# RWE Renewables UK Dogger Bank South (West) Limited

# RWE Renewables UK Dogger Bank South (East) Limited

# Dogger Bank South Offshore Wind Farms

**Cable Statement**

**Volume 8**

**June 2024**

**Application Reference: 8.20**

**APFP Regulation: 6(1)(b)(i)**

**Revision: 01**

Unrestricted

| | | | |
|---|---|---|---|
| Company: | **RWE Renewables UK Dogger Bank South (West) Limited and RWE Renewables UK Dogger Bank South (East) Limited** | Asset: | **Development** |
| Project: | **Dogger Bank South Offshore Wind Farms** | Sub Project/Package: | **Consents** |
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**Unrestricted**

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## Glossary

| Term | Definition |
|---|---|
| Accommodation Platform | An offshore platform (situated within either the DBS East or DBS West Array Area) that would provide accommodation and mess facilities for staff when carrying out activities for the Projects. |
| Array Areas | The DBS East and DBS West offshore Array Areas, where the wind turbines, offshore platforms and array cables would be located. The Array Areas do not include the Offshore Export Cable Corridor or [that part of] the Inter-Platform Cable Corridor [within which no wind turbines are proposed]. Each area is referred to separately as an Array Area. |
| Array cables | Offshore cables which link the wind turbines to the Offshore Converter Platform(s). |
| Collector Platforms (CPs) | Receive the AC power generated by the wind turbines through the array cables, collect it and transform the voltage for onward transmission to the Offshore Converter Platforms (OCPs). |
| Concurrent Scenario | A potential construction scenario for the Projects where DBS East and DBS West are both constructed at the same time. |
| Construction Buffer Zone | 1km zone around the Array Areas and Offshore Export Cable Corridor, and 500m zone around the Inter-Platform Cabling Corridor. Construction vessels may occupy this zone but no permanent infrastructure would be installed within these areas. |
| Development Scenario | Description of how the DBS East and/or DBS West Projects would be constructed either in isolation, sequentially or concurrently. |
| Dogger Bank South (DBS) Offshore Wind Farms | The collective name for the two Projects, DBS East and DBS West. |

| Term | Definition |
|---|---|
| Electrical Switching Platform (ESP) | The Electrical Switching Platform (ESP), if required would be located either within one of the Array Areas (alongside an Offshore Converter Platform (OCP)) or the Export Cable Platform Search Area. |
| Export Cable Platform Search Area | The Export Cable Platform Search Area is located mid-way along the Offshore Export Cable Corridor and is the area of search for the Electrical Switching Platform (ESP). |
| Haul Road | The track along the Onshore Export Cable Corridor used by traffic to access different sections of the onshore export cable route for construction. |
| Horizontal Directional Drill (HDD) | HDD is a trenchless technique to bring the offshore cables ashore at the landfall. It can also be used for crossing obstacles such as roads, railways and watercourses onshore. |
| In Isolation Scenario | A potential construction scenario for one Project which includes either the DBS East or DBS West array, associated offshore and onshore cabling and only the eastern Onshore Converter Station within the Onshore Substation Zone and only the northern route of the onward cable route to the proposed Birkhill Wood National Grid Substation. |
| Inter-Platform Cables | Buried offshore cables which link offshore platforms. |
| Inter-Platform Cable Corridor | The area where Inter-Platform Cables would route between the DBS East and DBS West Array Areas, should both Projects be constructed. |
| Intertidal | Area on a shore that lies between Mean High Water Springs (MHWS) and Mean Low Water Springs (MLWS). |
| Jointing Bays | Underground structures constructed at regular intervals along the onshore cable route to join sections of cable and facilitate installation of the cables into the buried ducts. |

| Term | Definition |
|---|---|
| Landfall | The point on the coastline at which the Offshore Export Cables are brought onshore, connecting to the Onshore Export Cables at the Transition Joint Bay (TJB) above mean high water. |
| Link Boxes | An underground metal box placed within a concrete pit where the metal sheaths between adjacent export cable sections are connected and earthed, installed with a ground level manhole to allow access to the Link Box for regular maintenance or fault-finding purposes. |
| Mean High Water Springs (MHWS) | MHWS is the average of the heights of two successive high waters during a 24 hour period. |
| Mean Low Water Springs (MLWS) | MLWS is the average of the heights of two successive low waters during a 24 hour period. |
| Nationally Significant Infrastructure Project (NSIP) | Large scale development including power generating stations which requires development consent under the Planning Act 2008. An offshore wind farm project with a capacity of more than 100 MW constitutes an NSIP. |
| Offshore Converter Platforms (OCPs) | The OCPs are fixed structures located within the Array Areas that collect the AC power generated by the wind turbines and convert the power to DC, before transmission through the Offshore Export Cables to the Project's Onshore Grid Connection Points. |
| Offshore Development Area | The Offshore Development Area for ES encompasses both the DBS East and West Array Areas, the Inter-Platform Cable Corridor, the Offshore Export Cable Corridor, plus the associated Construction Buffer Zones. |
| Offshore Export Cables | The cables which would bring electricity from the offshore platforms to the Transition Joint Bays (TJBs). |

| Term | Definition |
|---|---|
| Offshore Export Cable Corridor | This is the area which will contain the Offshore Export Cables (and potentially the ESP) between the Offshore Converter Platforms and Transition Joint Bays at the landfall. |
| Onshore Converter Stations | A compound containing electrical equipment required to transform HVDC and stabilise electricity generated by the Projects so that it can be connected to the electricity transmission network as HVAC. There will be one Onshore Converter Station for each Project. |
| Onshore Development Area | The Onshore Development Area for ES is the boundary within which all onshore infrastructure required for the Projects would be located including Landfall Zone, Onshore Export Cable Corridor, accesses, Temporary Construction Compounds and Onshore Converter Stations. (as shown on **Volume 7, Figure 5-2 (application ref: 7.5.1)**. |
| Onshore Export Cables | Onshore Export Cables take the electric from the Transition Joint Bay to the Onshore Converter Stations. |
| Onshore Export Cable Corridor | This is the area which includes cable trenches, Haul Roads, spoil storage areas, and limits of deviation for micro-siting. For assessment purposes, the cable corridor does not include the Onshore Converter Stations, Transition Joint Bays or temporary access routes; but includes Temporary Construction Compounds (purely for the cable route). |
| Onshore Substation Zone | Parcel of land within the Onshore Development Area where the Onshore Converter Station infrastructure (including the Haul Roads, temporary construction compounds and associated cable routeing) would be located. |
| Projects Design (or Rochdale) Envelope | A concept that ensures the EIA is based on assessing the realistic worst-case scenario where flexibility or a range of options is sought as part of the consent application. |
| Sand wave | Bedforms with wavelengths of 10 to 100m, with amplitudes of 1 to 10m. |

| Term | Definition |
|---|---|
| Scour protection | Protective materials to avoid sediment erosion from the base of the wind turbine foundations and offshore substation platform foundations due to water flow. |
| Sequential Scenario | A potential construction scenario for the Projects where DBS East and DBS West are constructed with a lag between the commencement of construction activities. Either Project could be built first. |
| The Applicants | The Applicants for the Projects are RWE Renewables UK Dogger Bank South (East) Limited and RWE Renewables UK Dogger Bank South (West) Limited. The Applicants are themselves jointly owned by the RWE Group of companies (51% stake) and Masdar (49% stake). |
| The Projects | DBS East and DBS West (collectively referred to as the Dogger Bank South Offshore Wind Farms). |
| Transition Joint Bay (TJB) | The Transition Joint Bay (TJB) is an underground structure at the landfall that houses the joints between the Offshore Export Cables and the Onshore Export Cables. |
| Transition Joint Bay (TJB) Compound | A temporary construction compound located within the 'Landfall Zone' to undertake the trenchless crossing technique e.g. Horizontal Directional Drilling (HDD) and for the construction of the Transition Joint Bays. |
| Turbine string | Term referring to a number of cables installed in series on a single cable branch forming a string (or collection) circuit. |
| Wind turbine | Power generating device that is driven by the kinetic energy of the wind. |

## Acronyms

| Term | Definition |
|---|---|
| APFP | Applications Prescribed Forms and Procedures |
| CP | Collector Platform |
| DBS | Dogger Bank South |
| DCO | Development Consent Order |
| EIA | Environmental Impact Assessment |
| ES | Environmental Statement |
| ESO | Electricity System Operator |
| ESP | Electrical Switching Platform |
| HND | Holistic Network Design |
| HVAC | High Voltage Alternating Current |
| HVDC | High Voltage Direct Current |
| km | Kilometre |
| $km^2$ | Kilometre squared |
| kV | Kilovolt |
| m | Metre |
| mm | Millimetre |
| NSIP | Nationally Significant Infrastructure Project |
| OCP | Offshore Convertor Platfom |
| PLGR | Pre-Lay Grapnel Run |
| ROV | Remotely operated vehicle |

| Term | Definition |
|---|---|
| TJB | Transition Joint Bay |
| UK | United Kingdom |
| UXO | Unexploded Ordnance |

# 1 Cable Statement

## 1.1 Introduction

1. RWE Renewables UK Dogger Bank South (West) Limited and RWE Renewables UK Dogger Bank South (East) Limited (hereafter referred to as the 'Applicants') has submitted an application to the Planning Inspectorate on behalf of the Secretary of State, for a Development Consent Order (DCO) for the Dogger Bank South (DBS) Offshore Wind Farms (hereafter referred to as 'The Projects'). The Projects comprise two separate sites, DBS West and DBS East situated at a minimum of 100 kilometre (km) and 122km from the northeast coast of England, respectively. When operational, DBS West and DBS East combined would have the potential to generate renewable power for up to 3 million UK homes.

2. The Projects include provision for the construction, operation, maintenance and decommissioning of the Dogger Bank South Offshore Wind Farms with up to 200 wind turbine generators. They also include associated works to connect this offshore generating capacity to the proposed Birkhill Wood National Grid Substation, through provision of works to construct, operate and maintain electricity export cables both Offshore and Onshore through a landfall adjacent to Skipsea and Onshore Converter Stations adjacent to the hamlet of Bentley to the south of the town of Beverley. All onshore connection infrastructure would be located in the administrative area of East Riding of Yorkshire Council.

## 1.2 Purpose of the Cable Statement

3. Regulation 6(1)(b)(i) of the Infrastructure Planning (Applications: Prescribed Forms and Procedures) Regulations 2009 (the APFP Regulations) requires the applicant for an offshore generating station to provide "*details of the proposed route and method of installation for any cable*"' to accompany an application for a DCO. This document contains the relevant details for the Projects cable infrastructure.

4. This document also sets out the considerations for cable route design and the approach to installation, presenting preliminary information regarding the cable specification, burial depths and cable protection both offshore and onshore. This high-level information would be factored into the final design and installation planning for the DBS cabling. Thus, this document establishes the basis for how the DBS projects will ensure a safe, reliable and protected grid connection for the Projects.

## 1.3 Scope

5. Whilst the Projects are each Nationally Significant Infrastructure Projects (NSIPs) in their own right, a single application for development consent has been made for both wind farms, and the associated transmission infrastructure. While a single DCO application has been made for both Projects, five separate Deemed Marine Licences are included as schedules to **Volume 3, Draft Development Consent Order (application ref: 3.1)** to cover each Array Area, their associated transmission infrastructure and the inter-project cabling required for the Projects. This approach allows for separate ownership of each asset should their ownership change over time.

6. The Applicants have developed DBS East and DBS West transmission infrastructure as co-ordinated projects in accordance with the National Grid Electricity System Operator (ESO) evolving Holistic Network Design (HND), as updated in February 2024 (ESO, 2024). The HND has confirmed the Projects will each have a radial connection to the proposed Birkhill Wood National Grid Substation. Where practicable the two Projects co-locate infrastructure to reduce overall environmental impacts and disruption.

7. Whilst the Projects are the subject of a single DCO application (with a combined Environmental Impact Assessment (EIA) process and associated submissions), each Project is assessed individually, so that mitigation is Project specific (where appropriate). As such, the assessments cover the following three Development Scenarios:

- DBS East or DBS West are developed In Isolation (the In Isolation Scenario);
- Both DBS East and DBS West are developed Concurrently (the Concurrent Scenario); or
- Both DBS East and DBS West are developed Sequentially (the Sequential Scenario).

8. Both the DBS West and DBS East Projects would use High Voltage Direct Current (HVDC) to transmit electricity generated offshore to the landfall and onward to the Onshore Converter Stations. The onward transmission from the Onshore Converter Stations to the Proposed Birkhill Wood National Grid Substation would use High Voltage Alternating Current (HVAC).

9. The locations of the Array Area and Offshore Export Cable Corridor are shown in **Figure 1-1** and **Volume 7, Figure 5-1 (application ref: 7.5.1)**. The route of the Onshore Export Cable Corridor is shown in **Figure 1-2** and **Volume 7, Figure 5-2 (application ref: 7.5.1)** as well as the indicative Onshore Development Area design on **Volume 7, Figure 5-3 (application ref: 7.5.1)**. Four Onshore Export Cables would be required for two HVDC projects, with two HVDC Onshore Converter Stations required within the Onshore Substation Zone. This is illustrated in **Volume 7, Figure 5-4 (application ref: 7.5.1)**.

10. In summary, the following principles set out the framework for how the Projects may be developed, and are further are detailed in **Table 1-1**.

*Table 1-1 Development Scenarios and Construction Durations*

| Development Scenario | Description | Total Maximum Construction Duration (Years) | Maximum Construction Duration Offshore (Years) | Maximum Construction Duration Onshore (Years) |
|---|---|---|---|---|
| **In Isolation** | Either DBS East or DBS West is built In Isolation | Five | Five | Four |
| **Sequential** | DBS East and DBS West are both built Sequentially, either Project could commence construction first with staggered / overlapping construction | Seven | A five year period of construction for each project with a lag of up to two years in the start of construction of the second project (excluding landfall duct installation) – reflecting the maximum duration of effects of seven years. | Construction works (i.e. onshore cable civil works, including duct installation) to be completed for both Projects simultaneously in the first four years, with additional works at the landfall, substation zone and cable joint bays in the following two years. Maximum duration of effects of six years. |

| Development Scenario | Description | Total Maximum Construction Duration (Years) | Maximum Construction Duration Offshore (Years) | Maximum Construction Duration Onshore (Years) |
|---|---|---|---|---|
| **Concurrent** | DBS East and DBS West are both built Concurrent reflecting the maximum peak effects | Five | Five | Four |

11. For the purposes of this document, information regarding the quantity and length of cables will outline the maximum requirements for both Projects.

12. The cables required to implement the proposed Projects include:

- Subsea cables to the landfall comprise:
  - Array cables (linking up to 200 wind turbines, 100 per project, to the Collector Platforms (CPs) and/or Offshore Converter Platforms (OCPs);
  - Inter-Platform Cables;
  - Offshore Export HVDC Cables (each in its own trench under a Worst Case Scenario), two per Project (linking the OCPs to the landfall); and
  - Two fibre optic communications cables, one per Project.
- Onshore cables include:
  - Four Onshore Export HVDC Cables, two per Project (linking the landfall to the Onshore Converter Stations);
  - Two fibre optic communications cables, one per Project;
  - Link boxes and Jointing Bays installed along the Onshore Export Cable Corridor;
  - Up to eight, 400 kilovolt (kV) cable circuits, four per Project (linking the Onshore Converter Stations to the proposed Birkhill Wood National Grid Substation).

13. **Table 1-2** shows parameters outlined within **Volume 7, Chapter 5 Project Description (application ref: 7.5)** for offshore cables.

*Table 1-2 Parameters for Offshore Export Cables*

| Parameter | Details | | |
|---|---|---|---|
| | DBS East Alone | DBS West Alone | DBS East and West Combined |
| Indicative construction duration (years) (excluding landfall works) | 5 | 5 | 5 (up to 7 years if sequential build) |
| Anticipated design life (years) | 30 | 30 | 30 (32 if sequential build) |
| Maximum number of wind turbines[1] | 57-100 | 57-100 | 113-200 |
| Closest point from Array Area to coast (km) | 122 | 100 | 100 |
| Maximum length of export cable to landfall (per cable) (km) | 188 | 153 | N/A |
| Maximum offshore cable length (km) for all cables | 376 | 306 | 682 |
| Maximum number of export cables and trenches | 2 | 2 | 4 |
| Maximum number of trenches | 2* | 2* | 4* |
| Maximum number of fibre-optic cables | 1 | 1 | 2 |
| Maximum total length of all array cables (km) | 325 | 325 | 650 |
| Maximum Inter-Platform Cable length (km) | 115 | 129 | 342 |
| Array Cable target depth | 0.5-1.0m | | N/A |

[1] In situations where a number does not divide equally between DBS East and DBS West (e.g. 113 turbines), the parameters are rounded up to higher number (e.g. 57 31.5MW turbines as opposed to 56.5).

| Parameter | Details | | |
|---|---|---|---|
| | **DBS East Alone** | **DBS West Alone** | **DBS East and West Combined** |
| Inter-platform Cable target depth | 0.5-1.5m | | |
| Export Cable target depth | 0.5-1.5m | | N/A |
| Array Cable diameter | 220mm | | |
| Inter-platform Cable | 275mm | | |
| Export Cable diameter | 155mm | | |
| Array Cable voltage | 125 kV | | |
| Inter-platform Cable voltage | 275 kV | | |
| Offshore Export Cable Voltage | 525 kV | | |
| Export cable corridor width (km) | Approximately 1km plus a 0.5km temporary construction area buffer on both sides, but widening and varying at a small number of locations to a maximum of 3km | | |
| Typical spacing between Offshore Export Cables in trenches | 50m | | |
| Maximum Offshore Export Cable Corridor temporary disturbance width during installation (per cable) (m) | 20 | | |
| Maximum Inter-platform cable temporary disturbance width during installation (per cable) (m) | 20m | | |
| Maximum array cable temporary disturbance width during installation (per cable) (m) | 20m | | |
| Export cable operating voltage (kV) | Up to +/-525 | | |

**Trenches would split from up to two per project to up to three per project on approach to landfall due to the co-located fibre-optic communications cable being separated from the Offshore Export Cables prior to making landfall.*

14. **Table 1-3** shows parameters outlined within **Volume 7, Chapter 5 Project Description (application ref: 7.5)** for onshore cables.

*Table 1-3 Parameters for Onshore Export Cables*

| Onshore Export Cable Corridor | DBS East or DBS West In Isolation | DBS East and DBS West Concurrently | DBS East and DBS West Sequentially |
|---|---|---|---|
| Onshore Export Cable Corridor length from the Landfall Zone to the Onshore Substation Zone (km) (approximate) | 32 | 32 | 32 |
| Number of Export circuits | 1 x HVDC | 2 x HVDC | 2 x HVDC |
| Number of power cables per circuit | 2no. 1-core power cables for each HVDC circuit | 2no. 1-core power cables for each HVDC circuit | 2no. 1-core power cables for each HVDC circuit |
| Number of fibre optic (communication) cables per circuit | 1 | 1 | 1 |
| Number of earth cables per circuits | 1 | 1 | 1 |
| Number of trenches | Up to 2 | Up to 4 | Up to 4 |
| Cable duct trench dimensions (m) | 1.1m base to 3.9m surface (x1 HVDC cable per trench)<br>3.35m base to 6.2m surface (x2 HVDC cables per trench) | 1.1m base to 3.9m surface (x1 HVDC cable per trench)<br>3.35m base to 6.2m surface (x2 HVDC cables per trench) | 1.1m base to 3.9m surface (x1 HVDC cable per trench)<br>3.35m base to 6.2m surface (x2 HVDC cables per trench) |
| Number of Temporary Construction Compounds | 17<br>2 main compounds<br>15 satellite compounds | 17<br>2 main compounds<br>15 satellite compounds | 17<br>2 main compounds<br>15 satellite compounds |

| Onshore Export Cable Corridor | DBS East or DBS West In Isolation | DBS East and DBS West Concurrently | DBS East and DBS West Sequentially |
|---|---|---|---|
| Size of Temporary Main Construction Compound ($m^2$) [2] | 10,000 (roughly 100x100m) | 10,000 (roughly 100x100m) | 10,000(roughly 100x100m) |
| Size of Temporary Satellite Construction Compounds($m^2$) [2] | 5,625 (roughly 75x75m) | 5,625 (roughly 75x75m) | 5,625 (roughly 75x75m) |
| Cable corridor width (m) | 41m | 75m | 75m |
| Cable corridor width at complex trenchless crossings (m) | 45m | 90m | 90m |
| Depth of trench to top of duct / cables (m) (approximate) | 1.3 – 1.7 | 1.3 – 1.7 | 1.3 – 1.7 |
| Burial depth (m) where restrictions are not present (average) | 2 | 2 | 2 |
| Indicative burial depth (m) (approximate) | 1.6 | 1.6 | 1.6 |
| Typical Jointing Bay frequency (km) | Every 0.75 – 1.5 | Every 0.75 – 1.5 | Every 0.75 – 1.5 |
| No. Jointing Bays (approximate) | 103 | 205 | 205 |
| Jointing Bay construction dimensions (m) | 10 x 25 | 10 x 25 | 10 x 25 |

[2] Actual size may vary due to site specifics

| Onshore Export Cable Corridor | DBS East or DBS West In Isolation | DBS East and DBS West Concurrently | DBS East and DBS West Sequentially |
|---|---|---|---|
| Jointing Bay infrastructure dimensions (all below ground) (m) | 3 x 8 | 3 x 8 | 3 x 8 |
| Jointing Bay burial depth from existing ground level to bottom of Jointing Bay (m) | 2.2 | 2.2 | 2.2 |
| Minimum Jointing Bay burial depth from existing ground level to top of Jointing Bay (m) | 1.35 | 1.35 | 1.35 |
| Number of Earth / Link Boxes and associated manhole covers | 103 | 205 | 205 |
| Link Box construction dimensions (m) | 6.5x8 | 6.5x8 | 6.5x8 |
| Link Box dimensions / manhole cover permanent infrastructure above ground (m) | 2.5x4 | 2.5x4 | 2.5x4 |
| Permanent easement[3] | 15m along the cable corridor. | 24m along the cable corridor | 24m along the cable corridor |

[3] At trenchless crossings the permanent easement width would be located within the Onshore Development Area and determined by the depth of the trenchless crossing at the detailed design stage.

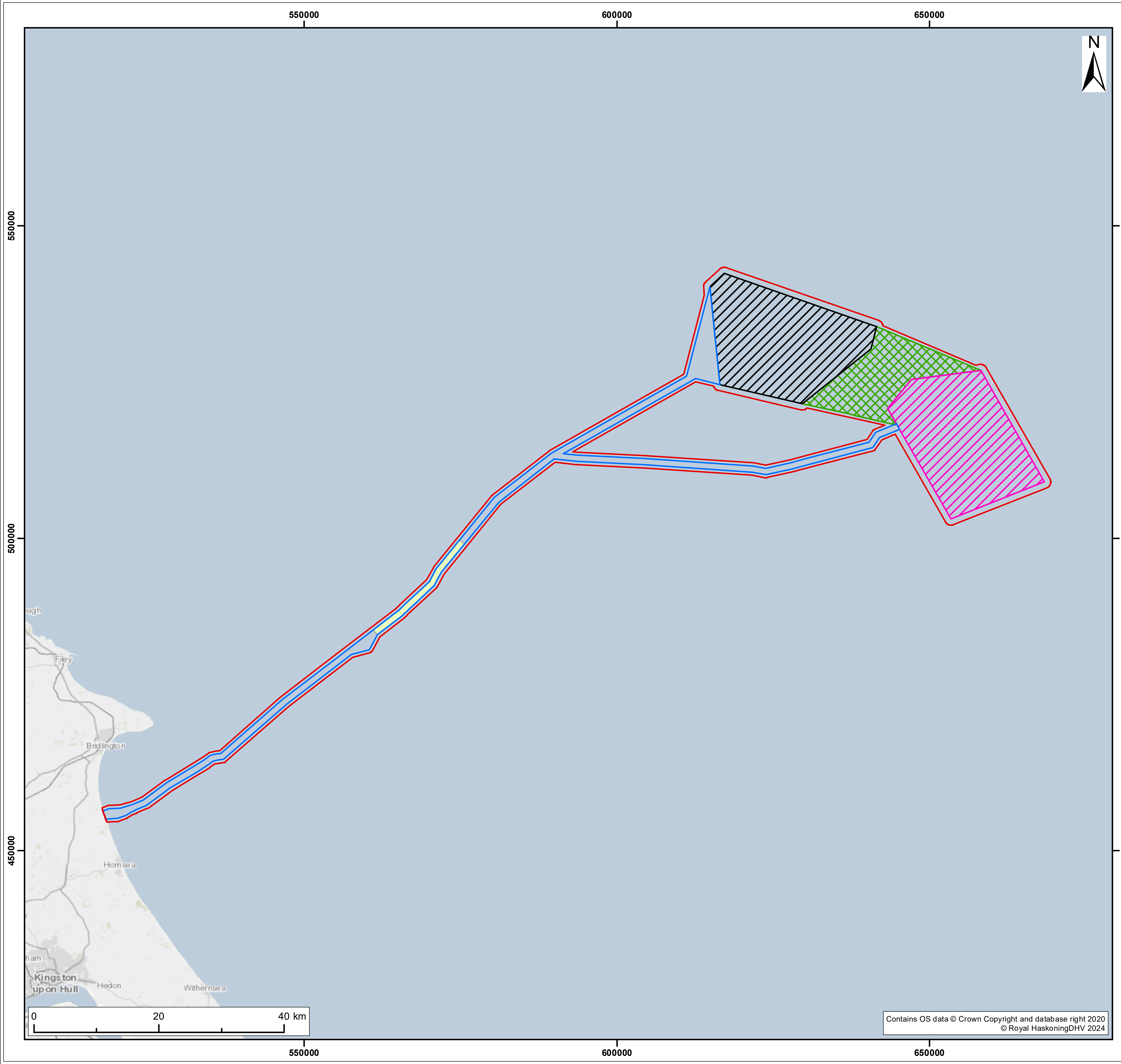
15. The site selection for the Offshore Export Cable Corridor and Onshore Export Cable Corridor is described in **Volume 7, Chapter 4 Site Selection and Alternatives (application ref: 7.4)**. The mitigation measures contained within the Environmental Statement (ES) have been developed in consultation with relevant stakeholders and statutory authorities.

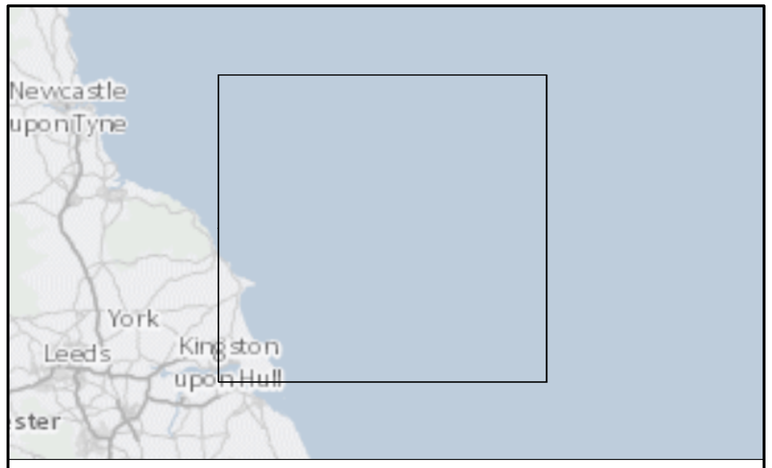
## 1.4 Description of Offshore Cables and Cable Corridor

16. The offshore cable description below, provides summarised detail of the cable route and installation method proposed for the Projects. A full description of the proposed works is provided in **Volume 7, Chapter 5 Project Description (application ref: 7.5)**.

### 1.4.1 Offshore Cable Corridor

17. There is not currently a detailed defined route for any of the offshore cables as the application is based around a Rochdale Envelope. However, the array cables, inter-platform and Offshore Export Cables would be installed within the areas indicated within the Offshore Export Cable Corridor, the Inter-Platform Cable Corridor and the Array Areas shown in **Figure 1-1**. Outside of these areas, but within the area bordered by the red line (Offshore Development Area), lies an area which would facilitate construction. No infrastructure would be installed in this Construction Buffer Zone.




Legend:

- Offshore Development Area
- Export Cable Platform Search Area
- Offshore Export Cable Corridor
- DBS East Array Area
- DBS West Array Area
- Inter-Platform Cable Corridor

| SUI | REV | DATE | DESCRIPTION | DRW | CHK | APR |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| S3 | P02 | 08/01/2024 | Suitable for Information | SB | CC | RF |
| S2 | P01 | 06/11/2023 | Suitable for Information | SB | CC | RF |

Title:

Offshore Development Area

Figure: 1-1

Drawing No: PC2340-RHD-OF-ZZ-DR-Z-0577

Co-ordinate system: WGS 1984 UTM Zone 31N

Page Size: A3

Scale: 1:600,000

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Report: Environmental Statement

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18. Preparatory works will be carried out prior to cable installation (see section 1.4.2). The cables will be buried below the seabed wherever possible. Where this is not possible, or where sufficient burial depths are not achieved, external cable protection would be required. In all cases, the amount of external cable protection would be minimised as far as is practicable. Two Preliminary Cable Burial Risk Assessments (CBRAs) are included in Appendix A and Appendix B of this Cable Statement. Appendix A presents a CBRA for the array and inter-platform cabling, whilst Appendix B presents a CBRA for the export cables.

19. It is intended that these documents will be refined and updated or replaced with new versions as project development progresses. As part of the design envelope, target burial depths of 0.5-1.5 metre (m) (relative to the non-mobile seafloor level) have been assumed for the inter-platform and export cables, whilst an indicative burial depth of 0.5-1m (relative to the non-mobile seafloor level) has been assumed for the array cables.

### 1.4.2 Array Cables

20. The wind farm electrical array cables would transmit the HVAC power produced at the wind turbines to the CPs (if required). This power would then be sent to OCPs via the Inter-Platform Cables, where the power is converted to HVDC. Alternatively, the array cables may be directly linked to an Offshore Converter Platform(s).

21. The array cables would be up to 132kV, with an indicative external cable diameter of up to 220 millimetre (mm). Cable circuits (strings) would be optimised according to the electrical load they are required to carry, with up to three different cable dimensions being used. They would be integrated with fibre optic cables. The array cables will consist of a number of conductor cores, usually made from copper or aluminium.

### 1.4.3 Inter-platform Cables

22. Inter-Platform Cables may be required to connect CPs (if required) to the OCPs, to connect the OCPs between the Projects, and to connect the OCPs to the Accommodation Platform and Electrical Switching Platform (if required).

23. The Inter-Platform Cable voltage would be up to 275kV, with an indicative external cable diameter of up to 275mm. They would be integrated with fibre optic cables.

### 1.4.4 Offshore Export Cables

24. Offshore Export Cables are used for the transfer of power from the OCPs to the landfall. As the decision has been made that the electricity transmission will utilise HVDC technology to transfer electricity from the OCPs to the Onshore Converter Stations, the export cables are expected to transfer electricity at up to 525kV.

25. The Offshore Export Cable Corridor is generally 1km wide, but funnels out to 3km near key crossings, and up to 15km on the approach to the Array Areas. A 500m Construction Buffer Zone lies either side of this corridor. The greater width of the corridor at these locations is designed to provide greater flexibility in the detailed routeing of the export cables at the pre-construction stage. The corridor provides space for the installation works and any foreseeable operation and maintenance activities such as cable reburial or repairs.

26. The Offshore Export Cables will each consist of one power core, usually made from copper or aluminium, surrounded by layers of insulation material and armour to protect the cable from external damage.

### 1.4.5 Offshore Seabed Preparation

27. Cable installation may require one or more forms of seabed preparation which may include pre-lay grapnel runs and / or pre-lay plough, boulder relocation, sand wave clearance, removal of existing out of service cables and / or Unexploded Ordnance (UXO) clearance. In general, the preparations would be limited to the area directly associated with the cable route, but some preparation (e.g. UXO clearance) would be required for the Construction Buffer Zones in addition. Any materials being cleared (e.g. sand, boulders) would be relocated to a site nearby or adjacent to the area from which they were removed.

#### 1.4.5.1 Boulder clearance

28. The presence of boulders that present an obstacle to the construction activities would be confirmed by pre-construction surveys. In the instance that a boulder cannot be avoided, it would be relocated to an adjacent area of seabed within the Offshore Development Area where they do not present an obstacle to the works, and where possible to an area of seabed with similar sediment type and avoiding any known sensitive habitats. If required, boulder clearance would be undertaken by sub-sea grab or plough.

#### 1.4.5.2 UXO Clearance

29. Specific surveys to identify potential locations of UXO would be undertaken after the DCO is granted. This is to allow more detailed engineering work to be carried out on the cable routes and locations of turbines to allow a targeted survey for potential UXO to be undertaken.

30. If UXO are found, a risk assessment will be undertaken and items of UXO are either avoided, removed or detonated in situ. The methods of UXO clearance considered may include:

- High-order detonation;
- Low-order detonation (deflagration); and
- Removal / relocation.

#### 1.4.5.3 Pre-lay Grapnel Run

31. Before cable-laying operations commence, it must be ensured that the route is free from obstructions such as discarded fishing gear, anchors or abandoned cables, wires and ropes that may be identified as part of the pre-construction surveys. A survey vessel would be used to undertake a pre-lay grapnel run (PLGR) to clear such identified debris.

32. The width of seabed disturbance along the PLGR is estimated to be approximately 6m, which would be encompassed within the maximum 20m footprint of cable installation works.

#### 1.4.5.4 Sand wave Levelling

33. In order to prevent free-spanning and to reduce the risk of cable exposures - and the risks this may present to other marine users - cables will be placed wherever possible in the troughs of sand waves to the seabed reference level. Where this is not possible, the sand waves may be dredged to the seabed reference level prior to installation.

### 1.4.6 Offshore Installation Methods

34. Cables will be manufactured at a specialist supplier's factory. The manufactured cables will be spooled from the factory to cable carousels situated on a transport vessel or directly onto the installation vessel itself, moored at the adjacent quayside. If a transport vessel is used, the cables will be subsequently transpooled onto the installation vessel at a local port before it transits to the proposed development site for installation.

35. Array, inter-platform and Offshore Export Cables would be buried below the seabed wherever possible. The installation method and burial depth will be defined post consent based on the final routes selected and updated cable burial risk assessments. It is anticipated that the offshore cables would be installed via either ploughing, jetting, trenching, or a combination of these techniques, depending on ground conditions along the specific cable route. Depending on the final installation method, it is possible that trial operations may be required in advance of cable installation. Temporary wet store locations may be designated within the Offshore Development Area for use during the construction phase if required.

36. The most likely techniques for cable installation are described in sections 1.4.6.1 to 1.4.6.3, below.

#### 1.4.6.1 Ploughing

37. This method involves a blade, which cuts through the seabed and the cable is laid behind. Ploughs are generally pulled directly by a surface vessel or they can be mounted onto a self-propelled tracked vehicle which runs along the seabed. Cable ploughs are usually deployed in simultaneous '*lay and trench*' mode although it is possible to use the plough to cut a trench for the cable to be installed at a later date provided the ground conditions are suitable. When installing the cable in simultaneous lay and trench operation the plough may use cable depressors to push the cable into position at the base of the cut trench; as the plough proceeds the trench is backfilled to provide immediate burial.

38. Ploughs can be used in seabed geology ranging from very soft mud through to firm clays but, in general, ploughs are not suited to harder substrates such as boulder clay or chalk. Some ploughs are fitted with water jet assist options and / or hydraulic chain cutters to work through patches of harder substrates.

#### 1.4.6.2 Jetting

39. This method involves directing water jets towards the seabed to fluidise and displace the seabed sediment. This forms a typically rectangular trench into which the cable generally settles under its own weight. The water jets are usually deployed on jetting arms beneath a Remotely Operated Vehicle (ROV) system that can be free-swimming, based on passive skids, active tracks or towed jetting skids. During the formation of the trench the displaced sediment is forced into localised suspension and settles out at a rate determined by the sediment particle size, density and ambient flow conditions.

40. The jetting process is not intended to displace sediment to an extent that it is totally removed from the trench; moreover, it requires that the fluidised sediment is available to fall back into the trench for immediate burial through settling. It is only the finer fractions of sediments that are likely to be held in suspension long enough to become prone to dispersal away from the trench as a plume. A key benefit of a jetting tool is that it can operate close to structures and it is also possible to use jetting tools for remedial burial if required. Typically, there are two methods of water jetting available: 'seabed fluidisation' and 'forward jetting a trench'.

41. Seabed fluidisation involves first laying the cable on the seabed and afterwards positioning a jetting sledge above the cable. Jets on the sledge flush water beneath the cable fluidising the soil whereby the cable, by its own weight, sinks to the depth set by the operator.

42. Forward jetting a trench uses water jets to jet out a trench ahead of cable lay. The cable can typically be laid into the trench behind the jetting lance.

#### 1.4.6.3 Trenching

43. Trenching involves the excavation of a trench whilst temporarily placing the excavated sediment adjacent to the trench. The cable is then laid, and the displaced sediment used to back-fill the trench, covering the cable. This is most commonly used where the cable must be installed through an area of rock or seabed composed of a more resistant material. Trenching is a complex, time-consuming and expensive method to use compared to other methods and therefore unlikely to be the preferred option for the majority of the Offshore Export Cable Corridor.

### 1.4.7 Array and Inter-platform Cable Installation

44. Each section of the array and Inter-Platform Cable would be laid from the cable lay vessel either from a static coil or a revolving carousel, turntable, or drum. The cable would be pulled into the turbine foundation via a J-tube (or alternative cable entry system) and hung-off inside the foundation structure before being connected to the turbine electrical system.

45. A typical methodology for installing the cable into a J-tube is:

- Mobilisation of a specialist cable installation vessel to site;
- A vessel would take up station adjacent to a wind turbine foundation; The cable end would be connected to a pre-installed messenger wire at the wind turbine foundation. The messenger wire would be recovered by a ROV. The messenger wire would then allow the cable to be pulled into the wind turbine foundation from a temporary pre-installed winch arrangement at the wind turbine foundation. An ROV would be used to monitor the cable entering the J-tube or cable entry system;
- When the first cable end is pulled in with required overlength, the cable is secured with a temporary hang-off arrangement and cable installation continue towards the wind turbine foundation for second end pull-in and hang-off. Separate teams would be mobilized for installing permanent
- Hang-off of the cable and terminate the cable cores and fibre optic cables;
- Second end cable pull-in, hang-off and termination would in principle be similar to the first end, except for over-boarding of the last end of the cable from the installation vessel that would be by means of a quadrant; and
- The same principle for cable installation is applicable for wind turbine foundations without a J-tube. The main differences are the interface between the cable protection system and the foundation entry; without a J-tube the cable is free hanging inside the foundation structure.

### 1.4.8 Offshore Export Cable Installation

46. The installation of the Offshore Export Cables is likely to involve the burial of the cables below the seabed using ploughing, trenching, or jetting as outlined in section 1.4.6. Sensitive areas of seabed, such as those supporting features of archaeological or nature conservation interest will be avoided as far as possible.

47. Due to the length of the Offshore Export Cable Corridor, and the limitations upon cable carousel size / weight on the installation vessel, it is very likely that the export cables would be installed in sections with pre-planned cable joints along the Offshore Export Cable Corridor. At the pre-planned cable jointing locations, the two ends of the cables would be laid on the seabed with sufficient slack to allow them to be lifted onto a suitable vessel. The cable jointing is then completed onboard the vessel before the cable is lowered back down to the seabed. The cable is then buried, if possible, or protected using measures as described in section 1.4.9.

### 1.4.9 Offshore Cable Protection

48. There may be a requirement for additional / external cable protection to be installed around the array, inter-platform and Offshore Export Cables. The exact amount of cable protection required would depend on the burial depths achieved and assessments of the scour and cable and seabed movement that could occur during the operating life of the wind farm. Cable protection could also be required at third party cable or pipeline crossings which may occur on the cable routes.

49. The exact form of cable protection used will depend upon local ground conditions, hydrodynamic processes and the selected cable protection contractor. However, the final choices may include one or more of the following:

- Concrete 'mattresses';
- Rock placement (loose and/or bagged);
- Geotextile bags filled with stone, rock or gravel;
- Polyethylene or steel pipe half shells, or sheathes; and / or
- Bags of grout, concrete, or another substance that cures hard over time.

50. The design and methodology of these cable and pipeline crossings would be confirmed in agreement with the asset owners post-consent. However, it is likely that a berm of rock (or mattress) would be placed over the existing asset for protection, known as a pre-lay berm, or separation layer.

51. The cable would then be laid across this at an angle as close to 90 degrees as possible. The DBS cables would then be covered by a second post lay berm to ensure that the cable remains protected and in place. The rock berms would be inspected regularly. They may need to be replenished with further rock placement through the lifetime of the Projects dependent on their condition. **Table 1-4** provides details of the offshore cable protection parameters. The first principle of the use of cable protection is that it will be minimised to the greatest practicable extent in all cases. Where cable protection is required within the Dogger Bank Special Area of Conservation no more than 10% of the total cable length will be protected, in line with the requirements of the Offshore Wind Round 4 Record of the Habitats Regulations Assessment (The Crown Estate, 2022).

52. In addition, the projects have made the commitment that any Offshore Export Cables associated with the Projects will be buried within the intertidal zone at landfall, and 350m seaward of MLWS. No surface cable protection will be used within these areas.

53. Cable protection will also be limited to 10% of the cumulative length of all cables laid between 350m seaward of MLWS and the 10m depth contour as measured against the lowest astronomical tide before the commencement of construction.

54. Where scour protection is required, MGN 654 will be adhered to with respect to changes greater than 5% to the charted water depth referenced to chart datum in consultation with the Maritime and Coastguard Agency and Trinity House. Compliance with MGN 654 would be secured within the DCO.

*Table 1-4 Offshore Cable Protection Parameters*

| Parameter | DBS East | DBS West | Both Projects |
|---|---|---|---|
| **Offshore Export Cable Protection** | | | |
| Indicative max proportion of export cable length requiring remedial protection (%) | 20% | 20% | 20% |
| Indicative total offshore export cable route protection (km) | 65.8 | 51.9 | 117.7 |
| **Array Cable Protection** | | | |

| Parameter | DBS East | DBS West | Both Projects |
|---|---|---|---|
| Indicative max proportion of array cable length requiring remedial protection (%) | 10% | 10% | 10% |
| Indicative total array cable length protection (km) | 51.75 | 51.75 | 103.9 |
| **Inter-Platform Cables** | | | |
| Indicative max proportion of inter-platform cable length requiring remedial protection (%) | 10% | 10% | 10% |
| Indicative total inter-platform cable protection (km) | 12.06 | 13.52 | 35.3 |

## 1.5 Offshore Cable Monitoring and Remedial Work

55. Throughout the life of the projects the on-going success of cable burial and cable protection will be monitoring through geophysical surveys (see **Volume 8, In Principle Monitoring Plan (application ref: 8.23)** for further details).

56. Where information obtained through survey reveals the need for cable reburial or the deposit of additional or remedial cable protection, the necessary steps will be undertaken in line with the principles relating to the licensing of such work as laid out in **Volume 8, Outline Offshore Operations and Maintenance Plan (application ref: 8.24)** submitted in support of this application.

## 1.6 Landfall

57. The Offshore Export Cables would make landfall near Skipsea using trenchless installation techniques. The Offshore Export Cables would be connected to the Onshore Export Cables in Transition Joint Bay (TJBs), which would be constructed prior to the installation of the Offshore Export Cables nearshore. The TJBs and cable alignments would be designed so as not to interfere with natural coastal processes across the life of the Projects. The landfall location near Skipsea is shown on **Volume 7, Figure 5-3b** and **Figure 5-3c (application ref: 7.5.1)**.

58. The Landfall Zone extends inland to allow the TJBs to be located beyond any areas at risk of natural coastal erosion, and to provide space for temporary construction logistics and access requirements.

59. The landfall location near Skipsea was chosen as the result of a site selection process, considering environmental and technical constraints. The site selection process is described in **Volume 7, Chapter 4 Site Selection and Assessment of Alternatives (application ref: 7.4)**.

60. To reduce the impact of the landfall, a trenchless installation method such as Horizonal Directional Drilling (HDD) is to be used to install ducts that will house the cables under the beach. The ducts would run from the TJB, located landward of landfall, to an exit location which may be at an intertidal location ("short HDD") or further offshore ("long HDD") (See **Plate 1-1**). To allow the connection of the Offshore and Onshore Export Cables, up to six completed ducts would be installed. This consists of three ducts per Project (two power cable ducts, plus a smaller duct for a fibre optic communications cable).

61. Landfall design is to be undertaken post consent and would consider potential future coastal erosion, nearshore coastal processes, natural features that influence wave action and local flood risk and access requirements for entry and exit locations of the proposed landfall trenchless installation. The Offshore Export Cables would be pulled ashore or offshore through the pre-installed HDD ducts and would interface with the onshore cables at the TJBs.

62. Duct extensions may be required to enable the landfall HDD ducts to be extended further offshore to facilitate cable installation from an installation vessel situated offshore. These duct extensions would be of a similar diameter to the HDD ducts and installed in their own trench at a similar depth of cover to the Offshore Export Cables. The duct extension excavations would be backfilled before the arrival of the cable installation vessel.

63. For the Sequential build of DBS East and DBS West, the landfall ducts for both Projects will be installed as part of the first project to help reduce impacts as far as practicable.

