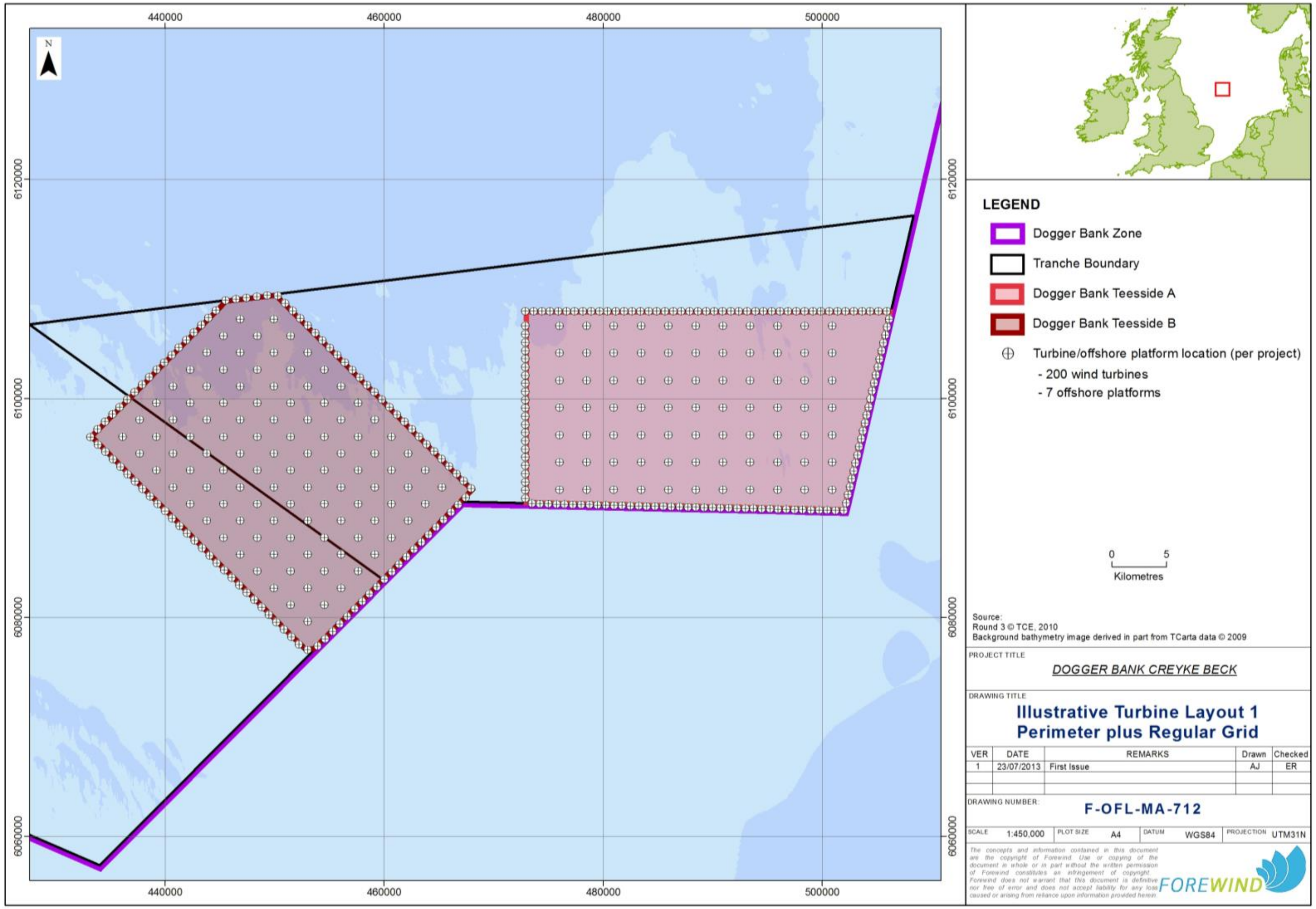
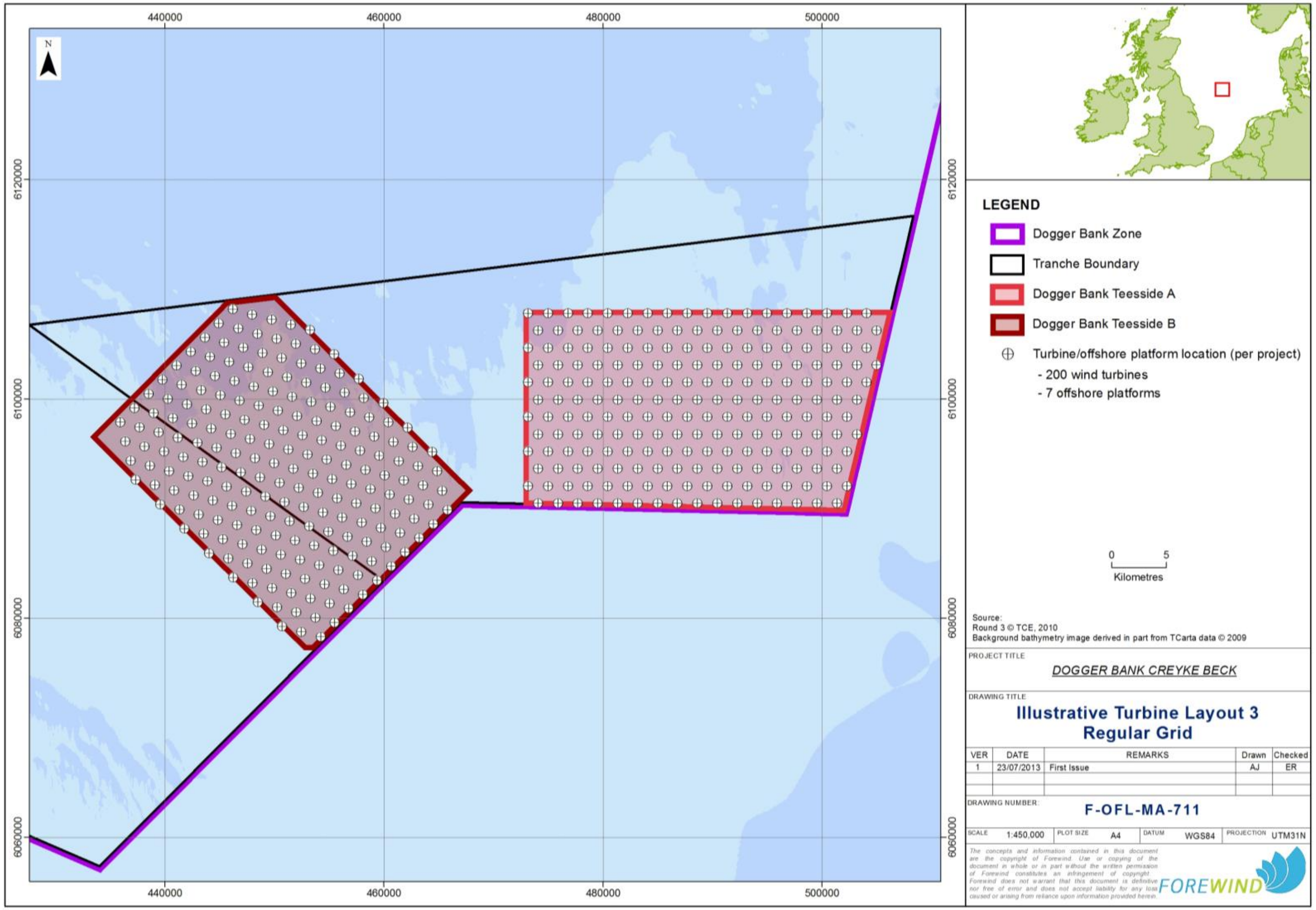


Figure 5.7 Dogger Bank Teesside A & B illustrative layout 2 – regular grid



5.3. Layout of Other Offshore Project Components

5.3.1. Meteorological monitoring stations have specific restrictions on their location in order to fulfil one of their primary functions as turbine power performance testing masts. These restrictions are defined by international standards and mean that meteorological monitoring stations are generally required to be located between approximately 2 to 5 rotor diameters from wind turbines, and will thus fall outside a regular layout pattern.

5.3.2. The location of any vessel moorings installed will be determined as part of the detailed design of the project. Mooring buoys will not be expected to follow the defined wind farm array layout rules, but will be sited with regards to safety of navigation. The potential for additional navigational safety mitigation measures is also discussed in **Section 3.14**.

5.4. Wind Turbine Spacing

5.4.1. Wind turbines extract energy from the wind and this process creates a wake downstream from the wind turbine where wind speed is reduced and flow is more turbulent. As the flow proceeds downstream the wake spreads out and the energy is recovered from the surrounding air, thus the wake decreases with distance. Wind turbine wake effects are greater with larger rotors and require greater spacing as a consequence, allowing a minimum spacing between wind turbines to be established.