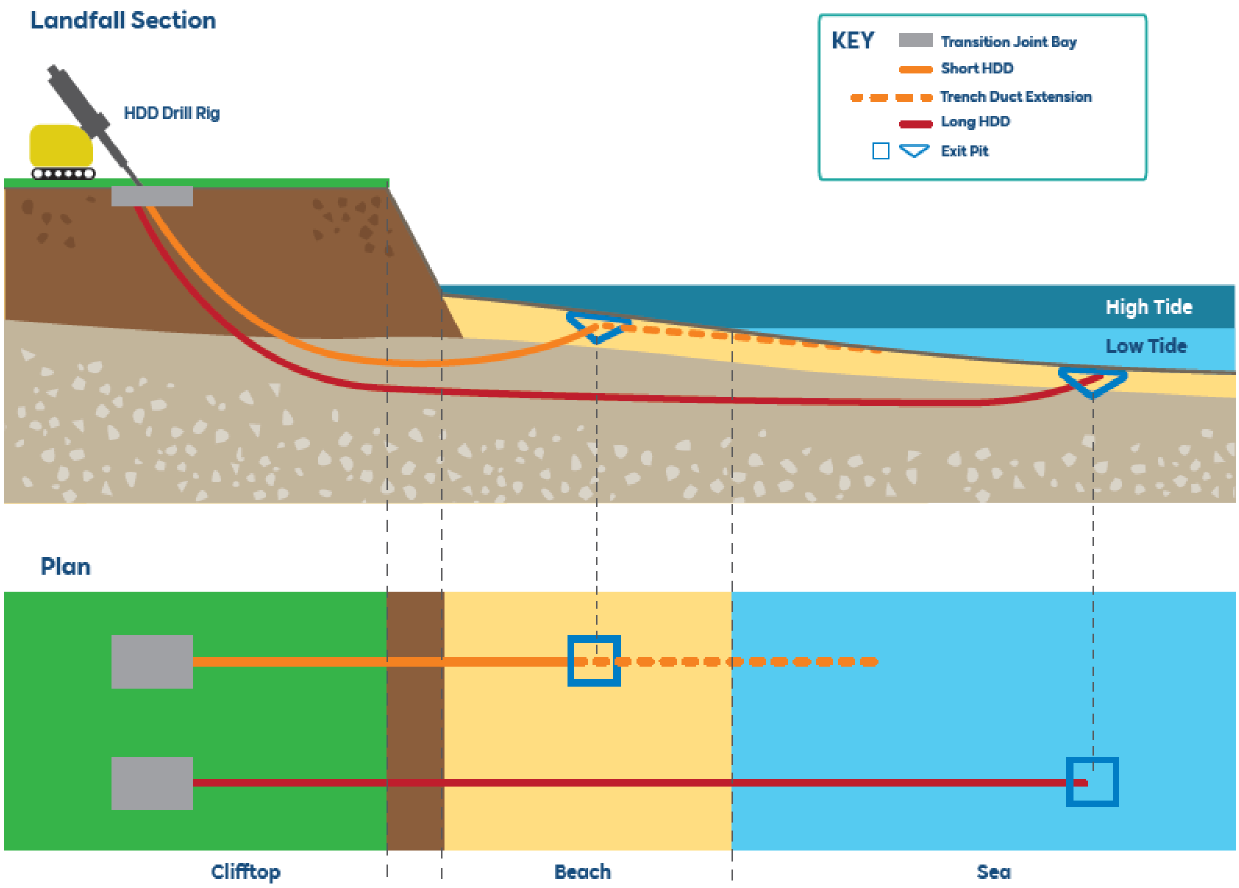



*Plate 1-1 Illustrative Section and Plan Landfall Works HDD options*

## 1.7 Description of Onshore Export Cables and Cable Corridor

64. The Onshore Export Cable description below provides summarised detail of the cable route and installation method proposed for the Projects.

65. The onshore aspects of the project include:

- Landfall: the area above Mean Low Water Springs (MLWS) where the Offshore Export Cables are connected to the Onshore Export Cable circuits within TJBs;
- Onshore Export Cable Corridor where permanent infrastructure connects the cables at Landfall Zone to the proposed Onshore Converter Station(s);
- Onshore Converter Station(s): contains specialist electrical equipment to convert the power from HVDC to HVAC for export along the Onward

Cable Corridor to the proposed Birkhill Wood National Grid Substation; and

- Connection to the National Grid will include 400kV underground circuit(s) running from the proposed Onshore Converter Station(s) to the proposed Birkhill Wood National Grid Substation.

66. For a full description of the Maximum Design Scenarios associated with the project see **Volume 7, Chapter 5 Project Description (application ref: 7.5)**.

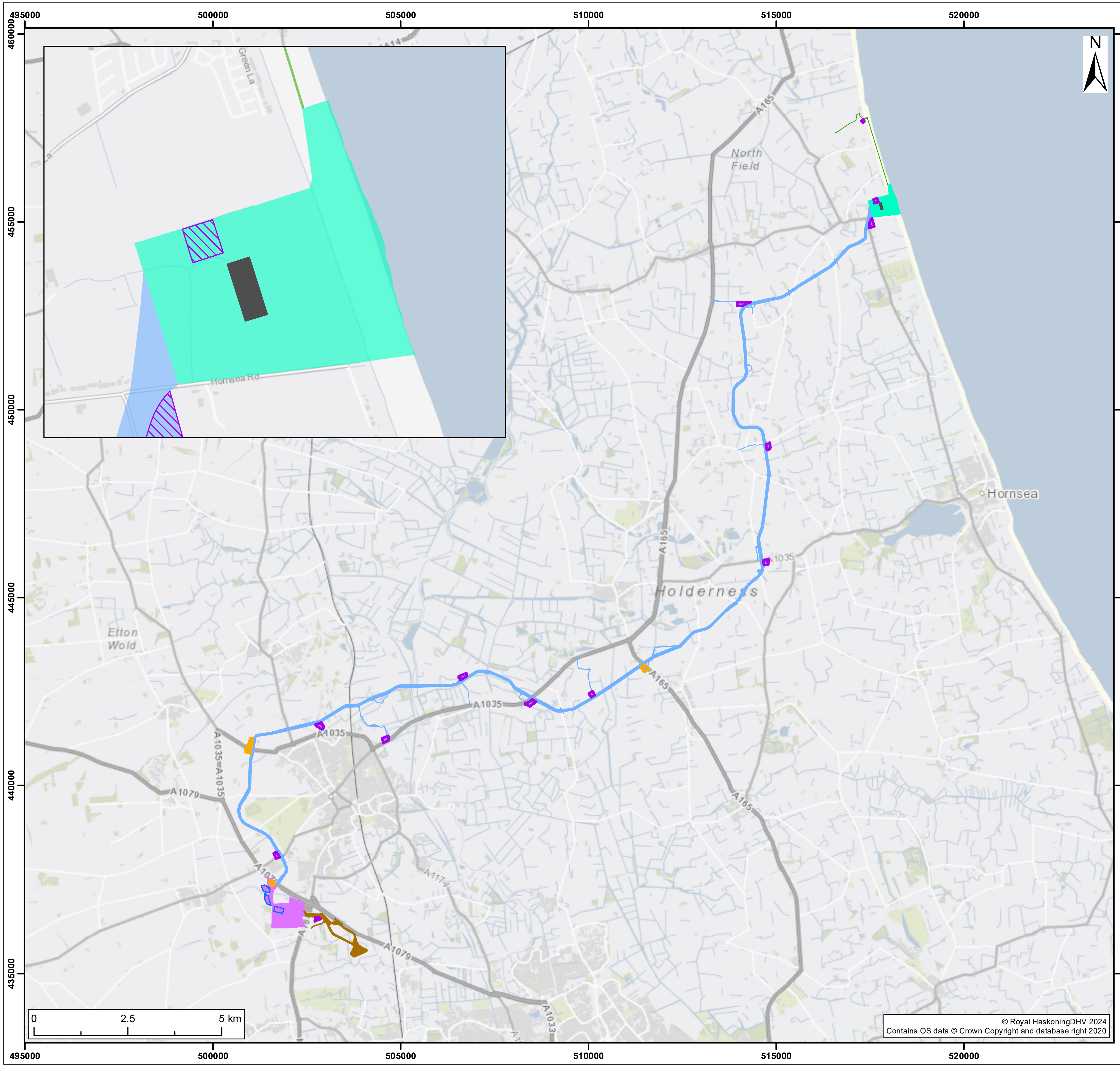
### 1.7.1 Onshore Export Cable Corridor

67. The Onshore Export Cable Corridor would run between the Landfall Zone near Skipsea to the Substation Zone, near Bentley where the Onshore Converter Station(s) are located. This is shown in **Figure 1-2**.

68. A 75m wide Onshore Export Cable Corridor from the TJBs to the Onshore Converter Stations, widening to 90m at complex trenchless crossings is being considered for the purposes of the EIA. The Onshore Export Cable Corridor will be approximately 32 km from the Landfall Zone to the Onshore Substation Zone.

69. The Onshore Export Cables will require trenches to be excavated, within which ducts will be installed to house the power cables and associated fibre optic cables. Major crossings, such as major roads, river and rail crossings will be undertaken using trenchless crossings techniques such as HDD. The HVDC export cables will enter the Substation Zone and connect to the Converter Station buildings. The electrical power will pass through the buildings and into the equipment in the yard, which will convert it from HVDC to HVAC.

70. Where the cable crosses flood defences this will likely require monitoring to ensure there is no detrimental impact to defences (i.e. no settlement occurs as a result of trenchless techniques).





Legend:

- Landfall Zone
- Onshore Export Cable Corridor
- Emergency Beach Access
- Onshore Substation Zone Temporary Construction Compounds
- Onshore Substation Zone
- Onward Cable Connection to the proposed Birkhill Wood National Grid Substation
- Transition Joint Bay (TJB) Compound
- Main Temporary Construction Compound
- Satellite Temporary Construction Compound

| SUI | REV | DATE | DESCRIPTION | DRW | CHK | APR |
|---|---|---|---|---|---|---|
| S4 | P05 | 13/05/2024 | Suitable for stage approval | SB | ND | RH |
| S4 | P04 | 25/04/2024 | Suitable for stage approval | SB | ND | RH |
| S4 | P03 | 11/04/2024 | Suitable for stage approval | SB | ND | RH |
| S3 | P02 | 15/02/2024 | Suitable for review & comment | SB | ND | RH |

Title:

Onshore Development Area

Figure: 1-2 | Drawing No: PC2340-RHD-ON-ZZ-DR-Z-0692

Co-ordinate system: British National Grid | Page Size: A3 | Scale: 1:100,000

Project: Dogger Bank South Offshore Wind Farms

Report: Environmental Statement

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### 1.7.2 Onward Cable Connection to the proposed Birkhill Wood National Grid Substation

71. A further section of buried cable is required to connect the Projects from the Onshore Converter Stations with the proposed Birkhill Wood National Grid Substation. It will exit the Substation Zone via underground 400kV HVAC cables which will connect to the proposed Birkhill Wood National Grid Substation. This section of cabling would be similar in design to the Onshore Export Cable Corridor cabling, but must be HVAC at 400kV. It will have four circuits for an In Isolation Scenario, and eight for a Concurrent and Sequential Scenario, installed with a 20m and 34m permanent easement within a 53.5 and 100m cable corridor respectively.

### 1.7.3 Onshore Cable Installation

72. Site enabling works will be required before starting the main construction of the Onshore Export Cable Corridor and Onward Cable Connection. These works are likely to include:

- Temporary fencing;
- Upgrade of existing, or installation of new, access from the public highways, only where required;
- Archaeological and ecological survey / mitigation works as necessary;
- Utility diversions and installation of temporary site drainage where required;
- Vegetation clearance; and
- Establishment of TCC site compounds, which could include site offices, welfare facilities, security, wheel washing facilities, lighting and signage.

73. Main Construction activities for the onshore Export Cable Corridor and Onward Cable Connection are likely to include:

- Topsoil removal (to edge of working area);
- Temporary haul road installation along all sections of the route;
- Trenchless duct installation beneath obstacles (such as major roads, railways, rivers and ecological features);
- Installation of header or interceptor drains at cable corridor boundaries;
- Trench excavation (up to four trenches);
- Duct installation;
- Trench backfilling;

- Existing field drainage repairs (where disruption occurs);
- Jointing Bay installation (including French drains to prevent water pooling above jointing bay); and
- Topsoil reinstatement.

74. Once the ducts are installed cable installation will commence for the two export circuits required for DBS West and DBS East respectively which includes:

- Cable installation (pulled through ducts from each joint pit);
- Cable Jointing; and
- Cable testing and commissioning.

75. The main cable installation method will be through the use of open-cut trenching with ducts installed, the trench backfilled and cables pulled through the pre-laid ducts.

76. For open trenching the cable circuits will be installed within an Onshore Export Cable Corridor generally up to 75m and 100m wide for the Onward Cable Connection, during the construction phase.

77. For the Sequential build of DBS East and DBS West, the cable ducts for both Projects will be laid as part of the construction of the first project to help reduce environmental, ecological and social impacts.

#### 1.7.3.1 Jointing Bays

78. Jointing Bays will be required along the Onshore Export Cable Corridor and the Onward Cable Connection cable route to allow cable pulling and jointing of two sections of cable. One Jointing Bay will be required approximately every 0.75km to 1.5km of each cable (to be determined by detailed design). The Jointing Bays will each have a maximum construction footprint of 250m$^2$ (indicatively up to 25m long by 10m wide) and a permanent footprint of 24m$^2$ (3m x 8m). While crossing agricultural land the highest point in the Jointing Bay – including the cable circuit and associated protection – will be at a minimum depth of 1.35m below the existing ground level. In some areas the Jointing Bays could be deeper, for example where there is extensive field drainage.

79. Each Jointing Bay would be accompanied by a Link Box to allow testing and monitoring of cable joints. The Link Boxes are generally much smaller in footprint than the Jointing Bays and at a much shallower depth with a manhole inspection cover at the surface. Each Link Box and associated manhole cover would be up to 2.5x4m and the only permanent infrastructure above ground infrastructure during operation. There would be up to 205 link boxes and manholes associated with the construction of two Projects.

#### 1.7.3.2 Cable Crossings

80. All crossings are listed within the Onshore Obstacle Crossing Register provided in **Volume 7, Appendix 5-2 (application ref: 7.5.5.2)**. The crossing methodology will be finalised at the detailed design stage. Where there is currently an option for either an open cut or a trenchless crossing option the worst case has been selected in the EIA.

81. Where open cut trenching is used for watercourse crossings, implementation may include damming of watercourses/drains with over-pumping or diversion of drains given further review during detailed design. Open cut crossings will typically involve the installation of ducts beneath the channel bed to avoid impacts to the active channel bed. Reinstatement of the trench would be conducted to the pre-construction depth of the watercourse, taking care to reinstate the channel bed material and subsoils in the correct order. The dams would then be removed. Temporary dam and divert would only be required for the duration of time that duct installation takes place in that location. A crossing agreement would be agreed with the relevant authority, either the Internal Drainage Board, Lead Local Flood Authority or the Environment Agency.

82. Open cut crossings of minor roads, Public Rights of Way and tracks will utilise either traffic management or short temporary closures or diversions.

83. Trenchless crossing techniques will be used at a number of locations as an alternative methodology to open-cut trenching to cross significant environmental and physical features such as main rivers, major drains, roads, and railways. There are a number of potential trenchless techniques which may be used such as HDD, microtunneling, auger boring, pipe jacking, pipe ramming and others. The type of trenchless crossing would be determined during detailed design, however, the HDD technique is likely to be a conservative case in terms of area required and likely impacts associated with the construction activities for use in the EIA.

84. The HDD process involves drilling under the feature being avoided. Typically, a drilling head is used to drill a pilot hole along a predetermined alignment, before this pilot hole is widened using larger drilling heads to the required bore size. Bentonite pumped to the drilling head is used to stabilize the hole and ensure it doesn't collapse.

85. Trenchless crossing construction compounds would be required within the Cable Corridor at the 'entry' and 'exit' pits (dependent on the technique chosen) at suitable locations adjacent to each obstacle, or group of obstacles, to be crossed. The distance that each compound will be from the obstacles will be determined during the construction stage of the Project and will depend on factors such as the length of the crossing, the height differential of the land either side of the obstacles, depth of the obstacle to be cleared, and the local ground conditions.

86. As the length of each crossing will not be finalised and known until the construction phase, the duration for each trenchless duct installation is not currently known.

### 1.7.4 Onshore Converter Station(s)

87. An Onshore Converter Station is required for each of the DBS West and DBS East projects. These are located to the south-west of Beverley near the hamlet of Bentley which is within 2.5km of the proposed Birkhill Wood National Grid Substation.

88. The Onshore Converter Stations convert the power from HVDC to 400Kv HVAC for export along the Onward Cable Corridor of 2.5 km to the proposed Birkhill Wood National Grid Substation. The DBS East and DBS West HVDC Onshore Converter Stations would be either Air Insulated or a gas insulated switchgear design. The parameters set out in the DCO application represent a worst case spatially for EIA.

89. The Onshore Converter Stations are expected to include the following:

- Control building;
- Gas insulated switchgear building (if required);
- External fire barriers;
- Static var compensator building (if required);
- Valve halls;
- Transformers;
- Lightning protection masts;
- Palisade fencing;
- Switchgear;

- Shunt reactors;
- Emergency diesel generators;
- Service buildings;
- Spare part building
- Cooling systems;
- Earth mat;
- Harmonic filters if required; and
- Access roads – for operation and maintenance access to equipment.

90. The Onshore Converter Stations would be constructed to accommodate the connection of both DBS East and DBS West to the transmission grid. The permanent footprint of one HVDC Converter Station would be up to 64,000m$^2$. The permanent footprint of two HVDC Converter Stations would be up to 129,000m$^2$.

91. The electrical equipment requires a carefully controlled environment (i.e. a climate controlled, clean room) to function safely, necessitating a large the valve hall building to be designed so that it is weathertight and meets airtightness standards. The Valve Halls, the tallest building in the Onshore Substation Zone and has a maximum height of 24m above existing ground level which is the highest building. Other tall features within the Onshore Substation Zone would be the lightning protection masts at a maximum height of 27m above ground level.

### 1.7.5 Grid Connection

92. National Grid Electricity Transmission own and maintain the high voltage electricity transmission network in England and Wales. National Grid ESO is responsible for operating the electricity transmission system in Great Britain in July 2020, the UK Government launched the Offshore Transmission Network Review to ensure offshore wind generation is delivered in the most appropriate way, taking into consideration the environment, cost to consumers, local communities and deliverability.

93. Resultant studies of the proposed Grid Connection by National Grid ESO is discussed further in **Volume 7, Chapter 4, Site Selection and Alternatives (application reference: 7.4)** which resulted in the identification of the proposed Birkhill National Grid Substation adjacent to the existing Creyke Bank National Grid Substation.

94. The proposed Birkhill Wood National Grid Substation is not part of the Projects and therefore not part of the DCO application. Ownership of the proposed Birkhill Wood National Grid Substation is with National Grid. Connections to the National Grid substation itself would be completed by National Grid or their appointed contractors. Connection to the proposed Birkhill Wood National Grid Substation is expected to be in 2029 at the earliest.

## 1.8 Summary

95. Through the information provided above this document has set out the "*details of the proposed route and method of installation for any cable*"' associated with the Project in accompaniment to the application as required by Regulation 6(1)(b)(i) of the Infrastructure Planning (Applications: Prescribed Forms and Procedures) Regulations 2009 (the APFP Regulations).

96. This document has also set out the considerations for cable route design and approach to installation, presenting preliminary information regarding the cable specification, burial depths and cable protection both offshore and onshore. The high-level information provided in this document would be factored into the final design and installation planning for the DBS cabling as the development of the Projects continue. Thus, this document establishes the basis for how the DBS projects will ensure a safe, reliable and protected grid connection for the Projects.

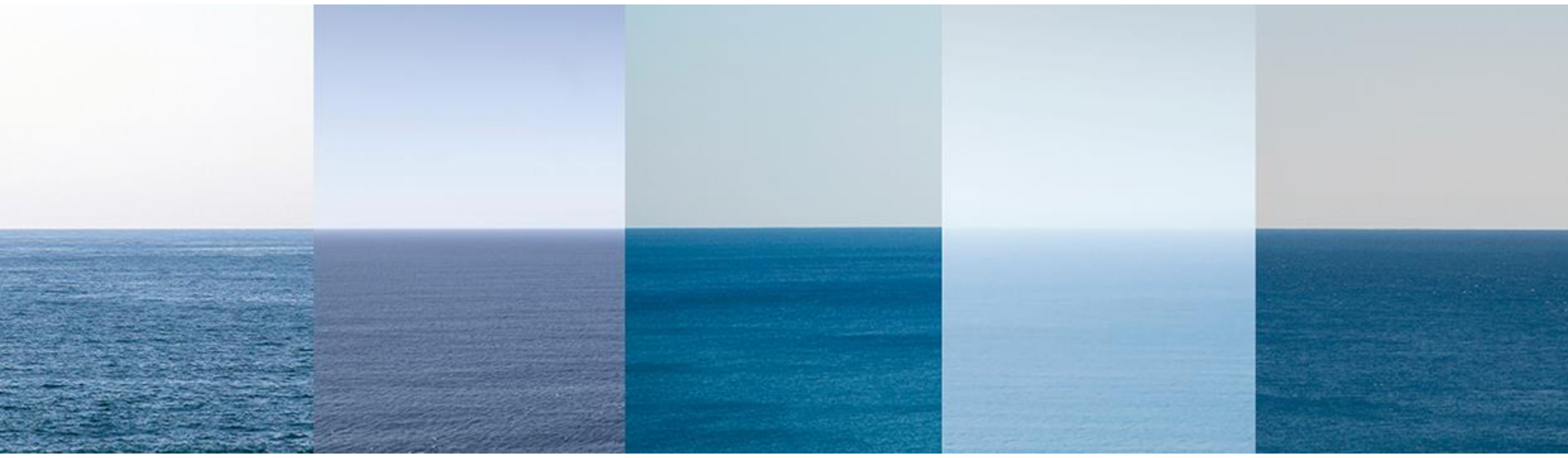
# References

Electricity System Operator (2024). HND Impact Assessment –South Cluster Outcome Summary.

The Crown Estate (2022). Offshore Wind Round 4: Record of the Habitats Regulations Assessment, document reference 38255-TCE-DOC-103.

# Appendix A

## Dogger Bank South Array Area – Preliminary Cable Burial Risk Assessment and Installation Report



# Dogger Bank South Array Area

Preliminary Cable Burial Risk Assessment and Installation Report

For RWE

GM-PRJ111361-GEO-RP-0002

004626111-02

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|---|---|---|---|---|---|
| 02 | 09/08/2023 | Issued for Review | **Subsea Cable Engineer**<br>F. Dick | **GIS Lead**<br>L. Murray | **Subsea Cable Engineering Lead**<br>M. Laing |

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## Figures



## Tables

## DOCUMENT ISSUE RECORD

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| 02 | Numerous | Numerous | Updated for client comments |
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# 1. SUMMARY

On behalf of RWE, Global Maritime have conducted a full CBRA and BAS study for both the Export Cable Route (ECR) and Inter-Array Cables (IAC) for the Dogger Bank South offshore wind farm. This document (004626111-02) focuses on the Inter-Array Cables, details the assessment of the geophysical and geotechnical survey data, including its suitability for application to the CBRA process; and both the CBRA and BAS results. Finally, based on the results of these works, a recommended method for cable installation and protection is provided. The comparable study for the ECR is available under the separate document (004626108-03).

A site conditions assessment has been performed to determine the geological layers of the seabed within the lease area. This assessment found that the majority of the area could be classified into sands of varying densities, with pockets of gravels and frequent shell and shell fragment content. The data from and results presented in Fugro's geotechnical and geophysical surveys formed the basis of all geological unit classification, and the associated survey data and deliverables provided their spatial definition.

Global Maritime's optimised CBRA method was applied with modelled post-windfarm installation vessel traffic to analyse the anchor strike risks to the cable and propose target burial depths along each RPL to minimise the risk to acceptable levels whilst also maintaining practical burial depths across the area. These burial depths vary across the area, due to the changes in soil properties along the cable route along with the density of modelled vessel traffic. The proposed burial depths and risk profile for a series of transects across the site is detailed in the alignment charts within this report. Indicative cable routes and burial zones produced by Global Maritime were used as the basis for the calculation and presentation of the CBRA and BAS results.

The results of the CBRA and BAS can be used as a basis for routing of the inter-array cables and provide a summary of how the site conditions effect the results, however once the final wind farm layout and final inter-array cable routes are available, the CBRA should be re-run using these to calculate more accurate results specific to the site layout and routes.

# 2. INTRODUCTION

## 2.1 Project Description

RWE Renewables UK Ltd. (RWE) are developing the Dogger Bank South (DBS) site located in the central North Sea. The DBS project is located to the southwest of the wind farms currently under development on the Dogger Bank. The DBS site consists of two adjacent sites, DBS East (DBSE), and DBS West (DBSW), and has a potential total installed capacity of 3 gigawatts (GW).

Global Maritime have executed the Cable Burial Risk Assessment (CBRA) and Burial Assessment Study (BAS) works for the offshore export cables and inter-array cables for the DBS site as detailed in RWE's scope of work document (Ref. 1).

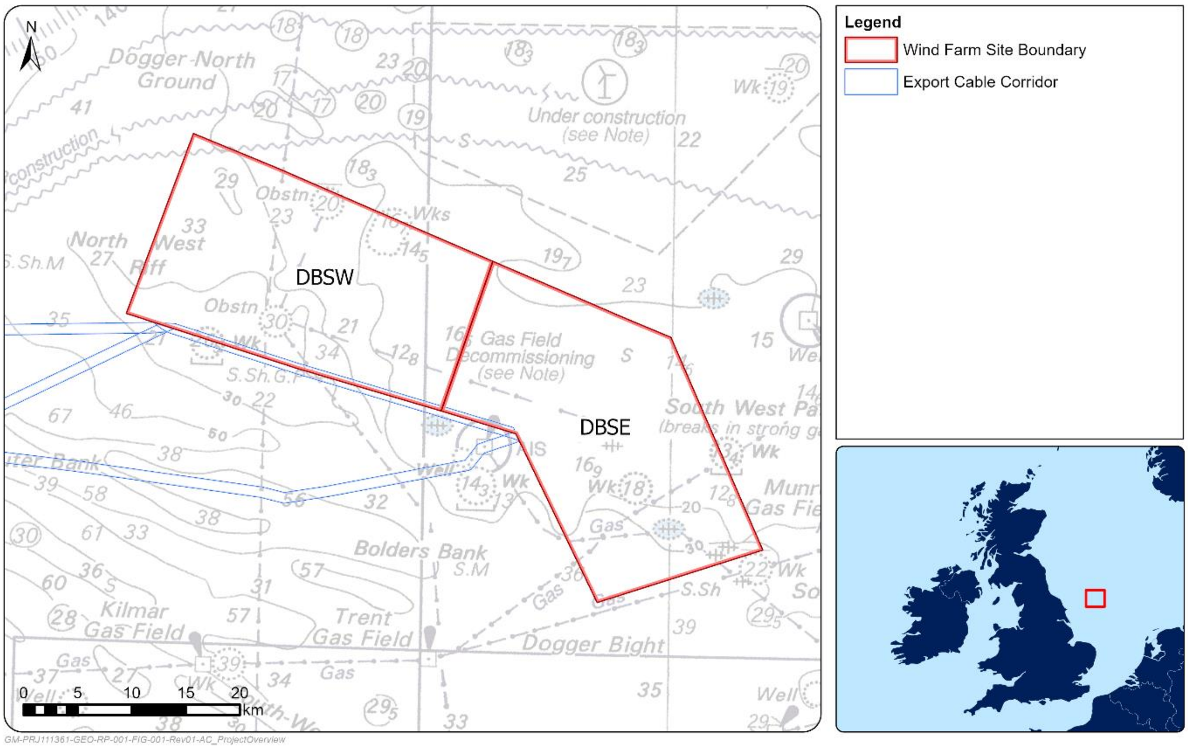



Figure 1: Project Overview

## 2.2 Purpose of Report

The purpose of this report is to present the results of the cable burial risk assessment and burial Assessment study completed by Global Maritime for the DBS Inter-Array Cables. The Wind Turbine Generator (WTG) positions, shown in Figure 2, are indicative only at the time of writing, and no IAC routes have been provided. Therefore, the CBRA and BAS results are presented for zones covering the array area, with extracted transects across the site to allow the results to inform future detailed cable routing.

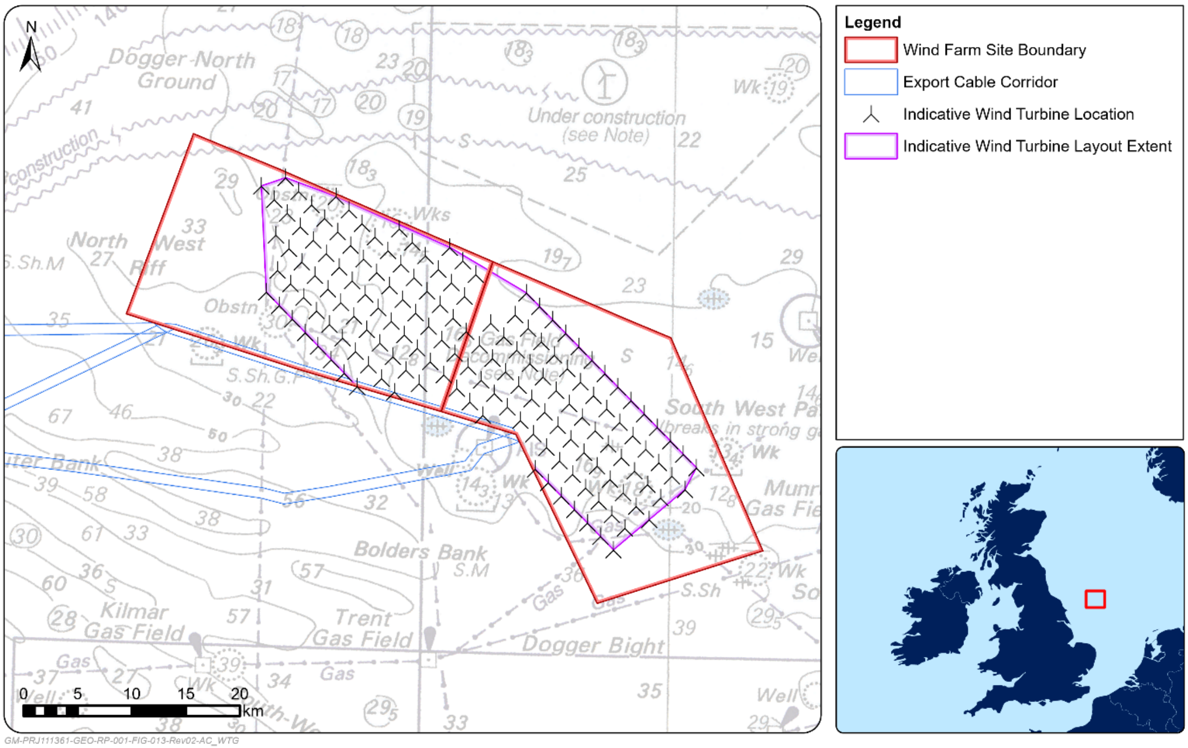



Figure 2: Route Option Schematic

The following works have been completed and results detailed within this report for each route option:

- Data review and gap analysis of all provided site data
- Review of the site conditions within the offshore export cable corridor
- Cable Burial Risk Assessment (CBRA)
- Burial Assessment Study (BAS)

## 2.3 Abbreviations

| Abbreviation | Description |
|---|---|
| AIS | Automatic Identification System |
| BSF | Below Sea Floor |
| BAS | Burial Assessment Study |

| Abbreviation | Description |
|---|---|
| CBRA | Cable Burial Risk Assessment |
| DBS | Dogger Bank South |
| DOB | Depth of Burial |
| DOC | Depth of Cover |
| DOL | Depth of Lowering |
| DNV | Det Norske Veritas |
| DWT | Dead Weight Tonnage |
| ECR | Export Cable Route |
| ECC | Export Cable Corridor |
| GIS | Geographic Information System |
| GM | Global Maritime |
| IAC(s) | Inter Array Cable(s) |
| ICPC | International Cable Protection Committee |
| KP | Kilometre Post |
| LA | Lease Area |
| LARS | Launch and Recovery System |
| LAT | Lowest Astronomical Tide |
| MBBS | Multibeam Backscatter |
| MBES | Multibeam Echosounder |
| OSP | Offshore Platform |
| OSS | Offshore Substation |
| ROV | Remotely Operated Vehicle |
| RPL | Route Position List |
| SBP | Sub-Bottom Profiler |
| SSS | Side Scan Sonar |
| UHC | Ultimate Holding Capacity |
| UHR | Ultra-High Resolution |
| WTG | Wind Turbine Generator |

Table 1: Table of Abbreviations

## 2.4 Geodetic Parameters

The following geodetic parameters, unless specified otherwise, have been used throughout this report.

| Reference | Description |
|---|---|
| Datum | WGS 1984 |
| Projection | UTM Zone 31N |
| Vertical Reference | Lowest Astronomical Tide (LAT) |

Table 2: Geodetic Parameters

## 2.5 Units

All distance and depth units within this report will be measured in metres, unless stated otherwise.

Dates will be given in dd/mm/yyyy format.

# 3. DATA REVIEW AND GAP ANALYSIS

## 3.1 Data Sources

The below project specific data:

1) RWE, Submarine Cable Burial Risk Assessment Specification, Dogger Banks South Offshore Wind Farm, Doc. No. 004485369-01, Rev. For Issue, September 2022.

2) Fugro, DBS WPM1 Array Area Seafloor Results Report, Dogger Bank South Offshore Wind Farm, UK, North Sea, Doc. No. 004267910-02, Rev. 01, April 2023.

3) Fugro, DBS WPM1 Array Area Shallow Geological Results Report, Dogger Bank South Offshore Wind Farm, UK, North Sea, Doc. No. 004267911-01, Rev. 01, April 2023.

4) Fugro, Measured and Derived Geotechnical Parameters, Dogger Bank Offshore Wind Farm, UK, North Sea, Doc. No. 004811202-01, Rev. 01, June 2023.

5) MarineSpace, 004688005-01-Marine Space - Dogger Bank South Background Review: Bed mobility & Thermal Environment, Version 1, January 2023.

6) UltraMap Global Ltd, Historical AIS data for 01/11/2020 – 31/10/2022.

7) RWE, Wind farm site boundary. DBS_LeaseAreas.shp. Received 10th November 2023.

The following additional non-project specific references have been used:

8) DNVGL, Recommended Practice, Subsea Power Cables in Shallow Water, Doc. No. DNVGL-RP-0360, March 2016

9) Cigre, Technical Brochure, Installation of Submarine Power Cables, Doc. No. TB883, October 2022.

10) DNV, Recommended Practice, Risk Assessment of Pipeline Protection, Doc. No. DNV-RP-F107, October 2010

11) Carbon Trust, Application Guide for the Specification of the Depth of Lowering using the Cable Burial Risk Assessment (CBRA) methodology, Dec 2015

12) Carbon Trust, Cable Burial Risk Assessment Methodology, Guidance for the Preparation of Cable Burial Depth of Lowering Specification, CTC835, February 2015

13) European Subsea Cables Association (2016), ESCA Guideline No. 6, The Proximity of Offshore Renewable Energy Installations & Submarine Cable Infrastructure in UK Waters, Issue 5, 10 March 2016

14) International Cable Protection Committee (2015), ICPC Recommendation No. 2, Recommended Routing and Reporting Criteria for Cables in Proximity to Others, Issue 11B, 3 November 2015

15) The Crown Estate (2012), Guideline for Leasing of Export Cable Routes/Corridors

16) BERR - Review of Cabling Techniques and Environmental Effects Applicable to the Offshore Wind Farm Industry.

17) Navigation Safety Branch, Maritime & Coastguard Agency, Marine Guidance Note MCN543 (M+F) Section 3d, File Ref: MNA/053/010/0626, January 2016.

## 3.2 Data Review and Gap Analysis

To inform the ground model created as part of the CBRA and BAS, Global Maritime were provided with a data pack from the Fugro 2022 geophysical survey (Ref. 2) and Ref. 3) and the factual report from the 2022 geotechnical survey (Ref. 3). An adequacy review of the provided data for the purposes of this study is provided in Table 3. Commentary and a traffic light assessment are also provided, representing **Adequate**, **Partially Adequate**, and **Inadequate**.

| Data Type | Source | Comment | Adequacy |
|---|---|---|---|
| Project Boundary | RWE (7) | Boundary for the wind farm lease area in shapefile format | Adequate |
| Bathymetry | Fugro (2) | 1m resolution MBES bathymetry, covering the entire lease area with a buffer of approximately 700m.<br>Relatively small missing section towards the centre of the site due to presence of weather buoy. | Adequate |
| Shallow Geology | Fugro (3) | High-resolution geological unit horizons derived from SBP data.<br>Ground-truthing of SBP data via geotechnical samples is limited due to small number of samples available.<br>Ground model can be built with combination of detailed horizons and geotechnical samples. | Adequate |
| Side Scan Sonar | Fugro (2) | High-resolution SSS data with full corridor coverage<br>Targets picked as small as 1m in any dimension | Adequate |
| Magnetometer | Fugro (2) | Mag targets supplied in shapefile format.<br>Targets picked with a minimum threshold of 5nT/m. | Adequate |
| Soil Provinces | Fugro (2 & 3) | High-detail sediment classification from SSS backscatter interpretation | Adequate |
| Seabed features & targets | Fugro (2) | Natural and anthropogenic targets and features identified by MBES, SSS and Mag. | Adequate |

| | | | |
|---|---|---|---|
| | | Suitable for informing recommended installation methodology | |
| Geotechnical | Fugro (4) | AGS file containing Borehole, CPT and SCPT results.<br>Factual report describing the results of the geotechnical survey, including all logs from the boreholes, CPTs and SCPTs.<br>Factual report and data provide sufficient detail for CBRA model to be developed, when used in conjunction with SBP data. | Adequate |

Table 3: Data Adequacy

# 4. SITE CONDITIONS

## 4.1 Bathymetry

The DBS lease area lies over the south-western extent of Dogger Bank, with a large variance in depth ranging from as deep as 43.3m near the westernmost extent of DBSW to as shallow as 14.2m toward the south-eastern corner of DBSE (Figure 3).

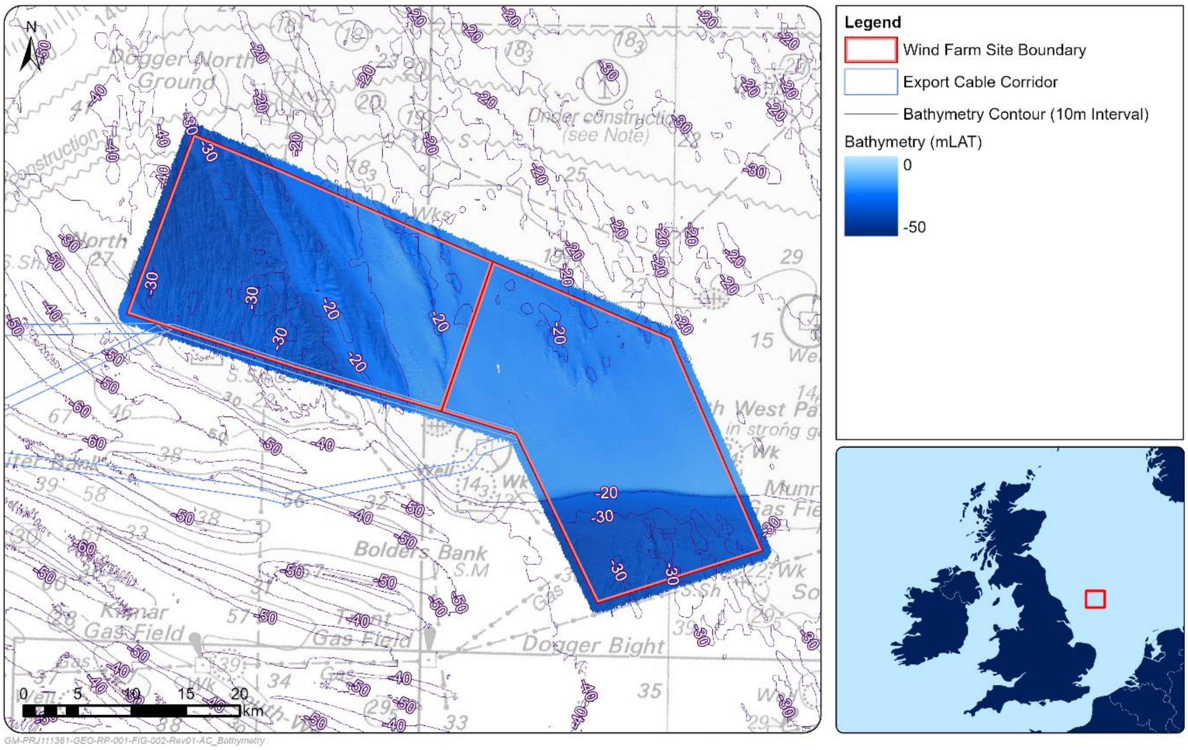



Figure 3: Regional Bathymetry (Fugro, 2023)

The morphology of the seabed within the lease area can be generally divided between the halves. DBSW contains numerous and irregular sedimentary features, with some indication of present or previous mobile sediments from the morphology. This part of the site shallows from west to east, as the bank increases in prominence. DBSE is mostly characterised by the presence of the bank, resulting in shallower waters and smoother seabed. Toward the southern extent of DBSE, there is a sudden depth increase off the southern edge of the bank.

The irregularities in the western and south-eastern limits of the lease area is largely caused by the geological origin of the site, consisting of fluvial and glacial deposits that have been deformed and re-deposited over time by currents. Based on the available data (Ref. 5), on a large scale, the site is mostly non-mobile on both an annual and decadal time scale. On a smaller-scale, evidence of mobile rippled scour depressions and depressions is present across the site (section 5.2.3.1).

## 4.2 Local Geology

The Dogger Bank forms a bathymetric high within the central North Sea thought to represent a thrust moraine complex formed during the Weichselian glaciation. The lease area lies across the south-eastern extent of the bank, around 140km from the export cable landing near Bridlington, North Yorkshire.

In the Dogger Bank area, the solid geology comprises folded Eocene fine-grained marine deposits of the Hordaland Group. The solid geology is unconformably overlain by shallow marine clayey sand of the Markham's Hole Formation and fluvial silty sand of the Yarmouth Roads Formation of Early to Middle Pleistocene age.

From Middle to Late Pleistocene, the Dogger Bank area was affected by repeated advances and retreats of the Fennoscandian Ice sheet and British-Irish Ice sheet. The interaction of these ice sheets resulted various periglacial, glacial and interglacial deposits and glaciotectonic deformation. During Holocene the sea level rose due to melting ice caps and the Dogger Bank area became gradually flooded and Holocene sediments were deposited on the older glacial deposits. This includes late Weichselian to early Holocene channel-fills of the Botney Cut Formation and early Holocene shallow marine deposits and locally Holocene sediments were reworked by contemporary marine processes (seafloor bedform formation). These postglacial sediments can locally reach more than 25 m in thickness, infilling older, glacially eroded, depressions and relict channels.

Sub bottom profiling was performed as part of the seafloor and shallow geological surveys performed by Fugro (Ref. 3) and interpretation was performed to identify horizons and seismostratigraphic units across the lease area. In total, seven horizons were interpreted delineating seven main seismostratigraphic units and two sub-units. Although all units were identified within the site boundary, the base of seismostratigraphic units are not always visible on the SBP data. The identified seismostratigraphic units are summarised in the below Table 4 and Figure 4.

| Unit | Horizon | | | Seismic Character | Expected Soil Conditions | Potential Geological Formation | Age | Depositional Environment |
|---|---|---|---|---|---|---|---|---|
| | Top | Base (Horizon Colour) | Internal Horizons | | | | | |
| A/B | H00 | H10 (Hot Pink) | H05 H07 H08 H09 | Acoustically transparent, horizontal bedding and clinoforms. Locally with erosion surfaces and strong positive internal reflectors. | Sand with shells and shell fragments, locally gravelly | Superficial Sediments | Holocene | Marine |
| C | H00 H10 | H20 (Yellow) | - | Channelised unit with a stratified to acousitically transparent or complex infill. Locally with high negative amplitude anomalies | Sand and/or clay | Botney Cut Fm | Late Weichselian to Early Holocene | Fluvial and estuarine |
| D | H00 H20 | H30 (Blue) | - | Acoustically chaotic (channel fill) | Gravelly and sandy clay | Botney Cut Fm | Weichselian | Tunnel Valley Fill |

| Unit | Horizon | | | Seismic Character | Expected Soil Conditions | Potential Geological Formation | Age | Depositional Environment |
|---|---|---|---|---|---|---|---|---|
| | Top | Base (Horizon Colour) | Internal Horizons | | | | | |
| E | H00<br>H10<br>H20<br>H30 | H40<br>(Dark Green) | - | Stratified and increasingly deformed towards the base | Clay locally with beds of sand | Dogger Bank Fm | Weichselian | Deformed glacio-lacustrine |
| F | H20<br>H30<br>H40 | H50<br>(Tan)<br>H55<br>(Gold) | - | Stratified to acoustically transparent | Sand with shells and shell fragments, locally with beds of clay | Eem Fm<br>Egmond Ground Fm | Holsteinian to Eemian | Marine |
| G | H30<br>H50<br>H55 | H60<br>(Green) | H59 | Valleys with an acoustically chaotic infill at the base and stratified seismic character at the top | Sand and/or clay | Swarte Bank Fm | Elsterian | Subglacial to marine |
| H | H40<br>H50<br>H60 | H70<br>(Orange) | H65 | Stratified at the base to complex at the top | Clayey and silty sand | Yarmouth Roads Fm Markham's Hole Fm | Early to Middle Pleistocene | Deltaic and fluvial |
| I<br>Bedrock | H30<br>H60<br>H70 | N/A | - | Stratified and folded | Clay or Claystone | Hordaland Gp | Eocene | Marine |

Table 4: Stratigraphic framework and summary of the Fugro interpreted seismostratigraphic units in the lease area (Ref. 3)

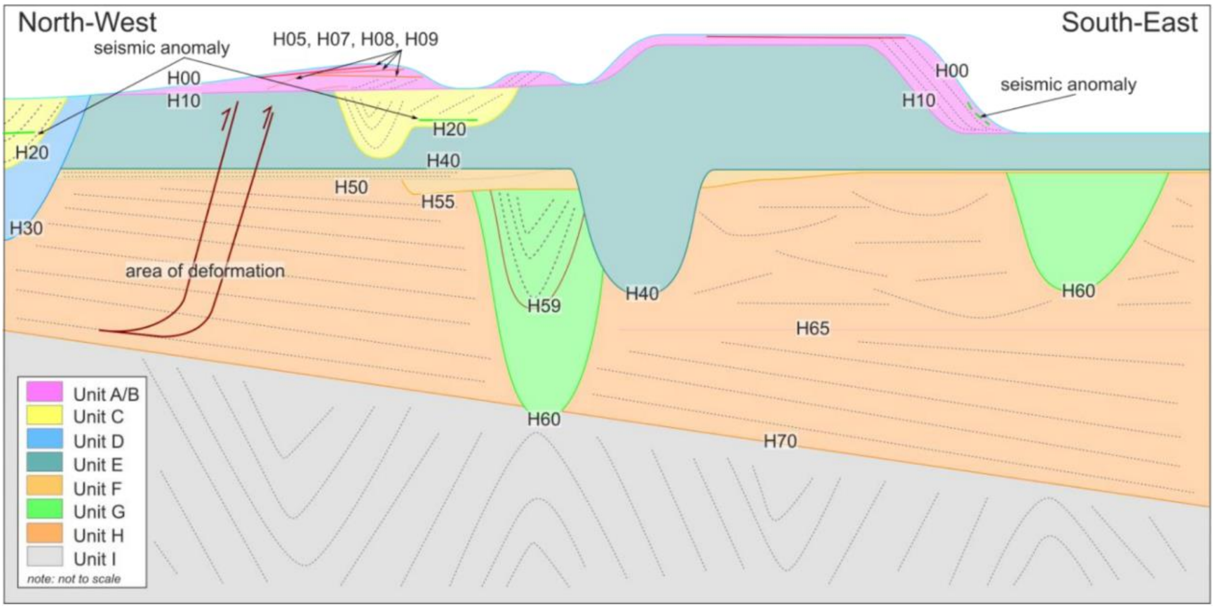



Figure 4: Fugro interpretation and relationship of the stratigraphic units present in the lease area (Ref. 3)

## 4.3 Lease Area Seafloor Sediments

An interpretation of the seafloor sediments was performed by Fugro (Ref. 2) using Multibeam Backscatter, Side-scan sonar data and Grab sampling. The following surficial sediments were found to be present:

| Sediment Class | Area ($km^2$) | % of Total Area |
|---|---|---|
| Muddy sand | 132.7 | 12.4 |
| Sand | 593.5 | 55.5 |
| Slightly gravelly muddy sand | 65.0 | 6.1 |
| Slightly gravelly sand | 35.7 | 3.3 |
| Slightly muddy sand | 29.9 | 2.8 |
| Gravelly sand | 212.2 | 19.9 |

Table 5: Surficial sediment distribution across the DBS lease area (Ref. 2)

No outcropping bedrock was detected in the geophysical survey data, with some areas showing shallow subcropping of the underlying layers. Figure 5 shows the spatial distribution of the seafloor sediments identified.

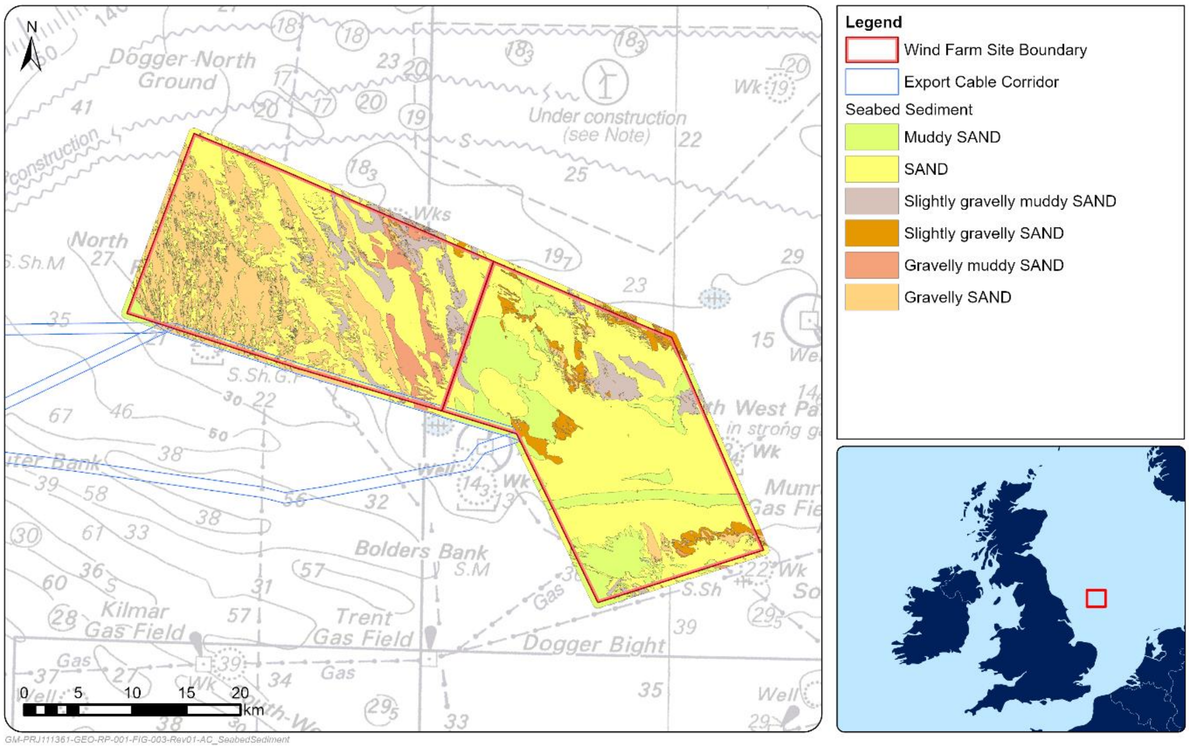



Figure 5: Seafloor sediments across the Dogger Bank South Lease Area

## 4.4 Ground Model

To develop a ground model for the lease area, datasets from both the geophysical and geotechnical surveys were consulted. The CPT and Borehole logs from the geotechnical survey were used to gauge the depths and descriptions of the shallow geological layers across the site. These were correlated with the horizons and units derived from the SBP data, detailed in Table 4. This allowed the allocation of units in three dimensions across the entirety of the site. Due to the likely depth of cable burial to be determined by the CBRA, only information from the upper 3 m below seabed was integrated into the ground model. The shallow geology consists mostly of sands of varying density with shell fragments and localised pockets of gravel or clay.

GM’s CBRA model units are described in Table 6 below, with the conversion from Fugro’s ground model units to GM’s CBRA model units shown in Table 7. The conversion was based on both the soil descriptions and undrained shear strength (Su) values. The relative densities (Dr) of the sand units are also shown, however, it should be noted that Dr is simplified in the CBRA model as it does not significantly affect the results.

| Unit Code | Soil Description | Su From | Su To | Dr From | Dr To |
|---|---|---|---|---|---|
| S1 | Loose SAND | n/a | n/a | 0% | 35% |
| S2 | Medium dense SAND | n/a | n/a | 36% | 65% |
| S3 | Dense SAND | n/a | n/a | 66% | 100% |
| C1a | extremely low strength CLAY | 1 | 5 | n/a | n/a |
| C1b | extremely low strength CLAY | 5 | 10 | n/a | n/a |
| C2 | very low strength CLAY | 10 | 20 | n/a | n/a |
| C3 | Low strength CLAY | 20 | 40 | n/a | n/a |
| C4 | Medium strength CLAY | 40 | 75 | n/a | n/a |
| C5 | High strength CLAY | 75 | 150 | n/a | n/a |
| C6 | Very high strength CLAY | 150 | 300 | n/a | n/a |
| C7 | Extremely high strength CLAY | 300 | 1000 | n/a | n/a |

Table 6: GM CBRA model Geological Unit

| Fugro Geotechnical Samples | | | | GM Model Units | | | |
|---|---|---|---|---|---|---|---|
| Sample Name | Upper Layer Description | Lower Layer Description | Upper Layer Depth BSF (m) | Upper Layer Description | Lower Layer Description | Model Unit Upper | Model Unit Lower |
| DBSE-009-BH | sandy fine to coarse GRAVEL with occasional shell fragments | very dense fine to medium SAND with occasional shell fragments and organic matter | 0.4 | Medium dense SAND | Dense SAND | S2 | S3 |
| DBSE-010-BH | silty fine SAND with occasional shell fragments. Occasional pockets of organic matter | silty fine SAND with occasional shell fragments | 1.7 | Dense SAND | loose SAND | S3 | S1 |
| DBSW-003-BH | fine to medium SAND with silty organic matter and shell fragments | very gravelly silty fine to coarse SAND with numerous shell fragments | 1.75 | Loose SAND | Dense SAND | S1 | S3 |
| DBSW-004-BH | fine to medium SAND with shell fragments | gravelly fine to medium SAND with shell fragments. | 2.5 | Loose SAND | Medium dense SAND | S1 | S2 |
| DBSW-005-BH-A | very dense silty fine SAND with shell fragments and rare clay pockets | very dense slightly gravelly fine to coarse SAND with shell fragments | 2.2 | Dense SAND | Dense SAND | S3 | S3 |
| DBSE_007_SCPT | very loose to medium dense SAND | high-strength CLAY | 0.5 | Loose SAND | High strength CLAY | S1 | C5 |
| DBSE_010_SCPT | medium dense to dense SAND | loose to medium-dense SAND | 1.1 | Dense SAND | loose SAND | S3 | S1 |
| DBSE_011_CPT | very loose to medium dense SAND | dense to very dense SAND | 0.3 | Loose SAND | Dense SAND | S1 | S3 |
| DBSE_012_CPT | 0.14m of very loose to medium dense SAND over low to medium strength CLAY | high-strength CLAY | 0.5 | Medium strength CLAY | High strength CLAY | C4 | C5 |
| DBSE_014_CPT | very loose to medium dense SAND | dense to very dense SAND | 0.2 | Loose SAND | Dense SAND | S1 | S3 |
| DBSW_001_CPT | very loose SAND | very high strength CLAY with thin beds of sand | 0.3 | Loose SAND | Very high strength CLAY | S1 | C6 |
| DBSW_002_CPT | very loose to loose SAND | high-strength CLAY with widely spaced thin to thick beds of medium dense to dense sand | 0.3 | Loose SAND | High strength CLAY | S1 | C5 |
| DBSW_003_SCPTA | very loose to medium dense SAND | dense to very dense SAND | 0.2 | Loose SAND | Dense SAND | S1 | S3 |
| DBSW_004_SCPT | very loose to loose SAND | medium dense to very dense SAND | 0.25 | Loose SAND | Medium dense SAND | S2 | S2 |
| DBSW_006_SCPT | very loose to loose SAND | medium dense to very dense SAND | 0.2 | Loose SAND | Medium dense SAND | S3 | S2 |
| DBSW_013_CPT | very loose to medium dense SAND | very dense SAND | 0.3 | Loose SAND | Dense SAND | S4 | S3 |
| DBSW_015_CPT | very loose to medium dense SAND | dense to very dense SAND | 0.3 | Loose SAND | Dense SAND | S5 | S3 |

Table 7: Fugro Geotechnical sample descriptions and the corresponding GM CBRA model geological units and Su value

# 5. CABLE BURIAL RISK ASSESSMENT (CBRA)

## 5.1 CBRA Methodology

### 5.1.1 Risk Assessment Methodology

There are a wide range of obstacles and seabed users that present potential hazards to subsea cables; or which have direct interactions with cables that risk damage. Such hazards include ship anchors, which could impact or snag the cable if dragged along the seabed; and fishing, where bottom trawling gear can snag and damage cables. The aim of this study is to evaluate potential risks to the cable and provide recommendations as to the most efficient risk mitigation, including recommendations of burial depth where appropriate.

The basis of a risk assessment for a submarine cable relies on identifying the potential hazards, associated risks, and evaluating the level of protection that may be afforded to the cable by its armouring (internal and/or external), cable burial beneath the seabed or any other means, such as rock dumping or concrete mattressing.

The most reliable and cost-effective form of cable protection is generally recognised to be ensuring no interaction between the cable and the identified hazards. This is most easily achieved by routing the cable away from such hazards or, where this is not practical, by burial below the seabed.

The simplified methodology followed in this report is adopted in accordance with the industry guidance documents:

- Carbon Trust, Cable Burial Risk Assessment (CBRA) Methodology (Ref. 12)
- Carbon Trust, CBRA Application Guide (Ref. 11)
- DNV-GL Subsea Power Cables in Shallow Water (Ref. 8)

The methodology for the CBRA includes an assessment of the seabed conditions followed by the identification and quantitative assessment of the threats/hazards for the area. A probabilistic assessment has then been performed using Global Maritime's in house GIS based software to assess the risk posed to the cable by external threats and a recommended burial depth has been established. This includes a full 3-dimensional approach to the probabilistic calculation of the threat of an anchor strike.

The CBRA method reviews an identified hazard based on its anticipated frequency and consequence. The combined outcome of frequency and consequence indicates whether risk is unacceptable, 'As Low As Reasonably Practical' (ALARP) or Acceptable. This adheres to the criteria outlined in DNVGL-RP-F107 (Ref. 10) The risk matrix used, and definitions of probability and severity are shown in the below tables.

| | | Probability | | | | |
|---|---|---|---|---|---|---|
| | | A | B | C | D | E |
| Consequence | 1 | | | | | |
| | 2 | | | | | |
| | 3 | | | | | |
| | 4 | | | | | |
| | 5 | | | | | |

Table 8: Risk Matrix

| Probability | Definition |
|---|---|
| A (Very Unlikely) | Never Heard of in Industry |
| B (Unlikely) | Heard of in Industry |
| C (Possible) | Incident has been known to occur, but rarely |
| D (Likely) | Happens several times a year in Industry |
| E (Very Likely) | Happens several times a year at project location |

Table 9: Probability Definitions

| Consequence | Definition |
|---|---|
| 1 | Negligible Damage |
| 2 | Minor Damage / Exposure to other hazards |
| 3 | Localised Damage / No unplanned loss of capacity |
| 4 | Major Damage - replacement of small section / Unplanned loss of capacity |
| 5 | Extensive Damage - replacement of significant section of cable/ Significant unplanned loss of capacity |

Table 10: Consequence Definitions

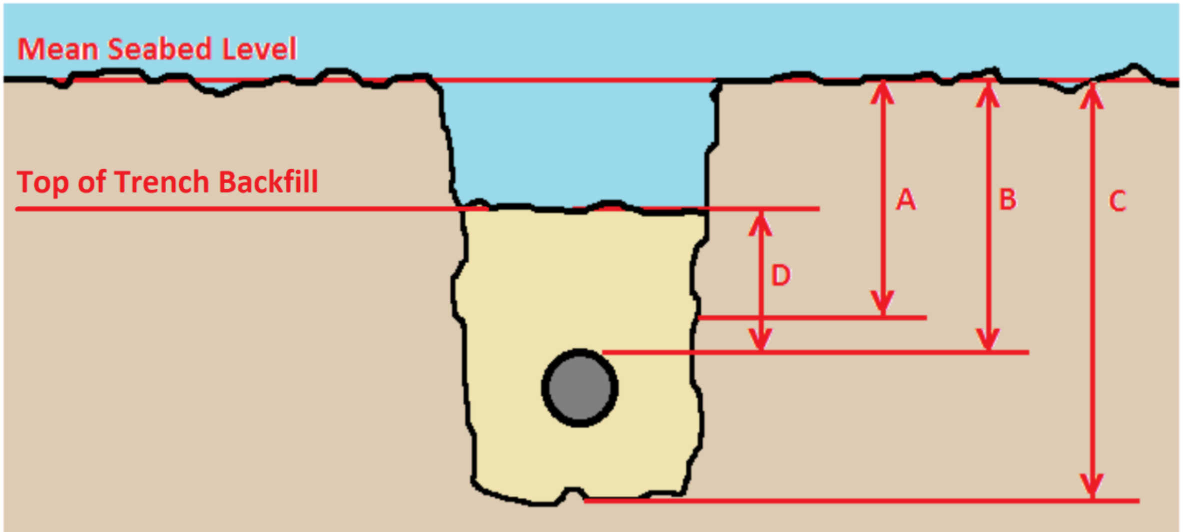
### 5.1.2 Hazard Classification

Hazards are classified as primary or secondary. Primary hazards are those that have a direct impact upon the cable and can cause damage and secondary hazards are those that do not damage the cable directly but can result in increased risk or susceptibility to damage from primary hazards.

An example of a primary hazard would be impact or snagging of the cable due to a ships anchor being deployed. An example of a secondary hazard would be seabed mobility resulting in reduced cable burial cover or exposure, leaving the cable vulnerable to primary hazards.

5.1.3 Cable Burial - Carbon Trust Terminology

As presented in the methodology above, threat lines have been suggested for the identified site hazards for cable burial (sections 5.2 and 5.3). These will follow the information and terminology described in the Carbon Trust Guidance Documents (Ref. 12). Figure 6 provides an illustration and summary of the main abbreviations and terminology used for burial in this report. The Target DOL generally includes an installation tolerance (or safety allowance).




A Recommended Minimum Depth of Lowering
B Target Depth of Lowering
C Target Trench Depth
D Depth of Cover

Figure 6: Definition of Trench Parameters and Abbreviations

## 5.2 Hazard Identification and Assessment

5.2.1 Introduction and Risk Register

Data supplied and acquired from third parties has been assessed to develop a risk register (Appendix A), which has been compiled using probability and severity classification to evaluate the potential risks to cables across the site for both installation phases and the operational lifetime of the wind farm. The purpose of this exercise is to ensure that all hazards are identified and assessed and the risk to cables appropriately acknowledged, with initial indications on mitigations presented where possible. The main hazards identified in the risk register are discussed in more detail below.

The Risk Register is considered a live document which will be updated throughout the life of the project and should be reviewed frequently.

### 5.2.2 Primary Hazards

#### 5.2.2.1 Shipping Activity

Shipping is generally the most onerous anthropogenic risk to cables in terms of threat line depth (even if not the most likely to occur). The main hazard associated with shipping is the deployment of an anchor in proximity to a cable leading to anchor strike. Anchor strike does not necessarily lead to cable damage though it is likely to occur if a cable is inadequately protected through burial to an appropriate depth. The risk of this hazard is associated with the type of vessel traffic, its density, and the frequency of transit in proximity to the cable or cables. The vessel traffic density for 01/11/2020 – 31/10/2022 (Ref. 6) is shown for all vessel categories and sizes in Figure 7.

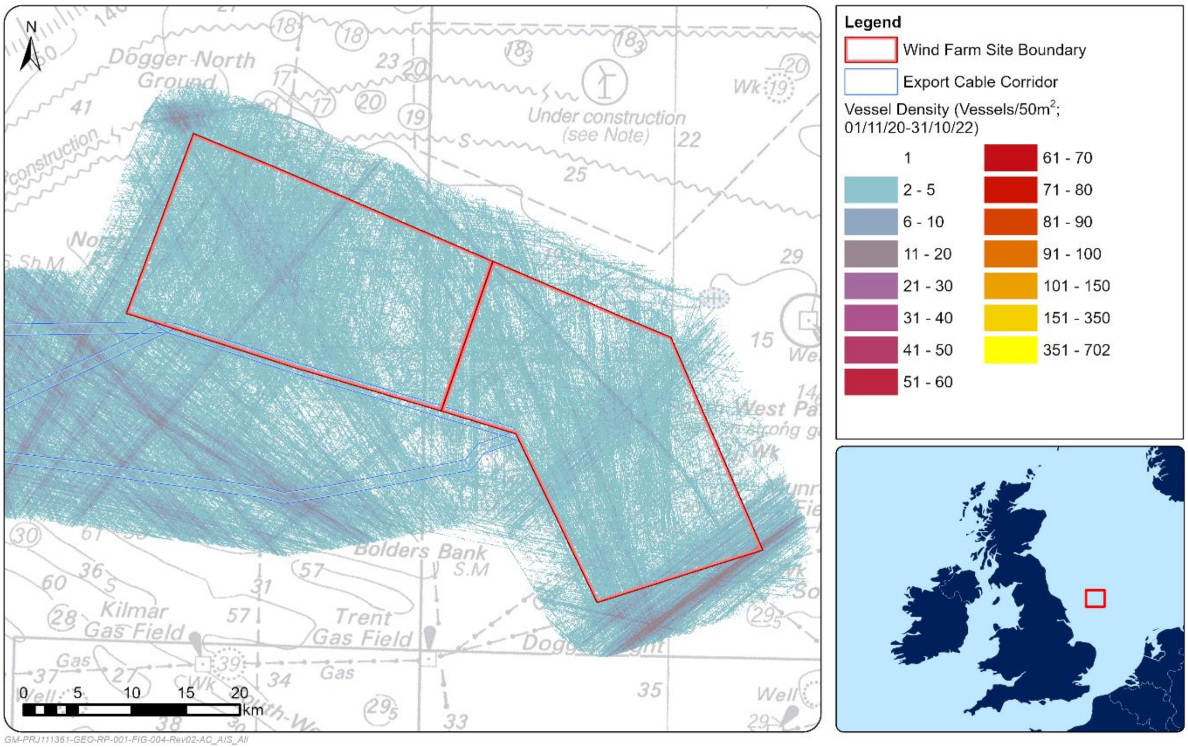



Figure 7: Overall Vessel Traffic Density

The hazard to subsea cables from shipping is associated with the deployment of anchors either in designated anchorage zones (which should be avoided through routing) or in emergency situations that result in anchor deployment through mechanical failure or deployment without due care. The potential impact on the seabed and/or the resultant snagging of a deployed anchor can result in damage to a buried cable.

The traffic can be seen to be most dense in the nearshore area running parallel to the coast, with overall traffic seen to reduce further offshore along the export cable route and within the lease area. It is expected that post-construction, the main route will avoid the wind farm area and give the turbines a wider berth where possible.

The marine traffic data can be further analysed and categorised into various vessel categories as follows:

- Cargo / Tanker Vessels
- Fishing Vessels
- Government Vessels
- Offshore Industry Vessels
- Passenger / Pleasure Vessels
- Port / Dredging Vessels

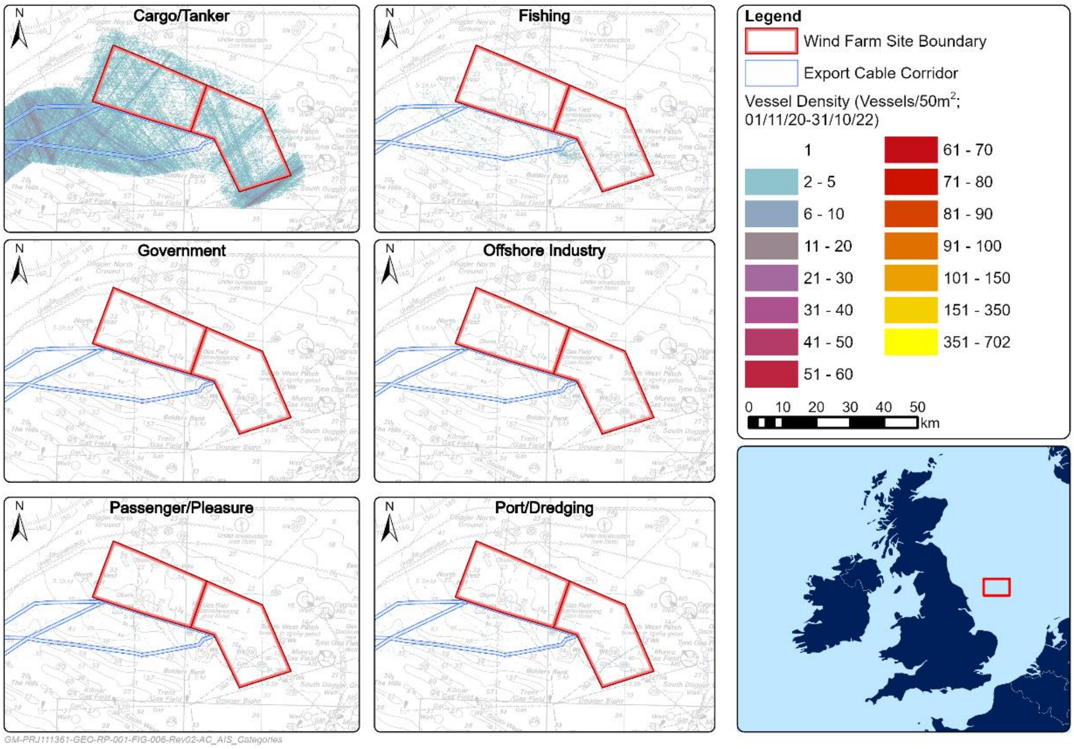



Figure 8: Pre-Construction Marine Vessel Traffic Density by Vessel Category

It can be seen that the highest density of marine traffic crossing the lease area comes from cargo vessels. When compared to the export cable route, the traffic within the lease area from other vessel types is minimal and will be further lessened by the presence of the wind farm once constructed, with the exception of the addition of vessels servicing the wind farm itself.

AIS transmitters also provide a status of the vessels, as determined by the vessels themselves. Few vessels in proximity of the lease area in the AIS data had their status as 'at anchor' or 'engaged in fishing', which suggests a reduced risk of impact associated with these activities, however it should be noted that this information relies on the vessel crews accurately updating their status, which is not necessarily always the case.

Global maritime have completed an exercise of re-distributing shipping traffic around the wind farm lease area to model the vessel traffic that would be expected post-wind farm installation, where it would be expected that the vessels previously transiting the lease area would adjust course to avoid the turbines once installed. The modelled vessel traffic follows the extent of the indicative wind turbine layout within a 2250m buffer, determined by the width of the largest shipping lane pre-wind farm installation. This was conducted with assistance from Senior Mariners within Global Maritime who provided input into the modelling and a review of the post installation shipping activity. The post-installation shipping activity was used to conduct the CBRA as this is more representative, with some of the vessels that are seen in the historic data crossing the lease area, now crossing the export cables, with an overall greater number of vessels crossing the export cable. A summary of the modelled traffic can be seen in the Figure 9. This shows the vessels previously crossing the windfarm and redistributes them to their most likely new transit route spatially given a criteria of exit point and entry point of the lease area, as well as the wider to and from destinations taken generally from wider open-source density mapping of the area. This also adds in any service vessels for the windfarm expected to be additionally used for operations and maintenance throughout the lifetime of the Wind farm, completed for the WTG layout provided at time of this report, known to be indicative and susceptible to change. This process typically redistributes a greater level of traffic crossing the export cable corridor, with a new pattern of vessel activity formed within the wind farm area and between the wind farm area the assumed port of operations for maintenance and operational traffic.

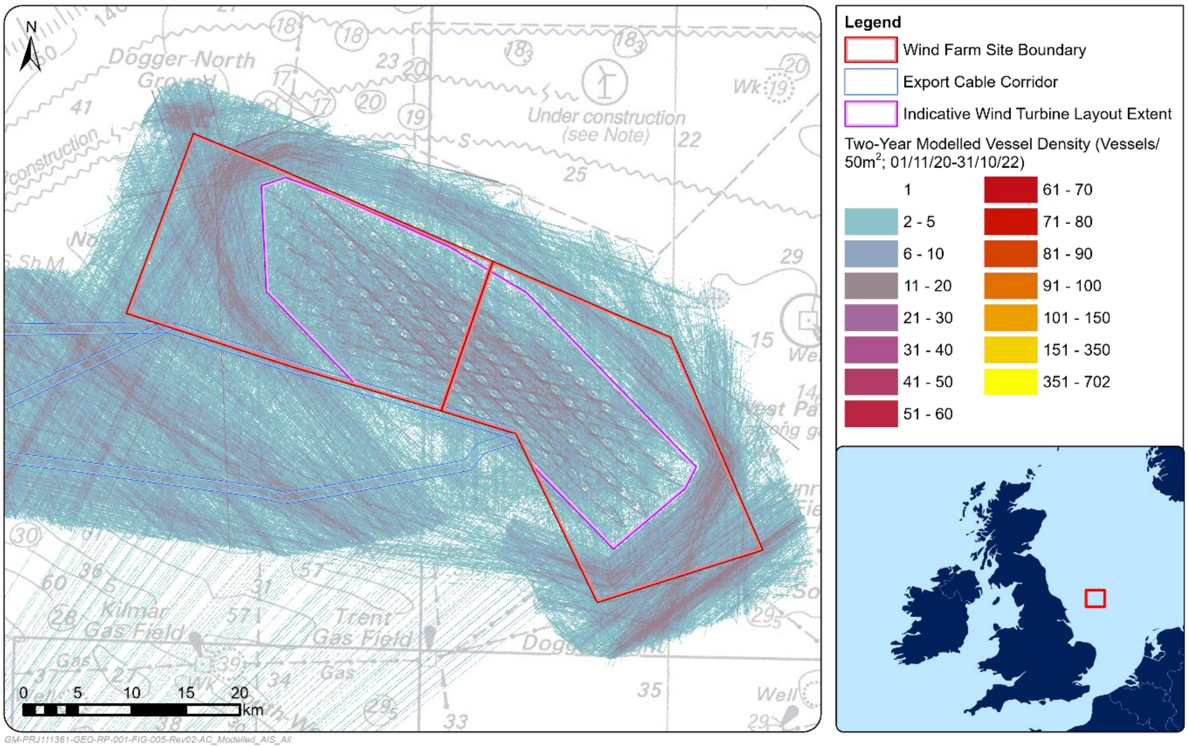



Figure 9: Two-Year Modelled Post-Installation Vessel Traffic

The main mitigation for shipping hazards (anchor strike) is typically burial beneath the identified threat line for a given return period/acceptable level of risk. The optimum burial depth is dependent on the results of the probabilistic risk assessment and cost of achieving the target burial depth. The method and results of the probabilistic assessment are discussed in Section 5.3 and 5.4.

This threat line should also only be considered as below a reference seabed level. This reference seabed level is in this case the MBES surface provided for the CBRA analysis. Future repeat MBES surveys can be used to identify and measure the size of any mobile features on the site, and the threatline can then be adjusted to account for a mobile layer.

#### 5.2.2.2 Fishing Activity

Commercial fishing is a hazard to subsea cables (even armoured cables) where fishing gear interacts with the seafloor, potentially resulting in damage due to impact or snagging. It should also be noted that a cable can pose a risk to the fishing vessels themselves if left on or close to the seabed, as small vessels can founder if snagged on a significant obstruction, of particular concern in areas of strong currents. For example, fishing vessels have been known to founder when trawl gear has become snagged on subsea infrastructure and attempts to free the gear have been unsuccessful.

As can be seen from the AIS data shown above, fishing vessels appear to rarely cross the lease area. This suggests the risk from fishing activity is low, however the results from the geophysical survey (ref. 2) 3) shows evidence of trawl marks and discarded/lost fishing gear across the lease area. Therefore, it is clear that protection will still need to be implemented against the risk of damage through impact / snagging of bottom trawl gear with the export cables. In the case of the identified fishing methods currently employed in the region the following threatline depth is considered reasonable below a non-mobile seabed:

- Fishing gear threatline depth in sand/mud ~0.2 m
- Fishing gear threatline in stiff clays ~0.1 m

These values are in line with the Carbon Trust CBRA guidance (Ref. 12)12), which provides an estimate of maximum penetration of fishing bottom trawl equipment. It is noted that the risk of emergency anchor deployment described previously provides a greater threatline and is the governing case along the cable routes.

#### 5.2.2.3 Stability/Fatigue

Surface laid cables are subject to loading from waves and currents and this could result in cable movement and migration across the seabed. Excessive movement on the seabed could cause abrasion and/or fatigue issues. Wave induced movements will be likely in shallow areas towards the shore approaches and during storm activities over the remainder of the site. If the cable is unstable then abrasion can occur where unburied cable is migrating across the seabed and 'rubbing against' outcropping rock, often causing significant damage.

Cable migration is also likely to increase the risk profile, as the cable movement is likely to cause a cable fault. It is also possible that the cable position will no longer be accurately identified on marine charts and this is likely to result in an increased risk from other primary hazards such as vessel anchors, fishing and construction activities. However, power cables such as the proposed are heavy and likely to have high friction with the seabed, therefore damage to the cable is more likely to occur than large displacements with suitable continued cable performance.

Whilst cable migration and fatigue may be issues for unburied cables, where a fatigue life of 20 years may be assumed in less energetic environments, experience indicates that minimal burial/embedment is usually required to ensure on-bottom stability. Therefore, where practical it is recommended that cable burial is planned unless not practical or proven to not be necessary with further in-depth analysis. If the cable is not to be buried due to outcropping rock or other factors, a more detailed cable protection strategy including the following is recommended:

- Micro-routing is undertaken to take advantage of any local features (gullies, ridges, depressions) to avoid freespans and shelter the cable where possible.
- On-bottom stability and fatigue assessments should be carried out to investigate the cable response and ascertain the likelihood for damage of the cable and the likely fatigue life under the loading regime.
- Plan appropriate mitigation methods i.e., pinning by anchoring or rock dumping, external around, additional internal stiffeners/armour, etc.

At minimum, shallow cable burial is recommended for the entirety of the Lease Area, regardless of the threatline depth for a particular location, to ensure the cables are stable. Cable Protection Systems (CPS) such as bend stiffeners should be utilised at J-tube bellmouths or apertures where cables enter the wind turbine monopiles, to ensure these sections which cannot be stabilised via burial are not subject to damage via fatigue. Scour protection may be required where the CPS and cable have been buried into the seabed, to prevent de-burial over time.

### 5.2.3 Secondary Hazards

#### 5.2.3.1 Mobile Sediments

The seabed in the lease area largely consists of morphological features, as detailed in the provided array area seafloor survey results report (ref. 2) Based on the collected SSS and MBBS data, the report identifies and categorises these features as small, medium and large bedforms, and a number of other more complex features including 'Reworked Flattened Bedforms', 'Composite Bedforms', 'Rippled Scour Depressions' and 'Complex Seafloor Morphology'. Though the report does not provide an assessment of the mobility of these features, their presence indicates that the seabed is presently or was formally mobile to some degree. MarineSpace's Bed Mobility and Thermal Environment report (ref. 5) reviews literature for the site which suggests that the large-scale bedforms are largely stable, whilst the medium-scale bedforms are mobile, with a bed level change of up to 0.9m in some locations. The rippled scour depressions are shown to form and dissipate over time, driven by the variable sea-states at different times across the site. The actual mobility of the morphological features such as sandwaves, megaripples and rippled scour depressions should be verified with repeat bathymetry surveys and further assessment.

The presence of sediment mobility at the site could result in (deeper) burial of cables sections and/or the exposure/freespanning of previously buried sections, as the bedforms migrate. Therefore, the following should be considered:

- The performance of the cable when buried, confirming that there is not a risk of overheating at the possible burial depth due to the mobile sediments in this area.
- The increased risk of primary hazards such as fishing, anchoring and stability/fatigue due to mobility and exposure of the cable.

It is recommended that an allowance be made for sediment mobility where appropriate, with increased burial depth in areas of confirmed mobile features following further studies. The threatlines discussed in this report are to be considered from the provided bathymetry as the reference seabed level. Should active mobile features be determined to be present after repeat bathymetric surveys, a stable seabed level assessment should be undertaken and the threatlines adjusted to be based on this new stable reference level. The actual burial depth at time of installation would then be the DOL below the stable seabed level, as determined by the CBRA, added to the local thickness of the mobile layer over the stable seabed level. If this total burial depth exceeds the ability of the chosen burial tool, sandwave clearance may be required using clearance ploughs or Mass/Controlled Flow Excavation to reach the target DOL.

#### 5.2.3.2 Surficial and Buried Boulders

Boulders on the seabed may cause free spans of cable if the cable laid over them, or at the least sections of exposed cable where it could not be buried due to the risk of damage to a burial tool from the boulders. Free spans and exposed sections of cable are more susceptible to fatigue and abrasion damage as a result of movement. Boulders buried below the seabed, if not identified, may cause ride-out of ploughs (where the plough share is involuntarily brought close to or to the surface), resulting in decreased burial or cable exposure. In the worst case, a boulder could be impacted and significantly damage a burial tool. If boulders are found to be present across the cable corridors, micro-routing around them, or boulder clearance campaigns may be required as mitigation.

## 5.3 Probabilistic Risk of Anchor Strike

A probabilistic assessment of the export cable anchor strike risk due to the identified shipping activity has been performed following the carbon trust guidelines (Ref. 12) using Global Maritime's GIS based approach. This has been performed using the site AIS data which was adjusted to model the post-windfarm construction traffic.

This method evaluates the external threat to the cable by considering the amount of time vessels spend within a critical distance of the cable and the probability that a vessel might have an incident that requires the deployment of an anchor. The effect of water depth and bathymetric profile is considered very important and is included as a qualitative factor.

The calculation for the probability of a cable strike is given by the following formula:

$$P_{strike} = P_{traffic}\, P_{wd} \sum_{1}^{No.\ ships\ in\ Section} \frac{D_{ship}}{V_{ship} * 8760hrs\ per\ year} P_{incident}$$

Where:

$P_{traffic}$ : Probability modifier based on the tolerable level of risk

$P_{wd}$ : Probability modifier for nature and depth of seabed

$V_{ship}$ : Ship speed (metre/hr)

$D_{ship}$ : Distance travelled by ship in area under consideration (metre)

$P_{incident}$ : Probability of incident occurring for that vessel size and type

$8760hrs$ : Facture to annualise the results

Values for the above parameters are shown in the table below:

| Parameter | Description / Comments | Value Used |
|---|---|---|
| $P_{traffic}$ | Probability modifier to determine acceptable level of risk. Indicates the percentage of vessels for which burial is required for protection.<br><br>Conservative value used for initial assessment. | 1 |
| $P_{wd}$ | Indication of risk due to seabed profile and water depth. Values chosen as per the Carbon Trust guidelines. | See Table 12 |
| $V_{ship}$ | Individual vessel speeds taken from AIS data when crossing cable, with a maximum speed of 2 knots | Various |
| $\boldsymbol{D_{ship}}$ | Distance travelled by the anchor when deployed to exert its holding capacity and immobilise the vessel. Vessel outside of a distance equal to $D_{ship}$ from the cable is not a hazard.<br><br>Calculated on vessel mass (m) taken as displacement, and estimated Ultimate Holding Capacity (UHC) which is estimated for each individual vessel. | $D_{ship} = \frac{m * V_{ship}^2}{4 * UHC}$ |
| $P_{incident}$ | This is the probability of an incident occurring on the vessel which requires the deployment of an anchor. This is taken as the probability of engine failure in single engine tankers in the North Sea, as per DNV guideline DNV-RP-F107 | $1.75 \times 10^{-1}$ incidents per year per vessel |

Table 11: Parameter Values of Probabilistic Risk Assessment

| Vessel DWT (t) | Minimum Water Depth (m) | | | |
|---|---|---|---|---|
| | **0-10** | **10-30** | **30-50** | **>50** |
| 0 | 1 | 0.1 | 0 | 0 |
| 2000 | 1 | 0.3 | 0 | 0 |
| 5000 | 1 | 0.5 | 0.1 | 0 |
| 20000 | 1 | 0.9 | 0.3 | 0.1 |

Table 12: $P_{wd}$ Values According to Water Depth and Vessel DWT

Possible anchor penetration can be estimated, based on the soil properties and the typical anchor sizes (fluke length) used by vessels categorised by their deadweight tonnage. As described within Section 4, the seabed within the lease area consists of sands of varying densities, with consistent shell fragments and pockets of gravel, with areas of subcropping and occasional outcropping clay. The penetrative ability of anchors of different sizes in these variable soil conditions must be considered in the CBRA. This is summarised in the below table for the vessels identified. This is representative results for a single soil layer only, the full modelling performed for the results presented later in this report and shown in the alignment charting utilises a multiple layer solution from the available geophysical data.

| Vessel Deadweight (DWT, Te) | Maximum Anchor Fluke Length (m) | Anchor Penetration (m) | | |
|---|---|---|---|---|
| | | **In Units S1, S2 & S3 (Sands)** | **In Unit C4 (Medium Strength Clay)** | **In Unit C5 & C6 (High & Very High Strength Clay)** |
| 1000 | 0.8 | 0.6 | 0.9 | 0.6 |
| 2000 | 0.9 | 0.7 | 1.0 | 0.7 |
| 5000 | 1.2 | 0.8 | 1.3 | 0.8 |
| 10000 | 1.3 | 1.0 | 1.5 | 0.9 |
| 20000 | 1.6 | 1.1 | 1.7 | 1.1 |
| 50000 | 1.9 | 1.4 | 2.1 | 1.3 |
| 100000 | 2.2 | 1.6 | 2.5 | 1.6 |
| 200000 | 2.6 | 1.8 | 2.9 | 1.8 |

Table 13: Anchor Penetration

The main mitigation for the hazard of anchor strike is generally burial beneath the identified threat line for a given return period / acceptable level of risk. This has been calculated in terms of a recommended depth of lowering across the lease area to sufficiently protect it to reduce the risk below acceptable levels. As such the recommended depth of lowering will vary across the site depending on the modelled traffic density and the seabed composition.

## 5.4 CBRA Results

The threat line depth based on modelled post-windfarm installation shipping density and seabed composition was produced for the whole of the lease area. The threat line depth was interpreted to define recommended burial depths within zones of the lease area to satisfy the risk requirement and minimise burial depth where possible to reduce installation costs through maximising tooling choice and reducing installation schedules. It is noted that the WTG layout is indicative only and no IAC layout is currently available.

The results for the site are summarised below and shown in the provided alignment charts (Appendix C) and drawings (Appendix B). Table 15 details the recommended depth of lowering for indicative inter-array cable strings. The strike return period and corresponding DNV risk category (Ref. 12) is also stated for each zone. The strike return period is equal to $1/P_{strike}$ . As $P_{strike}$ is annualised, this gives the theoretical period in years between anchor strikes on the cable based on the probabilistic CBRA calculation i.e. the number of years statistically within which one anchor strike will occur. When considering the risk and required depth of lowering, it is important to consider what risk profile for the cables is considered acceptable. For inter array cables, it can be considered that a risk return period of greater than 10,000 years is suitable for each cable string, where a strike in that period will, as a worst case, prevent transmission of electricity for that string only.

At the time of writing, only an indicative turbine layout and no inter-array cable routes were available. Therefore, to provide meaningful results that can inform future cable routing, six transects were drawn across the site. The transects are oriented roughly north to south and northwest to southeast to align with the indicative turbine layout, and to provide both coverage of the site and good indication of how the results differ dependant on location within the site. The transects were used to present CBRA results in the alignment charts in Appendix C.