5.4.2. The spacing parameters proposed for both Dogger Bank Teesside A & B projects are outlined in **Table 5.1**. The minimum permitted spacing will vary with the size of the wind turbine, and is defined as whichever is the greater of the stated limits in **Table 5.1**. The single absolute minimum spacing limit, therefore, is only stated in order to provide clarity for the smallest wind turbines and avoid the need to consider unrealistically small spacings. The majority of wind turbines with larger rotors would be limited by the variable '6 rotor diameter' value.

5.4.3. Micro-siting of offshore structures may be required to accommodate local site conditions identified by detailed site investigation or during construction. Micro-sited wind turbines will still be bound by these limiting spacing parameters.

Table 5.1 Wind turbine spacing parameters

The minimum permitted wind turbine spacing is defined as: whichever is the greater of the stated limits		
Parameter	Up to 6MW	10MW or greater
Minimum wind turbine spacing (centre to centre) (m)	750	
Minimum wind turbine spacing (centre to centre)	6 Rotor Diameters	

5.5. Proximity to Existing Infrastructure & International Boundaries

Offshore Infrastructure

5.5.1. Several operational subsea pipelines and cables exist within the vicinity of the Dogger Bank Teesside A & B projects. These existing structures have on-going maintenance requirements and require certain minimum separation distances from new wind farm structures to avoid mutual interference. There is also a need to maintain separation between existing infrastructure and intrusive seabed activities, such as anchoring and cable installation, to minimise the risk of damage.

5.5.2. Appropriate minimum separation distances have been developed by Forewind, and are outlined in **Table 5.2**. Any cables or intrusive works required within the distances proposed in **Table 5.2** would be assumed to require detailed crossing or proximity agreements with the owners of the infrastructure. These separation distances will be discussed during consultation with the operators of relevant existing infrastructure, and appropriate crossing or proximity agreements developed to enable coexistence. The final agreed separation distances may vary from these minimum values on a case-by-case basis. Further discussion of this subject is included within **Chapter 17 Other Marine Users**.

5.5.3. Crossings of cables and pipelines by Dogger Bank Teesside A & B cables will be required, and the technical aspects are discussed within **Section 3.11 Offshore Cable & Pipeline Crossings**. The commercial aspects will be addressed via detailed discussions with the owners of the infrastructure to develop crossing agreements which cover all necessary aspects of the operations.

5.5.4. Out of service telecommunications cables also exist within and near the zone, and operational cables and pipelines could become out of service at short notice. Where necessary, agreements would always be sought from the cable owners and it is assumed at this early stage that suitable crossing or proximity agreements would also be developed with the owners of out-of-service infrastructure. It is expected that out-of-service infrastructure may be removed where necessary, as discussed in **Section 3.9 Offshore Cable Installation and Removal**, where it cannot be avoided by wind farm structures and activities.

Table 5.2 Indicative separation distances from other marine users existing operational infrastructure (measured centre to centre)

Parameter	Operational Cables	Operational Pipelines
Minimum separation from wind farm surface structures (m)	750	500
Minimum routine separation from wind farm inter-array and inter-platform cables (m)	750	500
Minimum routine separation from wind farm export cables (m)	500	500
Minimum routine separation from wind farm intrusive works (m)	500	500

Near-Shore Infrastructure

5.5.5. In the offshore approaches to the cable landfall (the “near-shore” area), the approach to proximity will need to vary due to the restricted space available.

5.5.6. For infrastructure in the near-shore area, permitted proximity distances will therefore all be developed on a case-by-case basis, in consultation with their operators.

International Boundaries

5.5.7. As discussed in **Section 2** the eastern margin of Dogger Bank Teesside A adjoins the UK Continental Shelf limit, as defined by the UK Hydrographic Office, which acts an International Boundary. The distance between any proposed foundations or structures required for the Dogger Bank Teesside A project, including wind turbines, substation or other structure, surface and sub-surface, shall be at least 300 metres from an International Boundary.

6. Project Life Cycle

6.1.1. After consent for Dogger Bank Teesside A & B is granted, the projects would then progress through a lifecycle described within the following sections.

6.2. Pre-Construction Engineering Surveys

6.2.1. The engineering surveys described in this section aim at assessing the feasibility of the installation and assist the production of detailed designs and installation procedures. These will be carried out in conjunction with all the required health and safety, environmental, archaeological and ecology surveys.

6.2.2. It is noted that the final designs of the project, following the results of these pre-construction surveys and subsequent detailed design activities, will be subject to final approval under the terms of the DCO.

Offshore Pre-Construction

6.2.3. Before the start of offshore construction, a number of pre-construction surveys and other activities will be required. These may include:

- Further detailed geophysical surveys focussed on the actual locations of the projects' structures and cables, to understand in detail the seabed within the wind farm and export cable corridor areas. Sidescan sonar, multibeam echosounder, and magnetometry equipment are likely to be used in order to input into areas such as detailed design, installation planning, and Unexploded Ordnance (UXO) assessments;
- Detailed geotechnical survey campaigns may also be undertaken to assist in the design and siting of the wind farm structures. Boreholes, cone penetration tests, vibrocores, and cable plough trials may be undertaken to understand the shallow geology of each proposed structure site; and
- Additional survey activities may also be required including Remotely Operated Vehicle (ROV) or diver inspections of cable routes and identified seabed anomalies. Cable route clearance activities may also be undertaken as required, such as pre-lay grapnel runs.

Onshore Pre-Construction

6.2.4. Before the start of onshore construction, a number of pre-construction engineering surveys and other activities will be required. These may include:

- Geophysical surveys to understand in detail the conditions in the cable routes and converter station areas; and
- Geotechnical surveys to assist in the design, construction, and positioning

of the cable route, the horizontal directional drills and the converter stations. Boreholes, cone penetration tests, and vibrocores, may be undertaken to understand the geology of the proposed structure sites.

6.3. Construction

Construction Programme & Timing - Overview

6.3.1. Flexibility is required in the construction programme in order to accommodate a range of uncertainties. These include the time taken to undertake procurement activities and reach a financial investment decision, variable lead times for components and equipment, and variable task durations dependent on the suppliers, technologies and methodologies selected. This may be affected by factors such as supply chain bottlenecks and the number and size of turbines selected.

6.3.2. The key permutations with regards to the programme and timetable for the construction of the Dogger Bank Teesside A & B projects include:

- Construction of each of the Dogger Bank Teesside A & B projects may take place continuously or in phases, within a specified duration. This specified duration is referred to as a construction window. Offshore and onshore aspects of the projects have separate construction windows.
- Construction start may only occur within a specified time period after consent is achieved.
- If constructed at different times, either project may be first.
- The timescales for construction of Dogger Bank Teesside A and Dogger Bank Teesside B are not linked, except that there is a maximum gap between the two projects with no onshore construction.
- The first of the projects to be constructed may carry out onshore enabling works for the second project, in order to reduce overall construction effort of both projects combined.

6.3.3. A number of fundamental construction programme parameters have been developed to describe these options, and these are detailed within **Table 6.1**.

Table 6.1 Indicative construction programme parameters, per project

Parameter	Teesside Project A	Teesside Project B
Earliest construction start onshore	At consent award (subject to discharge of DCO conditions)	At consent award (subject to discharge of DCO conditions)
Earliest construction start offshore	18 months after consent award	18 months after consent award
Latest construction start onshore	7 years after consent award	7 years after consent award
Latest construction start offshore	7 years after consent award	7 years after consent award
Onshore construction duration window	Up to 36 months	Up to 36 months
Offshore construction duration window	Up to 6 years	Up to 6 years
Maximum onshore construction gap between the two projects (from first onshore construction finish to second onshore construction start)	5 years	5 years
Latest construction finish onshore	10 years after consent award	10 years after consent award
Latest construction finish offshore	13 years after consent award	13 years after consent award

6.3.4. Based on these programme parameters it can be seen that the Dogger Bank Teesside A & B projects could be built in line with the following overarching scenarios:

- Parallel – Dogger Bank Teesside A and Dogger Bank Teesside B are built together. Please note, in some assessments this has been referred to as a "Concurrent" build
- Sequential – Construction of one project commences after the start of the other. This may result in projects overlapping, occurring in series or having a gap between projects.

- Enabling – Partial installation of some onshore elements for the second project takes place while constructing the first project.

6.3.5. For all Environmental Impact Assessment all three overarching scenarios were considered as part of the assessment. Dependant on the assessment being undertaken each Chapter selected the most appropriate scenarios to model.

Construction Programme & Timing - Onshore

6.3.6. In order to better describe the onshore construction options, additional detail has been developed in line with the overarching installation scenarios identified. The timescales provided are indicative of what could conservatively be achieved in normal circumstances, but do not reflect all possible eventualities which could arise such as major supply chain issues, weather delays, etc.

Landfall Cables

6.3.7. The offshore export cables will come ashore at landfall to connect to the onshore export cable systems. The overarching construction scenarios and the construction durations applicable to each are summarised in **Table 6.2**.

Table 6.2 Landfall construction options

Scenario	Overview	First Construction Phase	Gap	Second Construction Phase
Single	1 project	• Setup landfall works • HDD activities • Cable pull through • Reinstate landfall **Time = up to 24 weeks**	n/a	n/a
Parallel	2 projects in parallel	• Setup landfall works • HDD activities • Cable pull through • Reinstate landfall **Time = up to 38 weeks**	None	None
Sequential	1 project gap 1 project	• Setup landfall works • HDD activities • Cable pull through • Reinstate landfall **Time = up to 24 weeks**	Up to 5 years	• Setup landfall works • HDD activities • Cable pull through • Reinstate landfall **Time = up to 24 weeks**
Enabling	1 project plus conduits gap 1 project	• Setup landfall works • HDD activities • Cable pull through • Reinstate landfall **Time = up to 31 weeks**	Up to 5 years	• Cable pull through **Time = up to 8 weeks**

HVDC Cables

6.3.8. From the landfall, underground HVDC export cable corridor will continue onshore to the proposed Dogger Bank Teesside A & B converter stations. The overarching construction scenarios and the construction durations applicable to each are summarised in **Table 6.3**.

Table 6.3 Onshore HVDC cable construction options

Scenario	Overview	First Construction Phase	Gap	Second Construction Phase
Single	1 project	• Build one haul road • Dig 1 trench • Lay cables (in one trench) • Re-instate width **Time = up to 24 months**	n/a	n/a
Parallel	2 projects in parallel	• Build two haul roads • Dig two trenches • Lay cables • Reinstate full width **Time = up to 24 months**	None	None
Sequential	1 project gap 1 project	• Build one haul road • Dig 1 trench • Lay cables (in one trench) • Re-instate width **Time = up to 24 months**	Up to 5 years	• Build one haul road • Dig 1 trench • Lay cables (for one trench) • Re-instate width **Time = up to 24 months**
Enabling	1 project plus conduits gap 1 project	• Build first project haul road • Dig two trenches one each side of haul road. • Lay cables in one trench • Lay conduits in other trench • Reinstate full width **Time = up to 28 months**	Up to 5 years	• Build 2nd project haul road (with spoil heap) • Use haul road to access joints • Pull cables through conduits • Reinstate full width including joint pits and haul road **Time = up to 20 months**

HVAC Cables

6.3.9. The construction scenarios for the HVAC cables connecting the converter stations to the existing National Grid substation will be the same as that for the HVDC cable but with a shorter construction timescale. The overarching construction scenarios and the construction durations applicable to each are summarised in **Table 6.4**.

Table 6.4 Onshore HVAC construction options

Scenario	Overview	First Construction Phase	Gap	Second Construction Phase
Single	1 project	• Build one haul road • Dig 1 trench • Lay cables (in one trench) • Re-instate width **Time = up to 18 months**	n/a	n/a
Parallel	2 projects in parallel	• Build two haul roads • Dig two trenches • Lay cables • Reinstate full width **Time = up to 18 months**	None	None
Sequential	1 project gap 1 project	• Build one haul road • Dig 1 trench • Lay cables (in one trench) • Re-instate width **Time = up to 18 months**	Up to 5 years	• Build one haul road • Dig 1 trench • Lay cables (for one trench) • Re-instate width **Time = up to 18 months**
Enabling	1 project plus conduits gap 1 project	• Build first project haul road • Dig two trenches one each side of haul road • Lay cables in one trench • Lay conduits in other trench • Reinstate full width **Time = up to 18 months**	Up to 5 years	• Build 2nd project haul road (with spoil heap) • Use haul road to access joints • Pull cables through conduits • Reinstate full width including joint pits and haul road **Time = up to 18 months**

Converter Station

6.3.10. The construction strategy for the converter stations will follow the same overarching scenarios adopted for the cables, with the exception that no material enabling works are assessed. The overarching construction scenarios and the construction durations applicable to each are summarised in **Table 6.5**.

Table 6.5 Onshore converter station construction options

Scenario	Overview	First Construction Phase	Gap	Second Construction Phase
Single	1 project	**Time = up to 36 months**	n/a	n/a
Parallel	2 projects in parallel	**Time = up to 36 months**	None	None
Sequential	1 project gap 1 project	**Time = up to 36 months**	Up to 5 years	**Time = up to 36 months**

Onshore Construction

Overview

6.3.11. The onshore construction covers the installation of the electrical systems for the connection of the Dogger Bank Teesside A & B projects. The onshore electrical system includes the landfall, and then extends from the joint transition bay, where the onshore cables connect to the offshore cables, to the existing National Grid substation at Lackenby.

6.3.12. The onshore system is comprised of the following main elements:

- The HVDC export system underground cables and related auxiliary/ancillary systems;
- The onshore converter stations;
- The HVAC export system underground cables; and
- National Grid unlicensed works.

6.3.13. Construction of the various elements of the onshore works is likely to be completed in a number of stages, typically including (noting that the order may vary):

- Onshore cable systems (applicable to both HVDC and HVAC cables, and including landfall cables):
  - i. Construction compound establishment
  - ii. Civil construction; haul roads and trenches
  - iii. Cable installation

iv. Horizontal Directional Drill (HDD) installation
v. Jointing and reinstatement
vi. Drainage works
vii. Landscaping and reseeding

- Converter Stations:

i. Construction site establishment;
ii. Civil construction; sub-structure and buildings;
iii. HVDC equipment installation;
iv. Transformers and outdoor equipment installation;
v. AC and DC cable connections installed;
vi. Protection and SCADA equipment installed;
vii. Drainage works
viii. Landscaping and re-seeding

6.3.14. During onshore construction, a wide range of vehicles will be required. These are likely to include a combination of key vehicle types shown in **Table 6.6**.

Table 6.6 Onshore construction vehicles

Activity	Indicative key construction vehicle types
Landfall works	Excavator, HDD drill rig, Dumper, Water pump & Mobile Crane
Haul road construction	Excavator, Aggregate Wagon & Dump Truck
Cable installation	Excavator, Backhoe Loader & Dump Truck
Operational access construction	Excavator, Aggregate Wagon & Dump Truck
HDD	HDD drill rig & Water pump
Converter station construction	Excavator, Mobile Crane, Backhoe Loader, Cement mixer truck (discharging), Dozer, Truck mounted concrete pump & boom arm & Dumper

Construction Methodologies

6.3.15. Construction methodology will be dependent upon the technical solutions selected for the project. Key techniques which may be required include:

- Construction site establishment, including topsoil/subsoil works, construction of haul roads, access roads, hard standing, and erection of boundary fencing.
- Civil construction of sub-structure and buildings. Most methodologies are expected to be typical of large, steel clad, metal frame buildings, with a raft foundation, bolted and trussed H-beam structure, and cladding for walls and roof.
- High voltage electrical equipment installation. Equipment typically mounted on insulators atop aluminium frames on individual concrete pad foundations.
- Transformers and outdoor equipment installation. Transformers typically mounted on raft foundations and the equipment on individual pad foundations
- AC and DC cable connections installed using open trenching, horizontal directional drilling, ducting, and culverts.
- Control, protection and SCADA equipment installed. To include various cubicle-type equipment mounted into designated equipment rooms within onshore substation buildings.
- Drainage works, including new construction and drainage reinstatement.
- Finishing works, including gravel walkways, surrounding roads, security fencing, landscaping, and reinstatement.

Offshore Construction

Overview

6.3.16. Construction of the offshore works is likely to be completed in a number of stages, typically including (noting that the order of actions may vary):

- Pre-fabrication (structures constructed onshore);
- Transportation (structures floated or transported offshore by vessels);
- Offshore foundation installation;
- Offshore platform installation and commissioning;
- Transition pieces installed;
- Inter-array and inter-platform cabling installed;
- Wind turbine installation;
- Cable landfall works; and
- Export cabling.

Construction Ports

6.3.17. It is not known at this stage which port or ports will be used as the construction base for the Dogger Bank Teesside A & B projects. The Dogger Bank Teesside A & B projects may use the same or separate construction ports. The choice of construction ports used for the projects will be driven by a number of considerations, including the technical solutions selected for the execution of the projects, and port availability at the time of construction. **Table 6.7** shows an indicative list of potential construction ports.

6.3.18. The following port elements may be required for the construction of these projects:

- Availability of sufficient marine port space, berthing, deep water and mooring capabilities to accommodate the required heavy lift, construction support, and logistical/transportation vessels;
- Adequate laydown area for pre-assembly and load-out operations;
- Equipment to move the wind farm components, primarily including adequate crane capacity;
- Good transportation links and access by water, road or rail;
- 24 hour operational availability during the life of the project for unrestricted access for operations;
- Port facilities available for a base to manage construction and other marine operations.