![GLOBAL MARITIME logo]

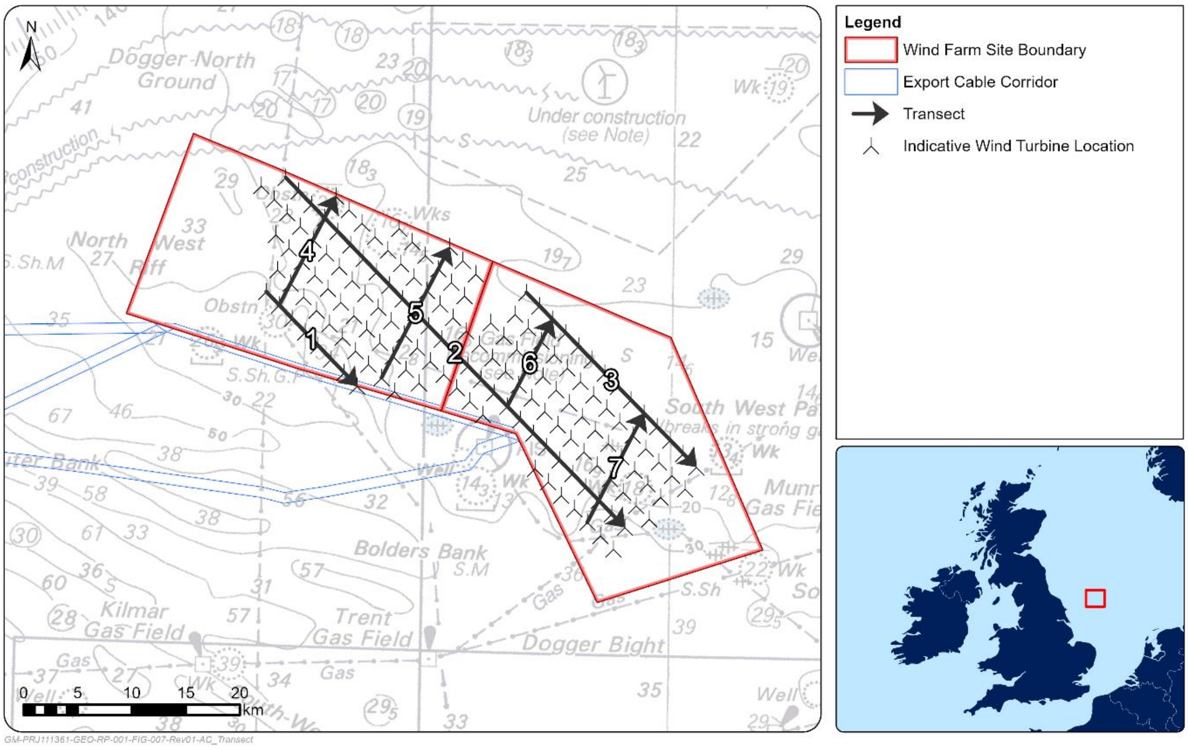



Figure 10: Example Transects across Lease Area

The transects provide an indication of how the risk varies across the wind farm site, however, they are too long to be considered representative of actual array cables. Therefore, two indicative inter array cable strings from an indicative OSS position, connecting an assumed seven turbines per string have been created to investigate typical risk profiles across relatively lower risk and relatively higher risk areas. As the risk return period is dependent on cable length, an average IAC length of 2.95km (maximum turbine spacing with 30% additional length to account for cable routing) was assumed. The results from the indicative routes are summarised in Table 15.

| DNV Risk Category | $P_{Strike}$ | Return Period (years) |
|---|---|---|
| 1 | 0.00001 | 100,000+ |
| 2 | 0.0001 | 10,000 to 100,000 |
| 3 | 0.001 | 1,000 to 10,000 |
| 4 | 1 | 1 to 1,000 |

Table 14: DNV Risk categories (ref 8)

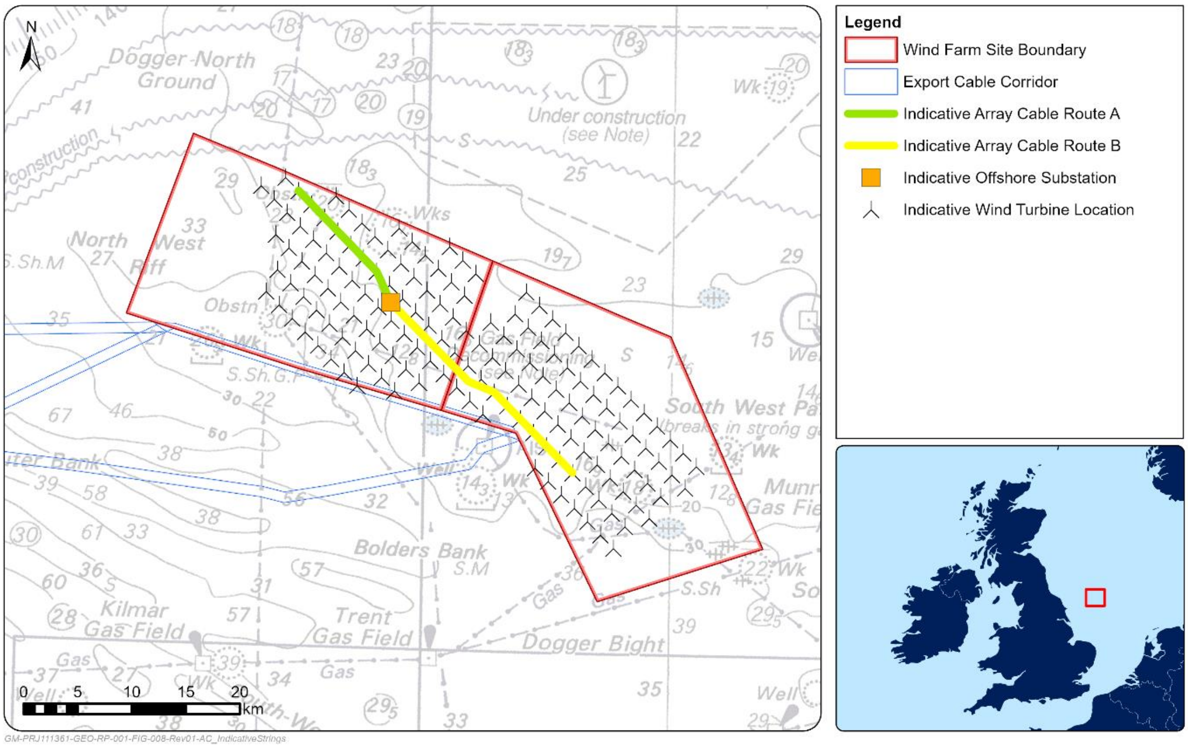
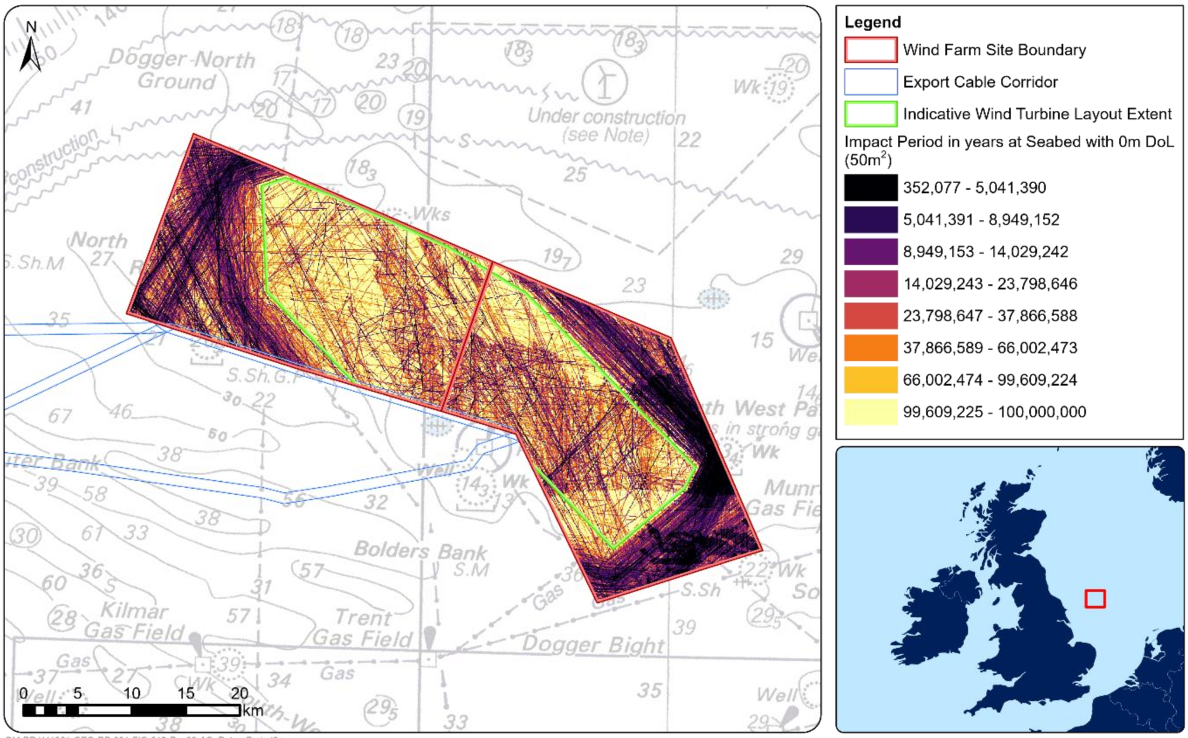



Figure 11: Indicative Inter Array Cable Strings

| Indicative Route | Route Length (km) | Cumulative Pstrike | Cumulative Impact Period (Years) | DNV Risk Category |
|---|---|---|---|---|
| A | 13.54 | 0.0000045 | 220,141 | 1 |
| B | 23.27 | 0.000018 | 54,826 | 2 |

Table 15: Indicative Inter Array Cable Strings - CBRA Results (Cumulative)

In conjunction with the transects and indicative routes, the CBRA results are also presented spatially by displaying the return period for anchor strike at both the seabed surface (Figure 12), and at 0.5m below the seabed (Figure 13).




GM-PRJ111361-GEO-RP-001-FIG-012-Rev02-AC_ReturnPeriod0m

Figure 12: Return period for anchor strike across the lease area with 0m burial depth (surface-laid)

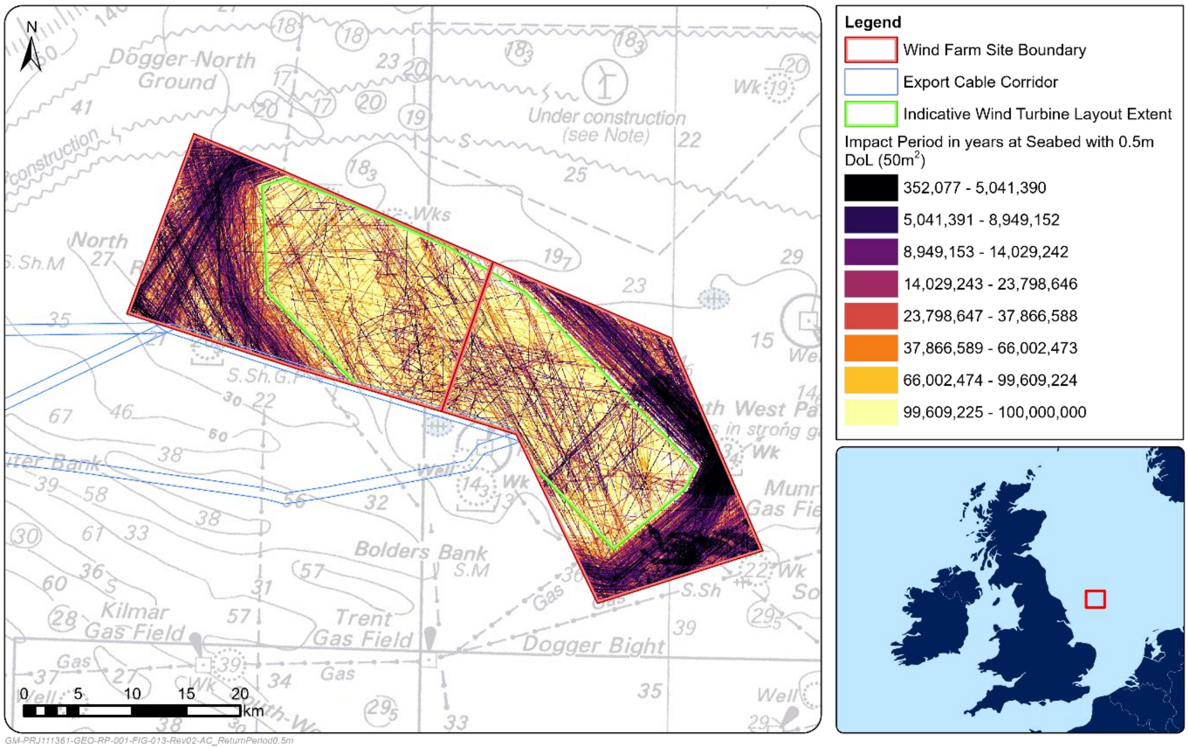



Figure 13: Return period for anchor strike across the lease area with 0.5m burial depth

### 5.4.1 Results Discussion and Summary

The results of the CBRA have allowed the determination of suitable target depth of burial, based on the strike return periods calculated across the Lease Area at different DoL options. The outcome of the analysis has shown that indicative cable routes within the limits of the indicative turbine layout do not fall below a cumulative return period of 10,000 years (DNV risk category above 2 - equivalent to the probability of the cable being struck by an anchor being between 10,000 and 100,000 years) with a burial depth of 0.5m. Outside of the indicative turbine layout, some areas are allocated a target DoL of 1m to maintain the same risk level. There is no standard of what risk level is acceptable, and this is down to the developer's appetite to risk, and the lowering of costs during the installation phase, but typically across the industry having a risk of DNV Category 2 is considered appropriate for inter-array cables.

It should be noted that if the turbines are moved further out, then the modelled vessel traffic would need to be re-modelled accordingly to accurately reflect the conditions for a new iteration of the CBRA calculation. In this scenario, the current recommended DOL of 1m outside of the current wind farm area may no longer be applicable due to the absence of traffic.

The indicative cable routes show that even in an example 'higher risk' part of the wind farm site (route B), with a DoL of 0.5m the strike return period still does not fall under 10,000 years, or DNV risk category 2.

Considering the results from the spatial return period imagery, indicative cable routes and the practicalities of cable burial campaigns, the DoL recommendation can be assigned in two categories of 0.5m and 1.0m for different zones across the lease area, which as previously described will maintain a strike return period of at least 10,000 years (DNV risk category 2).

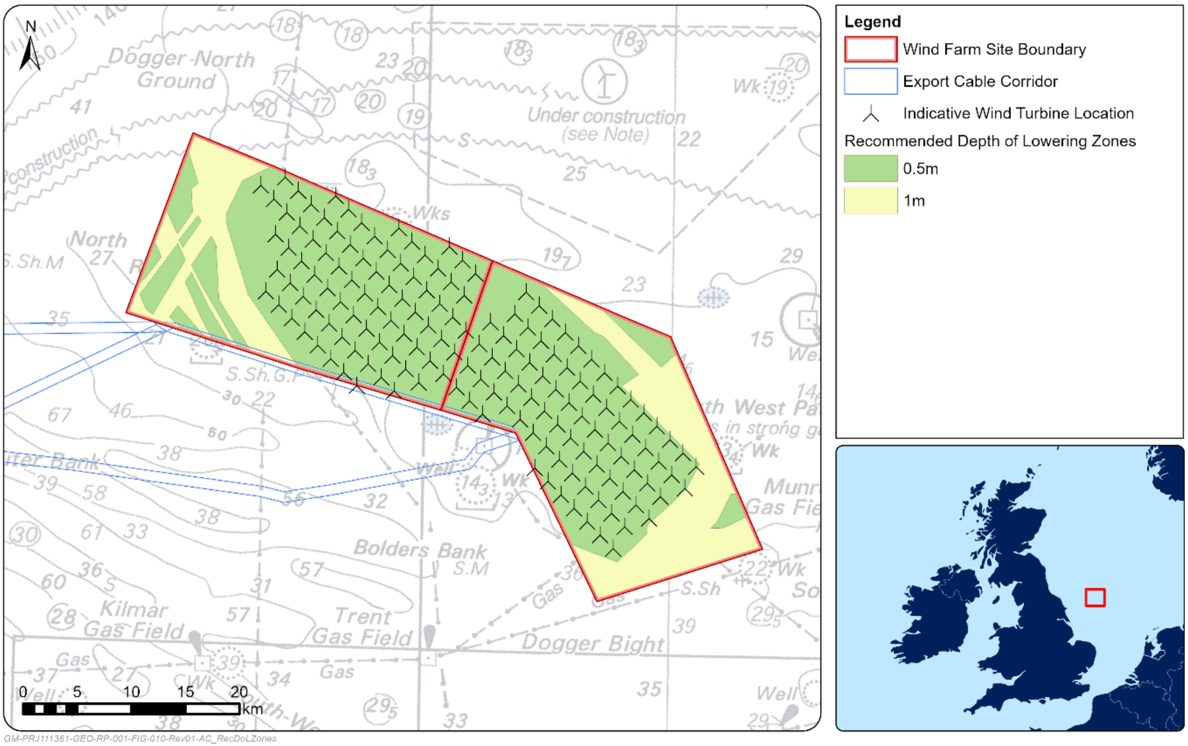



Figure 14: Recommended DoL zones in the Lease Area

The DNV risk categories are based upon oil and gas assets and the implications which come from failure of those assets, including environmental pollution etc. The DNV categories are commonly discussed to be considered onerous and therefore DNV Category 2 for the cumulative risk profile of an entire lease area is considered acceptable, although this should be confirmed by the developer. Though not likely to be necessary, further reductions in risk can be found with increased burial depths.

The risk levels will also change when applied to actual cable routes, where they can avoid higher risk areas of seabed via routing, and the model can account for actual cable lengths, with weighting applied for cable positions in their string (i.e. the number of turbines put out of operation in event of a cable fault).

In many of the 50x50m grid cells in the model, the calculated period of impact is infinite. This effect occurs in areas where the recommended DoL is below the calculated threat level, resulting in there being no chance of damage to the cable based on the historic data within the CBRA calculation. In these areas, hypothetically a cable could be surface laid and never be struck by an anchor, however a rogue anchor strike cannot be ruled out completely, and the cables should still be buried to some extent for stabilisation, and for continuity during installation between areas that do have a recommended DoL below the surface.

# 6. BURIAL ASSESSMENT STUDY

## 6.1 Overview

As described previously, GM have assessed seabed conditions for the lease area to define recommendations for cable installation methodology. Burial techniques considered, at this stage, to be most appropriate for the site, can be taken forwards for further consideration when additional information becomes available.

At a high level, the site can be described as consisting primarily of sand of varying densities with frequent shell fragments and localised gravel pockets and clay pockets. Parts of the site in the northwest and southeast consist of a veneer of sand over medium or high-strength clays.

## 6.2 Cable Lay Options

The main construction options available for the cable burial are:

- Post-lay burial of the cables utilising separate cable lay and burial campaigns with a cable buried by cable plough or trencher after it has been laid on the seabed.
- Simultaneous lay and burial with a cable plough or trencher deployed and operated from the cable lay vessel.
- Pre-lay trenching utilising separate trenching and cable lay campaigns where the trench is pre-cut by a large plough or trencher followed by cable lay directly into an open trench followed by backfill by plough, natural backfill or rock placement.

The most appropriate method will depend on a number of factors, for example the cable type being approved for the method to be utilised or the required vessel/trenching tool combination being available for the desired installation dates and the burial conditions on the cable route. These three methods are discussed briefly below.

### 6.2.1 Post-Lay Burial

In a post-lay burial operation, the cable is laid onto the seabed by a cable installation vessel. The same vessel can then return to carry out cable burial with the cable in place. Alternatively, a different vessel could carry out burial at a later date.

With the post-lay burial method, there is a risk of damage to the unburied cable during the intermediate stage between cable lay and burial operations from primary threats or cable instability at seabed due to metocean conditions. Post-lay burial with tools such as jet trenchers and mechanical cutters can induce tensions into the pre-laid cable due to cable friction as the cable travels through the machine. This can lead to free spans in sand wave areas. In addition, a kink can develop in the cable ahead of the machine.

Operational risks are always present surrounding launch and recovery of the burial machine from the vessel, especially in high sea states. Landing the machine on the seabed safely over the cable can also be a challenging operation in energetic seas and will be performed according to weather limitations identified through installation analysis. Cable routing through the machine can also be problematic, most modern tools are equipped with manipulators to manually pick up and load the cable into the trencher for burial, however, there are some machines in service that require diver assistance.

#### 6.2.2 Simultaneous Lay and Burial

During simultaneous lay and burial, cables are laid and buried simultaneously with burial equipment (plough or burial sled) being towed by the cable laying vessel or barge or operated from the cable laying vessel where a self-propelled Remotely Operated Vehicle (ROV) is utilised generally for jetting or mechanical cutting burial methods. These may be free flying ROVs, or self-propelled tracked machines (TROVs).

This approach offers immediate protection to the cable and cable tension can be managed by the cable lay system as the cable enters the plough or trencher. The cable catenary can be monitored by ROV during the process.

#### 6.2.3 Pre-Lay Trenching

For this method, a separate vessel would tow a plough or operate a trencher to cut a trench in the seabed for which the cable can be laid into by the cable lay vessel in a separate operation.

Laying the cable into a pre-cut trench is sometimes considered to offer a low-risk construction method, whereby a plough/trencher is used to create a large trench, carrying out the aggressive soil cutting without the presence of the cable. The cable can then be laid into this trench and back filled by a second pass with a backfill plough. This approach would mean that the risk of damage to the cable is much reduced compared to the post lay burial and the simultaneous lay and burial techniques. However, difficulties exist in co-ordination of the two vessels working together in this way, for accurate positioning of the cable and for maintaining an open trench, due to sediment infill. Broad disturbance of the seabed in this manner may also be less desirable from an environmental consenting perspective.

### 6.3 Cable Burial Options

The results of the CBRA detailed in section 5.4 will ultimately determine what type of burial tool to use to achieve the recommended DOL. In general, burial methods can be categorised as ploughing, jetting or mechanical cutting. Different burial tools are optimised to perform in certain sediments – the types of tools available on the market are discussed in sections 6.3.1, 6.3.2 and 6.3.3 below, and section 6.3.4 evaluates their suitability for the site based on conditions discussed in section  and the results of the CBRA, detailed in section 4.

#### 6.3.1 Cable Ploughs

Cable ploughing is the process of towing a subsea plough with a vessel with sufficient bollard pull capability to create a trench for the cable. This method has the largest effective range of soil conditions and will be suitable up to the dense / very dense sand and stiff clays. Ploughs are generally utilised for simultaneous lay and burial whereby the installation vessel tows the plough, and the cable is routed through the plough and laid into the open cut trench with assistance from a depressor on the plough. The trench can then either be left to backfill naturally or a backfill plough can be used to relocate the spoil from the initial trenching into the open trench on top of the laid cable.

Alternatively, ploughs can be used prior to cable lay to cut a trench along the lay route for which the cable can then be laid into. This may be required where boulder presence is a concern and the pre-lay trenching is used to clear smaller boulders, with some tooling setups quoting the capability to clear boulders up to 1m diameter. Where this is deemed necessary, specialist boulder clearance ploughs can be utilised. When pre-cutting a trench, this should only be undertaken if it can be performed close enough to cable lay operations or in a non-mobile seabed such that the trench will not naturally backfill prior to cable lay.

Some additional considerations should be made when considering ploughing operations. Firstly, manoeuvrability is restricted for ploughing compared with alternative burial methods. This limits the achievable cable turn radius and means that less complex lay routes can be achieved. Many ploughs also require longer burial transition lengths compared with alternate methods. Geological hazards should also be considered such as excessive seabed slope resulting in risk of tooling overturning or less control of cable burial depth, along with soft soils resulting in risk of plough sinkage. Tool selection should also be made considering features of available tooling on the market, for example some will require diver assistance for routing of the cable through the tooling and some will have diverless options which may be favourable in terms of project risk and commercial costs of diving operations.

As discussed, cable ploughs can work in a wide range of soils and are suitable for low to high strength clays which can be sheared but less suitable for dense sands which can increase tow force and likelihood of plough ride out. The high tow forces exhibited in sand are caused as the plough shears the granular material, this causes dilatancy in front of the shear. As the sand accumulates strain, the soil particles dilate, increasing void space. Pore pressures become negative causing apparent strength gain, until pore pressures eventually equalise due to water ingress. To reduce the high tow force generally exhibited in sands during ploughing, the cable plough shear can be fitted with a jet system. This addition of water reduces the negative pore pressure and therefore reduces the tow forces experienced.

The different types of cable burial ploughs are listed below:

- Conventional Narrow Share Cable Ploughs
- Advanced Cable Ploughs – a new generation of cable ploughs, which have been designed to achieve increased depth of lowering for subsea cables of depths up to 3.0 m.
- Rock Ripping Ploughs – suitable for outcropping rock, or where the seabed strata are exceptionally hard and beyond the capabilities of a conventional narrow share plough.
- Vibrating Share Ploughs - consists of a narrow share, which is vibrated to ensure cutting progress through difficult seabed conditions, such as gravel beds.

#### 6.3.2 Jet Trenchers

A jetting system works by fluidising and/or cutting the seabed using a combination of high flow low pressure and low flow high pressure water jets to cut into sands, gravels and soft to firm clays. Jetting tooling is generally effective from very loose up to medium dense or dense sands. In some cases, a dredging/eduction system is employed to suck out the fluidised material to leave an open trench into which the cable then falls by its own weight.

The mechanisms for jet trenching in clays and cohesionless sands/gravel soils are fundamentally different. Sands are most efficiently fluidised by a large volume of water (high flow / low pressure water jets) flowing over the trench cross sectional area, with a large water volume required to lift the sand particles into suspension. Coarser materials such as gravels fall rapidly through the water column and as a result it is very difficult to displace these soils and adequately bury a cable through coarse soils. Reduced DOL could be seen in areas of higher gravel content.

Conversely, in clays, the jet pressure (low flow / high pressure water jets) must be greater than a threshold value at which the clay can be cut, related to the undrained shear strength. As this pressure is partly generated through the available hydrostatic pressure at seabed, it may not be suitable in low water depths unless modified. A second pass may also be required utilising the high flow / low pressure setup, to remove the pre-cut clay blocks if the flow rate on the first pass is not sufficient.

The trench will naturally backfill due to settlement of sand particles out of suspension. Based on experience with jetting machines, between 60% and 80% backfill in the trench will be achieved to natural seabed level if one pass is required.

Jetting systems are most commonly used for post lay burial operations; however they can be used for simultaneous lay and burial. Tooling for this method are generally Tracked Remotely Operated Vehicles (TROVs) but may also be free flying tools or towed tools mounted on skids. Jetting nozzles are generally installed on two long jetting swords that are lowered into the seabed either side of the cable to fluidise / remove seabed material to allow the cable to be lowered. Sword lengths can be adjusted according to the required burial depth of the cable.

Jet trenchers generally reduce the risk of cable damage as there is no planned direct contact with the cable, and therefore can also be used near cable crossings. Multiple passes are possible in order to achieve target depth of lowering/depth of cover requirements. However, where deep burial is required, cable detection may be difficult.

Jetting tools are generally best suited to softer and looser ground conditions. Where bearing capacity of soil is a concern to support the TROV weight, buoyancy can be installed as required to reduce the submerged tooling weight, however lighter tools or free-flying tools are more susceptible to metocean conditions and may have high weather limitations. Tooling operations may be limited by water depth for submerged pumps to work, in which case surface water supply may be required when working in shallow water for example near landfall areas.

### 6.3.3 Mechanical Cutters

Mechanical trenchers are usually post lay burial machines suitable for consolidated high strength cohesive sediments and weak/fractured rock. They typically fall into two categories mechanical rock wheel cutters or mechanical chain Excavators. These two types are discussed below:

- Mechanical rock wheel cutters: Mechanical rock wheel cutters are used to cut narrow trenches into hard or rocky seabed and consist of a rotating wheel disc, which is fitted with rock cutting teeth.
- Mechanical chain Excavators: The chain Excavator tool consists of many cutting teeth and a further number of mechanical scoops which are used to transport the cut material away from the trench. An auger is sometimes in place, which helps move material away from the trench or clogging the chain cutters.

When trenching in hard clays and rock for both rock wheel cutter and mechanical chain trenchers a narrow slot is formed into which the cable is lowered. The material is removed as the action of the cutting causes it to be broken down into its constituent parts.

Significant thicknesses of sand and gravel are likely to hinder performance as the tool relies on the action of ripping cohesive soils. To aid with lowering, mechanical cutters can be fitted with a rear jet leg/eduction system which clears the trench of granular soils and back fill material. A mechanical cutter is generally fitted with a depressor which guides the cable through fluidised materials increasing DOL. On rocky outcrops, the seabed might be too uneven for the trencher to operate normally. Typically, sudden changes in elevation should be smaller than 0.3 m and slopes below 15°, although this is dependent on the size and limitations of the specific trencher. Aratellus' Leviathian Trencher, for example, has fully articulated separate tracks and so is likely to be much more capable of operating on an irregular, rocky seabed.

The magnitude of the seabed relief, in the context of the footprint of a mechanical trenching tool, must be understood in detail in order to assess the stability of the trencher and its ability to progress across the seafloor.

It is common that mechanical cutters are utilised for short sections of cable routes where required to trench within hard ground. These are generally avoided where possible due to slow progress rates, for this reason they are generally used for pre-lay or post-lay trenching rather than simultaneous lay and burial which would significantly slow the progress of the cable installation vessel.

Mechanical cutting tools are deployed and controlled from a vessel with sufficient capacity crane or A-frame LARS. They are generally TROV type vehicles and can include additional features such as cable loading manipulators. Cutting tool wear is a particular consideration for these tools, and rock wheel / cutting chain teeth should be selected carefully based on the seabed material.

#### 6.3.4 Cable Burial Tool Suitability

As described above, multiple different types of burial tools are available for subsea cable installation, however the performance of the tools will vary depending upon the sediment type and other factors. The general suitability of different burial equipment is given within Table 16, taken from the BERR report 2008 (Ref.16).

| Cable Burial Devices | Burial Device Options | Sediment Type | | | | | |
|---|---|---|---|---|---|---|---|
| | | Sands | Silts | Gravel | Weak Clays | Stiff Clays | Rock |
| Cable Burial Ploughs | Conventional narrow share cable ploughs | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ |
| | Advanced cable ploughs | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ |
| | Modular cable ploughs | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ |
| | Rock ripping ploughs | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Vibrating share ploughs | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Tracked Cable Burial Devices | Jetting systems | ✓ | ✓ | ? | ✓ | ✗ | ✗ |
| | Rock wheel cutters | P | P | P | ✓ | ✓ | ✓ |
| | Chain excavators | P | P | ✓ | ✓ | ✓ | ✗ |
| | Dredging systems | ✓ | ? | ? | ✗ | ✗ | ✗ |
| Free Swimming ROVs with Cable Burial Capability | Jetting systems | ✓ | ✓ | ? | ✓ | ✗ | ✗ |
| | Dredging systems | ✓ | ? | ? | ✗ | ✗ | ✗ |
| Burial Sleds | Jetting systems | ✓ | ✓ | ? | ✓ | ✗ | ✗ |
| | Rock wheel cutters | P | P | P | ✓ | ✓ | ✓ |
| | Chain excavators | P | P | ✓ | ✓ | ✓ | ✗ |
| | Dredging systems | ✓ | ? | ? | ✗ | ✗ | ✗ |

KEY

| | | |
|---|---|---|
| ✓ | = | Should be capable of burial. |
| ? | = | Performance will be related to the type of sediment and the power delivery to the burial device. |
| P | = | Performance possible in the sediment type but not an ideal application. |
| ✗ | = | Unlikely to be capable of burial. |

Table 16: Burial Performance Comparison

Figure 15 below from DNV (Ref. 8)also summarises burial method suitability in various ground conditions and thus the optimum ground conditions for each burial tool can be derived. As can be seen for cutting, by adding a dredging (or jetting) system, the graph could be extended into looser materials. The figure also highlights that ploughing is more suitable for a wider range of soils. Therefore, in sites with variable material, ploughing could be the optimum tool. However, this is based purely on soil conditions, other factors such as water depth, seabed features and commercial factors all influence the choice of burial asset used.

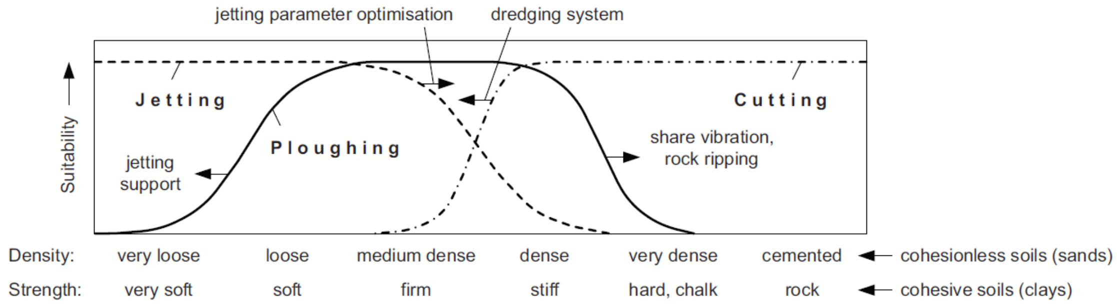



Figure 15: Indicative Burial Tool Suitability in Different Ground Conditions (Ref. 8)

In general, it can be summarised that the ploughing method is suitable for a wide range of ground conditions, jetting techniques are suitable for soft or loose soil conditions, and mechanical cutting is required in the hard or dense soils and rock.

The above is a guide that should be considered when selecting burial methodology, however, additional considerations need to be made with regards to the site conditions when selecting the burial tooling and methodology. For example, boulder presence within the lay route, geological features, potential mobility and expected metocean conditions will all factor into the decision-making process when selecting burial tooling, along with the overall methodology including if post-lay burial or simultaneous lay and burial will be most suitable. This is further described for each method in the sections below.

The three methods described above have differing anticipated progress rates within different seabed materials. These anticipated progress rates are shown in the table below:

| **Burial Tool** | **High Level Anticipated Progress Rate** | |
|---|---|---|
| | **Loose Sand / Soft Clay** | **Dense Sand / Stiff to Hard Clay and Rock** |
| Jet Trencher | 200-350 m/hr | 100-200 m/hr |
| Cable Plough | 200-400 m/hr | 200-400 m/hr |
| Mechanical Cutting | 200-350 m/hr | 70-150 m/hr |

Table 17: Anticipated Burial Tool Progress Rates

## 6.4 Burial Assessment Methodology

A preliminary burial assessment and tool suitability assessment has been undertaken for the lease area for most commonly used tools, as described above. This assessment was based on the anticipated ground conditions across the lease area, tool specifications and limitations that might affect suitability and the results of the CBRA. Each tool to be used alone is graded into the following system:

- Suitable – Likely to achieve burial

- Possible – Unlikely to achieve consistent burial throughout
- Not Suitable – Unlikely to achieve burial

The tool suitability has been assessed for the seabed conditions and required burial depths to achieve each risk level across the lease area. Broadly speaking, the site can be divided into zones, which can be categorised by burial class - determined by the seabed composition and the target depth of lowering established within the CBRA (Section 5). These burial classes are shown below:

| Burial Class | Description | | Achievable Burial Depth |
|---|---|---|---|
| | General | Geology | |
| A | Full burial expected to target depth in a single trencher pass. Constant burial conditions with low variability.<br><br>Optimal plough or jetting progress rate. | Thick very loose to medium dense sands / silts and soft to firm clays.<br><br>Generally flat seabed and absence of features hindering burial operations. | Target or beyond |
| B | Reduced and variable burial conditions.<br><br>Reduced progress rate possible.<br><br>Potential for reduced success with jetting tools and / or multiple passes expected with potentially different tooling such as mechanical cutters. | Medium dense to dense sand and stiff to very stiff clay or loose / soft sediment sitting over a dense to very dense unit.<br><br>Minor bedforms, slopes <10 degrees expected to impact tool progress. | Within Target |
| C | Poor burial expected, with possible areas of cable exposure.<br><br>Slow progress rate with high risk of not achieving full burial. | Stiff to very stiff clay and up to very dense sand/silt and consolidated sediment / bedrock, or a thin unit of loose/soft sediment sitting over a dense to very dense unit or rock.<br><br>Bedform slopes > 10 degrees. | Potentially Less than Target |

Table 18: Cable Burial Classification

To define the BAS zones, the recommended DoL calculated in the CBRA was combined with the ground model to enable creation of a plan view of burial classification and DoL, as would be listed in a conventional BAS table for a cable route. A BAS table to summarise the zones could be produced, describing the geology layers, tool suitability, burial class and DoL by zone (as opposed to KP in a conventional BAS table). These zones can be used to inform future array cable routes, though it is recommended that route-specific BAS tables are produced once the cable routes are established.

## 6.5 Burial Assessment Results

The results of this analysis, in the form of a Burial Assessment table, is shown in full in Appendix D. A summary of the burial class in combination with the DoL for each zone is provided in plan view in Figure 16, and summarised in Table 18. The zones defined in Figure 16 correspond to the zones listed in Appendix D.

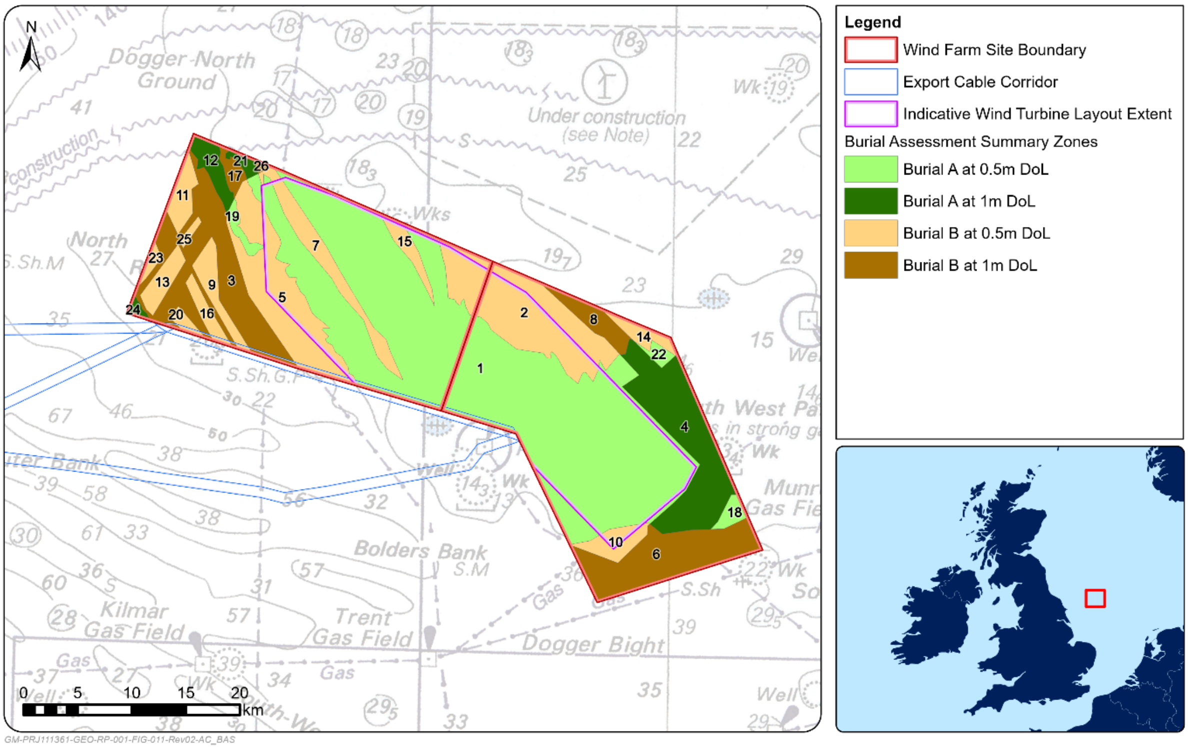



Figure 16: Burial Assessment Summary for the DBS Lease Area

| | Burial Class (By Zone Area in km$^2$) | | | Burial Class (By % of Site Area) | | |
|---|---|---|---|---|---|---|
| Recommended DoL (m) | A | B | C | A | B | C |
| 0.5 | 467.1 | 267.2 | 0.0 | 47.1 | 27.0 | 0.0 |
| 1 | 94.1 | 162.3 | 0.0 | 9.5 | 16.4 | 0.0 |

Table 19: Burial Classification and DoL by total zone area and Percentage of the total lease area

| | Burial Class (By Zone Area within Wind Farm in km$^2$) | | | Burial Class (By % of Wind Farm Area) | | |
|---|---|---|---|---|---|---|
| **Recommended DoL (m)** | **A** | **B** | **C** | **A** | **B** | **C** |
| **0.5** | 422.8 | 124.5 | 0.0 | 77.3 | 32.7 | 0.0 |
| **1** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

Table 20: Burial Classification and DoL by total zone area within wind farm area and Percentage of the total wind farm area

A burial strategy with regards to tool type and burial depths in the BAS allows the recommendation of an installation methodology utilising the options outlined in section 6.2, and suggested vessels and tools to conduct the operation. The recommended burial depth across the wind farm site itself is 0.5m, with a combination of burial class A and B. A jet-assisted plough as the recommended tool for installation.

## 6.6 Recommended Cable Installation Methodology

The suggested cable lay methodology is a simultaneous lay and burial solution using a jet-assisted plough and separate jetting tool to bury transitions where the plough needs to be graded in and out on approach to and departure from the turbine monopiles and OSS. The vast majority of the lease area has soils that are suitable for ploughing and jetting, with dense sands and shells and shell fragments across much of the site, and some small areas of gravel deposits where ploughing may become more difficult. In the dense sands, areas with shells and shell fragments, and gravel pockets, a plough with jet-assistance should improve both the progress rates and the depth of burial achieved.

Simultaneous lay and burial is recommended to avoid the risk of trench infill by the surficial sands found over much of the lease area that could happen if a pre-lay trenching approach is used. This method also benefits from the high efficiency of combining the lay and burial campaigns into one, which is particularly beneficial with inter-array campaigns due to the large number of individual cables resulting in multiple tool deployments and recoveries. As less preferential options and depending on burial asset and vessel availability, post-lay burial using a plough or high-power jetting tool could be used. Based on the water depths on the site, any cable ship with an appropriate carousel capacity, bollard pull and A-Frame for plough towing and deployment would be suitable.

Surficial boulders have been identified across much of the DBS lease area, with particularly high densities present at the western end of the site. The presence of surficial boulders often indicates that buried boulders may also be present. Both buried and surficial boulders could damage a potential burial tool during installation. It is therefore recommended that once inter-array cable routes are established, boulders are identified within the installation corridor of each cable during route-specific geophysical surveys. If necessary, a boulder clearance campaign should then be conducted prior to any cable lay and burial campaigns using either a towed clearance plough or a grab system, depending on boulder densities. Some clearance ploughs in the industry are reconfigurable for pre-lay trenching and post-lay backfill or can do both clearance and trenching simultaneously, meaning a pre-lay trenching methodology may become a more economic option.

### 6.6.1 Suggested Ploughing Tools

*DeepOcean's ACP2 Plough*

The ACP2 plough is specifically designed to handle larger diameter power cables up to 300mm in diameter, with a 5m minimum bend radius. Additional cable protection measures include a pivoting cable bellmouth and highly capable LARS system for deployment in higher sea-states. The ACP2's share can achieve a depth of burial up to 3.3m below seabed and houses a 150kw jetting system. The plough is designed to work in a range of seabed conditions from sands to weathered weak rock.

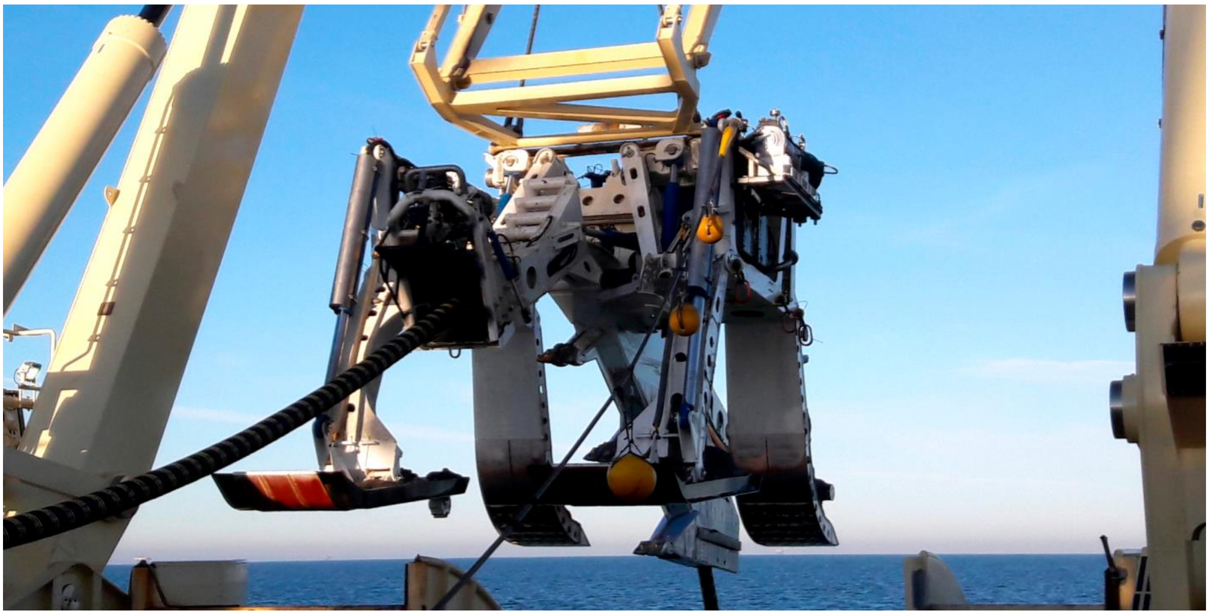


Figure 17: DeepOcean's ACP2 cable plough

*Boskalis HD3 Plough*

The HD3 plough is another tool designed specifically for larger-diameter cables and umbilicals up to 300mm in diameter. It is optimised to reduce the tow force required during operation, utilising a 265kW jetting system. It's maximum burial depth is 3.3m, and for added versatility in operation, it can remotely load cable on the seabed for post-lay burial.

Figure 18: Boskalis' HD3 cable plough

*Global Marine Hi-Plough*

The Hi-Plough originates from the telecom cable industry but more recently has been adapted to be compatible with larger-diameter power cables. It is a more compact and relatively lightweight tool than the previous two options, making the range of vessels that can operate it potentially greater. The burial depth can reach up to 2m, with increased sinkage potentially to 3m achieved in soft soils via an 'underfoot' jetting nozzle. It is able to operate in sands and stiff clays, with an optional rock tooth to extend its capability into soft rock.

Figure 19: Global Marine's Hi-Plough

*Enshore Subsea's PCP-2 Cable Plough*

The PCP-2 is another plough developed specifically for burial of power cables in wind farms, capable of handling product up to 240mm in diameter and with a 3.5m MBR. It has a maximum burial depth of 2.4m below seabed and has a 300kW jetting system to allow operation in sands and soft to hard clays.

Figure 20: Enshore Subsea's PCP-2 cable plough

## 6.6.2 Suggested Boulder Clearance and Pre-Lay Tools

*Helix Energy i-plough – Pre-Lay Clearance, Trenching and Post Lay Backfill*

As an alternate method to simultaneous lay and burial, the i-plough provides simultaneous boulder clearance and trenching to 1.9m depth and can be reconfigured and re-deployed after cable lay to backfill the trench. The plough is a large and heavy tool, requiring a dedicated high bollard pull vessel, but is capable of trenching in firm clays and diamicton and can remove sub-surface boulders and deposit them to the sides of the trench. Though the plough may not be as effective in areas of sands, it could still be used to clear boulders and sand waves for a jetting tool to then bury the cable. If the surficial sands are stable enough and cable lay happens shortly after the plough runs, a jetting tool would not be required at all. The plough was originally built to work on the nearby Kriegers Flak and Vesterhav North and South windfarms and performed well during operations.

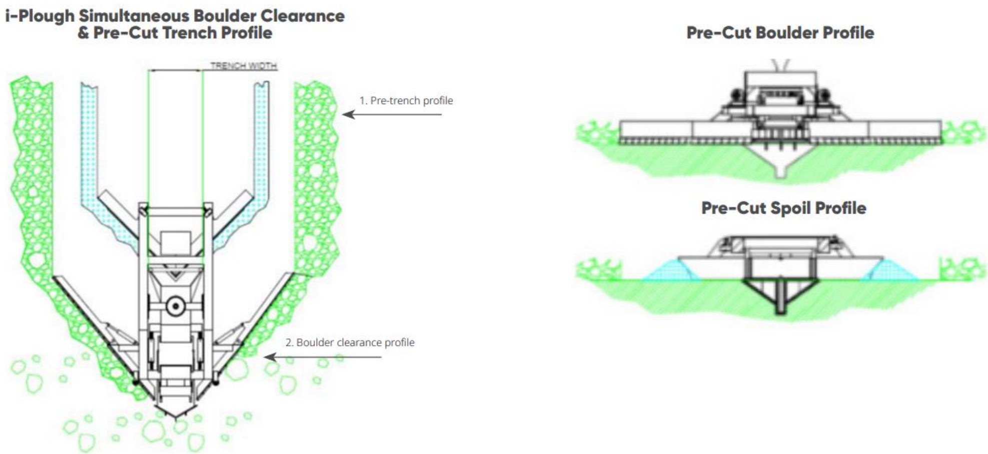



Figure 21: Diagram of the i-Plough's trenching profiles

*Asso Subsea's Multi-Functional Plough – Pre-Lay Clearance, Trenching and Post Lay Backfill*

The multi-functional plough is similar in design and ability to Helix Energy's i-plough, designed to be reconfigurable to conduct boulder clearance, pre-lay trenching and backfill in separate passes. The plough can clear boulders up to 2m in diameter and create a Y-shaped trench up to 1.7m in depth. Like the i-plough, it has been used previously in similar conditions on the Kriegers Flak wind farm site.