Table 6.7 Indicative project construction ports and distances to the centroids of projects

Potential construction port locations		Transit distance from Teesside A to port		Transit distance from Teesside B to port	
Port name	Region or estuary	km	Nautical miles	km	Nautical miles
Dundee	Tay	395	213	364	197
Blyth	N East	277	149	239	129
OGN	Tyne	279	151	241	130
Swan Hunter	Tyne	279	151	241	130
Shepherd Offshore Group	Tyne	282	152	244	132
Port of Tyne	Tyne	274	148	236	127
Sunderland	N East	268	145	230	124
Hartlepool	Tees	260	141	222	120
Able Seaton	Tees	263	142	224	121
Hull	Humber	279	150	248	134
Able Marine Energy Park	Humber	273	147	242	131
Great Yarmouth	East England	286	154	273	148
Harwich	East England	373	201	361	195
Ijmuiden	Netherlands	308	166	320	173
Eemshaven	Netherlands	315	170	345	186
Verbrugge, Vlissengen	Netherlands	421	227	422	228
Breakbulk and Offshore Wind Terminal, Vlissingen	Netherlands	413	223	413	223
Esbjerg	West Denmark	360	195	399	215
Offshore Terminal Bremerhaven	Germany	415	224	449	242

6.3.19. It is probable that all major components will be delivered by sea. These components may be transported to the construction port from their manufacturing location with numbers as shown in **Table 6.7**, or potentially via a marshalling port, or they may be shipped directly to the offshore project location.

Construction Vessels and Helicopters

6.3.20. Precise details of the vessels and helicopters that will be used and their total numbers and movements will not be finalised until the technical solutions are selected for execution of the projects, and details of the construction contracts are known.

6.3.21. For EIA purposes however, **Table 6.8** provides indicative values for the construction vessel movements associated with the construction of the Dogger Bank Teesside A & B projects.

Table 6.8 Indicative vessel movements to port during construction

Parameter	Teesside Project A	Teesside Project B
Indicative total return trips to port for construction vessels	5,510	5,150
Indicative total wind farm component deliveries by vessel to construction port	850	850

6.3.22. During offshore construction, a wide range of vessels will be required. These are likely to include a combination of the following types:

- Large and medium crane vessels, both floating (using dynamic positioning or anchor spreads) and jack-up type;
- Logistics, transportation and feeder vessels;
- Tugs and anchor handling vessels;
- Hotel and accommodation vessels;
- Personnel transfer craft (including for commissioning activities);
- Dredging, seabed preparation, and aggregate handling craft;
- Diving support vessels;
- Guardships;
- General offshore and subsea construction vessels, plus associated ROVs;
- Cable installation and maintenance vessels, and;
- Survey vessels, suitable for the range of pre and post-construction survey activities.

6.3.23. Dependent on vessel capabilities, vessels may be required to deploy anchors into the seabed or jack-up into position whilst undertaking construction activities such as crane operations or the installation of foundations or cables. This could be to provide a secure working position, to aid station keeping during poor weather, or otherwise as part of their working methodologies.

6.3.24. In addition to vessels, helicopters may also be required for transfer of personnel from shore, and between vessels and offshore structures. **Table 6.9** provides indicative values for annual helicopter movements associated with the construction of the Dogger Bank Teesside A & B projects.

Table 6.9 Indicative annual helicopter movements to port during construction phase

Parameter	Teesside Project A	Teesside Project B
Indicative annual return trips from site to shore	900	900

Construction Methodologies

6.3.25. Construction methodology will be dependent upon the technical solutions selected for the project. Key techniques which may be required include:

- Seabed preparation (based on dredging and/or rock dumping);
- Scour and subsea damage protection (based on rock or gravel placement, or deployment of various other purpose designed systems such as mattresses, frond mats or similar - as described in the section on subsea damage and scour protection);
- Installation of piles, through driving (impact piling and potentially vibration piling), and drilling of piles;
- Installation of screw piles;
- Installation of self-installing and self-buoyant platforms and foundation structures (including jack-up foundations – potentially onto pre-installed foundations);
- Installation of suction bucket footings (as in suction bucket foundations, or suction anchors);
- Lowering into place (as in gravity foundations) using cranes, buoyancy or a combination of both;
- Grouting (many operations can include use of grout, for instance: connecting piles to foundation or transition piece structures, and under gravity bases and suction buckets);
- Assembly of components (as in the assembly of turbines or substations on top of installed foundations, and including the bolting, swaging, or grouting of joints and connections);

- Installation of pre-assembled components, such as wind turbines (varying levels of pre-assembly are possible, including the installation of a complete wind turbine and foundation in one piece);
- Cable route preparation where necessary (potentially including methodologies such as boulder and obstacle clearance, dredging and pre-sweeping)
- Cable installation and burial (typically using powered installation vessels with dynamic positioning or towed barges, potentially via techniques such as ploughing, jetting, cutting, etc. as described in the cable installation sections);
- Cable protection (including the use of rock dumping, mattresses, and proprietary cable protection systems, as described in the cable protection section. Also including the construction of cable crossings, as discussed in the crossings section).

6.4. Commissioning

6.4.1. Once the construction of a wind farm component is complete, the project will enter the commissioning phase. During this phase inspections and tests are conducted to ensure that all components of the wind farm are complete, functioning correctly and in a safe manner before they are accepted into operation.

6.4.2. Commissioning activities will include activities such as: inspections and tests of the connection infrastructure and wind turbine electrical components, inspection of the mechanical and structural elements of the wind turbines and offshore platforms, and inspection of civil engineering quality records. Commissioning inspections encompass a wide range of activities, the scope of which is dependent on the technology being commissioned and the requirements set by the owner and regulators. Some commissioning plans may require multiple inspection visits to a component over a period of time.

6.4.3. An illustrative example commissioning plan for a wind turbine is outlined below:

- Inspection and test of control systems for the generator, switchgear, transformers, gearbox, yaw control and meteorological instrumentation;
- Inspection and test of safety systems in static and running modes of wind turbines;
- Inspection and test of wind turbine ancillary systems such as lifts, cranes, fans, etc. and hydraulic systems;
- Inspection of wind turbine against a standard commissioning check list;
- Energisation of the wind turbine.

6.4.4. Commissioning inspections will commence at some point after a wind farm element has been constructed. Due to the size of the projects and the duration of the construction phase it is probable that commissioning activities may occur concurrently with construction activities. For example, after a number of turbines have been installed commissioning inspections commence as construction crews move elsewhere on site.

6.4.5. In addition to the commissioning of individual elements of the projects, systems testing will also be required, to confirm elements of the wind farm are functioning together as a system, up to and including the connection into the existing National Grid substation.

6.4.6. Commissioning activities will require the transfer of inspection personnel and equipment, to the various elements of the wind farm. A range of different vehicles, vessels, and helicopters may be involved during this process.

6.4.7. Any items identified as unsatisfactory during commissioning may result in remedial activities to be undertaken during the construction and early operational phases of the wind farm.

6.5. Operation & Maintenance

Offshore Operation & Maintenance

Figure 6.1 Illustration of an example offshore support vessel design

Siem Moxie designed and developed by Siem Offshore and Ulstein Group. Courtesy of Siem Offshore

6.5.1. After commissioning the Dogger Bank Teesside A & B projects will enter their respective Operations and Maintenance (O&M) phases. O&M activities could overlap construction, commissioning, and decommissioning activities. Due to the scale of the Dogger Bank Teesside A & B projects, it is possible for the earliest project elements, for example, to have passed through the commissioning phase into the O&M stage before the last items have been constructed.

6.5.2. The operational wind farms will require regular planned and unplanned maintenance throughout their lifetimes, which will be carried out by a team of suitably qualified engineers, O&M technicians, technical specialists, and associated support staff. The O&M team will ensure that all the assets are maintained and operated in a safe and reliable manner, compliant with regulatory duties and in accordance with commercial objectives.

6.5.3. The O&M team will require a range of vehicles and equipment to carry out their duties. Offshore this could potentially include a range of vessel types and sizes, and helicopters. Offshore wind O&M is an area of rapidly developing technology, and there is a strong potential for new techniques and equipment to be introduced over the coming years.

O&M Port Facilities

6.5.4. There are a number of ports where O&M activities for the Dogger Bank Teesside A & B projects could be based. Factors to be considered in the final selection of O&M port(s) will include: distances from Dogger Bank Teesside, port facilities for berthing and operating the required vessels, storing equipment and parts, and management base requirements, onshore transport links, and availability of engineering resources and personnel in the region.

6.5.5. **Table 6.10** shows an indicative list of potential O&M ports, including the approximate distances to the centres of Dogger Bank Teesside A & B projects. The Dogger Bank Teesside A & B projects may each use the same O&M port facilities or separate port facilities.