Figure 22: Asso Subsea's Multi-Functional Plough

*Subsea Orange Peel/Tine Grab*

Grabs are versatile tools that can be used to deploy material or remove objects from a site. Large grabs can be useful for boulder removal scopes and can be used in conjunction to relocate the larger boulders that a plough alone may not be able to clear. Grabs are available in varying sizes and lift capacities and can generally be deployed by any vessel with a suitable crane.

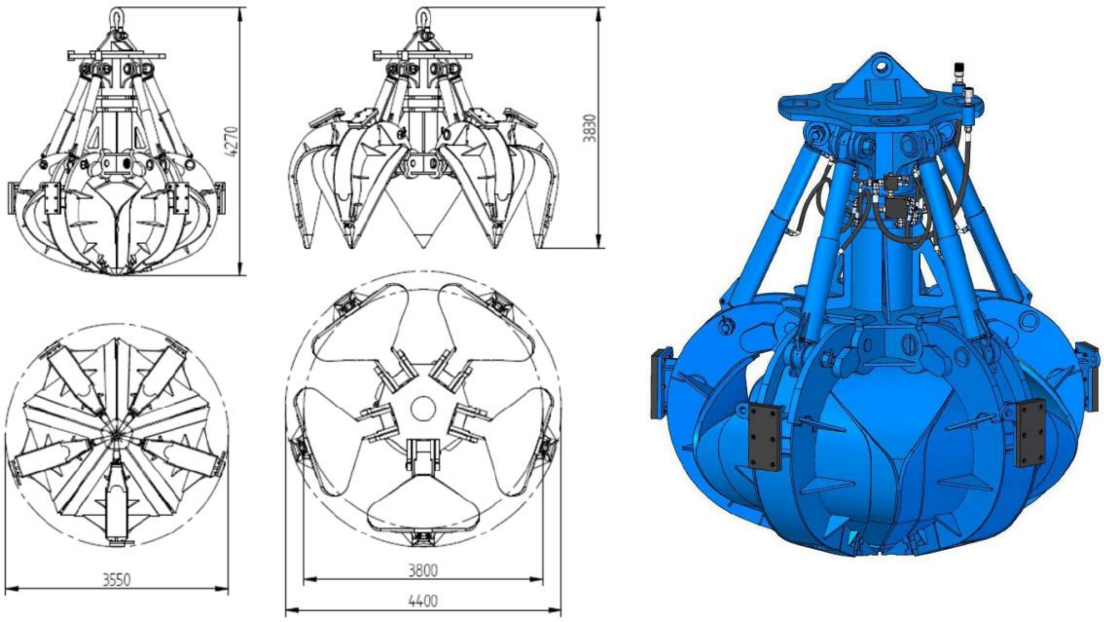



Figure 23: Schematic of James Fisher Offshore's 85Te Orange Peel Grab

### 6.6.3 Suggested Jetting Tools

*Delta Subsea T1000*

The T1000 is a 750kW jetting ROV capable of up to 3m burial depth. It is capable of jetting in sands to firm clays up to 80kPa resistance, allowing it to cover the hardest soils expected in the lease area. The T1000 is also self-propelled, which would be required to bury the end of the inter-array cables where the plough has graded in or out, and it can also be deployed under relatively high sea-state conditions.

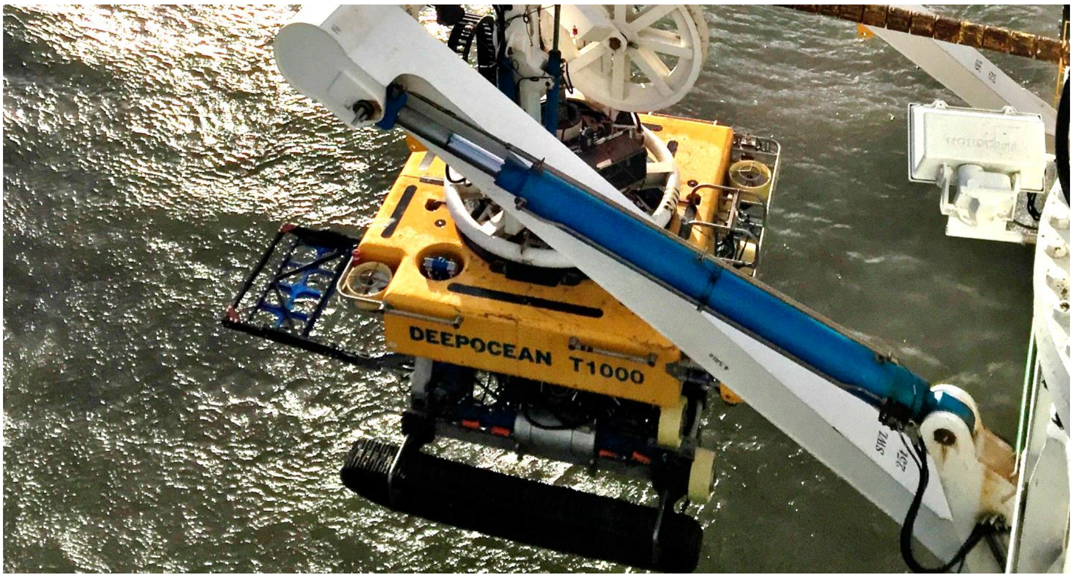



Figure 24: Delta Subsea's T1000 Jetting ROV

*Asso Subsea AssoJet III MK1*

As a more powerful jetting option, the AssoJet III MK1 has up to 1.3MW of power with a 3m burial depth capability, allowing it to work in soils up to 150kPa. This increased capability could allow it to be the sole burial tool for installation if a plough and jetting combination is determined to be unsuitable, though progress rates with a jet-assisted plough would likely be faster. The tool can be configured with sleds or tracks for towing or self-propelling and has multiple jetting sword options to cater for the expected soil conditions. It can be deployed in high-sea states and also has backfill/trench collapsing capability.

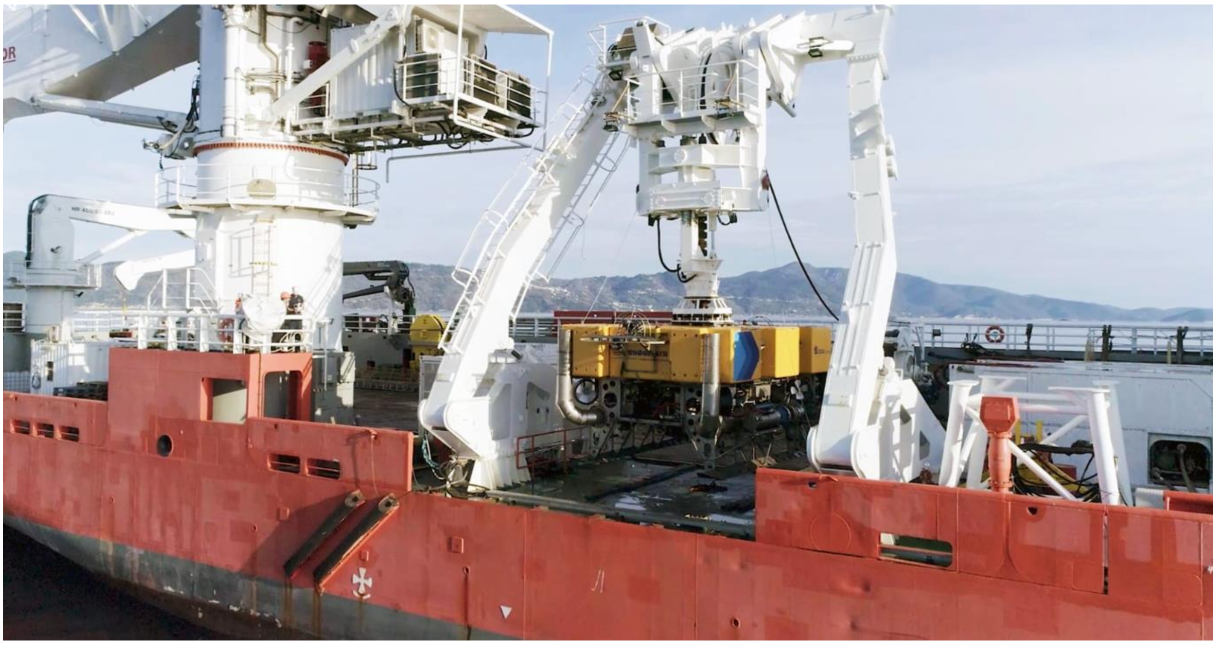


Figure 25: AssoJet III MK2 Jet Trencher

### 6.6.4 Suggested Installation Vessels

*Boskalis Ndeavour*

The Ndeavour is a shallow-draft cable vessel with a track record of both export and array cable projects. The vessel has a 100Te SWL A-frame allowing for deployment of large trenching vehicles and tools, can be equipped with ROV and subsea rock placement spreads, and features a 6-pount mooring system and DP2 classification.


Figure 26: Boskalis Ndeavour Cableship

*Delta Subsea Connector*

The Connector is a versatile cable ship with a demonstrated history of performing shore-end operations in shallow waters, including a successful beaching operation. With a minimum draught of 3.6m, it carries a 7000Te capacity turntable, a 60Te A-frame and has a 7-point mooring system. It has sufficient bollard pull for towing burial tools that are not self-propelled.


Figure 27: Delta Subsea's Connector performing a beached cable landing

*Van Oord Nexus*

The Nexus is a modern DP2 class 122m long cable ship with a 5000Te capacity carousel, equipped specifically for installation of export and inter-array cables. It has no A-frame so may not be suitable for plough operation, but it does have a 100Te main crane and bespoke cable protection and quadrant handling system to aid in installation of second-ends, making it a potentially efficient cable installation platform for an inter-array post-lay burial campaign.


Figure 28: Van Oord's Nexus Cableship installing cable at a wind turbine monopile

# 7. CONCLUSIONS AND RECOMMENDATIONS

Global Maritime have conducted a Cable Burial Risk Assessment (CBRA) for the Dogger Bank South wind farm lease area, including a review of the bathymetry and sub-seabed geology, and a resulting Burial Assessment Study (BAS), concluding on a recommended Depth of burial across the entire lease area and suggested installation methodology.

The site conditions were assessed to determine the geological layers of the seabed within the lease area. Using the provided Geotechnical data and Sub-Bottom Profiler data from Fugro, geological units could be spatially defined along the routes, and simplified into a two-layer ground model for input into the CBRA calculations.

The site condition assessment and two-layer ground model were then utilised using Global Maritime's CBRA method with modelled post-windfarm installation vessel traffic to analyse the anchor strike risks to the cable and propose target burial depths across the lease area to minimise the risk to acceptable levels whilst also maintaining practical burial depths. The burial depths and risk profile is summarised spatially and linearly in plan-view diagrams and transect-based alignment charts respectively.

The predominant geological conditions are sands of varying densities, containing gravel deposits and frequently occurring shell and shell fragment content. In some areas, the sands overly subcropping clays, which outcrop in the south-eastern corner of the site. The vast majority of the lease area consists of sands within the 3m depth limit of the model, with limited areas where channelised units of sandy clay or clay with pockets of sand and potential organic material would be encountered at the recommended DoL.

Key risks on the site can be defined as:

- Gravel deposits and shell and shell fragment content in the sands may reduce jettability of the seabed, potentially reducing progress rates of either a jet-assisted plough or jetting tool.
- Dense and very dense sands can reduce plough burial progress rates
- Stiff clays that have not yet been identified with the limited geotechnical survey may subcrop into the burial profile and reduce burial progress rates

It should be noted that whilst there is no specific acceptable risk value that must be attained through protection from anchor strike through burial, it is common for cables to be protected to specifications to DNV Cat 2, which is specified as a return period > 10,000 years. As this is not specified by cable length, target burial depths were determined based on maintaining > 10,000 years return period cumulative across each zone, as defined by changes in burial depth, hence there is a possibility that the cumulative return period of an entire string of cables could have a return period of < 10,000 years, if current recommended DoL is relied upon.

As mentioned, a key driving factor when determining the required burial depth for anchor strike protection is the soil properties, as these dictate anchor penetration. It is recommended that the CBRA is re-run once final cable routes have been chosen, and more geotechnical data is available. The recommended DoL zones defined in section 5.4.1 are based on the wind turbine layout provided for this report, and the arbitrary transects and indicative cable routes generated for use as a basis for assumptions in the CBRA, and therefore could change significantly with a new turbine layout and specific cable routes.

It is also recommended that a detailed BAS with the specific burial tool(s) and cable routes to be used for cable installation and consideration of the strengths of the geological units in relation to the specific tool's ability is conducted to further optimise the cable protection methodology, further reducing burial and vessel time.

# APPENDIX A DESIGN RISK REGISTER

# Geohazard & Geotechnical Risk Register (GRR) - Cables

| | |
|---|---|
| **Client :** | RED |
| **Project :** | Dogger Bank South Offshore Wind Farm Array Area |
| **Project No :** | PRJ111361 |
| **Revision History:** | 2 |

| **Revision** | **Date** | **Reason for Revision** | **Author** | **Reviewer** | **Approver** |
|---|---|---|---|---|---|
| 1 | 30/06/2023 | First issue | FDI | MLA | MLA |
| 2 | 08/08/2023 | Second Issue | FDI | MLA | MLA |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

## RISK MATRIX

| Severity | Consequences/ Impact | | | Probability | | | | |
|---|---|---|---|---|---|---|---|---|
| **Category** | **Injury/ Illness** | **Environmental Impact** | **Financial Loss/ Asset Damage/ Reputation** | **A (Very Unlikely)** | **B (Unlikely)** | **C (Possible)** | **D (Likely)** | **E (Very Likely)** |
| **1 (Negligible)** | Negligible injury or health implications, not affecting work performance or causing absence (First Aid Case) | - Pollution/ spills of <1 litre<br>- Minimal/ insignificant environmental impact | <USD $10,000, or <1% cost impact | L | L | L | M | M |
| **2 (Minor)** | Minor injury/ illness leading to Medical Treatment Case (MTC) | - Pollution/ spills between 1 - 10 litres<br>- Minor/ short term pollution impact | USD $10,000 - <USD $100,000, or 1-5% cost impact | L | L | M | M | M |
| **3 (Significant)** | Significant injury/ illness leading to Restricted Work Case (RWDC) | - Pollution/Spills between 10 - 100 litres<br>- Pollution with some worksite impact | USD $100,000 - <USD $500,000, or 5-10% cost impact | L | M | M | M | H |
| **4 (Serious)** | Serious injury/ill-health leading to days away from work (Lost Work Day Case - LWDC) | - Pollution/Spills between 100 litres - 100 m3<br>- Significant pollution with worksite and off-site impact | USD $500,000 - <USD $1,000,000, or 10-20% cost impact | M | M | M | H | H |
| **5 (Critical)** | Fatality(s), permanent disability, terminal occupational illness | - Pollution/Spills in excess of >100 m3<br>- Extensive pollution with long term implications or massive site impact | ≥USD $1,000,000, or >20% cost impact | M | M | H | H | H |

## GUIDELINES

| Severity | Further consequence/ impact definition | Probability | Probability Definition | Risk Level | | |
|---|---|---|---|---|---|---|
| **1 (Negligible)** | - Minimal injury or health implications requiring no treatment; no absence from work; requires first aid treatment only (First Aid Case FAC)<br>- Minimal or limited pollution effect/impact; negligible recovery work (spills of up to 1 litre of hydrocarbons, or an amount of other spill type resulting in equivalent environmental imapct)<br>- Insignificant or slight financial loss or equipment/ asset damage (<USD $10,000), or >1% of project/ asset cost<br>- Negligible damage to reputation, including some minor negative feedback | **A (Very Unlikely)** | - Not known by GM to have happened within the industry<br>- A freak combination of factors would be required for an incident to occur | **LOW** | As a guide, when a LOW risk level is calculated, then no additional controls are required. However monitoring should take place to ensure that the controls are implemented and where possible, improved. | **Acceptable**<br>Task/ Activity may be carried out by those authorised to do so |
| **2 (Minor)** | - Minor injury or illness requiring medical treatment (Medical Treatment Case - MTC)<br>- An Environmental incident contained within the site boundary; short-term impact; recovery work by worksite personnel (spills of 1-10 litres of hydrocarbons, or an amount of other spill type resulting in equivalent environmental imapct)<br>- Minor financial loss, or repairs required for damaged asset/ equipment (USD $10,000 - <USD $100,000), or 1-5% of project/ asset cost<br>- Formal complaint by a Client or 3rd party (reputation damage) | **B (Unlikely)** | - Unlikely to occur<br>- May have happened once at GM, or in the industry<br>- A rare combination of factors would be required for an incident to occur | **MEDIUM** | Where a risk level has been calculated to be MEDIUM, further controls should be identifed where possible, in order to reduce the risk to As Low As Reasonably Practical (ALARP). | **Tolerable**<br>Task/ Activity may only proceed with Management authorisation |
| **3 (Significant)** | - Restricted Work Case (RWC) injury; without long term disablement<br>- An Environmental incident went beyond the site boundary, moderate short-term impact, recovery may requires external assistance (10-100 litres of hydrocarbons, or an amount of other spill type resulting in equivalent environmental imapct)<br>- Damage to property/equipment requiring significant repair with costs up to USD $500,000, or 5-10% of project/ asset cost<br>- Local media coverage, and local community complaint | **C (Possible)** | - Could possibly occur<br>- Additional external factors to be combined/ present for an incident to occur | **HIGH** | A HIGH risk level is considered intolerable, and work must commence or continue until the risk has been reduced significantly. If it is not possible to reduce the risk, work is not permitted | **Unacceptable**<br>Work must not proceed change task or further control measures required to reduce risk |
| **4 (Serious)** | - Serious injury/illness leading to days away from work or involving a single lost work day case (LWDC)<br>- Serious medium-term environmental effects; recovery requires external assistance; pollution incurring significant restitution costs (spills between 100 litres to 100 m3 of hydrocarbons, or an amount of other spill type resulting in equivalent environmental impact)<br>- Damage to property/equipment resulting in major loss of operational capability; costs up to USD $1,000,000, or 10-20% of project/ asset cost<br>- Regional-level negative publicity/ media coverage | **D (Likely)** | - Has happened more often than once, at GM, or known to have happened multiple times within the industry<br>- An additional factor may be required to result in an incident | | | |
| **5 (Critical)** | - A fatality(s) or multiple serious injuries leading to permanent disability or terminal disease<br>- Extensive pollution with long-term implications or massive site impact and recovery work; very high restitution costs resulting in serious economic liability on the business; spill in excess of 100m3 of hydrocarbons, or an amount of other spill type resulting in equivalent environmental imapct)<br>- Damage with major long-term implications on operational capability; extensive costs in excess of USD $1,000,000 or >20% of project/ asset cost<br>- International negative publicity/ media coverage | **E (Very Likely)** | - A regular occurrence in the industry<br>- Almost inevitable that an incident will happen | | | |

GLOBAL MARITIME

**Global Maritime Risk Matrix | G-HSE-FM-002 | Rev. 2**

# GEOHAZARD & GEOTECHNICAL RISK Register (GRR) - Cables

| Project Number: | PRJ111361 | | | | Project Name: | Dogger Bank South Offshore Wind Farm Array Area | | | |
|---|---|---|---|---|---|---|---|---|---|
| GRR Review Date: | 07/07/2023 | | | | Project Manager: | Matthew Laing | | | |
| | | | Risk Evaluation | | | | Risk Evaluation | | |
| Ref. | | Hazard Details | Inherent Risk Severity | Inherent Risk Probability | Inherent Risk Level | Control Measures | Residual Risk Severity | Residual Risk Probability | Residual Risk Level |
| Cable Installation | PRJ111361 | | | | | | | | |
| 1 | Bedrock Outcropping at Seabed | Presence of outcropping rock can cause issues to cable installation.<br><br>Trenchability along those areas is highly dependable on the geotechnical parameters of the rock and cables might be not sufficiently protected if targeted burial depths are not achieved.<br><br>Exposed cables have increased risks to internal and external threats. | 3 | A | L | At present, geotechnical sampling and geophysical data suggests subcropping bedrock within the burial profile is unlikely to be encountered.<br><br>Further geotechnical survey along the final array cable routes can confirm if the site is clear of shallow subcropping bedrock. | 3 | A | L |
| 2 | Hard Soils Within Burial Profile | Presence of high-strength clays can cause issues to cable installation.<br><br>Trenchability along those areas is highly dependable on the geotechnical parameters of the soils and cables might be not sufficiently protected if targeted burial depths are not achieved.<br><br>Exposed cables have increased risks to internal and external threats. | 3 | D | M | Detail assessment of the geotechnical parameters of the tertiary soil units is recommended, in order to understand the burial feasibility.<br>The recommended burial strategy already limits exposure, in so far as possible, with use of a jet-assisted plough capable of trenching into the stiffer clays.<br>Alternative protection methods such as rock dumping or mattressing might be required. | 3 | C | M |
| 3 | Boulders at and within Seabed | Boulders of indurated and cemented material derived from the underlying geological units.<br><br>Boulders create obstructions for trenching and installation activities.<br><br>Buried boulders can cause reduced burial. | 4 | E | H | Detailed, high resolution bathymetric and side scan sonar survey.<br><br>Sympathetic routing design, resilient trenching methods, boulder clearance campaigns ahead of installation. | 4 | D | M |
| 4 | Soft Soils at and within Seabed | Presence of soft, unconsolidated soils can cause issues to cable installation.<br><br>Soft soils can cause trencher sinkage and less efficient trenching if not planned for. | 3 | D | M | Detailed installation engineering examining trencher types, bearing pressures and means of reducing bearing pressure if necessary. | 3 | C | L |

# GEOHAZARD & GEOTECHNICAL RISK Register (GRR) - Cables

| Project Number: | PRJ111361 | | Project Name: | Dogger Bank South Offshore Wind Farm Array Area | | | |
|---|---|---|---|---|---|---|---|
| GRR Review Date: | 07/07/2023 | | Project Manager: | Matthew Laing | | | |

| | | | Risk Evaluation | | | | Risk Evaluation | | |
|---|---|---|---|---|---|---|---|---|---|
| Ref. | | Hazard Details | Inherent Risk Severity | Inherent Risk Probability | Inherent Risk Level | Control Measures | Residual Risk Severity | Residual Risk Probability | Residual Risk Level |
| 5 | Irregular Seabed | Presence of irregular seabed can cause issues with trencher traction and progress, also reduced burial where trencher tools pull out of seabed. | 3 | C | M | Detailed installation engineering examining routing, trencher types, utilise suitable trencher. | 3 | B | L |
| 6 | Gravel Reduces Depth of Lowering | Gravels present within seabed soils, or even flints within chalk, may not be fully removed from trench, limiting the depth to which lowering can occur. | 3 | C | M | Evaluate detailed geotechnical and geophysical survey. Account for risk with increased trench depth and trenching methods to maximise suspension and eduction. | 3 | B | M |
| 7 | Dense Sands across site | Dense sands can greatly reduce plough progress rates | 3 | D | M | If plough burial is chosen for installation, ensure the plough has jetting assistance to fluidise sands and increase progress rates. | 3 | C | M |
| 8 | Organic Material within Burial Profile | Organic materials in soil can reduce jettability | 3 | B | M | Interrogation of geotechnical samples, surficial sediments and sub-bottom data to ensure avoidance of any organic material deposits within the corridor. | 3 | A | L |
| 9 | Shells and shell fragments reducing Depth of Lowering | Shells and shell fragments, may behave similarly to gravel, limiting the depth to which lowering can occur | 3 | C | M | Acquire and evaluate existing and further geotechnical data to assess the shell content in the seabed and how likely it will affect jetting. Account for risk with increased trench depth and trenching methods to maximise suspension and eduction. | 3 | B | M |
| **Cable Operation** | | | | | | | | | |
| 1 | Shipping | Ships can cause direct damage to exposed or insufficiently buried cables by deploying anchors either deliberately (in case of anchorages) or accidentally over / next to a cable. Direct cable strike or more likely snagging of cable can cause damage to cable (and potentially the vessel). | 2 | C | M | Probabilistic assessment of shipping and estimation of likely anchor penetration depth relative to seabed geology and shipping activity. Conservative approach to be taken with regard to unknown factors (e.g. number of smaller vessels without AIS). Risk is inherently lower for array cables as they are within the wind farm boundary.<br><br>Determination of appropriate cable burial depths to provide adequate protection. | 2 | B | L |

# GEOHAZARD & GEOTECHNICAL RISK Register (GRR) - Cables

| **Project Number:** | **PRJ111361** | | | | **Project Name:** | **Dogger Bank South Offshore Wind Farm Array Area** | | | |
|---|---|---|---|---|---|---|---|---|---|
| **GRR Review Date:** | **07/07/2023** | | | | **Project Manager:** | **Matthew Laing** | | | |
| | | | **Risk Evaluation** | | | | **Risk Evaluation** | | |
| **Ref.** | | **Hazard Details** | **Inherent Risk Severity** | **Inherent Risk Probability** | **Inherent Risk Level** | **Control Measures** | **Residual Risk Severity** | **Residual Risk Probability** | **Residual Risk Level** |
| 2 | Fishing | Fishing activities can result in direct damage to exposed or insufficiently buried cables by fishing gear snagging on the cable. Also (greater) risk to the fishing vessel in the event of a snagging incident.<br><br>Fishing vessels account for a proportion of the traffic in the area. | 2 | C | M | Assessment of likely fishing gear penetration based on identified fishing types relative to seabed geology and recommendation of burial to sufficient depth to afford adequate protection.<br><br>Ongoing monitoring of fishing activity and methods as part of IMR regime.<br><br>Identification of new cables on nautical charts / fishermen awareness initiatives. | 2 | B | L |
| 3 | Fishing - future variations in equipment | Fishing methods and equipment could vary with time resulting in increased risk to the cables. | 2 | C | M | Ongoing monitoring of fishing activity and methods as part of IMR regime.<br><br>The risk to the cables should be reassessed if there is a significant change in fishing activities which results in greater penetration of fishing equipment into the seabed. If necessary, mitigation actions to be taken (deeper burial, rock dump, fishing exclusion zones, etc.).<br><br>Given the increased vessel running costs of deeper penetrating fishing gear (higher towing force), increase in this factor is considered unlikely, however it is possible that the locations of fishing grounds will change in future. | 2 | B | L |
| 4 | On-bottom Stability | Water depth and metocean conditions influence cable on bottom stability (abrasion / fatigue effects on surface laid cables, which could be exacerbated by the uneven seabed surface in areas of outcropping rock or sand waves). | 2 | B | L | Cables are planned to be buried for the entirety of the route. Where burial may not be possible, and alternative method of cable protection is to be considered. | 2 | A | L |

## GEOHAZARD & GEOTECHNICAL RISK Register (GRR) - Cables

| Project Number: | PRJ111361 | | Project Name: | | | Dogger Bank South Offshore Wind Farm Array Area | | | |
|---|---|---|---|---|---|---|---|---|---|
| GRR Review Date: | 07/07/2023 | | Project Manager: | | | Matthew Laing | | | |
| | | | Risk Evaluation | | | | Risk Evaluation | | |
| Ref. | | Hazard Details | Inherent Risk Severity | Inherent Risk Probability | Inherent Risk Level | Control Measures | Residual Risk Severity | Residual Risk Probability | Residual Risk Level |
| 5 | Dredging / Dumping | Dredging activity can result in direct damage to cables as well as exposure of buried cables or reduction in burial, increasing risk to primary hazards such as shipping or fishing. Over-burial by dumping, can result in exceeding cable thermal / physical design parameters. | 2 | B | L | Consultation with dredging licence holders, as required.<br><br>Identification of new cables on nautical charts / implementation of exclusion zones for dredging / dumping activity. | 2 | A | L |

# APPENDIX B DRAWINGS

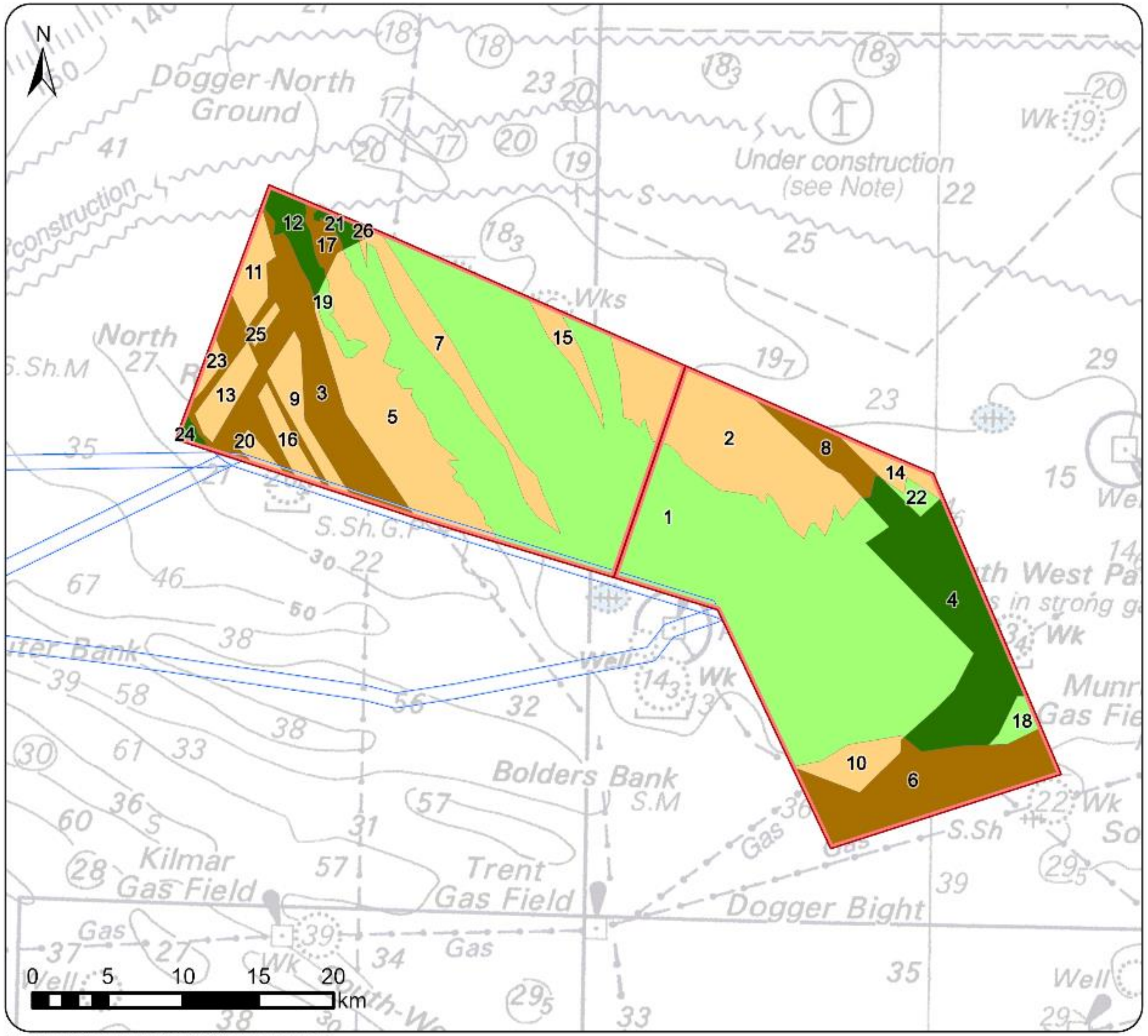
# APPENDIX C CBRA ALIGNMENT CHARTS

# APPENDIX D BAS TABLES

| Zone No. | Area (km²) | Water Depth (mLAT) | | Target DoL (m) | Upper Layer Soil Type | Model Upper Unit Code | Lower Layer Soil Type | Model Lower Unit Code | Burial Method Suitability | | | Burial Class | Key Risks in Zone | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Min | Max | | | | | | Jetting | Ploughing | Mechanical Cutting | | | |
| 1 | 453.291 | -39.0 | -15.0 | 0.5 | Medium Dense Sand | S2 | Dense Sand | S3 | Suitable | Possible | Not Suitable | A | Gravel is present in many parts of this zone, which will cause reduced jettability. Dense Sands could reduce plough progress. | Shell fragments and organic material found in geotechnical samples DBSW-005-BH-A, DBSE-009 BH, DBSE-010-BH and grab sample ST110. |
| 2 | 87.974 | -27.5 | -18.2 | 0.5 | Loose Sand | S1 | High Strength Clay | C5 | Suitable | Suitable | Possible | B | Gravels and High strength clay, if present in burial profile, may reduce jettability, reducing progress rates | Some regions of Gravelly Sand and shell fragments found in grab samples ST072, ST057 |
| 3 | 77.867 | -41.2 | -27.7 | 1 | Loose Sand | S1 | Very High Strength Clay | C6 | Suitable | Suitable | Possible | B | Gravels and Very high strength clay, if present in burial profile, may reduce jettability, reducing progress rates | Gravelly Sand and shell fragments found in grab samples ST080, ST063 |
| 4 | 75.657 | -36.0 | -14.8 | 1 | Medium Dense Sand | S2 | Dense Sand | S3 | Suitable | Possible | Not Suitable | A | Dense Sands could reduce plough progress. Some regions of gravelly Sand | Some regions of Gravelly Sand at surface. |
| 5 | 70.239 | -38.5 | -26.6 | 0.5 | Loose Sand | S1 | Very High Strength Clay | C6 | Suitable | Suitable | Possible | B | Gravels and Very high strength clay, if present in burial profile, may reduce jettability, reducing progress rates | Gravelly Sand at surface. Shell fragments found in grab samples ST119, ST109, ST081 |
| 6 | 62.447 | -38.8 | -29.1 | 1 | Medium Strength Clay | C4 | High Strength Clay | C5 | Possible | Suitable | Possible | B | High strength clay, may reduce jettability, reducing progress rates | Gravelly Sand at surface. Shell Fragments found in grab sample ST012 |
| 7 | 26.6 | -37.0 | -24.3 | 0.5 | Loose Sand | S1 | High Strength Clay | C5 | Suitable | Suitable | Possible | B | Gravels and High strength clay, if present in burial profile, may reduce jettability, reducing progress rates | Gravelly Sand at surface. Shell fragments found in geotechnical sample DBSW-004-BH, and grab samples ST120, ST051 |
| 8 | 14.152 | -26.5 | -19.9 | 1 | Loose Sand | S1 | High Strength Clay | C5 | Suitable | Suitable | Possible | B | High strength clay, if present in burial profile, may reduce jettability, reducing progress rates | Some regions of Gravelly Sand at surface. Shell fragments found in grab sample ST074 |
| 9 | 13.27 | -38.0 | -29.3 | 0.5 | Loose Sand | S1 | Very High Strength Clay | C6 | Suitable | Suitable | Possible | B | Very high strength clay, if present in burial profile, may reduce jettability, reducing progress rates | Gravelly Sand at surface. |
| 10 | 12.922 | -39.1 | -33.0 | 0.5 | Medium Strength Clay | C4 | High Strength Clay | C5 | Possible | Suitable | Possible | B | High strength clay may reduce jettability, reducing progress rates | Gravelly Sand at surface. |
| 11 | 11.843 | -41.8 | -35.3 | 0.5 | Loose Sand | S1 | Very HighStrength Clay | C6 | Suitable | Suitable | Possible | B | Very high strength clay, if present in burial profile, may reduce jettability, reducing progress rates | Gravelly Sand at surface. |
| 12 | 11.558 | -39.7 | -29.1 | 1 | Loose Sand | S1 | Dense Sand | S3 | Suitable | Suitable | Not Suitable | A | Dense Sands could reduce plough progress | Some regions of Gravelly Sand at surface. |
| 13 | 10.522 | -38.6 | -29.5 | 0.5 | Loose Sand | S1 | Very High Strength Clay | C6 | Suitable | Suitable | Possible | B | Gravels and Very high strength clay, if present in burial profile, may reduce jettability, reducing progress rates | Gravelly Sand at surface. |
| 14 | 8.799 | -25.1 | -18.7 | 0.5 | Loose Sand | S1 | High Strength Clay | C5 | Suitable | Suitable | Possible | B | Gravels and High strength clay, if present in burial profile, may reduce jettability, reducing progress rates | Gravelly Sand at surface. Shell fragments found in grab sample ST075 |
| 15 | 8.647 | -31.3 | -17.6 | 0.5 | Loose Sand | S1 | High Strength Clay | C5 | Suitable | Suitable | Possible | B | Gravels and High strength clay, if present in burial profile, may reduce jettability, reducing progress rates | Some regions of Gravelly Sand at surface. |
| 16 | 7.697 | -36.7 | -26.8 | 0.5 | Loose Sand | S1 | Very High Strength Clay | C6 | Suitable | Suitable | Possible | B | Gravels and Very high strength clay, if present in burial profile, may reduce jettability, reducing progress rates | Gravelly Sand at surface. |
| 17 | 5.679 | -37.6 | -31.0 | 1 | Loose Sand | S1 | Very High Strength Clay | C6 | Suitable | Suitable | Possible | B | Gravels and Very high strength clay, if present in burial profile, may reduce jettability, reducing progress rates | Gravelly Sand at surface. |
| 18 | 5.499 | -34.3 | -19.7 | 0.5 | Medium Dense Sand | S2 | Dense Sand | S3 | Suitable | Possible | Not Suitable | A | Dense Sands could reduce plough progress. Gravels may reduce jettability. | Some regions of Gravelly Sand at surface. |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 19 | 4.795 | -37.3 | -30.7 | 0.5 | Loose Sand | S1 | Dense Sand | S3 | Suitable | Suitable | Not Suitable | A | Dense Sands, if present in burial profile, contain gravel and could reduce jettability and plough progress. | Shell fragments and organic material found in geotechnical sample DBSW-003-BH |
| 20 | 3.598 | -34.1 | -29.5 | 0.5 | Loose Sand | S1 | Very High Strength Clay | C6 | Suitable | Suitable | Possible | B | Gravels and Very high strength clay, if present in burial profile, may reduce jettability, reducing progress rates | Gravelly Sand at surface. |
| 21 | 3.543 | -36.5 | -27.5 | 1 | Medium Dense Sand | S2 | Dense Sand | S3 | Suitable | Possible | Not Suitable | A | Dense Sands could reduce plough progress. Gravels may reduce jettability. | Some regions of Gravelly Sand at surface. |
| 22 | 3.49 | -21.6 | -18.5 | 0.5 | Medium Dense Sand | S2 | Dense Sand | S3 | Suitable | Possible | Not Suitable | A | Dense Sands could reduce plough progress | Small region of Gravelly Sand at surface. |
| 23 | 3.302 | -37.1 | -32.8 | 0.5 | Loose Sand | S1 | Very High Strength Clay | C6 | Suitable | Suitable | Possible | B | Gravels and Very high strength clay, if present in burial profile, may reduce jettability, reducing progress rates | Gravelly Sand at surface. |
| 24 | 2.342 | -34.2 | -24.4 | 1 | Loose Sand | S1 | Dense Sand | S3 | Suitable | Suitable | Not Suitable | A | Dense Sands could reduce plough progress. Gravels may reduce jettability. | Gravelly Sand at surface. |
| 25 | 1.862 | -39.6 | -34.4 | 0.5 | Loose Sand | S1 | Very High Strength Clay | C6 | Suitable | Suitable | Possible | B | Gravels and Very high strength clay, if present in burial profile, may reduce jettability, reducing progress rates | Gravelly Sand at surface. |
| 26 | 1.181 | -36.4 | -31.0 | 1 | Loose Sand | S1 | High Strength Clay | C5 | Suitable | Suitable | Possible | B | Gravles and High strength clay, if present in burial profile, may reduce jettability, reducing progress rates | Gravelly Sand at surface. |

## DBS Lease Area - BAS Zones Map




Legend

Wind Farm Site Boundary

Export Cable Corridor

Burial Assessment Summary Zones

Burial A at 0.5m DoL

Burial A at 1m DoL

Burial B at 0.5m DoL

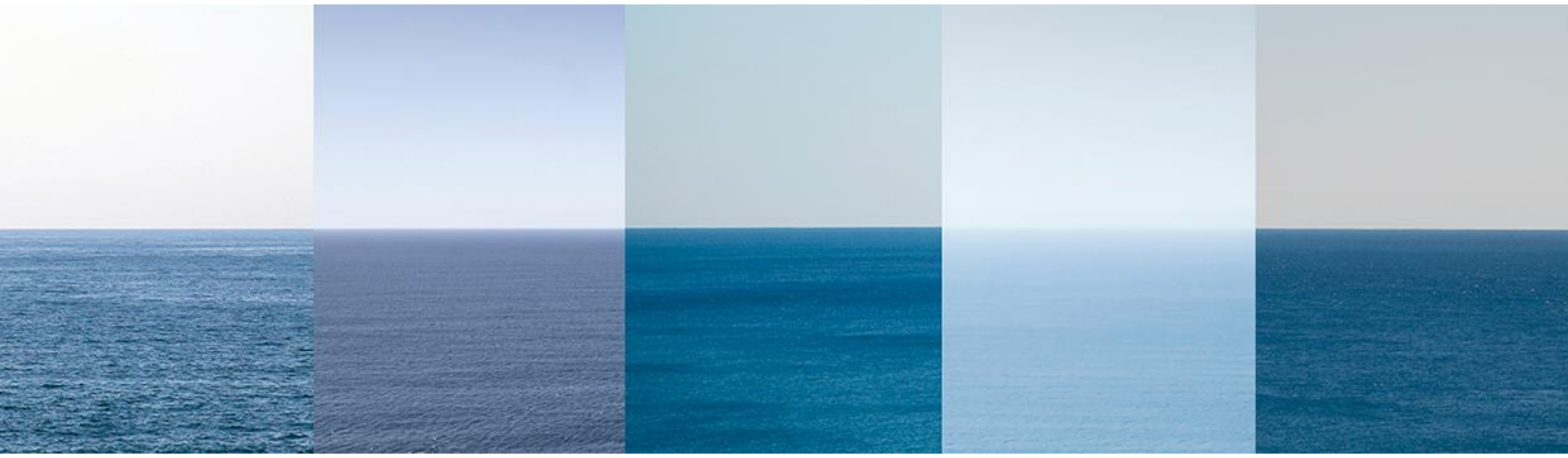
Burial B at 1m DoL

GM-PRJ111361-GEO-RP-001-FIG-011-Rev01-AC_BAS

## APPENDIX E DATA PACK

# Appendix B

## Dogger Bank South ECR – Preliminary Cable Burial Risk Assessment and Installation Report



# Dogger Bank South ECR

Preliminary Cable Burial Risk Assessment and Installation Report

For RWE

GM-PRJ111361-GEO-RP-0001

004626108-02

| | | | | | |
|---|---|---|---|---|---|
| | | | **Subsea Cables Engineer** | **GIS Technical Lead** | **Subsea Cables Technical Lead** |
| 03 | 30/06/2023 | Issued for Review | | | |
| | | | F. Dick | L. Murray | M. Laing |
| **Rev** | **Date** | **Document Status** | **Prepared by** | **Reviewed by** | **Approved by** |

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# 1. SUMMARY

On behalf of RWE, Global Maritime have conducted a full CBRA and BAS study for both the Export Cable Route (ECR) and Inter-Array Cables (IAC) for the Dogger Bank South offshore wind farm. This document (004626108-03) focuses on the ECR, details the assessment of the geophysical and geotechnical survey data, including its suitability for application to the CBRA process; and both the CBRA and BAS results. Finally, based on the results of these works, a recommended method for cable installation and protection is provided. The comparable study for the array area is available under the separate document 4626111-01.

A site conditions assessment has been performed to determine the geological layers of the seabed within the export cable route. This assessment found that the majority of the routes could be classified into sand and sand with gravel, with several areas of large sand dunes traversed. In some areas, the mobile sands lie over subcropping clays, glacial till or bedrock consisting of chalk, sandstone and mudstone. The results presented in Fugro's ECR Geological Ground Model Report formed the basis of all geological unit classification, and the associated survey data and deliverables provided their spatial definition.

Global Maritime's optimised CBRA method was applied with modelled post-windfarm installation vessel traffic to analyse the anchor strike risks to the cable and propose target burial depths along each RPL to minimise the risk to acceptable levels whilst also maintaining practical burial depths along each cable route. These burial depths vary along each cable route, due to the changes in soil properties along the cable route along with the density of modelled vessel traffic. The proposed burial depths and risk profile for each cable is detailed in the alignment charts within this report. The provided RPLs for route options A, A1, A2, B and C were used as the basis for the calculation and presentation of the CBRA and BAS results.

Cable route options A1 and A2 have missing sections of survey data, where a generalised assumption on the geological units and conditions based on descriptions from the ECR Geological Ground Model Report had to be used to inform the CBRA model. It is therefore recommended that the CBRA model is re-run with full survey data coverage if these routes are to be further developed. Similarly, it is recommended that the BAS is adjusted to reflect any changes in seabed conditions found as a result, and with the final burial tool(s) taken into consideration.

## 2. INTRODUCTION

### 2.1 Project Description

RWE Renewables UK Ltd. (RWE) are developing the Dogger Bank South (DBS) site located in the central North Sea. The DBS project is located to the southwest of the wind farms currently under development on the Dogger Bank. The DBS site consists of two adjacent sites, DBS East, and DBS West, and has a potential total installed capacity of 3 gigawatts (GW).

Global Maritime have executed the Cable Burial Risk Assessment (CBRA) and Burial Assessment Study (BAS) works for the offshore export cables and inter-array cables for the DBS site as detailed in RWE's scope of work document (Ref. 1).

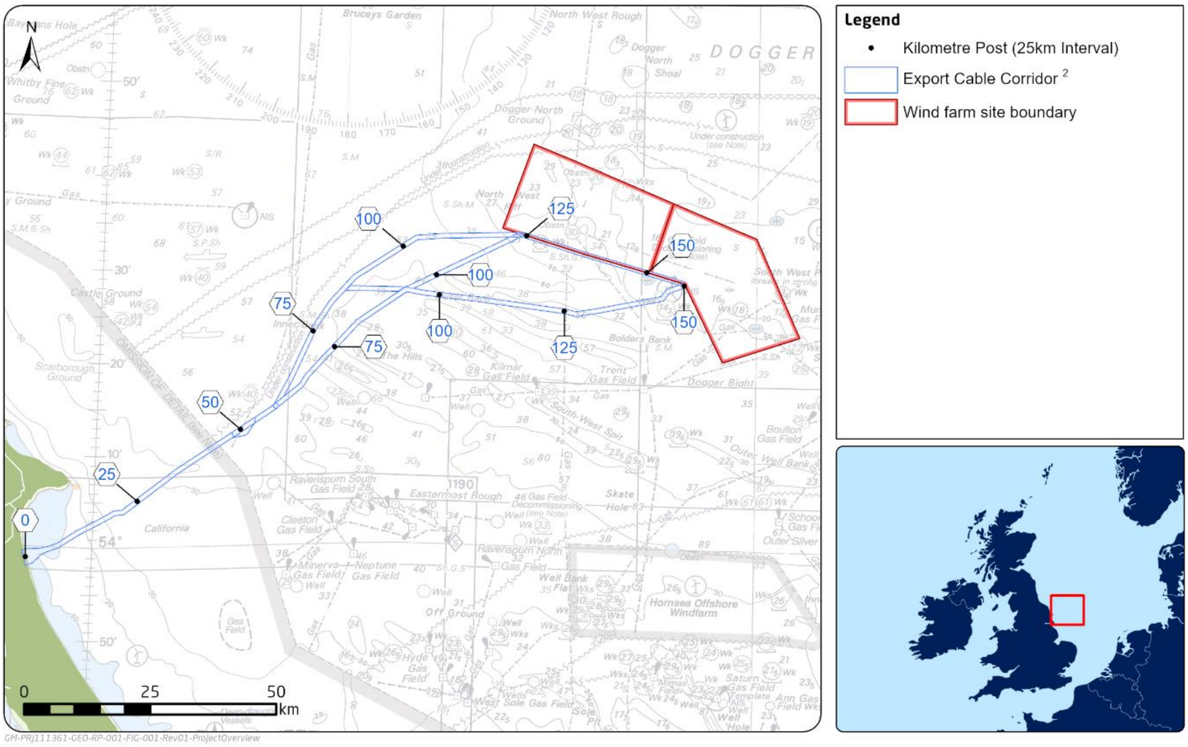



Figure 1: Project Overview

## 2.2 Purpose of Report

The purpose of this report is to present the results of the CBRA and BAS completed by Global Maritime for the DBS export cable routes. The export cable routes have multiple options, shown in Figure 2, which are discussed throughout the reports and results presented for each route option.

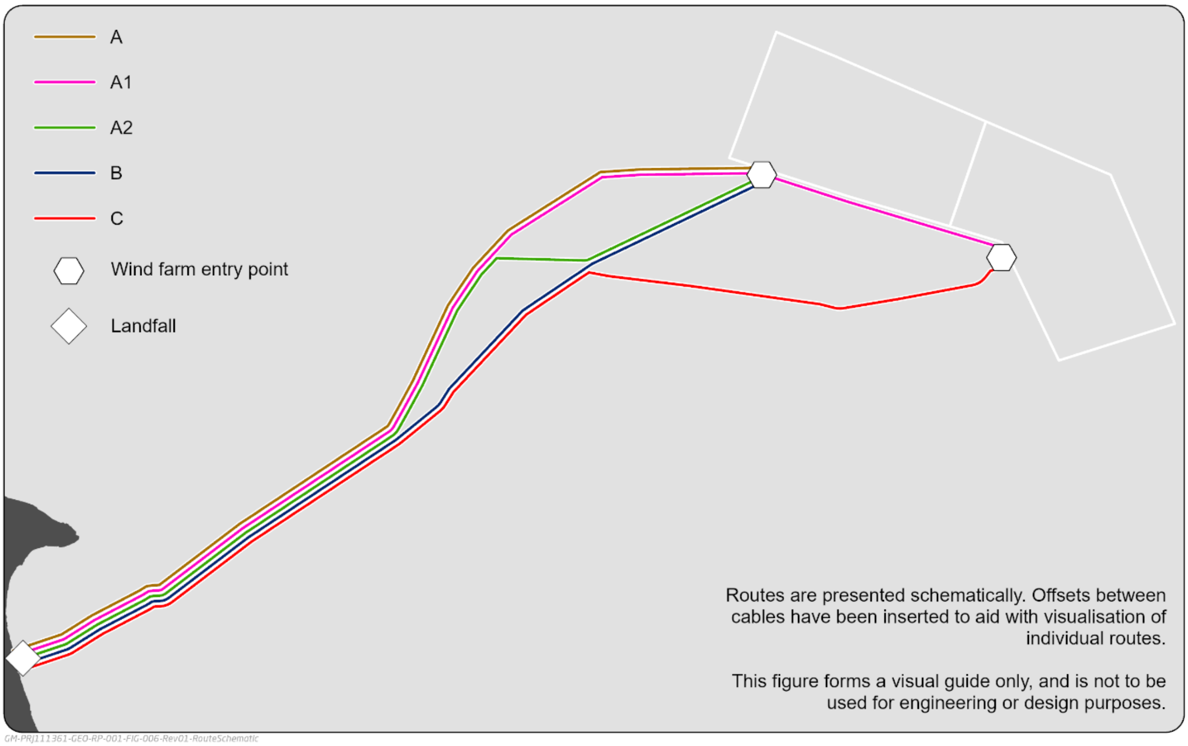



Figure 2: Route Option Schematic

The following works have been completed and results detailed within this report for each route option:

- Data review and gap analysis of all provided site data
- Review of the site conditions within the offshore export cable corridor
- Cable Burial Risk Assessment (CBRA)
- Burial Assessment Study (BAS)

## 2.3 Abbreviations

| Abbreviation | Description |
|---|---|
| AIS | Automatic Identification System |
| BSF | Below Sea Floor |
| BAS | Burial Assessment Study |

| Abbreviation | Description |
|---|---|
| CBRA | Cable Burial Risk Assessment |
| CFE | Controlled Flow Excavation |
| DBS | Dogger Bank South |
| DOB | Depth of Burial |
| DOC | Depth of Cover |
| DOL | Depth of Lowering |
| DNV | Det Norske Veritas |
| DWT | Dead Weight Tonnage |
| ECR | Export Cable Route |
| ECC | Export Cable Corridor |
| GIS | Geographic Information System |
| GM | Global Maritime |
| GW | Gigawatts |
| ICPC | International Cable Protection Committee |
| KP | Kilometre Post |
| LA | Lease Area |
| LARS | Launch and Recovery System |
| LAT | Lowest Astronomical Tide |
| MBES | Multibeam Echosounder |
| MFE | Mass Flow Excavation |
| OSP | Offshore Platform |
| ROV | Remotely Operated Vehicle |
| RPL | Route Position List |
| SBP | Sub-Bottom Profiler |
| SRI | Subsea Rock Installation |
| SSS | Side Scan Sonar |
| TSV | Trenching Support Vessel |
| UHC | Ultimate Holding Capacity |

| Abbreviation | Description |
|---|---|
| 2DUHRS | Two-Dimensional Ultra-High Resolution Seismic |

Table 1: Table of Abbreviations

## 2.4 Geodetic Parameters

The following geodetic parameters, unless specified otherwise, have been used throughout this report.

| Reference | Description |
|---|---|
| Datum | WGS 1984 |
| Projection | UTM Zone 31N |
| Vertical Reference | Lowest Astronomical Tide (LAT) |

Table 2: Geodetic Parameters

## 2.5 Units

All distance and depth units within this report are measured in metres, unless stated otherwise.

Dates are given in dd/mm/yyyy format.

# 3. DATA REVIEW AND GAP ANALYSIS

## 3.1 Data Sources

The below project specific data:

1) RWE, Submarine Cable Burial Risk Assessment Specification, Dogger Banks South Offshore Wind Farm, Doc. No. 004485369-01, Rev. For Issue, September 2022.

2) Fugro, DBS WPM2 WPM3 ECR Seafloor and Shallow Geological Results Report, Dogger Bank South Offshore Wind Farm, UK, North Sea, Doc. No. 004267912-01, Rev. 01, November 2022.

3) Fugro, DBS ECR Interim Geological Ground Model Report, Dogger Bank South Offshore Wind Farm, UK, North Sea, Doc. No. 004734949-01, Rev. 01, November 2022.

4) MarineSpace, 004688005-01-Marine Space - Dogger Bank South Background Review: Bed mobility & Thermal Environment, Version 1, January 2023.

5) RWE, Export cable corridor options A – C. File reference "Export Cable Corridor.shp". Received 25th November 2022.

6) RWE, Export cable corridor centrelines. File references:
OF_RPL_Route_A_Centreline_20230216.shp,
OF_RPL_Route_A1_Centreline_20230216.shp,
OF_RPL_Route_A2_Centreline_20230216.shp,
OF_RPL_Route_B_Centreline_20230216.shp,
OF_RPL_Route_C_Centreline_20230216.shp. Received 16th February 2023.

7) UltraMap Global Ltd, Historical AIS data for 01/11/2020 – 31/10/2022.

8) RWE, Wind farm site boundary. DBS_LeaseAreas.shp. Received 10th November 2023.

The following additional non-project specific references have been used:

9) DNVGL, Recommended Practice, Subsea Power Cables in Shallow Water, Doc. No. DNVGL-RP-0360, March 2016

10) Cigre, Technical Brochure, Installation of Submarine Power Cables, Doc. No. TB883, October 2022.

11) DNV, Recommended Practice, Risk Assessment of Pipeline Protection, Doc. No. DNV-RP-F107, October 2010

12) Carbon Trust, Application Guide for the Specification of the Depth of Lowering using the Cable Burial Risk Assessment (CBRA) methodology, Dec 2015

13) Carbon Trust, Cable Burial Risk Assessment Methodology, Guidance for the Preparation of Cable Burial Depth of Lowering Specification, CTC835, February 2015

14) European Subsea Cables Association (2016), ESCA Guideline No. 6, The Proximity of Offshore Renewable Energy Installations & Submarine Cable Infrastructure in UK Waters, Issue 5, 10 March 2016

15) International Cable Protection Committee (2015), ICPC Recommendation No. 2, Recommended Routing and Reporting Criteria for Cables in Proximity to Others, Issue 11B, 3 November 2015

16) The Crown Estate (2012), Guideline for Leasing of Export Cable Routes/Corridors

17) BERR - Review of Cabling Techniques and Environmental Effects Applicable to the Offshore Wind Farm Industry.

18) Navigation Safety Branch, Maritime & Coastguard Agency, Marine Guidance Note MCN543 (M+F) Section 3d, File Ref: MNA/053/010/0626, January 2016.

19) Ashley et al. (1990). Classification of large-scale subaqueous bedforms: a new look at an old problem. Journal of Sedimentary Petrology. 60. 160-172.

## 3.2 Data Review and Gap Analysis

To inform the routing, CBRA, and BAS, Global Maritime were provided with a geophysical data pack from the Fugro 2022 survey (Ref. 2) and provided with a summary of the key information within Fugro's ECR Interim Geological Ground Model Report (Ref. 3). An adequacy review of the provided data for the purposes of this study is provided in Table 3. Commentary and a traffic light assessment are also provided, representing **Adequate**, **Partially Adequate**, and **Inadequate**.

| Data Type | Source | Comment | Adequacy |
|---|---|---|---|
| Project Boundary / RPL | RWE (5), (6), (8) | Boundaries for wind farm and cable corridor options provided in shapefile format. RPLs and associated KP listings modified by GM to address minor data errors, without modifying the route geometries. | Adequate |
| Bathymetry | Fugro (2) | 1m resolution MBES bathymetry, covering a 1200m (±600m) corridor.<br>Section on cable route option A2 between ~KP86.400 and ~KP96.800 where only a centreline is available. | Adequate |
| Shallow Geology | Fugro (2) | High-resolution SBP and 2DUHRS data<br>Section along route option A1 between ~KP124.000 and ~158.000 is not fully interpreted, to be supplemented with information on average sediment depth from Fugro ECR report. | Partially adequate |

| | | | |
|---|---|---|---|
| | | Data are considered adequate data where available. Agreement made on how to interpret uninterpreted section. | |
| Side Scan Sonar | Fugro (2) | High-resolution SSS data with full corridor coverage<br><br>Targets picked as small as 1m in length | Adequate |
| Magnetometer | Fugro (2) | Mag targets supplied in shapefile format. Gridded amplitudes provided for available runlines in .flt format. | Adequate |
| Soil Provinces | Fugro (2 & 3) | High-detail surface sediment classification from SSS backscatter and Multibeam Backscatter interpretation. Subsurface soils interpreted from shallow geophysical data. | Adequate |
| Seabed features & targets | Fugro (2) | Natural and anthropogenic targets and features identified by MBES, SSS and Mag.<br><br>Suitable for informing recommended installation methodology | Adequate |
| Geotechnical | Fugro (2 & 3) | No specific geotechnical data available<br><br>ECR report provides good detail on three layers of geological units including Su values in top 5m of seabed. SBP was still required to build full 3D model for CBRA.<br><br>ECR report and data provide sufficient detail for CBRA model to be developed, when used in conjunction with SBP data. | Partially adequate |

Table 3: Data Adequacy

# 4. SITE CONDITIONS

## 4.1 Bathymetry

The DBS export cable routes runs between the landfall located south of Flamborough Head and the southwest boundary of the DBS lease areas. The bathymetry across the ECR varies from the shore, down to a maximum depth of approximately 69mLAT within the central portion of the ECR, before the depth shallows again towards the lease area, where the depth reduces to approximately 15 - 20mLAT. Generalised regional bathymetry from EMODnet is shown below in Figure 3 - this shows bathymetric trends across the site but differs from the recent survey bathymetry significantly in some places (Ref. 2). Surveyed bathymetry is shown on the alignment charts included in Appendix C.

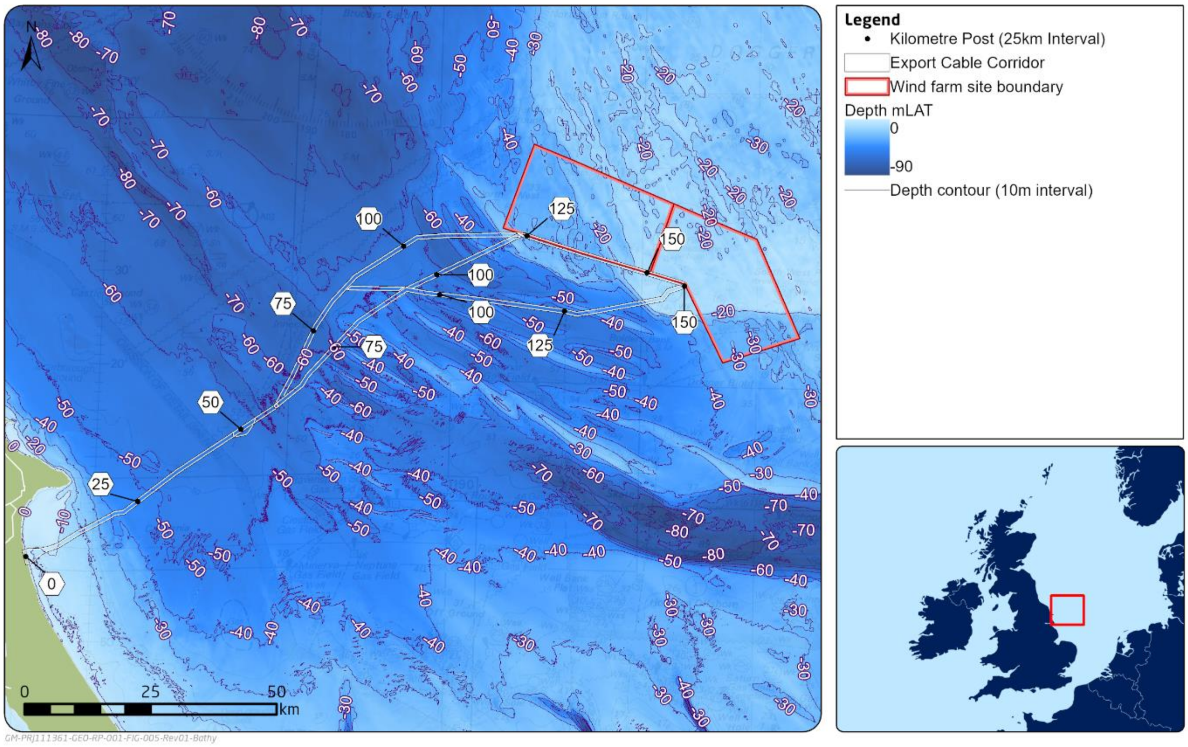



Figure 3: Regional Bathymetry (EMODnet, 2022)

The morphology of the seabed within the export cable route is variable and uneven throughout, with primary morphological features in the area framed by the relic pre-Holocenic landscape and secondary morphological features characterised by bedforms formed by reworking and redeposition of available material in the present-day shallow marine conditions. Bedforms are sedimentary structures and morphologies produced by a flow of water over seabed sediments. The flow can be periodic (such as in the case of tidal- and wave-induced flow) or unidirectional (such as fluvial or glacial sediment transportation flow, and bottom current circulations).

The southwestern portion of the ECR generally sees the presence of smaller bedforms (up to 0.1m wave height and up to 5m wavelength). The size of the bedforms in the central and offshore sections of the ECR generally increases, and medium, large, and very large bedforms with wave heights of 6m and even up to 15m in certain cases. The large bedforms are present primarily between KP63 and KP72 on route option A, A1 and A2, KP63 and KP101 on route option B and KP63 and KP110 on route option C. Size classifications are as described in Ashley 1990 (Ref. 19), summarised in Table 4.

| | **Ashley 1990 Subaqueous Dune Classification Scheme** | | | |
|---|---|---|---|---|
| | **Small** | **Medium** | **Large** | **Very Large** |
| **Wavelength** | 0.6-5m | 5-10m | 10-100m | >100m |
| **Wave Height** | 0.075-0.4m | 0.4-0.75m | 0.75-5m | >5m |

Table 4: Subaqueous Dune (sandwave) size classification scheme as defined in Ashley 1990 (Ref. 19)

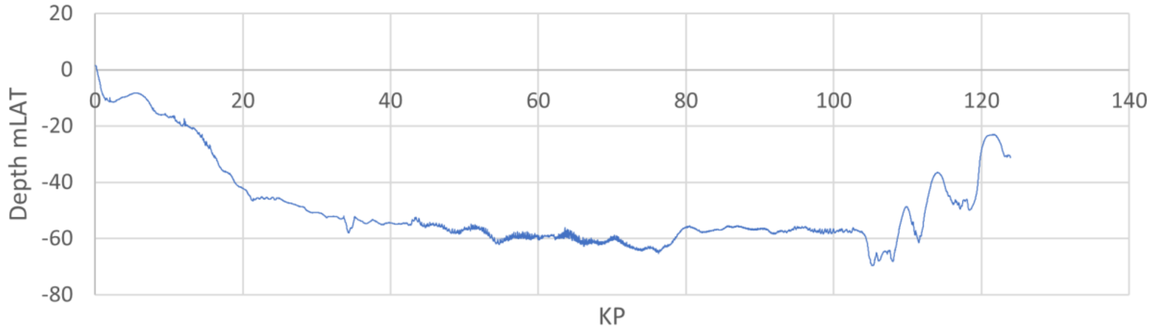



Figure 4: Bathymetric Profile: Route Option A

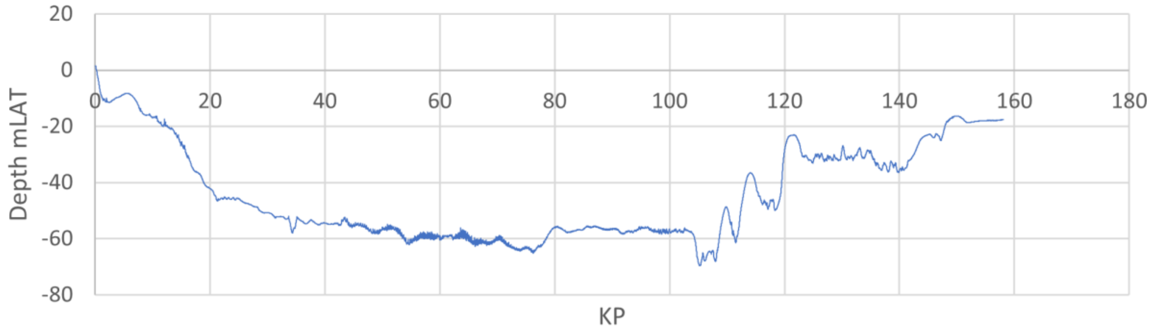



Figure 5: Bathymetric Profile: Route Option A1

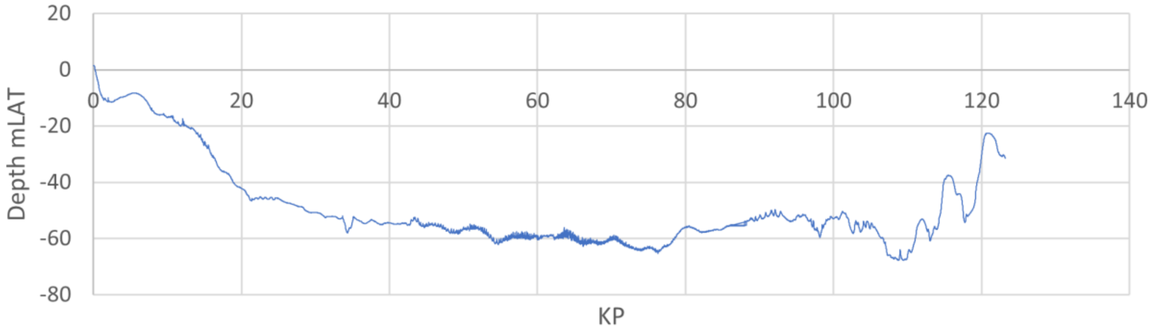



Figure 6: Bathymetric Profile: Route Option A2

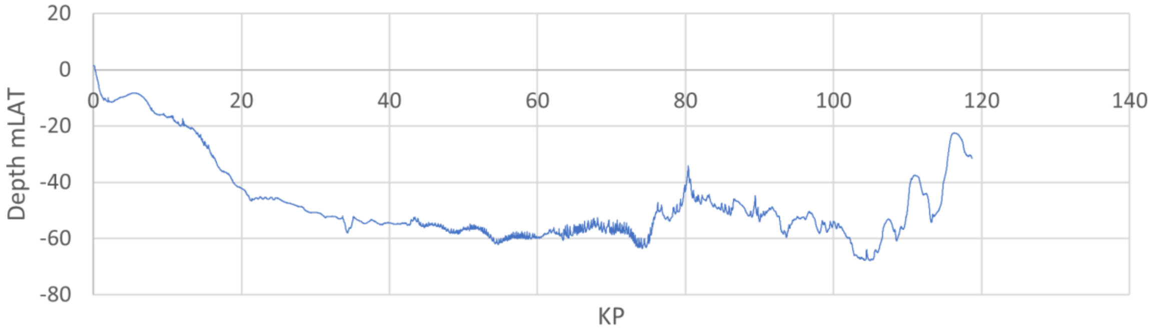



Figure 7: Bathymetric Profile: Route Option B

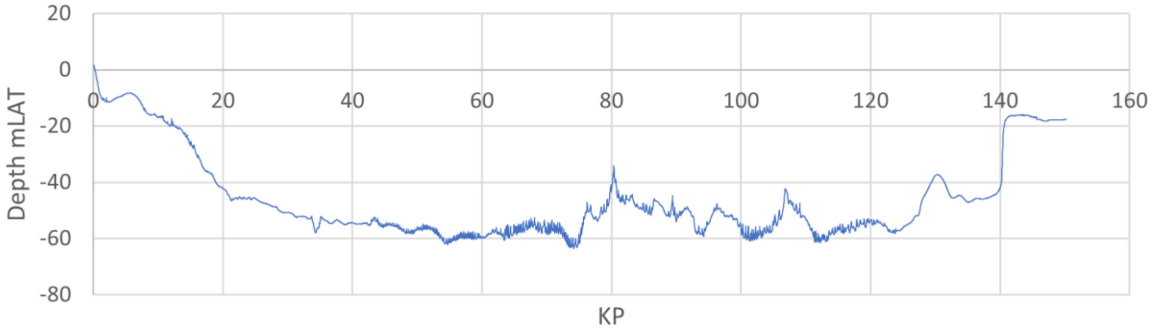



Figure 8: Bathymetric Profile: Route Option C

## 4.2 Local Geology

The Dogger Bank forms a bathymetric high within the central North Sea thought to represent a thrust moraine complex formed during the Weichselian glaciation. The ECR running between the lease area and the mainland connects the site to the landfall which lands on the Yorkshire coast, south of Bridlington.

Pleistocene and Holocene sediments are present along the ECR increasing west to east. A thin cover of sediment is present in the west, overlying folded bedrock of siltstone, mudstones and limestones. The western extent of the corridor also features thin sediment cover over cretaceous chalk bedrock, particularly close to shore and approximately 19km to 29km offshore. In the eastern section of the ECR, bedrock is overlain by deltaic, prodelta and marine sediments and locally incised by glacial tunnel valleys and covered by Late Pleistocene sediments.

Sub bottom profiling and 2D Ultra-High Resolution Seismic testing was performed as part of the seafloor and shallow geological surveys performed by Fugro (Ref. 2) and interpretation was performed to identify horizons and seismostratigraphic units along the ECR. In total, 14 horizons were interpreted delineating 9 main seismostratigraphic units and 5 sub-units. Although all units were identified along the ECR, the base of seismostratigraphic units are not always visible on the SBP data. The identified seismostratigraphic units are summarised in the below table and figure.

| Unit | Horizon | | | Seismic Character | Expected Soul Conditions | Formation | Age | Depositional Environment |
|---|---|---|---|---|---|---|---|---|
| | Top | Base (Horizon Colour) | Internal Horizons | | | | | |
| A | H00 | H05 (red) | - | Surficial layer, acoustically transparent, high amplitude base (i.e., base of seafloor bedforms), locally internal high amplitude point reflections, locally absent or not recognizable | sand, with shells and shell fragments, locally gravelly | Recent | Holocene | Marine |
| B | H00 H05 | H10 (Hot Pink) | - | Stratified, sub-horizontal parallel bedded, medium to high amplitude, grading locally into acoustically transparent character. Locally internal high amplitude point reflections | sand, locally gravelly | Recent sand | Holocene | Marine |
| C | H00 H05 H10 | H20 (Yellow) | - | Stratified, inclined reflections (cross-bedded), low to medium amplitudes, locally grading into acoustically transparent character. Locally internal high amplitude point reflections | sand, locally gravelly | Dogger Bank Fm / Botney Cut Fm | Late Weichselian to Early Holocene | Peri-glacial (glaci-fluvio) |
| D | H00 H05 H10 H20 | H30 (Blue) | H22 H24 H26 | Chaotic, to seismically transparent (medium to high amplitudes), irregular to undulating top, internal and base reflectors, locally high amplitude point reflectors (boulders) | till, variable | Bolders Bank Fm | Weichselian | Sub-glacial, peri-glacial |

<table>
<tr><th rowspan="2">Unit</th><th colspan="3">Horizon</th><th rowspan="2">Seismic Character</th><th rowspan="2">Expected Soul Conditions</th><th rowspan="2">Formation</th><th rowspan="2">Age</th><th rowspan="2">Depositional Environment</th></tr>
<tr><th>Top</th><th>Base (Horizon Colour)</th><th>Internal Horizons</th></tr>
<tr><td>E</td><td>H10</td><td>H40<br>(Dark Green)</td><td>H39</td><td>Stratified and increasingly deformed towards the base</td><td>mud with locally beds of sand</td><td>Dogger Bank Fm</td><td>Weichselian</td><td>Deformed glaci-lacustrine</td></tr>
<tr><td>F</td><td>H40</td><td>H55<br>(Gold)</td><td>-</td><td>Low frequency, low amplitude stratification</td><td>sand with shells and shell fragments, locally with beds of mud</td><td>Eem Fm<br>Egmond Ground Fm</td><td>Holsteinian to Eemian</td><td>Marine</td></tr>
<tr><td>G</td><td>H10<br>H30<br>H40<br>H55</td><td>H60<br>(Green)</td><td>-</td><td>Valleys with an acoustically transparent to chaotic seismic character</td><td>sand and/or mud</td><td>Swarte Bank Fm</td><td>Elsterian</td><td>Glacial valley fill</td></tr>
<tr><td>H</td><td>H30<br>H40<br>H55<br>H60</td><td>H70<br>(Orange)</td><td>H65</td><td>Low frequency, low amplitude stratification at the base to complex at the top<br>Marks to the top of bedrock (i.e., folded rock)</td><td>Upward coarsening muddy to silty sand</td><td>Yarmouth Roads Fm Markham's Hole Fm</td><td>Early to Middle Pleistocene</td><td>Deltaic and fluvial</td></tr>
<tr><td>I<br>Bedrock</td><td>H00<br>H05<br>H10<br>H30<br>H60<br>H70</td><td>(black)</td><td>N/A</td><td>This unit is well-stratified and folded</td><td>Claystone, Siltstone, Mudstone and Carbonates (chalk)</td><td>-</td><td>Triassic, Jurassic, Cretaceous</td><td>Marine</td></tr>
</table>

Table 5: Stratigraphic framework and summary of the interpreted seismostratigraphic units along the ECR (Ref. 2).

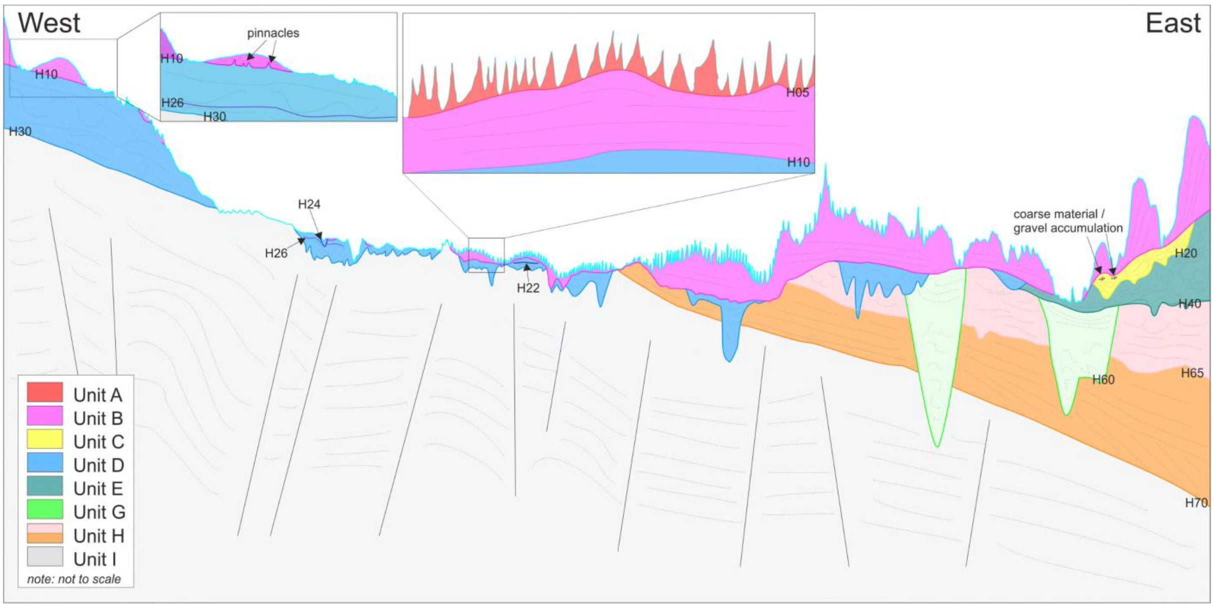



Figure 9: Fugro interpretation and relationship of the stratigraphic units present in the ECR (Ref. 3)

### 4.3 ECR Seafloor Sediments

An interpretation of the seafloor sediments was performed by Fugro (Ref. 2) and is summarised in the below table for each of the ECR blocks considered.

| Route Option(s) | KP Start | KP End | Seabed Sediment |
|---|---|---|---|
| All | 0.00 | 8.68 | KP 0.104 to KP 2.88, is characterised by outcropping and subcropping till. Subcropping till covered < 0.5 m sandy mud and muddy sand. KP 2.88 to KP 7.61 consists of muddy sand. Patches of subcropping till, covered with < 0.5 m muddy sand observed. In the easternmost part, sediments again consist of outcropping and subcropping till. |
| All | 8.68 | 20.55 | Subcropping till present from KP 8.68 until KP 9.41. The till is outcropping further along the route and subcropping again at KP 16.60. The seafloor in the north-easternmost of block B consists of an area of gravelly sandy mud surrounded by out – and subcropping till. |

| Route Option(s) | KP Start | KP End | Seabed Sediment |
|---|---|---|---|
| All | 20.55 | 59.66 | The seabed sediments between KP 20.55 and KP 43.90 mainly consist of alternating outcropping and subcropping bedrock and till. An area of gravelly muddy sand present between KP 34.03 and KP 34.35 and another area of muddy sand is present between KP 43.07 and KP 43.17. The seafloor in the north-eastern part of block C is characterised by muddy sand, partially overlying subcropping till. |
| A, A1, A2 | 59.66 | 90.00 | Seabed is predominantly characterised by sand of varying thickness overlying either till, or chalk, sandstone, mudstone or limestone bedrock. Bedrock is typically deeper than 0.5m for this whole section. |
| A, A1 | 90.00 | 104.70 | Seabed consists of sands, to a depth beyond the acoustic basement of the SBP and 2DUHRS data. |
| A, A1 | 104.70 | 111.90 | Deep sand layer continues through this section, interspersed with short sections of sand over subcropping till and clay between KP104.70 and KP108.4, and KP110.55 and KP111.90. |
| A, A1 | 111.90 | 123.93 | Seabed consists of sands, to a depth beyond the acoustic basement of the SBP and 2DUHRS data. Short section of subcropping clay and till between KP118.10 and 119.43. |
| A1 | 123.93 | 158.57 | Array Area data |
| A2 | 86.66 | 107.00 | Seabed consists of sands, to a depth beyond the acoustic basement of the SBP and 2DUHRS data. |
| A2 | 107.00 | 119.15 | Seabed consists of sand over subcopping clay of varying strengths and till. Small section of outcropping till at KP108.88 |
| A2 | 119.15 | 124.16 | Seabed consists of sands, to a depth beyond the acoustic basement of the SBP and 2DUHRS data. Short section of subcropping till between KP122 and KP122.6. |
| B, C | 59.66 | 65.52 | The seabed in this section consists of sand over subcropping clay and till, with a section of potentially mobile sands overlying sandstone and mudstone bedrock between KP59.80 and 62.98. |

| Route Option(s) | KP Start | KP End | Seabed Sediment |
|---|---|---|---|
| B, C | 65.52 | 93.31 | Seabed consists of sands, to a depth beyond the acoustic basement of the SBP and 2DUHRS data, with patches of subcropping limestone and mudstone bedrock between KP73.2 and KP75. |
| B | 93.31 | 102.5 | Seabed consists of sands, to a depth beyond the acoustic basement of the SBP and 2DUHRS data. |
| B | 102.5 | 114.64 | Seabed consists of sand over subcopping clay of varying strengths and till. Small section of outcropping till at KP104.37 |
| B | 114.64 | 118.68 | Seabed consists of sands, to a depth beyond the acoustic basement of the SBP and 2DUHRS data. Short section of subcropping till between KP117.5 and KP118.17 |
| C | 93.31 | 100.15 | Seabed consists of sands, to a depth beyond the acoustic basement of the SBP and 2DUHRS data. |
| C | 100.15 | 105.20 | Primarily sand overlying subcropping till, with some sections of deeper sands and consistent potentially mobile or formally mobile features. |
| C | 105.20 | 111.10 | Seabed consists of sands, to a depth beyond the acoustic basement of the SBP and 2DUHRS data. |
| C | 111.10 | 117.75 | Potentially mobile sands over stable sand and subcropping till between KP112.50 and 116.14 |
| C | 117.75 | 150.23 | Seabed consists of sands, to a depth beyond the acoustic basement of the SBP and 2DUHRS data. Subcropping clay between KP122.28 and KP126.20, but only reach up to 2m below seabed. |

Table 6: Seafloor Sediment Summary Table

## 4.4 Ground Model

The Fugro ECR Interim Geological Ground Model Report (Ref. 3) describes the ground model developed from the sub-bottom profiler data collected as part of the surveys conducted on the DBS site. The report details the classification of the ECR corridor into 27 zones based on their 3D geological characteristics. Fugro's interim ground model report describes each zone with two to three individual geological units, which are defined in Table 5, from the seabed surface to 5m BSF. Figure 10 shows the units within each zone defined in the ground model.

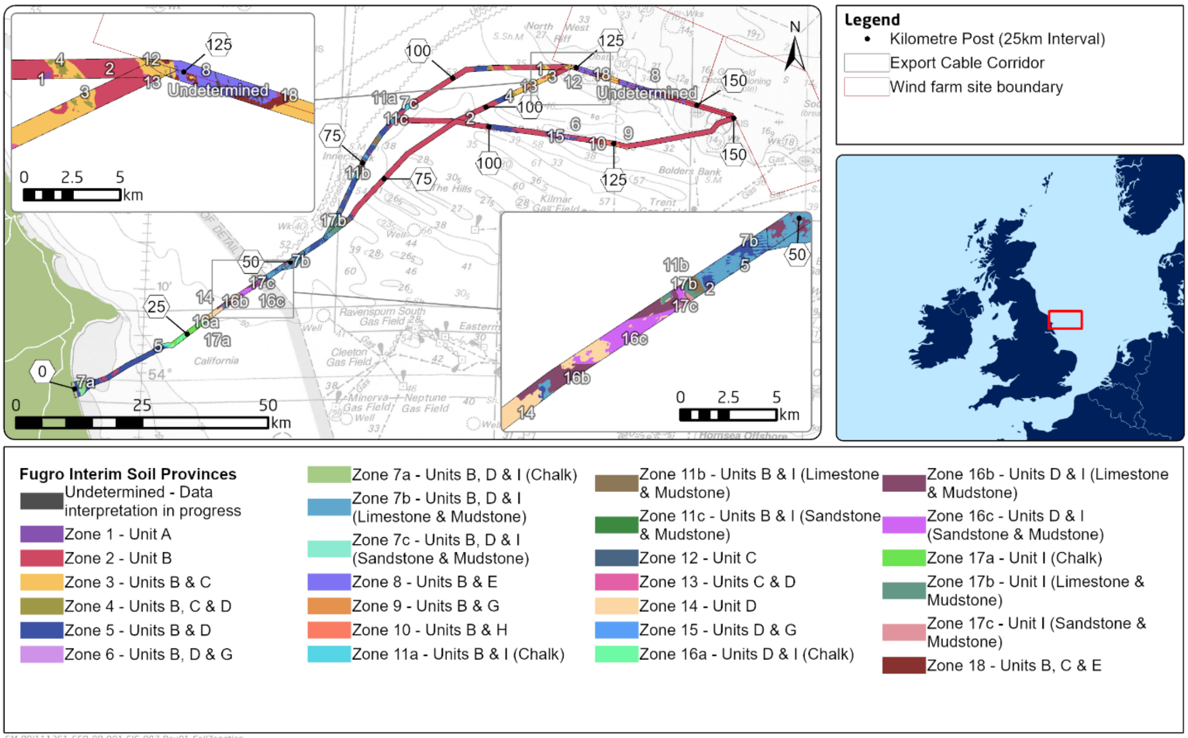



Figure 10: Soil Zonation defined in Fugro's ECR Interim Ground Model Report

The ground model information provided by Fugro (Ref. 3) was used in Global Maritime's 3D CBRA model, with the zones categorised into two geological units for the CBRA modelling procedure. The layers were defined using the soil types and strengths provided by Fugro, and depth BSF for the transition between these units. This is provided as average depth and depth range plots by Fugro; This combined approach meant that the soil properties in Fugro's ground model are integrated in GM's CBRA model, whilst ensuring that the model results are spatially accurate in three dimensions. One section of the cable corridor for route option A1 did not have fully interpreted SBP data available, so the average depth values for each unit in the Ground Model Report were used in the CBRA model as an alternative.

The 'undetermined' zones noted by Fugro were geologically defined in consultation with RWE, after confirmation with the authors of Fugro's Interim Ground Model Report, as expected to be very similar in soil properties to zone 8. This was used as the assumption for these areas in the modelling by GM.

GM's CBRA model units are described in Table 7 below, with the conversion from Fugro's ground model units to GM's CBRA model units shown in Table 8. The conversion was based on both the soil descriptions and undrained shear strength (Su) values. The relative densities (Dr) of the sand units are also shown however it should be noted that Dr is simplified in the CBRA model as it does not greatly significantly affect the results.

| Unit Code | Soil Description | Su From | Su To | Dr From | Dr To |
|---|---|---|---|---|---|
| S1 | Loose SAND | n/a | n/a | 0% | 35% |
| S2 | Medium dense SAND | n/a | n/a | 36% | 65% |
| S3 | Dense SAND | n/a | n/a | 66% | 100% |
| C1a | extremely low strength CLAY | 1 | 5 | n/a | n/a |
| C1b | extremely low strength CLAY | 5 | 10 | n/a | n/a |
| C2 | very low strength CLAY | 10 | 20 | n/a | n/a |
| C3 | Low strength CLAY | 20 | 40 | n/a | n/a |
| C4 | Medium strength CLAY | 40 | 75 | n/a | n/a |
| C5 | High strength CLAY | 75 | 150 | n/a | n/a |
| C6 | Very high strength CLAY | 150 | 300 | n/a | n/a |
| C7 | Extremely high strength CLAY | 300 | 1000 | n/a | n/a |

Table 7: GM CBRA model Geological Units

| Cable Route Soil Zone | Route Option | | | | | % Coverage of ECR | Fugro Ground Model Unit | | | GM CBRA Model Unit | | Su Range (kPa) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | A1 | A2 | B | C | | Upper | Mid | Lower | Upper | Lower | Upper From | Upper To | Lower From | Lower To |
| 1 | | | | | | 0.1 | A | A | A | S1 | S1 | n/a | n/a | n/a | n/a |
| 2 | | | | | | 47.41 | B | B | B | S1 | S1 | n/a | n/a | n/a | n/a |
| 3 | | | | | | 4.62 | B | C | C | S1 | C4 | n/a | n/a | 40 | 75 |
| 4 | | | | | | 1.22 | B | C | D | S1 | C5 | n/a | n/a | 75 | 150 |
| 5 | | | | | | 18.06 | B | B | D | S1 | C5 | n/a | n/a | 75 | 150 |
| 6 | | | | | | 0.81 | B | D | G | S1 | C5 | n/a | n/a | 75 | 150 |
| 7a | | | | | | 0.92 | B | D | Ia | S1 | C7 | n/a | n/a | 300 | 1000 |
| 7b | | | | | | 5.17 | B | D | Ib | S1 | C7 | n/a | n/a | 300 | 1000 |
| 7c | | | | | | 0.16 | B | D | Ic | S1 | C7 | n/a | n/a | 300 | 1000 |
| 8 | | | | | | 4.58 | B | E | E | S1 | C5 | n/a | n/a | 75 | 150 |
| 9 | | | | | | 0.21 | B | B | G | S1 | C5 | n/a | n/a | 75 | 150 |
| 10 | | | | | | 0.93 | B | B | H | S1 | C6 | n/a | n/a | 150 | 300 |
| 11a | | | | | | 0.96 | B | B | Ia | S1 | C7 | n/a | n/a | 300 | 1000 |
| 11b | | | | | | 2.71 | B | B | Ib | S1 | C7 | n/a | n/a | 300 | 1000 |
| 11c | | | | | | 0.01 | B | B | Ic | S1 | S1 | n/a | n/a | n/a | n/a |
| 12 | | | | | | 0.03 | C | C | C | C4 | C4 | 40 | 75 | 40 | 75 |
| 13 | | | | | | 0.26 | C | C | D | C4 | C5 | 40 | 75 | 75 | 150 |
| 14 | | | | | | 2.12 | D | D | D | C5 | C5 | 75 | 150 | 75 | 150 |
| 15 | | | | | | 0.01 | D | D | G | C5 | C5 | 75 | 150 | 75 | 150 |
| 16a | | | | | | 1.71 | D | Ia | Ia | C5 | C7 | 75 | 150 | 300 | 1000 |
| 16b | | | | | | 1.61 | D | Ib | Ib | C5 | C7 | 75 | 150 | 300 | 1000 |
| 16c | | | | | | 1.18 | D | D | Ic | C5 | C7 | 75 | 150 | 300 | 1000 |
| 17a | | | | | | 1.8 | Ia | Ia | Ia | C7 | C7 | 300 | 1000 | 300 | 1000 |
| 17b | | | | | | 2.26 | Ib | Ib | Ib | C7 | C7 | 300 | 1000 | 300 | 1000 |
| 17c | | | | | | 0.09 | Ic | Ic | Ic | C7 | C7 | 300 | 1000 | 300 | 1000 |
| 18 | | | | | | 0.6 | B | C | E | C4 | C5 | 40 | 75 | 75 | 150 |
| Undetermined | | | | | | 0.46 | B | E | E | S1 | C5 | n/a | n/a | 75 | 150 |

Table 8: Fugro ECR Interim Ground Model Report corridor soil zonation and geological units and the corresponding GM CBRA model geological units and Su values

# 5. CABLE BURIAL RISK ASSESSMENT (CBRA)

## 5.1 CBRA Methodology

### 5.1.1 Risk Assessment Methodology

There are a wide range of obstacles and seabed users that present potential hazards to subsea cables; or which have direct interactions with cables that risk damage. Such hazards include ship anchors, which could impact or snag the cable if dragged along the seabed; and fishing, where bottom trawling gear can snag and damage cables. The aim of this study is to evaluate potential risks to the cable and provide recommendations as to the most efficient risk mitigation, including recommendations of burial depth where appropriate.