Table 6.10 Indicative O&M ports for Dogger Bank Teesside A & B and distances to centroids of the projects

Indicative O&M port options		Transit distance from Teesside A to port		Transit distance from Teesside B to port	
Port name	Region or estuary	km	Nautical miles	km	Nautical miles
Blyth	North East	277	149	239	129
OGN Group	Tyne	279	151	241	130
Swan Hunter	Tyne	279	151	241	130
Shepherd Offshore Group	Tyne	282	152	244	132
Port of Tyne	Tyne	274	148	236	127
Sunderland	North East	268	145	230	124
Seaham	North East	266	144	228	123
Hartlepool	Tees	260	141	222	120
Able Seaton	Tees	263	142	224	121
Whitby	North East	229	124	191	103
Hull	Humber	279	150	248	134
Grimsby & Immingham Dock	Humber	256	138	225	122
Grimsby Fish Dock	Humber	258	139	227	123
Able Marine Energy Park	Humber	273	147	242	131
Great Yarmouth	East England	286	154	273	148
Lowestoft	East England	295	159	282	152

Offshore O&M Vessels and Equipment

Figure 6.2 Example of a large crew transfer vessel

Windserver trimaran courtesy of Fjellstrand

6.5.6. During offshore O&M, a wide range of vessels and equipment may be required dependent upon the final strategy and technology options selected. These are likely to include a combination of the following types:

- Offshore support vessels. (General purpose large offshore O&M support vessel, potentially including accommodation, parts storage, medium crane, and personnel transfer capabilities. Could act as a central offshore operations 'hub'. Indicatively 90m in length. An example of this vessel type is shown in **Figure 6.1**).
- Offshore motherships. (With potentially similar capabilities to offshore support vessels, plus the ability to launch and recover small crew transfer vessels (daughter-craft). Indicatively 90m in length).
- Offshore accommodation or floatel vessels. (Specialised version of offshore support vessels, focussed on providing accommodation and welfare facilities),
- Crew transfer vessels. (Primary capability is crew transfer – between vessels and/or offshore structures. May also have other general O&M capabilities. Various transfer systems (heave compensated gangways, etc.) and hull forms are possible. Potentially varies between larger shore-based and smaller daughter-craft types. Indicatively up to 35m in length. Example vessel is shown in **Figure 6.2**).
- Large offshore crane vessels. (Major offshore construction vessels, potentially jack-up, semi-submersible, or other hull forms. Could be in excess of 150m in length. An example vessel is shown in **Figure 6.3**).

- Cable maintenance and repair vessels. (Could vary widely in size up to very large cable installation vessels if significant cable repairs are required. Indicatively up to 150m in length).
- General purpose, support, and survey vessels. (Including tugs, guardships, and anchor handlers to support large vessel operations. Also survey vessels, small cargo and parts transportation, and various specialised and general-purpose vessels as required to support the operation of Dogger Bank Teesside).
- Specialised offshore maintenance equipment. (Including examples such as remotely operated underwater vehicles (ROVs), autonomous underwater vehicles (AUVs), and specialised wind turbine cranes which are connected onto the wind turbine structures to provide a stable base for their operation).

Figure 6.3 GMS Endeavour jack up vessel in operation

Courtesy of Scira Offshore Energy

6.5.7. Offshore O&M may also require the use of helicopters for emergency response, personnel transfer between shore and offshore vessels or accommodation, and potentially also to turbines themselves. Suitable helicopter movement parameters are provided in **Table 6.13** assuming an O&M strategy relying primarily on helicopter transportation. Any helicopters used would be operated in accordance with appropriate best practice guidance, and all procedures and systems would be approved in consultation with the Civil Aviation Authority (CAA) and relevant regulatory authorities.

6.5.8. Fixed accommodation platforms may also be required, co-located with offshore collector or converter platforms, or separate, and are described in detail within **Section 3.7 Offshore Platforms**. Accommodation platforms could also act as a central offshore operations 'hub' in a similar manner to offshore support or accommodation vessels. Accommodation platforms may also act as a base for platform-based crew transfer vessels, similar to the daughter-craft associated with motherships.

6.5.9. Precise details of the vessels and equipment that will be used, and their total numbers and movements will not be finalised until the technical solutions are selected for execution of the projects, and details of the O&M contracts are known.

6.5.10. **Table 6.11** shows indicative vessel numbers resulting from a representative O&M strategy based upon vessel access only. **Table 6.12** shows the indicative number of round trips to port these vessels might make each year. Final vessel numbers and related movements will be dependent on the detailed scenario selected and the operational requirements of the wind farm.

Table 6.11 Indicative O&M vessel numbers per project for a representative vessel-based strategy

	Indicative numbers of vessels	
Vessel type	Teesside Project A	Teesside Project B
Large O&M vessels (such as offshore support vessels)	3	3
Small O&M vessels (such as large crew transfer vessels)	11	11
Large crane vessels	2	2
Cable maintenance vessels	2	2
Auxiliary vessels	8	8
Total	26	26

Table 6.12 Indicative annual O&M vessel journeys to port for a representative vessel-based strategy

	Indicative number of annual return journeys to port	
Vessel type	Teesside Project A	Teesside Project B
Large O&M vessels (such as offshore support vessels)	40	40
Small O&M vessels (such as crew transfer vessels)	430	430
Large crane vessels	40	40
Cable maintenance vessels	10	10
Auxiliary vessels	210	210
Total	730	730

Table 6.13 Indicative annual O&M helicopter journeys for a helicopter-based strategy

	Indicative number of annual return journeys	
Vessel type	Teesside Project A	Teesside Project B
Indicative annual return trips to shore for helicopters during the O&M phase	900	900
Indicative annual helicopter return trips within the project during the O&M phase	3000	3000

Offshore O&M Strategies and Activities

Figure 6.4 Helicopter winching operation

Courtesy of Vestas Wind Systems

6.5.11. There are a wide range of O&M strategies available for the Dogger Bank Teesside A & B projects. Factors considered in the development of O&M strategies include; safety of personnel, transit duration, port location, the amount of weather downtime, and the economic viability of each O&M option. The optimum strategy is strongly influenced by factors such as the wind turbine type selected and must therefore be selected during the final detail design process.

6.5.12. It is probable that different O&M methodologies may be selected for the different Dogger Bank Teesside A & B projects. The differences in O&M methodologies will reflect the wind farm technologies selected for each project and the distinctive operating philosophy of each operator. Based on the technologies currently in use and under development, the selected O&M strategy could be based on one of the following illustrative approaches:

- A small number of offshore support vessels act as offshore operations hubs, with a fleet of large crew transfer vessels, operating from shore bases and remaining in the field for around a week at a time, transporting O&M personnel to tasks as required. Some concepts exist in which the offshore support vessel becomes the primary transfer vessel, and far fewer small crew transfer vessels are therefore required. Larger crane vessels and specialised vessels may be required throughout the year, or may be brought in when required.
- Offshore motherships could be used instead of offshore support vessels, with smaller daughter-craft replacing the large crew transfer vessels. Again, larger crane vessels and specialised vessels may be required

throughout the year, or be brought in when required.

- Fixed accommodation platforms could be used instead of offshore motherships, with platform-based crew transfer vessels replacing daughter-craft. Again, larger crane vessels and specialised vessels may be required throughout the year, or be brought in when required.
- Helicopters could be used as part of any of the strategies described above, to assist in the movement of personnel between shore and offshore vessels or accommodation, and potentially also to turbines themselves, as shown in **Figure 6.4**. In the most extreme case, helicopters could be the primary form of access to offshore structures, in place of crew transfer vessels.

6.5.13. O&M methodologies will be dependent upon the technical solutions and strategies selected for the project. Key tasks which may be undertaken include:

- Inspections and surveys (including of corrosion, cable protection, coatings, wind turbine components. Also including investigating remotely identified faults. May be carried out manually or using remote sensing).
- Sampling and testing (including of lubricating oils, etc)
- Replacement of consumable items (such as filters, and hydraulic oils).
- Repair or replacement of worn, failed, or defective systems (such as wind turbine blades, gearboxes, bolts, corrosion protection systems, protective coatings, cables, etc. Including cleaning off subsea marine growth, realigning machinery, renewing cable protection using additional rock dumping or mattress placement, etc.).
- Updating or improving systems (such as control systems, sensors, etc.).
- Disposal of waste materials and parts (in line with best practice and regulatory requirements).