The basis of a risk assessment for a submarine cable relies on identifying the potential hazards, associated risks, and evaluating the level of protection that may be afforded to the cable by its armouring (internal and/or external), cable burial beneath the seabed or any other means, such as rock dumping or concrete mattressing.

The most reliable and cost-effective form of cable protection is generally recognised to be ensuring no interaction between the cable and the identified hazards. This is most easily achieved by routing the cable away from such hazards or, where this is not practical, by burial below the seabed.

The simplified methodology followed in this report is adopted in accordance with the industry guidance documents:

- Carbon Trust, Cable Burial Risk Assessment (CBRA) Methodology (Ref. 13)
- Carbon Trust, CBRA Application Guide (Ref. 12)
- DNV-GL Subsea Power Cables in Shallow Water (Ref. 9)

The methodology for the CBRA includes an assessment of the seabed conditions followed by the identification and quantitative assessment of the threats/hazards for the area. A probabilistic assessment has then been performed using Global Maritime's in house GIS based software to assess the risk posed to the cable by external threats and a recommended burial depth has been established. This includes a full 3-dimensional approach to the probabilistic calculation of the threat of an anchor strike.

The CBRA method reviews an identified hazard based on its anticipated frequency and consequence. The combined outcome of frequency and consequence indicates whether risk is unacceptable, 'As Low As Reasonably Practical' (ALARP) or Acceptable. This adheres to the criteria outlined in DNVGL-RP-F107 (Ref. 11) The risk matrix used, and definitions of probability and severity are shown in the below tables.

| | | Probability | | | | |
|---|---|---|---|---|---|---|
| | | A | B | C | D | E |
| Consequence | 1 | | | | | |
| | 2 | | | | | |
| | 3 | | | | | |
| | 4 | | | | | |
| | 5 | | | | | |

Table 9: Risk Matrix

| Probability | Definition |
|---|---|
| A (Very Unlikely) | Never Heard of in Industry |
| B (Unlikely) | Heard of in Industry |
| C (Possible) | Incident has been known to occur, but rarely |
| D (Likely) | Happens several times a year in Industry |
| E (Very Likely) | Happens several times a year at project location |

Table 10: Probability Definitions

| Consequence | Definition |
|---|---|
| 1 | Negligible Damage |
| 2 | Minor Damage / Exposure to other hazards |
| 3 | Localised Damage / No unplanned loss of capacity |
| 4 | Major Damage - replacement of small section / Unplanned loss of capacity |
| 5 | Extensive Damage - replacement of significant section of cable/ Significant unplanned loss of capacity |

Table 11: Consequence Definitions

#### 5.1.2 Hazard Classification

Hazards are classified as primary or secondary. Primary hazards are those that have a direct impact upon the cable and can cause damage and secondary hazards are those that do not damage the cable directly but can result in increased risk or susceptibility to damage from primary hazards.

An example of a primary hazard would be impact or snagging of the cable due to a ships anchor being deployed. An example of a secondary hazard would be seabed mobility resulting in reduced cable burial cover or exposure, leaving the cable vulnerable to primary hazards.

#### 5.1.3 Cable Burial - Carbon Trust Terminology

As presented in the methodology above, threat lines have been suggested for the identified site hazards for cable burial (sections 5.2 and 5.3). These follow the information and terminology described in the Carbon Trust Guidance Documents (Ref. 13). Figure 11 provides an illustration and summary of the main abbreviations and terminology used for burial in this report. The Target DOL generally includes an installation tolerance (or safety allowance).

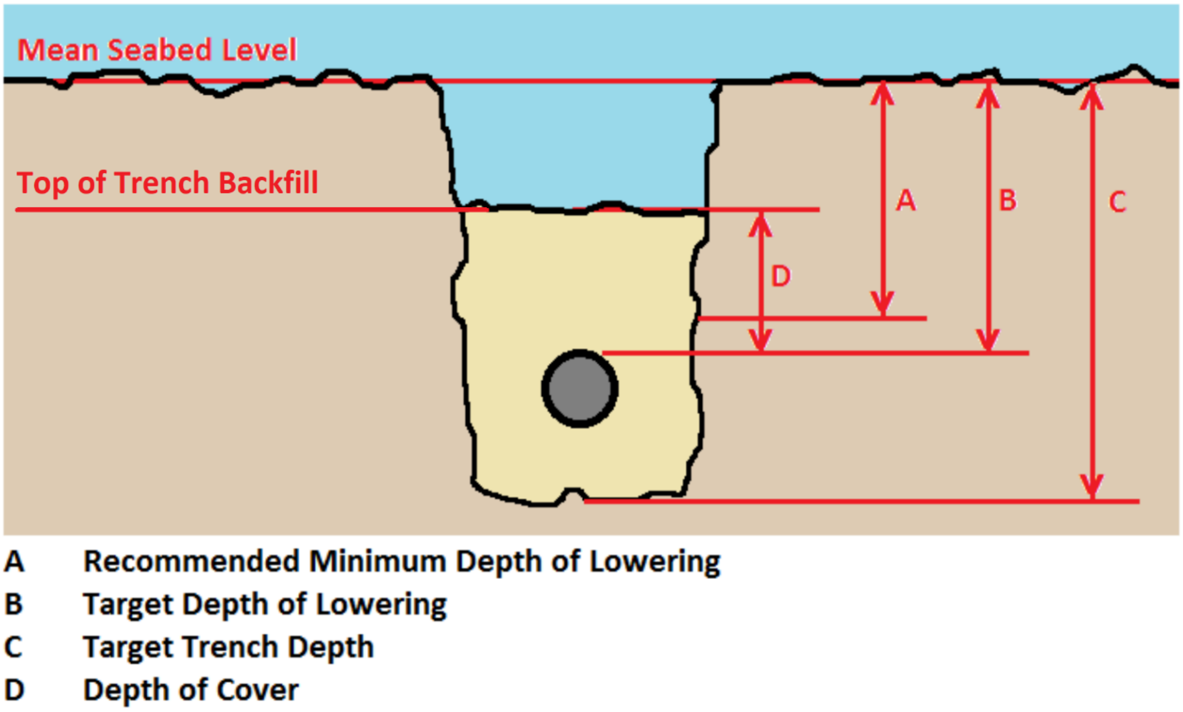



Figure 11: Definition of Trench Parameters and Abbreviations

### 5.2 Hazard Identification and Assessment

#### 5.2.1 Introduction and Risk Register

Data supplied and acquired from third parties has been assessed to develop a risk register (Appendix A), which has been compiled using probability and severity classification to evaluate the potential risks to cables across the site for both installation phases and the operational lifetime of the wind farm. The purpose of this exercise is to ensure that all hazards are identified and assessed and the risk to cables appropriately acknowledged, with initial indications on mitigations presented where possible. The main hazards identified in the risk register are discussed in more detail below.

The Risk Register is considered a live document which is to be updated throughout the life of the project and should be reviewed frequently.

### 5.2.2 Primary Hazards

#### 5.2.2.1 Shipping Activity

Shipping is generally the most onerous anthropogenic risk to cables in terms of threat line depth (even if not the most likely to occur). The main hazard associated with shipping is the deployment of an anchor in proximity to a cable leading to anchor strike. Anchor strike does not necessarily lead to cable damage though it is likely to occur if a cable is inadequately protected through burial to an appropriate depth. The risk of this hazard is associated with the type of vessel traffic, its density, and the frequency of transit in proximity to the cable or cables. The vessel traffic density for 01/11/2020 – 31/10/2022 (Ref. 7) is shown for all vessel categories and sizes in Figure 12.

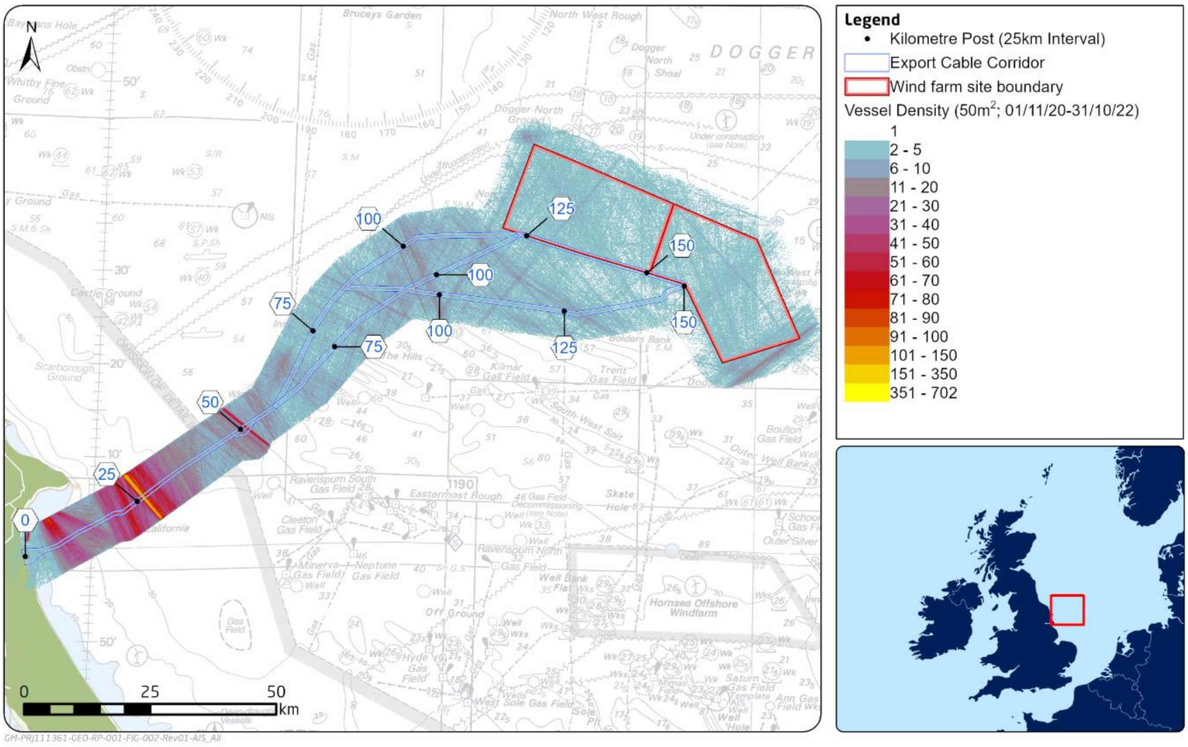



Figure 12: Overall Vessel Traffic Density

The hazard to subsea cables from shipping is associated with the deployment of anchors either in designated anchorage zones (which should be avoided through routing) or in emergency situations that result in anchor deployment through mechanical failure or deployment without due care. The potential impact on the seabed and/or the resultant snagging of a deployed anchor can result in damage to a buried cable.

The traffic can be seen to be most dense in the nearshore area running parallel to the coast, with overall traffic seen to reduce further offshore along the export cable route and within the lease area. It is expected that post-construction, traffic will avoid the wind farm area and give the turbines a wider berth where possible.

The marine traffic data can be further analysed and categorised into various vessel categories as follows:

- Cargo / Tanker Vessels
- Fishing Vessels
- Government Vessels
- Offshore Industry Vessels
- Passenger / Pleasure Vessels
- Port / Dredging Vessels

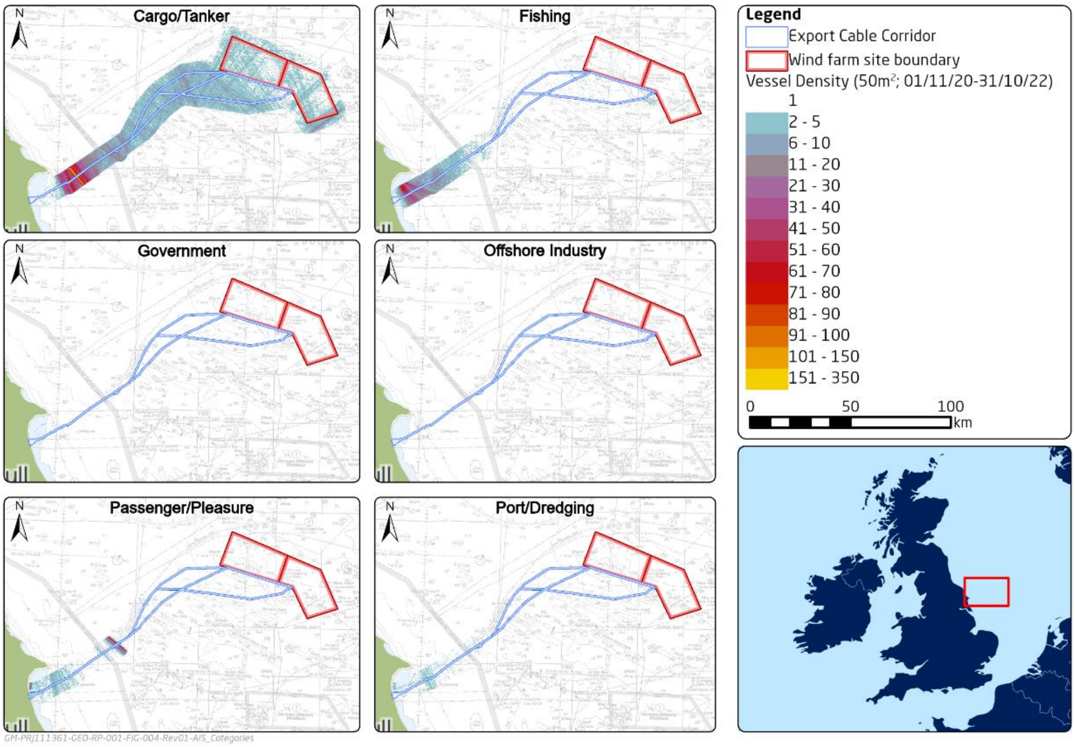



Figure 13: Pre-Construction Marine Vessel Traffic Density by Vessel Category

It can be seen that the highest density of marine traffic crossing the export cable comes from cargo vessels. There is also a high density of fishing vessels crossing the export cable route with an increased volume in the nearshore area. This is confirmed through observation of the significant number of trawl marks within the export corridor identified in the geophysical survey (Ref. 2).

AIS transmitters also provide a status of the vessels, as determined by the vessels themselves. Few vessels in proximity of the ECR in the AIS data had their status as 'at anchor' or 'engaged in fishing', which suggests a reduced risk of impact associated with these activities, however it should be noted that this information relies on the vessel crews accurately updating their status, which is not necessarily always the case.

Global maritime have completed an exercise of re-distributing shipping traffic around the wind farm lease area to model the vessel traffic that would be expected post-wind farm installation, where it would be expected that the vessels previously transiting the lease area would adjust course to avoid the turbines once installed. This was conducted with assistance from Senior Mariners within Global Maritime who provided input into the modelling and a review of the post installation shipping activity. The post-installation shipping activity was used to conduct the CBRA as this is more representative, with some of the vessels that are seen in the historic data crossing the lease area, now crossing the export cables, with an overall greater number of vessels crossing the export cable. A summary of the modelled traffic can be seen in the Figure 14. This shows the vessels previously crossing the windfarm and redistributes them to their most likely new transit route spatially given a criteria of exit point and entry point of the lease area, as well as the wider to and from destinations taken generally from wider open-source density mapping of the area. This also adds in any service vessels for the windfarm expected to be additionally used for operations and maintenance throughout the lifetime of the Wind farm. This process typically redistributes a greater level of traffic crossing the export cable corridor, and here, it can be seen that the density of vessels running parallel to the south side of the lease area has increased.

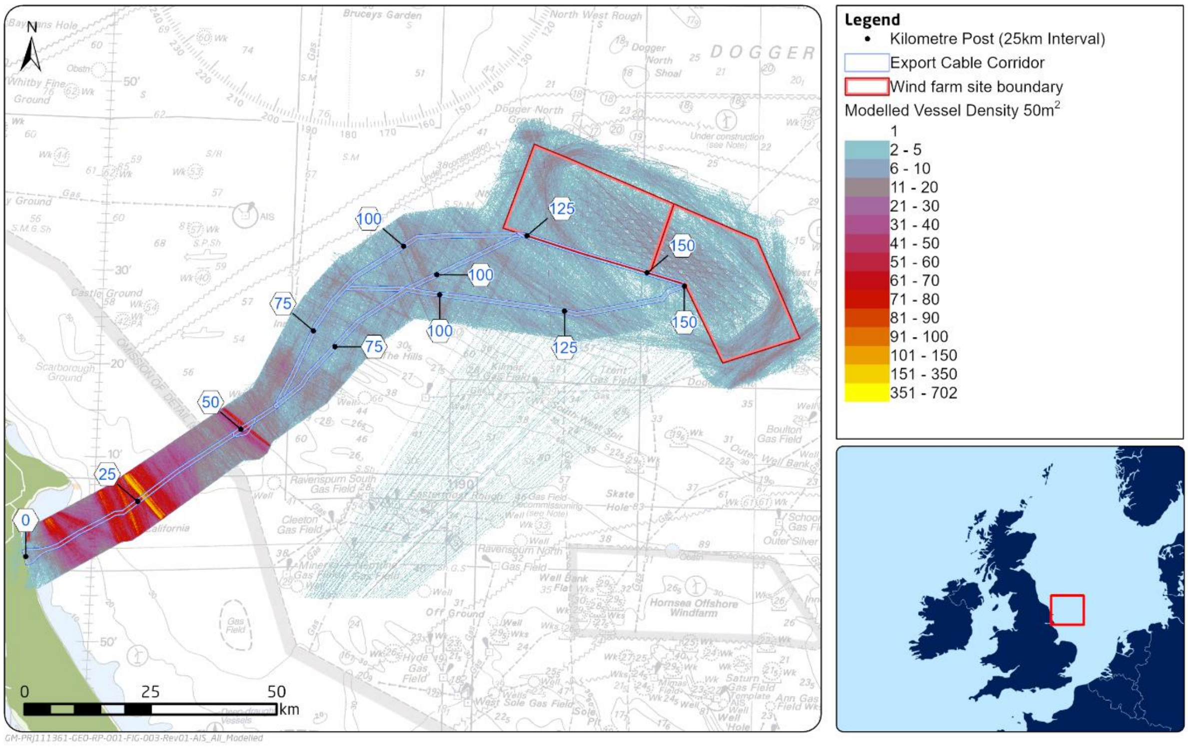



Figure 14: Two-Year Modelled Post-Installation Vessel Traffic

The main mitigation for shipping hazards (anchor strike) is typically burial beneath the identified threat line for a given return period/acceptable level of risk. The optimum burial depth is dependent on the results of the probabilistic risk assessment and cost of achieving the target burial depth. The method and results of the probabilistic assessment are discussed in Section 5.3 and 5.4.

This threat line should also only be considered as below a reference seabed level. This reference seabed level should be taken as the base seabed level taken below any mobile bedforms therefore ensuring that the minimum depth of lowering specified is always maintained despite any seabed movement observed throughout the life of the cable.

#### 5.2.2.2 Fishing Activity

Commercial fishing is a hazard to subsea cables (even armoured cables) where fishing gear interacts with the seafloor, potentially resulting in damage due to impact or snagging. It should also be noted that a cable can pose a risk to the fishing vessels themselves if left on or close to the seabed, as small vessels can founder if snagged on a significant obstruction, of particular concern in areas of strong currents. For example, fishing vessels have been known to founder when trawl gear has become snagged on subsea infrastructure and attempts to free the gear have been unsuccessful.

As can be seen from the AIS data shown above, fishing vessels are shown to frequently cross the export cable route with a higher density observed within the nearshore area. Given this high volume of fishing activity observed from the AIS tracks, along with trawl marks observed along the export cable corridor, it is clear that protection will need to be implemented against the risk of damage through impact / snagging of bottom trawl gear with the export cables. In the case of the identified fishing methods currently employed in the region the following threatline depth is considered reasonable below a non-mobile seabed:

- Fishing gear threatline depth in sand/mud ~0.2 m
- Fishing gear threatline in bedrock/glacial till ~0.1 m

These values are in line with the Carbon Trust CBRA guidance (Ref. 13), which provides an estimate of maximum penetration of fishing bottom trawl equipment. It is noted that the risk of emergency anchor deployment described previously provides a greater threatline and is the governing case along the cable routes.

#### 5.2.2.3 Stability/Fatigue

Surface laid cables are subject to loading from waves and currents and this could result in cable movement and migration across the seabed. Excessive movement on the seabed could cause abrasion and/or fatigue issues. Wave induced movements will be likely in shallow areas towards the shore approaches and during storm activities over the remainder of the site. If the cable is unstable then abrasion can occur where unburied cable is migrating across the seabed and 'rubbing against' outcropping rock, often causing significant damage.

Cable migration is also likely to increase the risk profile, as the cable movement is likely to cause a cable fault. It is also possible that the cable position will no longer be accurately identified on marine charts and this is likely to result in an increased risk from other primary hazards such as vessel anchors, fishing and construction activities. However, power cables such as the proposed are heavy and likely to have high friction with the seabed, therefore damage to the cable is more likely to occur than large displacements with suitable continued cable performance.

Whilst cable migration and fatigue may be issues for unburied cables, where a fatigue life of 20 years may be assumed in less energetic environments, experience indicates that minimal burial/embedment is usually required to ensure on-bottom stability. Therefore, where practical it is recommended that cable burial is planned unless not practical or proven to not be necessary with further in-depth analysis. If the cable is not to be buried due to outcropping rock or other factors, a more detailed cable protection strategy including the following is recommended:

- Micro-routing is undertaken to take advantage of any local features (gullies, ridges, depressions) to avoid freespans and shelter the cable where possible.
- On-bottom stability and fatigue assessments should be carried out to investigate the cable response and ascertain the likelihood for damage of the cable and the likely fatigue life under the loading regime.
- Plan appropriate mitigation methods i.e., pinning by anchoring or rock dumping, external around, additional internal stiffeners/armour, etc.

Cable burial is planned for the full length of the export cable regardless of route option, however, nearshore (as discussed in Section 4) there is bedrock near the surface and burial may be more difficult to accomplish. This is discussed further within the burial assessment in Section 6, and understood greater following further geotechnical survey campaigns, however, if burial is not possible then the stability and fatigue implications and mitigations should be further investigated with external protection likely required.

#### 5.2.3 Secondary Hazards

##### 5.2.3.1 Mobile Sediments

There is evidence of sediment mobility bedforms present on the site, with the expected maximum range of seabed change expected to be up to 1m vertical change, with horizontal changes in the decimeter scale. Other apparent mobile features such as those in the route corridor between KP44 and the node split enveloping the Langeled pipeline show minor change over the time span of current available bathymetry datasets (Ref. 4). The mobility of smaller features such as the smaller sandwaves that may remain mobile, megaripples and scour marks should be verified with repeat bathymetry surveys and further assessment.

Where there is the presence of sediment mobility at the site, this could result in (deeper) burial of cables sections and/or the exposure/freespanning of previously buried sections, as the bedforms migrate. Therefore, the following should be considered:

- The performance of the cable when buried, confirming that there is not a risk of overheating at the possible burial depth due to the mobile sediments in this area.
- The increased risk of primary hazards such as fishing, anchoring and stability/fatigue due to mobility and exposure of the cable.

It is recommended that an allowance be made for sediment mobility where appropriate, with increased burial depth in areas of confirmed mobile features following further studies.

The threatlines discussed in this report are based on the non-mobile layer as described by Fugro's Interim Ground Model Report (ref. 3). As Unit A is present across much of the site, it is not considered in the CBRA calculations, to ensure they account for where the mobile layer is at its lowest thickness. RWE currently have sediment mobility studies ongoing (Ref. 4), and the results of those should be considered alongside this CBRA study and further repeat bathymetry surveys to calculate the total installation depth of lowering required to adequately protect the cable for its full design life.

### 5.3 Probabilistic Risk of Anchor Strike

A probabilistic assessment of the export cable anchor strike risk due to the identified shipping activity has been performed following the carbon trust guidelines (Ref. 13) using Global Maritime's GIS based approach. This has been performed using the site AIS data which was adjusted to model the post-windfarm construction traffic.

This method evaluates the external threat to the cable by considering the amount of time vessels spend within a critical distance of the cable and the probability that a vessel might have an incident that requires the deployment of an anchor. The effect of water depth and bathymetric profile is considered very important and is included as a qualitative factor.

The calculation for the probability of a cable strike is given by the following formula:

$$P_{strike} = P_{traffic}\, P_{wd} \sum_{1}^{No.\ ships\ in\ Section} \frac{D_{ship}}{V_{ship} * 8760hrs\ per\ year} P_{incident}$$

Where:

$P_{traffic}$ : Probability modifier based on the tolerable level of risk

$P_{wd}$ : Probability modifier for nature and depth of seabed

$V_{ship}$ : Ship speed (metre/hr)

$D_{ship}$ : Distance travelled by ship's deployed anchor in area under consideration (metre)

$P_{incident}$ : Probability of incident occurring for that vessel size and type

$8760hrs$ : Facture to annualise the results

Values for the above parameters are shown in the table below:

| Parameter | Description / Comments | Value Used |
|---|---|---|
| $P_{traffic}$ | Probability modifier to determine acceptable level of risk. Indicates the percentage of vessels for which burial is required for protection. | 1 |

| | | |
|---|---|---|
| | Conservative value used for initial assessment. | |
| $P_{wd}$ | Indication of risk due to seabed profile and water depth. Values chosen as per the Carbon Trust guidelines. | See Table 13 |
| $V_{ship}$ | Individual vessel speeds taken from AIS data when crossing cable, with a maximum speed of 2 knots | Various |
| $\boldsymbol{D_{ship}}$ | Distance travelled by the anchor when deployed to exert its holding capacity and immobilise the vessel. Vessel outside of a distance equal to $D_{ship}$ from the cable is not a hazard.<br><br>Calculated on vessel mass (m) taken as displacement, and estimated Ultimate Holding Capacity (UHC) which is estimated for each individual vessel. | $D_{ship} = \frac{m * V_{ship}^2}{4 * UHC}$ |
| $P_{incident}$ | This is the probability of an incident occurring on the vessel which requires the deployment of an anchor. This is taken as the probability of engine failure in single engine tankers in the North Sea, as per DNV guideline DNV-RP-F107 | $1.75 \times 10^{-1}$ incidents per year per vessel |

Table 12: Parameter Values of Probabilistic Risk Assessment

| Vessel DWT (t) | Minimum Water Depth (m) | | | |
|---|---|---|---|---|
| | 0-10 | 10-30 | 30-50 | >50 |
| 0 | 1 | 0.1 | 0 | 0 |
| 2000 | 1 | 0.3 | 0 | 0 |
| 5000 | 1 | 0.5 | 0.1 | 0 |
| 20000 | 1 | 0.9 | 0.3 | 0.1 |

Table 13: $P_{wd}$ Values According to Water Depth and Vessel DWT

Possible anchor penetration can be estimated, based on the soil properties and the typical anchor sizes (fluke length) used by vessels categorised by their deadweight tonnage. As described within Section 4, the seabed along the ECR options consists primarily of sand units of varying thickness overlying clay, glacial till or chalk, mudstone or sandstone bedrock. The penetrative ability of anchors of different sizes in these variable soil conditions must be considered in the CBRA. This is summarised in the below table for the vessels identified. This is representative results for a single soil layer only, the full modelling performed for the results presented later in this report and shown in the alignment charting utilises a multiple layer solution from the available geophysical data.

| Vessel Deadweight (DWT, Te) | Maximum Anchor Fluke Length (m) | Anchor Penetration in Unit S1 (Sands) (m) | Anchor Penetration in Unit C5 (Clays and Till) (m) | Anchor Penetration in Unit C7 (Chalk, Sandstone and Mudstone) (m) |
|---|---|---|---|---|
| 1000 | 0.8 | 0.6 | 0.6 | 0.4 |
| 2000 | 0.9 | 0.7 | 0.7 | 0.5 |
| 5000 | 1.2 | 0.8 | 0.8 | 0.6 |
| 10000 | 1.3 | 1.0 | 0.9 | 0.7 |
| 20000 | 1.6 | 1.1 | 1.1 | 0.8 |
| 50000 | 1.9 | 1.4 | 1.3 | 1.0 |
| 100000 | 2.2 | 1.6 | 1.6 | 1.1 |
| 200000 | 2.6 | 1.8 | 1.8 | 1.3 |

Table 14: Anchor Penetrations for different sizes of vessel in the expected soil conditions

The main mitigation for the hazard of anchor strike is generally burial beneath the identified threat line for a given return period / acceptable level of risk. This has been calculated in terms of a recommended depth of lowering along the length of each cable to sufficiently protect it to reduce the risk below acceptable levels. As such the recommended depth of lowering will vary along the ECR depending on the modelled traffic density and the seabed composition.

## 5.4 CBRA Results

The threat lines based on modelled post-windfarm installation shipping density and seabed composition were produced for each of the five cable route options. The threat lines were interpreted to define recommended burial depths for sections of the cables to satisfy the risk requirement and minimise burial depth where possible to reduce installation costs through maximising tooling choice and reducing installation schedules. The results for each cable are summarised below and shown clearly in the provided alignment charts (Appendix C). The tables detail the recommended depth of lowering of the cable within zones established along the cable length. The strike return period and corresponding DNV risk category (Ref. 13) is also stated for each zone along with the values for the entire cable. The strike return period is equal to $1/P_{strike}$. As $P_{strike}$ is annualised, this gives the theoretical period in years between anchor strikes on the cable based on the probabilistic

CBRA calculation i.e. the number of years statistically within which one anchor strike will occur.

| DNV Risk Category | $P_{Strike}$ | Return Period (years) |
|---|---|---|
| 1 | <0.00001 | 100,000+ |
| 2 | 0.00001 - 0.0001 | 10,000 to 100,000 |
| 3 | 0.0001 - 0.001 | 1,000 to 10,000 |
| 4 | 0.001 - 1 | 1 to 1,000 |

Table 15: DNV Risk categories (Ref. 8)

| Cable Start/End Point | | Zone Length (km) | Recommended Burial Depth (m) | Strike Return Period (Years) | DNV Risk Category |
|---|---|---|---|---|---|
| KP Start (km) | KP End (km) | | | | |
| 0.000 | 14.500 | 14.5 | 0.75 | ∞ | 1 |
| 14.500 | 29.000 | 14.5 | 1.00 | 81,263 | 2 |
| 29.000 | 100.500 | 71.5 | 0.50 | 21,189 | 2 |
| 100.500 | 102.500 | 2.0 | 1.00 | 276,165 | 1 |
| 102.500 | 109.500 | 7.0 | 0.50 | 140,483 | 1 |
| 109.500 | 123.943 | 14.4 | 1.00 | 22,089 | 2 |

Table 16: ECR Option A CBRA Results Summary

| Cable Start/End Point | | Zone Length (km) | Recommended Burial Depth (m) | Strike Return Period (Years) | DNV Risk Category |
|---|---|---|---|---|---|
| KP Start (km) | KP End (km) | | | | |
| 0.000 | 14.500 | 14.5 | 0.75 | ∞ | 1 |
| 14.500 | 29.000 | 14.5 | 1.00 | 81,263 | 2 |
| 29.000 | 100.500 | 71.5 | 0.50 | 21,189 | 2 |
| 100.500 | 102.500 | 2.0 | 1.00 | 276,165 | 1 |
| 102.500 | 109.500 | 7.0 | 0.50 | 140,483 | 1 |
| 109.500 | 137.000 | 27.5 | 1.00 | 15,486 | 2 |
| 137.000 | 158.058 | 21.1 | 0.50 | 73,909 | 2 |

Table 17: ECR Option A1 CBRA Results Summary

| Cable Start/End Point | | Zone Length (km) | Recommended Burial Depth (m) | Strike Return Period (Years) | DNV Risk Category |
|---|---|---|---|---|---|
| KP Start (km) | KP End (km) | | | | |
| 14.500 | 29.000 | 14.5 | 1.00 | ∞ | 1 |
| 29.000 | 101.500 | 72.5 | 0.50 | 81,263 | 2 |
| 101.500 | 102.700 | 1.2 | 1.00 | 20,402 | 2 |
| 102.700 | 113.500 | 10.8 | 0.50 | 524,507 | 1 |
| 113.500 | 117.500 | 4.0 | 1.00 | 124,567 | 1 |
| 117.500 | 119.000 | 1.5 | 0.50 | 52,681 | 2 |
| 119.000 | 123.200 | 4.2 | 1.50 | 933,146 | 1 |

Table 18: ECR Option A2 CBRA Results Summary

| Cable Start/End Point | | Zone Length (km) | Recommended Burial Depth (m) | Strike Return Period (Years) | DNV Risk Category |
|---|---|---|---|---|---|
| KP Start (km) | KP End (km) | | | | |
| 0.000 | 14.500 | 14.5 | 0.75 | ∞ | 1 |
| 14.500 | 29.000 | 14.5 | 1.00 | 81,263 | 2 |
| 29.000 | 79.000 | 50.0 | 0.50 | 30,979 | 2 |
| 79.000 | 88.000 | 9.0 | 1.00 | 48,812 | 2 |
| 88.000 | 108.000 | 20.0 | 0.50 | 56,517 | 2 |
| 108.000 | 114.500 | 6.5 | 1.00 | 47,980 | 2 |
| 114.500 | 118.677 | 4.2 | 1.50 | 107,911 | 1 |

Table 19: ECR Option B CBRA Results Summary

| Cable Start/End Point | | Zone Length (km) | Recommended Burial Depth (m) | Strike Return Period (Years) | DNV Risk Category |
|---|---|---|---|---|---|
| KP Start (km) | KP End (km) | | | | |
| 0.000 | 14.500 | 14.5 | 0.75 | ∞ | 1 |
| 14.500 | 29.000 | 14.5 | 1.00 | 81,263 | 2 |
| 29.000 | 79.000 | 50.0 | 0.50 | 30,979 | 2 |
| 79.000 | 92.000 | 13.0 | 1.00 | 40,189 | 2 |
| 92.000 | 125.000 | 33.0 | 0.50 | 38,384 | 2 |
| 125.000 | 137.000 | 12.0 | 1.00 | 37,507 | 2 |
| 137.000 | 150.221 | 13.2 | 0.50 | 89,348 | 2 |

Table 20: ECR Option C CBRA Results Summary

| Cable | Cumulative Pstrike | Cumulative Impact period (years) | DNV Risk Category |
|---|---|---|---|
| A | 0.00011 | 8,657 | 3 |
| A1 | 0.00014 | 6,741 | 3 |
| A2 | 0.00010 | 9,940 | 3 |
| B | 0.00011 | 8,859 | 3 |
| C | 0.00013 | 7,498 | 3 |

Table 21: Cumulative CBRA Results Summary for Each ECR Option

### 5.4.1 Results Discussion and Summary

The results of the CBRA have allowed the determination of suitable target depth of burial along all four cable routes. The outcome of the analysis has shown that no individual sections of the cable, when categorised by the recommended DOB, have a DNV risk category above 2 (equivalent to the probability of the cable being struck by an anchor being between 10,000 and 100,000 years). There is no standard of what risk level is acceptable, and this is down to the developers appetite to risk, and the lowering of costs during the installation phase, but typically across the industry having a risk of DNV Category 2 is considered appropriate for export cable sections. Here, for each option, the total cumulative risk is DNV category 3, although typically at the upper end of this category. This risk is still considered low-medium by DNV, which is based upon oil and gas assets and the implications which come from failure of those assets, including environmental etc. The DNV categories are commonly discussed to be considered onerous and therefore DNV Category 3 for the cumulative risk profile of a full export route, especially given the length of the routes, is considered acceptable, although this should be confirmed by the developer. Reductions in risk can be found with increased burial depths in local sections of the export route or generally across the route length.

In some cases, the period of impact is infinite. This effect occurs in some areas where the recommended DoL is below the calculated threat level, resulting in there being no chance of damage to the cable based on the historic data within the CBRA calculation. A rogue anchor strike cannot be ruled out completely however, especially when considering the high sediment mobility across large areas of the cable corridor, which could cause cable exposure over time even if DoL is achieved. The total length of the cable routes designated for each DoL is detailed in Table 22 below.

| | | **Route Option** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **A** | | **A1** | | **A2** | | **B** | | **C** | |
| **Burial Depth (m)** | **0.5** | 63.3 % | 78.5 km | 63 % | 99.6 km | 68.8 % | 84.8 km | 59 % | 70 km | 64 % | 96.2 km |
| | **0.75** | 11.7 % | 14.5 km | 9.2 % | 14.5 km | 11.8 % | 14.5 km | 12.2 % | 14.5 km | 9.7 % | 14.5 km |
| | **1** | 25 % | 30.9 km | 27.8 % | 44 km | 16 % | 19.7 km | 25.3 % | 30 km | 26.3 % | 39.5 km |
| | **1.5** | 0 % | 0 km | 0 % | 0 km | 3.4 % | 4.2 km | 3.5 % | 4.2 km | 0 % | 0 km |

Table 22: Total ECR Lengths and Percentages at each DoL

All route options share the same route for the first 57.67km, and therefore have the same recommended DoL. 0.75m is recommended for the first 14.5km, where the shallow bathymetry means a there is a greater chance of the vessel master dropping anchor in an emergency situation, and the upper sediment layer consists of sand. Further offshore, between KP14 and KP29, the DoL increases to 1m where the routes pass through three areas where the AIS suggests shipping lanes are present – though these are not marked on admiralty charts.

After KP29, there is a long section of all the route options with recommended DoL of 0.5m. With the exception of several short distinct sections, the risk of an anchor strike in this section is very low. The DoL is 0.5m to provide stability to the cable in areas of mobile sediment and prevent damage from non-penetrative sources of external aggression such as fishing gear.

Further offshore, after the 'node split' where the cable route options diverge, each options has differing sections of 0.5m, 1m and 1.5m DoL. In areas of 0.5m burial, generally the threatline is shallower due to reduced vessel traffic in combination with the presence of higher-strength clay and till within the burial profile. Conversely, other sections have a recommended DoL of 1m and 1.5m due to either higher vessel traffic increasing the anchor strike probability, or areas of softer loose sands resulting in greater anchor penetration. Only route options A2 and B have been designated a target DoL of of 1.5m, due to a short section at the end of their routes encountering a higher-risk area. This is caused by a decrease in depth as the Bank is approached. Route option A enters the area, though slightly to the north. This slight difference in route means a difference in bathymetry and vessel traffic encountered, so 1m burial was still sufficient to produce an acceptable strike return period. Though option A1 also enters this area, it continues past it on a longer overall route, which means this relatively shallow section has a smaller influence on the cumulative risk profile, resulting in 1m burial still producing an acceptable strike return period for the route.

# 6. BURIAL ASSESSMENT STUDY

## 6.1 Overview

As described previously, GM have assessed seabed conditions for the export cable routes to define recommendations for cable installation methodology. Burial techniques considered, at this stage, to be most appropriate for the site, can be taken forwards for further consideration when additional information becomes available.

At a high level, the site can be described as consisting primarily of sand or medium to stiff clays within the top sediment layer, with varying thickness up to 3m. There are areas in which the surface sediments are thin, with underlying hard substrate of till type material.

## 6.2 Cable Lay Options

The main construction options available for the offshore sections of the cable burial are:

- Post-lay burial of the cable utilising separate cable lay and burial campaigns with cable buried by cable plough or trencher after it has been laid on the seabed.
- Simultaneous lay and burial with a cable plough or trencher deployed and operated from the cable lay vessel.
- Pre-lay trenching utilising separate trenching and cable lay campaigns where the trench is pre-cut by a large plough or trencher followed by cable lay directly into an open trench followed by backfill by plough, natural backfill or rock placement.

The most appropriate method will depend on a number of factors, for example the cable type being approved for the method to be utilised or the required vessel/trenching tool combination being available for the desired installation dates and the burial conditions on the cable route. These three methods are discussed briefly below.

### 6.2.1 Post-Lay Burial

In a post-lay burial operation, the cable is laid onto the seabed by a cable installation vessel. The same vessel can then return to carry out cable burial with the cable in place. Alternatively, a different vessel could carry out burial at a later date.

With the post-lay burial method, there is a risk of damage to the unburied cable during the intermediate stage between cable lay and burial operations from primary threats or cable instability at seabed due to metocean conditions. Post-lay burial with tools such as jet trenchers and mechanical cutters can induce tensions into the pre-laid cable due to cable friction as the cable travels through the machine. This can lead to free spans in sand wave areas. In addition, a kink can develop in the cable ahead of the machine.

Operational risks are always present surrounding launch and recovery of the burial machine from the vessel, especially in high sea states. Landing the machine on the seabed safely over the cable can also be a challenging operation in energetic seas and will be performed according to weather limitations identified through installation analysis. Cable routing through the machine can also be problematic, most modern tools are equipped with manipulators to manually pick up and load the cable into the trencher for burial, however, there are some machines in service that require diver assistance.

#### 6.2.2 Simultaneous Lay and Burial

During simultaneous lay and burial, cables are laid and buried simultaneously with burial equipment (plough or burial sled) being towed by the cable laying vessel or barge or operated from the cable laying vessel where a self-propelled Remotely Operated Vehicle (ROV) is utilised generally for jetting or mechanical cutting burial methods. These may be free flying ROVs, or self-propelled tracked machines (TROVs).

This approach offers immediate protection to the cable and cable tension can be managed by the cable lay system as the cable enters the plough or trencher. The cable catenary can be monitored by ROV during the process.

#### 6.2.3 Pre-Lay Trenching

For this method, a separate vessel would tow a plough or operate a trencher to cut a trench in the seabed for which the cable can be laid into by the cable lay vessel in a separate operation.

Laying the cable into a pre-cut trench is sometimes considered to offer a low-risk construction method, whereby a plough/trencher is used to create a large trench, carrying out the aggressive soil cutting without the presence of the cable. The cable can then be laid into this trench and back filled by a second pass with a backfill plough. This approach would mean that the risk of damage to the cable is much reduced compared to the post lay burial and the simultaneous lay and burial techniques. However, difficulties exist in co-ordination of the two vessels working together in this way, for accurate positioning of the cable and for maintaining an open trench, due to sediment infill. Broad disturbance of the seabed in this manner may also be less desirable from an environmental consenting perspective.

### 6.3 Cable Burial Options

The results of the CBRA detailed in section 5.4 ultimately determine what type of burial tool to use to achieve the recommended DOL. In general, burial methods can be categorised as ploughing, jetting or mechanical cutting. Different burial tools are optimised to perform in certain sediments – the types of tools available on the market are discussed in sections 6.3.1, 6.3.2 and 6.3.3 below, and section 6.3.4 evaluates their suitability for the site based on conditions discussed in section  and the results of the CBRA, detailed in section 4.

#### 6.3.1 Cable Ploughs

Cable ploughing is the process of towing a subsea plough with a vessel with sufficient bollard pull capability to create a trench for the cable. This method has the largest effective range of soil conditions and will be suitable up to the dense / very dense sand and stiff clays. Ploughs are generally utilised for simultaneous lay and burial whereby the installation vessel tows the plough, and the cable is routed through the plough and laid into the open cut trench with assistance from a depressor on the plough. The trench can then either be left to backfill naturally or a backfill plough can be used to relocate the spoil from the initial trenching into the open trench on top of the laid cable.

Alternatively, ploughs can be used prior to cable lay to cut a trench along the lay route for which the cable can then be laid into. This may be required where boulder presence is a concern and the pre-lay trenching is used to clear smaller boulders, with some tooling setups quoting the capability to clear boulders up to 1m diameter. Where this is deemed necessary, specialist boulder clearance ploughs can be utilised. When pre-cutting a trench, this should only be undertaken if it can be performed close enough to cable lay operations or in a non-mobile seabed such that the trench will not naturally backfill prior to cable lay.

Some additional considerations should be made when considering ploughing operations. Firstly, manoeuvrability is restricted for ploughing compared with alternative burial methods. This limits the achievable cable turn radius and means that less complex lay routes can be achieved. Many ploughs also require longer burial transition lengths compared with alternate methods. Geological hazards should also be considered such as excessive seabed slope resulting in risk of tooling overturning or less control of cable burial depth, along with soft soils resulting in risk of plough sinkage. Tool selection should also be made considering features of available tooling on the market, for example some will require diver assistance for routing of the cable through the tooling and some will have diverless options which may be favourable in terms of project risk and commercial costs of diving operations.

As discussed, cable ploughs can work in a wide range of soils and are suitable for low to high strength clays which can be sheared but less suitable for dense sands which can increase tow force and likelihood of plough ride out. The high tow forces exhibited in sand are caused as the plough shears the granular material, this causes dilatancy in front of the shear. As the sand accumulates strain, the soil particles dilate, increasing void space. Pore pressures become negative causing apparent strength gain, until pore pressures eventually equalise due to water ingress. To reduce the high tow force generally exhibited in sands during ploughing, the cable plough shear can be fitted with a jet system. This addition of water reduces the negative pore pressure and therefore reduces the tow forces experienced.

The different types of cable burial ploughs are listed below:

- Conventional Narrow Share Cable Ploughs
- Advanced Cable Ploughs – a new generation of cable ploughs, which have been designed to achieve increased depth of lowering for subsea cables of depths up to 3.0 m.
- Rock Ripping Ploughs – suitable for outcropping rock, or where the seabed strata are exceptionally hard and beyond the capabilities of a conventional narrow share plough.
- Vibrating Share Ploughs - consists of a narrow share, which is vibrated to ensure cutting progress through difficult seabed conditions, such as gravel beds.