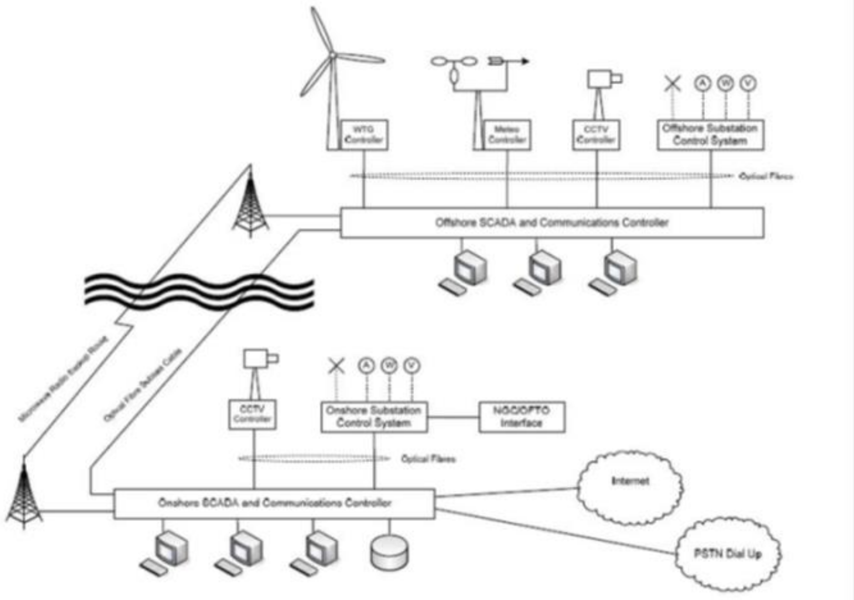
6.5.14. In order to carry out these tasks, a range of activities will be required. Key activities which may be undertaken include:

- transfer of personnel using vessels, helicopters or specialist transfer systems;
- lifting;
- working at heights;
- working in enclosed spaces;
- working with high voltage electricity;
- diving and other subsea operations (including ROV or AUVs);
- transport of parts, consumables and equipment to and from site;
- jacking–up, mooring, and anchoring of vessels; and
- the safe navigation of vessels and aircraft in and around the site.

Operational Control of the Wind Farm

6.5.15. All elements of the onshore and offshore wind farm projects will be designed to operate with minimal day-to-day supervisory input, with the key systems monitored from a central location 24 hours a day.

Figure 6.5 Indicative Operation and Control System of a Wind Farm



Courtesy of RWE npower renewables

6.5.16. Each wind turbine will be controlled by internal microprocessor control systems, which, for example, automatically manage wind turbine start-up at the cut-in wind speed, optimisation of energy production during normal operation, and shut down at wind speeds exceeding the operational envelope (during storm conditions).

6.5.17. The wind turbines and associated equipment will also be monitored centrally using a software system often referred to as a Supervisory Control And Data Acquisition, or SCADA system. The SCADA system acts as an interface for a number of sensors and controls throughout the wind farm, allowing the wind farm status and performance to be monitored, and for systems to be controlled remotely where required. Wind farm control systems are typically linked to onshore management facilities using optical fibres integrated into the various project power cables, although alternative communication systems, such as satellite or microwave links, are possible. **Figure 6.5** shows an indicative diagram for a wind farm control and communication system.

6.5.18. Manual and automated emergency stop facilities will be included within the wind turbines and other relevant systems, and can typically be activated locally or remotely. In the event of an emergency and at the request of the emergency services, the wind farm as a whole can be shut down or controlled remotely, in line with MCA guidelines documented within MGN 371.

Operational Noise

6.5.19. Offshore operational noise generated by the wind farm has been considered, and is discussed within **Section 3.6 Piling & Noise Modelling**.

Onshore Operation & Maintenance

Maintenance of Landfall

6.5.20. No maintenance of the landfall is envisaged during the operational phase of the project. The landfall will be designed to ensure that the cables will remain buried for the lifetime of the project, allowing for coastal erosion. The cable joints between onshore and offshore systems may require inspections and/or repairs during the lifetime of the wind farms, although the joints would be expected to be designed at the outset for the same design life as the cables.

Onshore Cables

6.5.21. For both HVDC and HVAC cables no planned maintenance activity is envisaged during the operational phase of the project. A cable system design life of approximately 40 years is typically provided for by manufacturers. Occasional access may be required to the cable for fault finding and repair purposes. This would require the area around the fault to be excavated and the fault repaired. If the fault cannot be repaired, a new length of cable may be inserted and jointed to replace the failed section.

Converter stations

6.5.22. Regular access will be required to the converter station throughout the lifetime of the project for monitoring, fault repairs and planned maintenance purposes. However, vehicle movements are likely to be low, as significant maintenance activities are expected to be infrequent. Predicted usage and resulting traffic levels are discussed in detail within **Chapter 28 Traffic and Access**.

6.5.23. Onshore converter station noise is discussed in **Chapter 29 Noise and Vibration**.

6.6. Replanting/Life Extension

6.6.1. The Crown Estate's leases for the Dogger Bank Teesside A & B projects currently have durations of 50 years. However, manufacturers of the key wind farm components, including wind turbines and offshore platforms, typically design for an operational life of 20 to 30 years. This design life varies with the wind farm component, and depending on operational circumstances it may be possible for a component to operate beyond the original design life. For example, testing may identify that a wind turbine structure has experienced lower loading than originally assumed or key turbine components may be replaced due to routine maintenance or as part of a planned life extension programme, and this may allow the predicted operational life to be extended.

6.6.2. In addition to life extension, the wind farm may be replanted at the end of its design life of 20 to 30 years. It is envisaged that replanting (such as replacement of the wind turbines) would be subject to an additional planning consent application, and as such is not considered within the current application and EIA process.

6.7. Decommissioning

6.7.1. At the end of the wind farm's life, decommissioning may be undertaken that broadly follows a reverse programme to the construction process. The requirement to decommission is a condition of The Crown Estate lease and is also incorporated in the statutory consenting process through the provisions of the Energy Act 2004. A detailed decommissioning programme, including a decommissioning EIA, is required to be set out for the Secretary of State, and funds must be set aside for the purposes of decommissioning in accordance with Government's Guidance Note for 'Decommissioning Offshore Renewable Energy Installations under the Energy Act 2004'.

6.7.2. The decommissioning plan will take into account the latest technological advances as well as legislative and environmental requirements at the time that the work is due to be undertaken.

6.7.3. Where the operator has opted to undertake replanting, as described previously in **Section 6.6 Replanting/Life Extension**, this may result in decommissioning of the entire wind farm or removal and decommissioning of selected components. For example, the original turbines may be replaced during re-planting but the offshore export cables and platforms may remain to continue in use.

6.7.4. Final decommissioning of the Dogger Bank Teesside A & B projects components or their replacements would be expected to take place at the end of The Crown Estate lease term. Preliminary decommissioning plans for some key components of Dogger Bank Teesside A & B are outlined in the following sections.

Offshore Decommissioning

Decommissioning of Wind Turbines

6.7.5. The removal of the structure is expected to involve the approximate reverse of the installation process. The following steps are anticipated:

i. Assessment of the potential hazards during planned decommissioning and development of suitable procedures for mitigating them.
ii. Assessment of potential risk of pollutants entering the environment.
iii. Disconnecting of wind turbines from electrical distribution network and SCADA system (Including any additional condition monitoring and communications systems).
iv. Mobilisation of decommissioning vessels.
v. Removal of any potentially hazardous or polluting materials from the turbine. With the use of appropriate vessels, remove rotor blades, then nacelle, then tower sections.
vi. Transport all components to onshore facility for processing and reuse/recycling/disposal.

6.7.6. It should be noted that the decommissioning may not happen in the precise order outlined above. For example, in a wind turbine with a gearbox it may not be possible to remove the lubricating oil until after the rotor blades have been removed, as the gearbox may need to operate to position the rotor prior to removal of the blades.

Decommissioning of Offshore Wind Turbine Foundations

Piled foundations

6.7.7. It is envisaged that piled foundations would be cut below seabed level, and the protruding section removed. Typical current methods for cutting piles are abrasive water jet cutters or diamond wire cutting. The final method chosen shall be dependent on the technologies available at the time of decommissioning.

6.7.8. The indicative methodology would be:

i. Deployment of ROV's or divers to inspect each pile footing and reinstate lifting attachments if necessary.
ii. Mobilise a jack-up barge/heavy lifting vessel.
iii. Remove any scour protection or sediment obstructing the cutting process. It may be necessary to dig a small trench around the foundation.
iv. Deploy crane hooks from the decommissioning vessel and attach to the lift points.
v. Cut piles at just below seabed level.
vi. Inspect seabed for debris and remove debris where necessary.
vii. Considering the current technology, the decommissioned components are likely to be transported back to shore by lifting onto a jack-up or heavy lift vessels, freighter, barge, or by buoyant tow.

viii. Transport all components to an onshore site where they will be processed for reuse/recycling/disposal.
ix. Inspect seabed and remove debris.

Decommissioning of Gravity Base Structures

6.7.9. In the case of gravity base foundations, it may be preferable to leave gravity base structures on the seabed to preserve the marine habitat that has established over their life, subject to discussions with key stakeholders and regulators. In this case the central tubular section would be cut off and removed whilst the base remains in place. However, where removal of the entire base is considered necessary, for example if it is considered a navigational hazard, it would probably be achieved in a manner similar to the following:

i. Deploy remotely operated vehicles or divers to establish the base structural integrity and reinstate lifting attachments if necessary.
ii. Mobilise suction dredging vessel to remove ballast from base and dispose of it appropriately.
iii. Deploy remotely operated vehicles or diver to inspect the base to ensure remaining ballast is removed.
iv. Disaggregate compacted sediments below gravity base.
v. Mobilise heavy lift vessel, to lift the bases completely out of the seabed and onto a transportation vessel.
vi. Transport to an onshore site, where it will be processed for reuse/recycling/disposal.
vii. Inspect seabed and remove debris.

Suction Foundations

6.7.10. Suction bucket foundations can be removed using approximately the reverse of the process required to install them. This could include use of a pump system to apply pressure inside the buckets, and allow the foundation to be released and extracted from the seabed. During the release process, any seawater or ballast inside the foundation shaft could be pumped out to make the structure buoyant, so that it can be recovered by an appropriate barge for transport from the site.

Decommissioning of Meteorological Monitoring Masts

6.7.11. The removal of the structure is expected to involve the approximate reverse of the installation process. The methodology would be expected to be broadly similar to that described above for wind turbine generators and the appropriate foundation type described above.

Removal of Scour Protection and Subsea Protection

6.7.12. It may be preferable to leave any scour or subsea protection around the turbine bases or covering cables in-situ, in order to preserve the marine habitat that has been established over the life of the wind farm. However, if it is considered preferable to remove the scour protection this could be achieved using the following techniques:

i. Dredging of the scour protection with subsequent transportation to an approved site for appropriate disposal or re-use.
ii. For rock fill, the individual boulders may be recovered using a grab vessel, deposited in a hopper barge, and transported to an approved site for appropriate disposal or re-use.
iii. For other systems such as frond mats, concrete aprons, or proprietary cable protection systems, the components could be recovered onto a crane vessel for appropriate recycling or disposal.

Decommissioning of Offshore Cabling

6.7.13. It is envisaged that, where appropriate, buried assets such as cables will be left in situ when the project is decommissioned. Discussions with stakeholders and regulators may identify the need for cables to be wholly or partially removed. Potential recovery of these cables may then be possible using techniques including mass flow excavation, grapnels or other available future techniques, but this will require environmental impact assessment at the time to investigate the potential effects of the retrieval operations.

6.7.14. An indicative methodology using current technology would be:

i. Identify the location where cable removal is required. This may require deployment of remotely operated vehicles.
ii. It may be necessary to remove seabed material or cable protection measures to allow access to the cable.
iii. Mobilise suitable vessels for cable removal.
iv. Using a grapnel the cables will be raised from the seabed.
v. The required sections will be cut and removed. The remaining ends weighted and returned to the seabed
vi. Transport cable to onshore facility for processing and reuse/recycling/disposal.

6.7.15. The question of whether or not cable crossing infrastructure should be left in situ will also depend on the commercial arrangements and requirements in the individual crossing agreements.

Decommissioning of Offshore Platforms

Platform Topside

6.7.16. It is envisaged that any offshore platforms, (collector, converter, or accommodation) will be removed at the end of the project life and returned to shore for decommissioning, and disposal. The decommissioning programme would be expected to be similar to the decommissioning method employed for the wind turbine structures:

i. Assessment of the potential hazards during planned decommissioning and development of suitable procedures for mitigating them.
ii. Assessment of potential risk of pollutants entering the environment.
iii. Disconnecting of offshore platform from grid and SCADA system (Including any additional condition monitoring and communications

systems).

iv. Mobilisation of decommissioning vessels. It should be noted that a heavy lift vessel may be required for some tasks.
v. Removal of any potentially hazardous or polluting materials from the offshore platform.
vi. With the use of appropriate vessels remove topside structure.
vii. Transport all components to onshore facility for processing and reuse/recycling/disposal.

Platform Foundation

6.7.17. The decommissioning programme for any platform foundations will be dependent on the foundation type selected for the platform. The decommissioning of the foundations will be in line with the descriptions given for the wind turbine foundations.

Onshore Decommissioning

Landfall Infrastructure

6.7.18. Landfall infrastructure will be left in-situ where considered appropriate. Any requirements for decommissioning at the landfall will be agreed with statutory consultees.

Underground Cables

6.7.19. There is currently no statutory requirement for decommissioned cables to be removed and it is likely judged that removal of the cables would bring about further environmental impacts. At present it is therefore proposed that the cables will be left in-situ, but this will be reviewed over the design life of the project.

Onshore Converter Substations

6.7.20. The onshore converter stations for Dogger Bank Teesside A & B, and any associated equipment, will be removed at the end of the project life, and the land will be restored and reinstated to their previous condition where feasible.

7. Health & Safety and Environmental Management

7.1. Health and Safety

7.1.1. The construction and operation of the projects will be subject to full health, safety and environment controls and risk assessments. All onshore and offshore construction and operational work will be conducted in accordance with appropriate best practice guidelines and in line with the relevant regulatory legislation.

7.1.2. All work throughout the life of both projects will follow the corporate health and safety policies of their respective owners. Health and safety management systems shall be put in place. Employment of such systems will enhance health and safety by utilising experience gained throughout the construction and operation of the wind farm. Examples of health and safety management systems may include regular inspections of wind farm elements, routine audits and near-miss reporting. The selection of health and safety management systems will be dependent on construction and operation practices used for the projects.

7.1.3. All elements of the projects shall be designed and manufactured in accordance with the relevant industry codes.

7.1.4. In order to mitigate the impacts of the construction of the onshore works of Dogger Bank Teesside A & B, both on the amenity of local residents and the local environment, a broad range of mitigation measures are proposed throughout the draft Environmental Statement. To bring together and secure all these measures the draft DCO includes a draft code of construction practice.

7.1.5. If consent is granted, the content of the Code must be approved by Redcar and Cleveland Borough Council before construction starts. The requirements of the approved Code will then be implemented both by the developer and its contractors, and compliance with the Code will be enforceable by the Council throughout the onshore construction phase.

7.2. Waste Management

Waste Management Construction Phase

7.2.1. Waste will be generated during the construction of the offshore and onshore elements of the projects. At this stage it is not possible to estimate waste arising from construction activities. Waste products will cover a range of substances. These substances may include, but are not limited to: black water (water containing sewage, medical waste, etc.), grey water (water from dish washing, bathing, etc.), bentonite fluid (from horizontal directional drilling), waste grout, component packaging, and general waste (e.g. food, drinks, cans and general rubbish).

7.2.2. During the installation of the onshore cables and the construction of the converter station waste top soil and sub soil will be generated. It will be possible to re-use the majority of this excavated material on site.

7.2.3. As described in **Section 2.3 Onshore Site Description** the majority of the onshore cable route passes through agricultural land. However, the route does pass through a number of areas that have been used for non-agricultural purposes such as a known historic landfill site, gravel pits and electrical substations. These areas may contain a number of contaminants depending on the materials that have been used to fill them. Materials excavated from these areas will be analysed to assess if they are suitable for re-use or should be disposed. The materials will also be assessed to identify if they should be treated as a hazardous material. The site waste management plan is discussed further in **Appendix 24.C** of **Chapter 24 Geology, Water Resources and Land Quality**.

7.2.4. Some areas, such as the electrical substations, may require the minimal excavation of concrete pavement, sub-base and made ground. It will be possible to re-use the majority of this material on site.

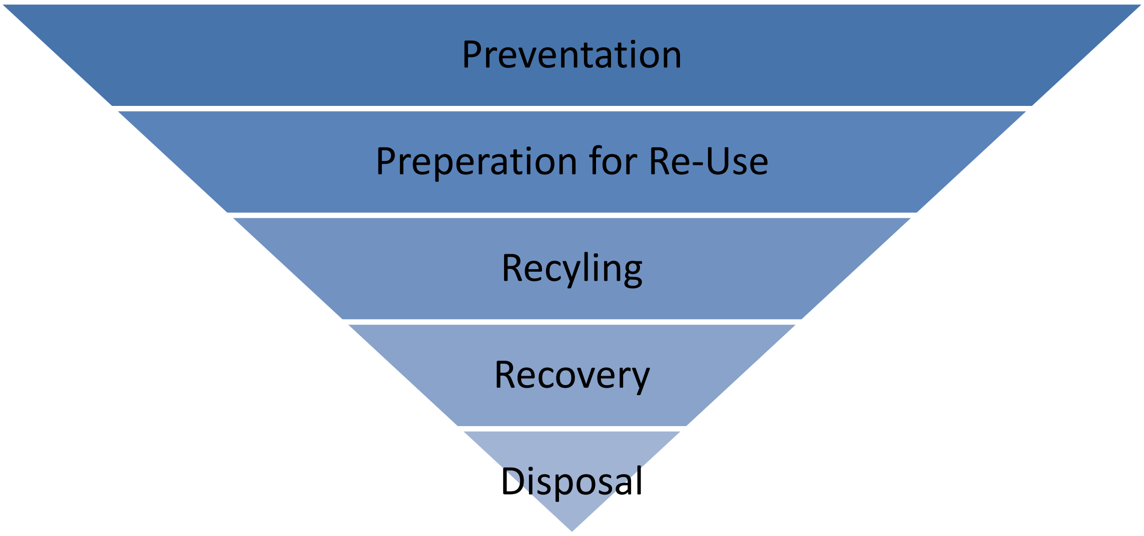
7.2.5. Prior to construction of the projects the estimated quantities and types of waste will be confirmed through the detailed design work.

Waste Management Operations & Maintenance Phase

7.2.6. During the operational phase of the projects routine and light industrial type waste will be generated and this will be dealt with appropriately in accordance with local waste management requirements.

Waste Management Control and Mitigation

Figure 7.1 Waste management hierarchy



7.2.7. Any waste materials will be dealt with in accordance with appropriate best practice guidelines and in line with the relevant regulatory legislation to avoid harm to employees, third parties and the environment. Where practical, the waste management hierarchy, shown in **Figure 7.1**, will be followed in developing procedures for waste management, in order to reduce environmental impact. When waste cannot be prevented or reduced, priority will be given to preparing it for re-use, then recycling, then recovery and finally disposal. Waste materials requiring controlled disposal may be sent to licenced contractors for controlled recycling or disposal dependent on the waste material.

7.2.8. Vessels, offshore substation platforms and onshore converter stations will include drainage and waste management systems, as required to meet regulatory requirements. These will collect waste products such as grey and black water, and waste oil. Bunding, to collect and contain leaks, will be included around relevant areas as required.

7.2.9. Waste management systems may store waste products for controlled processing or disposal onshore or elsewhere, or incorporate appropriate purification units which comply with requirements if waste is to be discharged to the sea.

7.2.10. A fuller description of waste management can be found in **Appendix 24.C** of **Chapter 24 Geology, Water Resources and Land Quality**.

7.3. Hazardous Material

Hazardous Material Construction Phase

7.3.1. During the construction of the offshore and onshore elements of the projects a limited amount of hazardous or polluting materials may be used. Potential materials may include, but are not limited to; fuel, lubricants, grouting material, epoxy-based materials and drilling fluid. In addition to the materials listed, construction activities, such as welding, may result in dust or fumes that will be treated as hazardous.

7.3.2. Electrical components also contain a number of hazardous materials which may be released during the construction phase. Potential materials may include, but are not limited to; insulating oil in transformers and sulphur hexafluoride gas used in switch gear.

Hazardous Material Operations and Maintenance Phase

7.3.3. Hazardous or polluting materials may be generated as a result of operations & maintenance activities for the Dogger Bank Teesside A & B projects. The primary waste products generated by the routine maintenance of the wind turbines and substation platforms may include:

- Gearbox and other lubricating oils from preventive and corrective maintenance.
- Lubricating grease in turbines from preventive and corrective maintenance.
- Hydraulic Oil in turbines from preventive and corrective maintenance activities.
- Sulphur hexafluoride in gas insulated switchgear both on the turbines and substation platforms.

7.3.4. In addition to the materials listed above, operation and maintenance activities, such as grinding, may result in dust or fumes that may be treated as hazardous.

7.3.5. During the operation & maintenance phase a number of other hazardous materials may be held on site. These materials are required for operation of the wind farm. Potential materials may include, but are not limited to; insulating oil for transformers, glycol for cooling plant, fuel & epoxy-based materials.

7.3.6. However, it should be noted that types and quantities of material will be dependent on the type of equipment used on site and the activities undertaken. For example, a wind turbine using a hydraulic transmission system will have no gearbox oil, but a greater quantity of hydraulic fluid.

Hazardous Material Control and Mitigation Phase

7.3.7. Any hazardous or polluting materials will be dealt with in accordance with appropriate best practice guidelines and in line with the relevant regulatory instructions to avoid harm to employees, third parties and the marine environment. Where possible the requirement for hazardous materials on site during the construction and operational phases of the projects will be eliminated, reduced or isolated.

7.3.8. Where hazardous materials cannot be eliminated, control measures shall be put in place. Methods may include the installation of bunding, appropriate ventilation, or vapour detection systems. Where it is deemed that the failure of an item of equipment might result in large quantities of a hazardous material being leaked additional measures shall be put in place. For example, oil containing transformers at the onshore converter station may have secondary containment incorporated through an underground containment facility with the addition of further safety measures such as flame traps. The additional measures shall be dependent on the technology used and the risks identified.

7.3.9. In addition, during both the construction and operation phases, procedures and management systems will be put in place to mitigate against the release of hazardous or polluting materials. This shall include procedures describing the handling of hazardous or polluting materials and plans put in place to respond to any emergency activity, such as a spill.

7.3.10. Where possible, hazardous or polluting waste materials will be dealt with in accordance with the waste hierarchy as described in **Section 7.2 Waste Management**. Hazardous or polluting materials requiring disposal will be sent to licenced contractors for controlled recycling or disposal.

7.4. Safety Zones and Other Potential Navigation Safety Measures

7.4.1. During the lifetime of the Dogger Bank Teesside A & B projects, permanent and temporary safety zones may be requested around individual structures. Safety zones are intended to ensure the safety of other sea users and to avoid damage to marine infrastructure by creating defined areas which may typically not be entered by other marine users. In addition, charted Development Areas (DAs), Areas to Be Avoided (ATBAs) or other similar advisory safety designations, may be requested to clearly communicate the potential hazards associated with transit through a wind farm area. The ultimate need for navigational safety measures will be defined based on the final project design, on-going risk reviews and in consultation with the relevant marine authorities. It is noted that under the Energy Act 2004, the Secretary of State may impose alternative arrangements for operational safety zones where this is considered appropriate and that the need for safety zones can be reviewed as further information becomes available throughout project life.

7.4.2. During construction, commissioning, decommissioning and any exceptional major maintenance works, safety zones of up to 500m radius may be sought around active works, and potentially any hazardous partially completed structures.

7.4.3. Safety zones are not expected to be requested for the operational phase of Dogger Bank Teesside A & B, with the possible exception of activities discussed above and key structures such as offshore collector, converter or accommodation platforms, for which safety zones of up to 500m may be requested.

7.4.4. DAs, ATBAs and other similar advisory safety designations are not being requested at this time, as part of the initial construction and operation of the project, but the need for them will be kept under review. Such measures would be intended to clearly communicate, via a charted area and note, that navigation and other marine operations close to and within the wind farm boundaries may experience specific hazards and are discouraged where possible. They would not be intended to enable any prosecutions of vessels entering the areas. It is anticipated that such areas would cover the full wind farm array areas, plus potentially any spaces between adjacent projects and appropriate buffers around them. In the event areas were requested during construction, the potential to introduce them in a phased manner as construction progresses across the project areas would be explored. Should a need be identified in the future. Details of any proposed areas will be presented to the MCA and other navigational stakeholders at a suitable time for further discussion.

7.4.5. Reference should also be made to the DCO **Safety Zones Statement** and **Chapter 16 Shipping and Navigation**, and associated appendices.

7.5. Navigation and Aviation Safety Markings

7.5.1. The project as a whole, plus individual components, such as offshore platforms, meteorological masts, turbines and associated support structures will bear safety markings, lighting, and aids to navigation in accordance with the United Kingdom Maritime and Coastguard Agency (MCA), Trinity House, and Civil Aviation Authority (CAA) requirements. The final marking and lighting requirements will ultimately depend upon the final project design and will be developed in consultation with these organisations; Trinity House, MCA and the CAA. Indicative marking requirements are expected to include the following:

- Transition pieces and above-water foundation structures shall be painted high-visibility yellow to approximately 15m above highest astronomical tide (HAT);
- Significant peripheral structures (SPS - such as turbines on the corners of the array) and intermediate peripheral structures (IPS - such as turbines in the middle of a long edge) shall have yellow navigation lights positioned, and with a range and flash characteristic, as agreed with Trinity House;
- Individual isolated structures outside the turbine array will be marked with a white navigation light flashing morse code “U”, as per the standard IALA (International Association of Lighthouse Authorities), and Trinity House, requirement;
- Navigation sound signals will be installed where necessary, with characteristics as agreed with Trinity House;
- Individual wind turbines, offshore platforms, and met masts will be marked with a unique alphanumeric identifier which is designed and lit so as to be clearly visible at a distance of not less than 150m in day or night without interfering with navigational lighting;
- The wind farm will be marked with fixed red and/or infrared aviation warning lights as required by the CAA and MOD. It is expected that only a limited number of turbines would be lit, located similarly to the SPS, typically with lights fitted to the turbine nacelles;
- The positions of all offshore structures and sub-sea cables will be reported to the UK Hydrographic Office so that they can be appropriately charted and incorporated into notice to mariner procedures. All relevant information will also be supplied to the MCA, CAA, fishermen, and other key stakeholders to ensure necessary information is available to other sea users.

7.5.2. In addition, construction phase lighting and marking will be agreed with Trinity House, to include aspects such as any detailed requirements for lighting and/or marking partially completed structures.

7.5.3. Reference should also be made to **Chapter 16 Shipping and Navigation, Chapter 19 Military Activities, Chapter 20 Civil Aviation** and their associated appendices.