#### 6.3.2 Jet Trenchers

A jetting system works by fluidising and/or cutting the seabed using a combination of high flow low pressure and low flow high pressure water jets to cut into sands, gravels and soft to firm clays. Jetting tooling is generally effective from very loose up to medium dense or dense sands. In some cases, a dredging/eduction system is employed to suck out the fluidised material to leave an open trench into which the cable then falls by its own weight.

The mechanisms for jet trenching in clays and cohesionless sands/gravel soils are fundamentally different. Sands are most efficiently fluidised by a large volume of water (high flow / low pressure water jets) flowing over the trench cross sectional area, with a large water volume required to lift the sand particles into suspension. Coarser materials such as gravels fall rapidly through the water column and as a result it is very difficult to displace these soils and adequately bury a cable through coarse soils. Reduced DOL could be seen in areas of higher gravel content.

Conversely, in clays, the jet pressure (low flow / high pressure water jets) must be greater than a threshold value at which the clay can be cut, related to the undrained shear strength. As this pressure is partly generated through the available hydrostatic pressure at seabed, it may not be suitable in low water depths unless modified. A second pass may also be required utilising the high flow / low pressure setup, to remove the pre-cut clay blocks if the flow rate on the first pass is not sufficient.

The trench will naturally backfill due to settlement of sand particles out of suspension. Based on experience with jetting machines, between 60% and 80% backfill in the trench will be achieved to natural seabed level if one pass is required.

Jetting systems are most commonly used for post lay burial operations; however they can be used for simultaneous lay and burial. Tooling for this method are generally Tracked Remotely Operated Vehicles (TROVs) but may also be free flying tools or towed tools mounted on skids. Jetting nozzles are generally installed on two long jetting swords that are lowered into the seabed either side of the cable to fluidise / remove seabed material to allow the cable to be lowered. Sword lengths can be adjusted according to the required burial depth of the cable.

Jet trenchers generally reduce the risk of cable damage as there is no planned direct contact with the cable, and therefore can also be used near cable crossings. Multiple passes are possible in order to achieve target depth of lowering/depth of cover requirements. However, where deep burial is required, cable detection may be difficult.

Jetting tools are generally best suited to softer and looser ground conditions. Where bearing capacity of soil is a concern to support the TROV weight, buoyancy can be installed as required to reduce the submerged tooling weight, however lighter tools or free-flying tools are more susceptible to metocean conditions and may have high weather limitations. Tooling operations may be limited by water depth for submerged pumps to work, in which case surface water supply may be required when working in shallow water for example near landfall areas.

### 6.3.3 Mechanical Cutters

Mechanical trenchers are usually post lay burial machines suitable for consolidated high strength cohesive sediments and weak/fractured rock. They typically fall into two categories mechanical rock wheel cutters or mechanical chain Excavators. These two types are discussed below:

- Mechanical rock wheel cutters: Mechanical rock wheel cutters are used to cut narrow trenches into hard or rocky seabed and consist of a rotating wheel disc, which is fitted with rock cutting teeth.
- Mechanical chain Excavators: The chain Excavator tool consists of many cutting teeth and a further number of mechanical scoops which are used to transport the cut material away from the trench. An auger is sometimes in place, which helps move material away from the trench or clogging the chain cutters.

When trenching in hard clays and rock for both rock wheel cutter and mechanical chain trenchers a narrow slot is formed into which the cable is lowered. The material is removed as the action of the cutting causes it to be broken down into its constituent parts.

Significant thicknesses of sand and gravel are likely to hinder performance as the tool relies on the action of ripping cohesive soils. To aid with lowering, mechanical cutters can be fitted with a rear jet leg/eduction system which clears the trench of granular soils and back fill material. A mechanical cutter is generally fitted with a depressor which guides the cable through fluidised materials increasing DOL. On rocky outcrops, the seabed might be too uneven for the trencher to operate normally. Typically, sudden changes in elevation should be smaller than 0.3 m and slopes below 15°, although this is dependent on the size and limitations of the specific trencher. Aratellus' Leviathian Trencher, for example, has fully articulated separate tracks and so is likely to be much more capable of operating on an irregular, rocky seabed.

The magnitude of the seabed relief, in the context of the footprint of a mechanical trenching tool, must be understood in detail in order to assess the stability of the trencher and its ability to progress across the seafloor.

It is common that mechanical cutters are utilised for short sections of cable routes where required to trench within hard ground. These are generally avoided where possible due to slow progress rates, for this reason they are generally used for pre-lay or post-lay trenching rather than simultaneous lay and burial which would significantly slow the progress of the cable installation vessel.

Mechanical cutting tools are deployed and controlled from a vessel with sufficient capacity crane or A-frame LARS. They are generally TROV type vehicles and can include additional features such as cable loading manipulators. Cutting tool wear is a particular consideration for these tools, and rock wheel / cutting chain teeth should be selected carefully based on the seabed material.

Mechanical cutting can cause substantial suspension of sediments in the vicinity of the tool, which can be a risk for environmental consenting. The relevant authorities should be consulted on what mitigation is required, but this could include for example turbidity monitoring buoys.

#### 6.3.4 Cable Burial Tool Suitability

As described above, multiple different types of burial tools are available for subsea cable installation, however the performance of the tools will vary depending upon the sediment type and other factors. The general suitability of different burial equipment is given within Table 23, taken from the BERR report 2008 (Ref. 17).

| Cable Burial Devices | Burial Device Options | Sediment Type | | | | | |
|---|---|---|---|---|---|---|---|
| | | Sands | Silts | Gravel | Weak Clays | Stiff Clays | Rock |
| Cable Burial Ploughs | Conventional narrow share cable ploughs | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ |
| | Advanced cable ploughs | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ |
| | Modular cable ploughs | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ |
| | Rock ripping ploughs | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Vibrating share ploughs | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Tracked Cable Burial Devices | Jetting systems | ✓ | ✓ | ? | ✓ | ✗ | ✗ |
| | Rock wheel cutters | P | P | P | ✓ | ✓ | ✓ |
| | Chain excavators | P | P | ✓ | ✓ | ✓ | ✗ |
| | Dredging systems | ✓ | ? | ? | ✗ | ✗ | ✗ |
| Free Swimming ROVs with Cable Burial Capability | Jetting systems | ✓ | ✓ | ? | ✓ | ✗ | ✗ |
| | Dredging systems | ✓ | ? | ? | ✗ | ✗ | ✗ |
| Burial Sleds | Jetting systems | ✓ | ✓ | ? | ✓ | ✗ | ✗ |
| | Rock wheel cutters | P | P | P | ✓ | ✓ | ✓ |
| | Chain excavators | P | P | ✓ | ✓ | ✓ | ✗ |
| | Dredging systems | ✓ | ? | ? | ✗ | ✗ | ✗ |

KEY

| | | |
|---|---|---|
| ✓ | = | Should be capable of burial. |
| ? | = | Performance will be related to the type of sediment and the power delivery to the burial device. |
| P | = | Performance possible in the sediment type but not an ideal application. |
| ✗ | = | Unlikely to be capable of burial. |

Table 23: Burial Performance Comparison

Figure 15 below from DNV (Ref. 9) also summarises burial method suitability in various ground conditions and thus the optimum ground conditions for each burial tool can be derived. As can be seen for cutting, by adding a dredging (or jetting) system, the graph could be extended into looser materials. The figure also highlights that ploughing is more suitable for a wider range of soils. Therefore, in sites with variable material, ploughing could be the optimum tool. However, this is based purely on soil conditions, other factors such as water depth, seabed features and commercial factors all influence the choice of burial asset used.

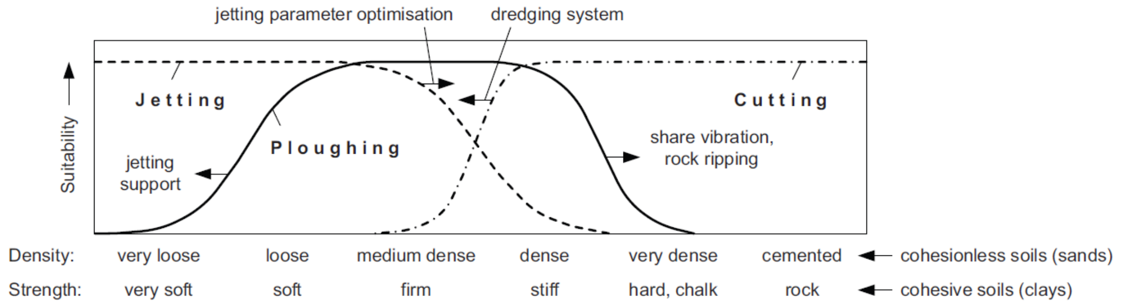



Figure 15: Indicative Burial Tool Suitability in Different Ground Conditions (Ref. 9)

In general, it can be summarised that the ploughing method is suitable for a wide range of ground conditions, jetting techniques are suitable for soft or loose soil conditions, and mechanical cutting is required in the hard or dense soils and rock.

The above is a guide that should be considered when selecting burial methodology, however, additional considerations need to be made with regards to the site conditions when selecting the burial tooling and methodology. For example, boulder presence within the lay route, geological features, potential mobility and expected metocean conditions will all factor into the decision-making process when selecting burial tooling, along with the overall methodology including if post-lay burial or simultaneous lay and burial will be most suitable. This is further described for each method in the sections below.

The three methods described above have differing anticipated progress rates within different seabed materials. These anticipated progress rates are shown in the table below:

| **Burial Tool** | **High Level Anticipated Progress Rate** | |
|---|---|---|
| | **Loose Sand / Soft Clay** | **Dense Sand / Stiff to Hard Clay and Rock** |
| Jet Trencher | 200-350 m/hr | 100-200 m/hr |
| Cable Plough | 200-400 m/hr | 200-400 m/hr |
| Mechanical Cutting | 200-350 m/hr | 70-150 m/hr |

Table 24: Anticipated Burial Tool Progress Rates

## 6.4 Burial Assessment Methodology

A preliminary burial assessment and tool suitability assessment has been undertaken for the cable route options for most commonly used tools, as described above. This assessment was based on the anticipated ground conditions along each cable as well as tool specifications and limitations that might affect suitability. Each tool to be used alone is graded into the following system:

- Suitable – Likely to achieve burial
- Possible – Unlikely to achieve consistent burial throughout
- Not Suitable – Unlikely to achieve burial

The tool suitability has been assessed for the seabed conditions and required burial depths for each of the export cable options. Broadly speaking, sections of the export cable routes can be categorised by burial class which is determined by the seabed composition within the target depth of lowering established within the CBRA (Section 5). These burial classes are shown below:

| Burial Class | Description | | Achievable Burial Depth |
|---|---|---|---|
| | General | Geology | |
| A | Full burial expected to target depth in a single trencher pass. Constant burial conditions with low variability.<br><br>Optimal plough or jetting progress rate. | Thick very loose to medium dense sands / silts and soft to firm clays.<br><br>Generally flat seabed and absence of features hindering burial operations. | Target or beyond |
| B | Reduced and variable burial conditions.<br><br>Reduced progress rate possible.<br><br>Potential for reduced success with jetting tools and / or multiple passes expected with potentially different tooling such as mechanical cutters. | Medium dense to dense sand and stiff to very stiff clay or loose / soft sediment sitting over a dense to very dense unit.<br><br>Minor bedforms, slopes <10 degrees expected to impact tool progress. | Within Target |
| C | Poor burial expected, with possible areas of cable exposure.<br><br>Slow progress rate with high risk of not achieving full burial. | Stiff to very stiff clay and up to very dense sand/silt and consolidated sediment / bedrock, or a thin unit of loose/soft sediment sitting over a dense to very dense unit or rock.<br><br>Bedform slopes > 10 degrees. | Potentially Less than Target |

Table 25: Cable Burial Classification

## 6.5 Burial Assessment Results

The results of this analysis, in the form of Burial Assessment tables, are shown in full in Appendix D. The most suitable tools for the sections of all of the cable route options are summarised in Figure 16. A summary of the burial class noted for each cable route is also provided in Table 26.

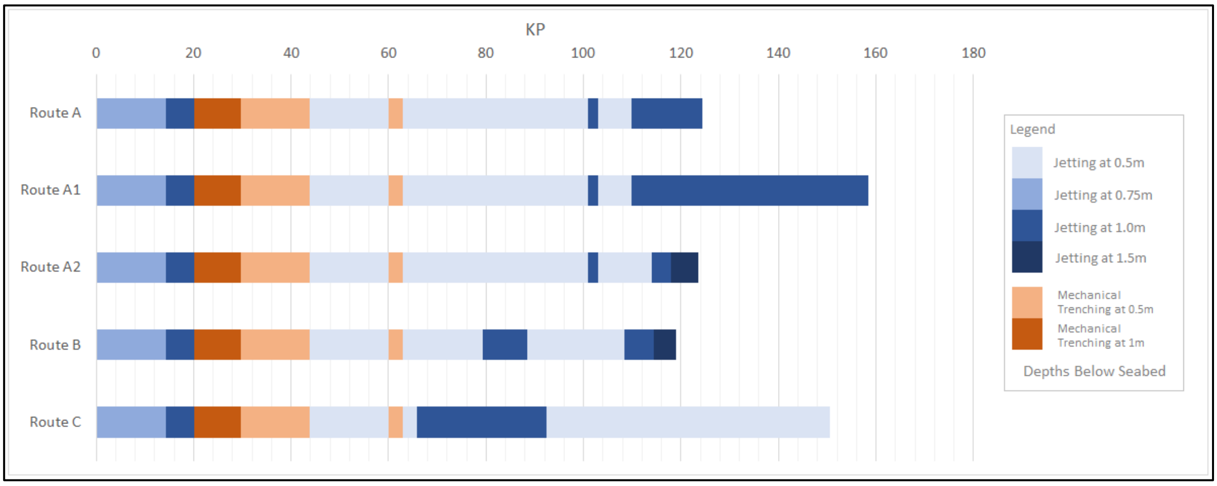



Figure 16: Burial Assessment Summary for All Cable Route Options

| | | Burial Class (By Distance in km) | | | Burial Class (By % of Route Length) | | |
|---|---|---|---|---|---|---|---|
| | | A | B | C | A | B | C |
| Route Option | A | 57.3 | 43.3 | 23.7 | 46.1 | 34.8 | 19.1 |
| | A1 | 91.4 | 43.3 | 23.7 | 57.7 | 27.3 | 15.0 |
| | A2 | 56.6 | 43.3 | 23.7 | 45.8 | 35.0 | 19.2 |
| | B | 90.1 | 5.3 | 23.7 | 75.6 | 4.5 | 19.9 |
| | C | 121.6 | 5.3 | 23.7 | 80.7 | 3.5 | 15.7 |

Table 26: Burial Class by Total Distance per Route and by Percentage of Route Length

Using the results from the CBRA and planning a burial strategy with regards to tool type and burial depths in the BAS allows the recommendation of an installation methodology of the options outlined in section 6.2, and suggested vessels and tools to conduct the operation. Burial depths are set at 0.5m, 0.75m, 1m, and 1.5m, with a combination of jetting (covering the majority of the routes) and mechanical trenching.

## 6.6 Recommended Cable Installation Methodology

The suggested cable lay methodology is a post-lay burial solution, using a powerful jetting tool in combination with Mechanical Trenching and potentially Mass Flow Excavation and remedial protection measures. The vast majority of the cable corridor(s) have soils that are suitable for jet trenching, with some small areas where jetting may become more difficult due to the presence of subcropping chalk, sandstone, limestone or mudstone bedrock. These areas occur for all routes in the nearshore between KP0.7 and KP2.3, and further offshore intermittently and sparsely between KP19.7 and KP28.5. In these limited areas, a tool that can be reconfigured with a mechanical chain cutter will be advantageous - mobilising a dedicated chain cutting tool and TSV in addition to a jetting spread may not be cost-effective. Subsea Rock Installation (SRI) may be required in these sections if the target DoL is not met after the trenching campaign, either due to challenging conditions preventing full burial being reached or for scenarios such as bights for tool deployment and grade-in/out. SRI is further described in section 6.6.5.

Mass or Controlled Flow Excavation (MFE or CFE) is further described in section 6.6.5. MFE/CFE may be required on the potentially mobile features in the export cable corridor between KP44 and KP72, and KP96 and KP101 on route options A, A1 and A2, and KP44 and KP109 on route option B and KP44 and KP122 on route option C. To determine precisely where MFE/CFE may be required, repeat bathymetric surveys should be conducted and used to calculate a stable seabed level (SSBL), equivalent to the depth below seabed at which sediments are not mobile. Where the sum of the depth of the mobile layer and DoL below the SSL are greater than a chosen burial tool's maximum burial depth capability, MFE/CFE will be required.

Post-lay burial is recommended to avoid the risk of trench infill by the surficial sands found over much of the corridors for each cable route option that could happen if a pre-lay trenching approach is used. Despite the risks outlined in section 6.2.1, most modern post-lay burial solutions are now equipped to mitigate issues locating and acquiring the cable on the seabed. As much of the route is jettable, using a dedicated jetting tool (or configuration of a hybrid tool) and a small amount of mechanical trenching maximises efficiency of the burial campaign, whilst separating the two burial phases allows more flexibility in scheduling. This method also decreases the amount of time a dedicated cable ship is required, as all the burial can be conducted using a TSV, after the cable is laid on the seabed.

Mechanical chain cutters should be sufficient for the mechanical trenching scope, as the sediments requiring excavation are stiff clay, glacial till or in fewer cases sedimentary rocks (i.e., mudstone, limestone and chalk). Tools capable of digging in extremely high-strength seabed such as rock-wheel excavators could be used but would not be suitable for most of the route length and are more limited in burial depth capability compared to chain cutters due to the diameter of their cutting wheels. A chain cutting tool with the ability to cut the highest strength bedrock to be encountered (850kPa) is recommended.

As less preferential options and depending on burial asset and vessel availability, simultaneous lay and burial using a jet-assisted plough, or pre-lay trenching if the sediments are stable enough could also be used. Simultaneous lay and burial is less preferential as there is a greater risk of damage to the cable during installation, and using this method may limit the cable ship that could be used, as it would need sufficient bollard pull for a plough and would take more time when compared to surface-laying the cable. Additionally, ploughs typically encounter grade-out issues and reduced or changeable burial in dense sands, which are likely to be present across much of the site.

Based on the water depths nearshore, most cable ships with relatively shallow draughts should be capable of getting close enough to shore during neap tides to safely carry out a cable float-in operation. To mitigate the risk of damage to the cable in between laying on the seabed and the burial campaign, guard vessel(s) can be utilised along with working with the relevant authorities to impose navigational restrictions on the cable route if feasible.

### 6.6.1 Suggested Jetting Tools

*Delta Subsea T1000 – Post-lay Burial*

The T1000 is a 750kW jetting ROV capable of up to 3m burial depth. It is capable of jetting in sands to firm clays up to 80kPa resistance, allowing it to cover the majority of the cable route. Whilst not amphibious, it can operate in as little as 0.5m, which in conjunction with a sufficient umbilical and cable ship or barge, would allow burial almost all the way onto shore. The T1000 is also self-propelled meaning a high bollard pull vessel is not required, and it can also be deployed under relatively high sea-state conditions.

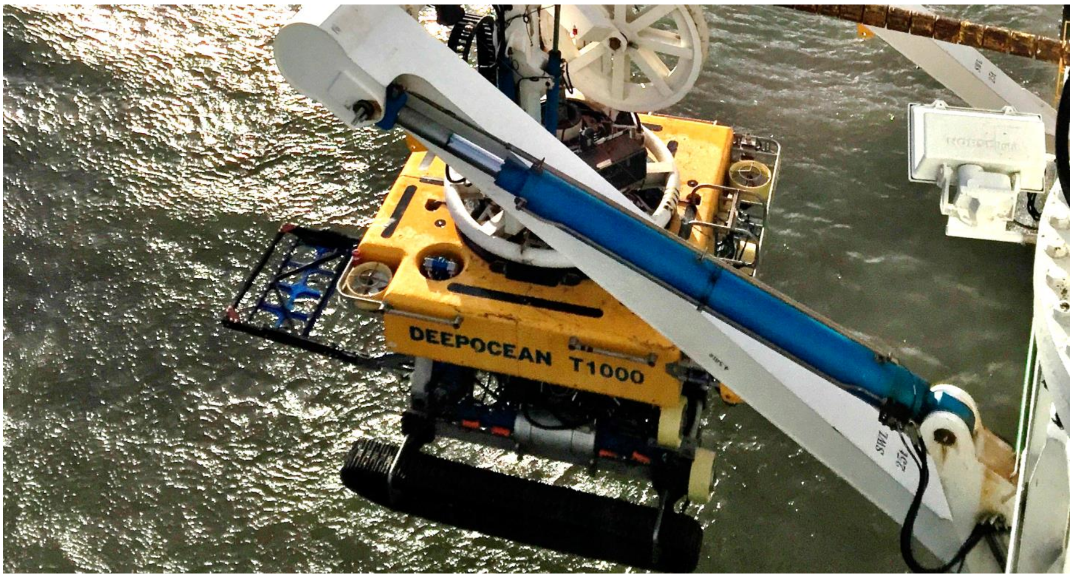



Figure 17: Delta Subsea's T1000 Jetting ROV

*Asso Subsea AssoJet III MK2 – Post Lay Burial*

As a more powerful jetting option, the newly developed AssoJet III MK2 has up to 1.56MW of power with a 3.2m burial depth capability, allowing it to work in soils up to 150kPa. This capability means it should achieve burial in approximately 80% of soil conditions across the site. The tool can be configured with sleds or tracks for towing or self-propelling and has multiple jetting sword options to cater for the expected soil conditions. It can be deployed in high-sea states and also has backfill/trench collapsing capability.

Figure 18: AssoJet III MK2 Jet Trencher

### 6.6.2 Suggested Combined Jetting and Mechanical Trenchers

*Jan de Nul UTV1200 – Post or Pre-Lay Burial*

This trencher, whilst not self-powered, has the ability to work over 1km from its support vessel due to the long umbilical available. It can use either a chain cutting tool or jetting sword to facilitate burial, both of which can be swapped at sea, saving on mobilisation and reconfiguration time. With the site conditions expected, the cutting tool would likely be the tool of choice for section of the cable with burial class C. The jetting sword could be used for sections classed A or B, the latter of which may need multiple jetting passes or cutting if jetting fails. The overall design is low and wide, meaning it will be stable in turbulent metocean conditions.

Figure 19: Jan de Nul's UTV1200 Mechanical cutter

*Boskalis Trenchformer – Post or Pre-lay Burial*

The Trenchformer is a 1200kW vehicle designed to work in sands, silts, clays and rock, using a variety of interchangeable tools. This means it could be used both for cutting and jetting scopes of the protection campaign, if reconfigured. It is suitable for post-lay trenching but can also work in simultaneous lay and burial mode. It has amphibious capability, meaning it could start burial on the beach and progress offshore, if deployed with a suitable cableship or barge. As with the UTV1200, the Trenchformer's cutting tool would be most suitable for areas designated burial class C, and the jetting spread could be used for areas classed A and B.

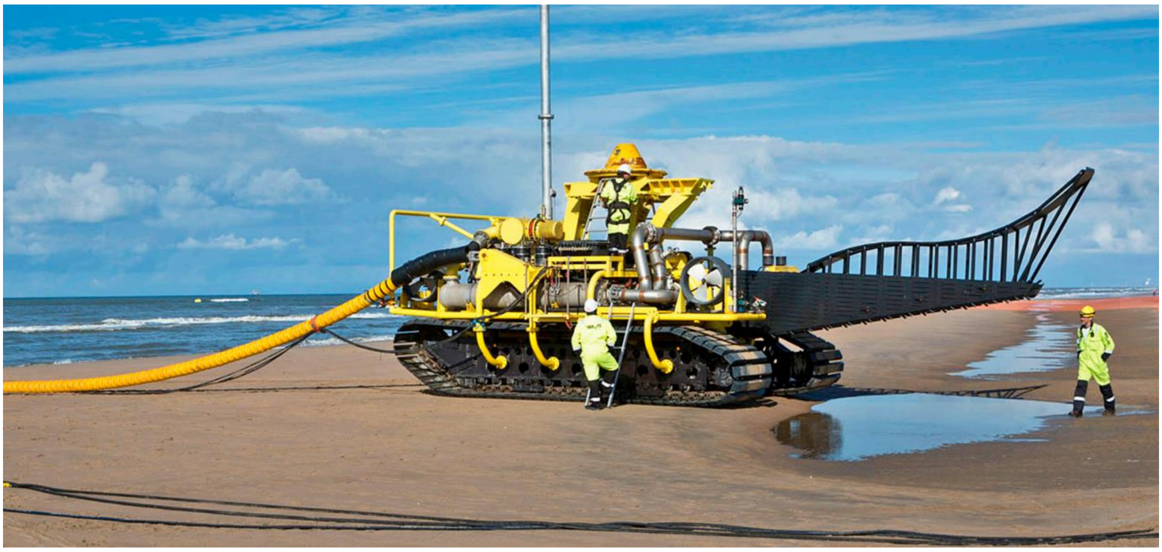


Figure 20: The Boskalis Trenchformer

### 6.6.3 Suggested Ploughing Tools

*Delta Subsea ACP2 Plough (or equivalent) – Simultaneous Installation and Burial*

As an alternative to post-lay jetting, simultaneous lay and burial of the cable could be conducted using a jet-assisted plough like the ACP2. Many companies now own and operate jet-assisted cable ploughs as they are cost-effective ways of installing cables based on the smaller well-established telecom cable ploughs. The main disadvantage of using ploughs is having to run the cable through them to achieve burial, which can increase the risk of cable damage. A jet-assisted plough should however perform well in all but the hardest soil conditions encountered on the route. Ploughs can also be started from the beach and towed offshore, allowing potentially uninterrupted burial from landing to deep water, though they can only be operated by a cable lay vessel with a sufficient bollard pull and A-frame.

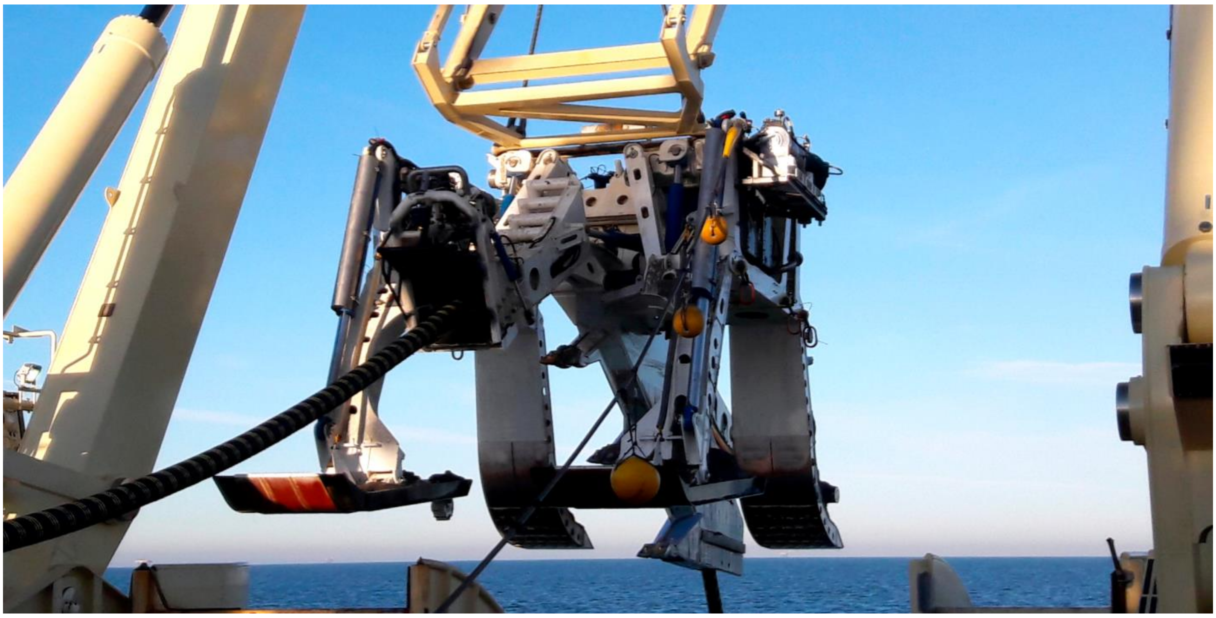


Figure 21: Delta Subsea's ACP2 cable plough

*Helix Energy i-plough – Pre-Lay Trenching and Post Lay Backfill*

As an alternate method to post-lay burial, the i-plough provides simultaneous boulder clearance and trenching to 1.9m depth, and can be reconfigured and re-deployed after cable lay to backfill the trench. The plough is a large and heavy tool, requiring a dedicated high bollard pull vessel, but is capable of trenching in firm clays and glacial till and can remove sub-surface boulders and deposit them to the sides of the trench. Though the plough may not be as effective in areas of sands, it could still be used to clear boulders and sand waves for a jetting tool to then bury the cable. If the surficial sands are stable enough and cable lay happens shortly after the plough runs, a jetting tool would not be required at all.

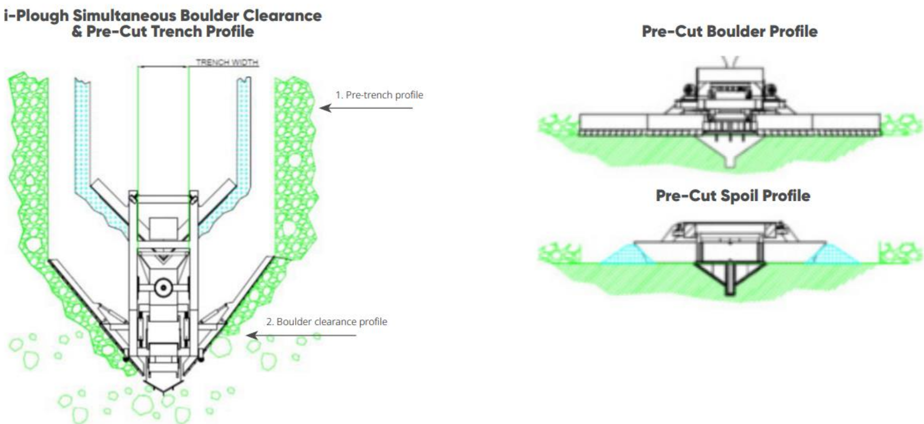



Figure 22: Diagram of the i-Plough's trenching profiles

### 6.6.4 Suggested Installation Vessels

*Boskalis Ndeavour*

Though not specifically a Cable barge, the Ndeavour has retractable thrusters allowing a flat-bottom draught of as little as 2.75m and the ability to beach itself, which would allow it to get very close to shore and minimise the length of a floated section of cable. The vessel has a 100Te SWL A-frame allowing for deployment of large trenching vehicles and tools.


Figure 23: Boskalis Ndeavour Cableship

*Cable Enterprise*

Prysmian's Cable Enterprise is a highly capable Cable Laying Barge with a 4000Te capacity carousel, DP2 positioning, a seven-point mooring system for station-keeping and beaching capability. Cable Enterprise has a 60Te A-frame and sufficient bollard pull for towing Burial tools that are not self-propelled, though it is larger and has a slightly deeper draught of 5m.


Figure 24: Prysmian’s Cable Enterprise Barge

*Delta Subsea Connector*

The Connector is a versatile cable ship with a demonstrated history of performing shore-end operations in shallow waters, including a successful beaching operation. With a minimum draught of 3.6m, it carries a 7000Te capacity turntable, a 60Te A-frame and has a 7-point mooring system. It has sufficient bollard pull for towing burial tools that are not self-propelled.


Figure 25: Delta Subsea’s Connector performing a beached cable landing

### 6.6.5 Suggested Remedial Protection and Seabed Preparation

*Mass or Controlled Flow Excavation*

MFE (also called CFE by some operators) is the process of trenching using a large, directed flow of water through a shaped funnel to 'blow' away loose sediment. MFE tools are relatively simple to operate, usually being deployed by crane from a surface vessel with an umbilical to deliver a power supply and will usually have on-board thrusters for accurate subsea positioning and station-keeping. They are most useful in the context of cable protection for seabed preparation in the form of levelling mobile sediment features to improve gradients, ease the reaching of DoL for trenchers and can also be used post cable laying to provide shallow remedial burial, for example of a Cable Protection System close to a J-tube on an offshore substation or wind turbine. They are either not economic or not suitable for reaching deeper burial depths, burying long sections of cable or for use in more consolidated sediments.


Figure 26: James Fisher Offshore's T4000 Controlled Flow Excavator

*Subsea Rock Installation or Rock Dumping*

Subsea Rock Installation (SRI) is the process of accurately piling rock on a location or along a route, using a specialised vessel and subsea tool. The vessels have large bulk stores for carrying the rock material, which is deposited via a fallpipe with a controllable opening at the seabed-end. The opening is controlled by the subsea tool, which usually features cameras and sonar to monitor the rock placement and thrusters for accurate positioning. SRI is typically used to provide scour protection to subsea structures and additional protection to buried or surface-laid products by means of 'artificially' increasing the burial depth.

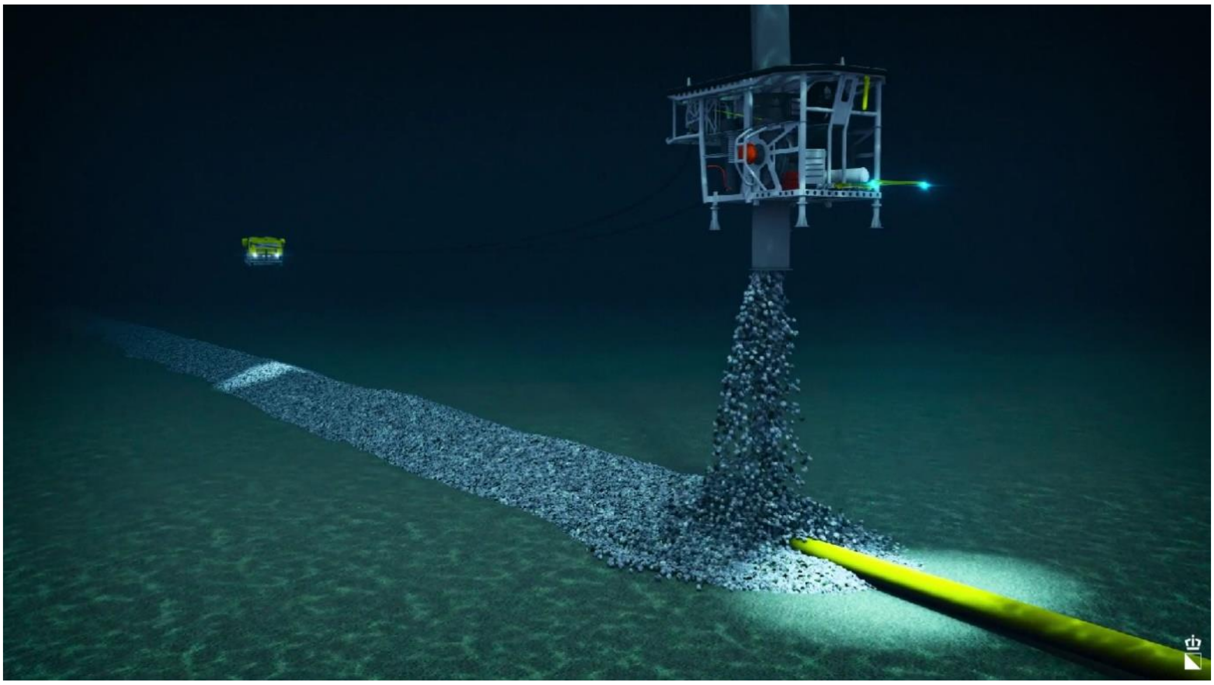


Figure 27: Boskalis’ Fall Pipe ROV with integrated inspection ROV conducting rock placement

# 7. CONCLUSIONS AND RECOMMENDATIONS

Global Maritime have conducted CBRA for the Dogger Bank South ECR options, including a review of the bathymetry and sub-seabed geology, and a resulting BAS, concluding on a recommended Depth of Lowering across all routes and suggested installation methodology.

The site conditions were assessed to determine the geological layers of the seabed within the export cable route option corridors. Using the provided Interim Ground Model Report 2DUHRS and SBP data from Fugro, geological units could be spatially defined along the routes, and simplified into a two-layer ground model for input into the CBRA calculations.

The site condition assessment and two-layer ground model were then utilised using Global Maritime's CBRA method with modelled post-windfarm installation vessel traffic to analyse the anchor strike risks to the cable and propose target burial depths along each RPL to minimise the risk to acceptable levels whilst also maintaining practical burial depths along each cable route. The burial depths and risk profile for each cable is detailed within the alignment charts appended.

The predominant geological conditions are areas of mobile sand features overlying either more (non-mobile) sand, sand and clay, clay, glacial till or chalk, mudstone or sandstone bedrock. The thickness of the upper softer sediment layer varies dramatically across the site, which strongly influenced the burial tool and installation methodology recommendation.

Key risks on the site can be defined as:

- Areas where shallow water, high vessel traffic and thinner or softer sediment layers coincide, resulting in a deeper DoL recommendation in areas with challenging burial conditions. These locations are as follows:
    - In the nearshore between KP0.000 and KP3.000, where the risk level is low but burial may be difficult in subcropping and outcropping bedrock
    - Between KP17.000 and KP29.000, where the calculated threatline depth results in a target DoL of 1m in the presence of subcropping bedrock within the burial profile
    - The last ~4km of routes A2 and B where the relatively shallow waters over Dogger Bank and presence of vessel traffic result in an increased DoL of 1.5m
- Large mobile features that may prevent DoL being achieved below the non-mobile layer, and create a hazard for the operation of burial tools due to steep gradients

It should be noted that whilst there is no specific acceptable risk value that must be attained through protection from anchor strike through burial, it is common for cables to be protected to specifications to DNV Cat 2, which is specified as a return period > 10,000 years. As this is not specified by cable length, target burial depths were determined based on maintaining > 10,000 years return period cumulative across each section of the cable routes as defined by changes in burial depth, hence where the cumulative return period across the entire cable routes in this case have a return period of less than 10,000 years.

As mentioned, a key driving factor when determining the required burial depth for anchor strike protection is the soil properties, as these dictate anchor penetration. It is recommended that the CBRA is re-run once a full SBP dataset is available for route A2 (if selected for installation) and following a route specific geotechnical survey. The results of the CBRA should also be computed once a final cable route has been chosen, as this study is performed on corridor centrelines only. With this additional information, it is also recommended that a detailed BAS with the specific burial tool(s) to be used for cable installation and consideration of the strengths of the geological units in relation to the specific tool's ability is conducted to further optimise the cable protection methodology, further reducing burial and vessel time.

# APPENDIX A DESIGN RISK REGISTER

# Geohazard & Geotechnical Risk Register (GRR) - Cables

| | |
|---|---|
| **Client :** | RED |
| **Project :** | Dogger Bank South Offshore Wind Farm Export Cables |
| **Project No :** | PRJ111361 |
| **Revision History:** | 3 |

| Revision | Date | Reason for Revision | Author | Reviewer | Approver |
|---|---|---|---|---|---|
| 1 | 28/04/2023 | First issue | FDI | MLA | MLA |
| 2 | 05/06/2023 | Second issue | FDI | MLA | MLA |
| 3 | 22/06/2023 | Third Issue | FDI | MLA | MLA |
| | | | | | |
| | | | | | |
| | | | | | |

## RISK MATRIX

| Severity | Consequences/ Impact | | | Probability | | | | |
|---|---|---|---|---|---|---|---|---|
| **Category** | **Injury/ Illness** | **Environmental Impact** | **Financial Loss/ Asset Damage/ Reputation** | **A (Very Unlikely)** | **B (Unlikely)** | **C (Possible)** | **D (Likely)** | **E (Very Likely)** |
| **1 (Negligible)** | Negligible injury or health implications, not affecting work performance or causing absence (First Aid Case) | - Pollution/ spills of <1 litre<br>- Minimal/ insignificant environmental impact | <USD $10,000, or <1% cost impact | L | L | L | M | M |
| **2 (Minor)** | Minor injury/ illness leading to Medical Treatment Case (MTC) | - Pollution/ spills between 1 - 10 litres<br>- Minor/ short term pollution impact | USD $10,000 - <USD $100,000, or 1-5% cost impact | L | L | M | M | M |
| **3 (Significant)** | Significant injury/ illness leading to Restricted Work Case (RWDC) | - Pollution/Spills between 10 - 100 litres<br>- Pollution with some worksite impact | USD $100,000 - <USD $500,000, or 5-10% cost impact | L | M | M | M | H |
| **4 (Serious)** | Serious injury/ill-health leading to days away from work (Lost Work Day Case - LWDC) | - Pollution/Spills between 100 litres - 100 m3<br>- Significant pollution with worksite and off-site impact | USD $500,000 - <USD $1,000,000, or 10-20% cost impact | M | M | M | H | H |
| **5 (Critical)** | Fatality(s), permanent disability, terminal occupational illness | - Pollution/Spills in excess of >100 m3<br>- Extensive pollution with long term implications or massive site impact | ≥USD $1,000,000, or >20% cost impact | M | M | H | H | H |

## GUIDELINES

| Severity | Further consequence/ impact definition | Probability | Probability Definition | Risk Level | | |
|---|---|---|---|---|---|---|
| **1 (Negligible)** | - Minimal injury or health implications requiring no treatment; no absence from work; requires first aid treatment only (First Aid Case FAC)<br>- Minimal or limited pollution effect/impact; negligible recovery work (spills of up to 1 litre of hydrocarbons, or an amount of other spill type resulting in equivalent environmental imapct)<br>- Insignificant or slight financial loss or equipment/ asset damage (<USD $10,000), or >1% of project/ asset cost<br>- Negligible damage to reputation, including some minor negative feedback | **A (Very Unlikely)** | - Not known by GM to have happened within the industry<br>- A freak combination of factors would be required for an incident to occur | **LOW** | As a guide, when a LOW risk level is calculated, then no additional controls are required. However monitoring should take place to ensure that the controls are implemented and where possible, improved. | **Acceptable**<br>Task/ Activity may be carried out by those authorised to do so |
| **2 (Minor)** | - Minor injury or illness requiring medical treatment (Medical Treatment Case - MTC)<br>- An Environmental incident contained within the site boundary; short-term impact; recovery work by worksite personnel (spills of 1-10 litres of hydrocarbons, or an amount of other spill type resulting in equivalent environmental imapct)<br>- Minor financial loss, or repairs required for damaged asset/ equipment (USD $10,000 - <USD $100,000), or 1-5% of project/ asset cost<br>- Formal complaint by a Client or 3rd party (reputation damage) | **B (Unlikely)** | - Unlikely to occur<br>- May have happened once at GM, or in the industry<br>- A rare combination of factors would be required for an incident to occur | **MEDIUM** | Where a risk level has been calculated to be MEDIUM, further controls should be identifed where possible, in order to reduce the risk to As Low As Reasonably Practical (ALARP). | **Tolerable**<br>Task/ Activity may only proceed with Management authorisation |
| **3 (Significant)** | - Restricted Work Case (RWC) injury; without long term disablement<br>- An Environmental incident went beyond the site boundary, moderate short-term impact, recovery may requires external assistance (10-100 litres of hydrocarbons, or an amount of other spill type resulting in equivalent environmental imapct)<br>- Damage to property/equipment requiring significant repair with costs up to USD $500,000, or 5-10% of project/ asset cost<br>- Local media coverage, and local community complaint | **C (Possible)** | - Could possibly occur<br>- Additional external factors to be combined/ present for an incident to occur | **HIGH** | A HIGH risk level is considered intolerable, and work must not commence or continue until the risk has been reduced significantly. If it is not possible to reduce the risk, work is not permitted | **Unacceptable**<br>Work must not proceed change task or further control measures required to reduce risk |
| **4 (Serious)** | - Serious injury/illness leading to days away from work or involving a single lost work day case (LWDC)<br>- Serious medium-term environmental effects; recovery requires external assistance; pollution incurring significant restitution costs (spills between 100 litres to 100 m3 of hydrocarbons, or an amount of other spill type resulting in equivalent environmental imapct)<br>- Damage to property/equipment resulting in major loss of operational capability; costs up to USD $1,000,000, or 10-20% of project/ asset cost<br>- Regional-level negative publicity/ media coverage | **D (Likely)** | - Has happened more often than once, at GM, or known to have happened multiple times within the industry<br>- An additional factor may be required to result in an incident | GLOBAL MARITIME<br>**Global Maritime Risk Matrix \| G-HSE-FM-002 \| Rev. 2** | | |
| **5 (Critical)** | - A fatality(s) or multiple serious injuries leading to permanent disability or terminal disease<br>- Extensive pollution with long-term implications or massive site impact and recovery work; very high restitution costs resulting in serious economic liability on the business; spill in excess of 100m3 of hydrocarbons, or an amount of other spill type resulting in equivalent environmental imapct)<br>- Damage with major long-term implications on operational capability; extensive costs in excess of USD $1,000,000 or >20% of project/ asset cost<br>- International negative publicity/ media coverage | **E (Very Likely)** | - A regular occurrence in the industry<br>- Almost inevitable that an incident will happen | | | |

## GEOHAZARD & GEOTECHNICAL RISK Register (GRR) - Cables

| Project Number: | PRJ111361 | | Project Name: | | | Dogger Bank South Offshore Wind Farm Export Cables | | | |
|---|---|---|---|---|---|---|---|---|---|
| GRR Review Date: | 22/06/2022 | | Project Manager: | | | Matthew Laing | | | |
| | | | Risk Evaluation | | | | Risk Evaluation | | |
| Ref. | | Hazard Details | Inherent Risk Severity | Inherent Risk Probability | Inherent Risk Level | Control Measures | Residual Risk Severity | Residual Risk Probability | Residual Risk Level |
| Cable Installation | PRJ111361 | | | | | | | | |
| 1 | Bedrock Outcropping at Seabed | Presence of outcropping rock can cause issues to cable installation.<br><br>Trenchability along those areas is highly dependable on the geotechnical parameters of the rock and cables might be not sufficiently protected if targeted burial depths are not achieved.<br><br>Exposed cables have increased risks to internal and external threats. | 3 | C | M | Detail assessment of the geotechnical parameters of the chalk, sandstone and mudstone units is recommended, in order to understand the burial feasibility, and wear on burial tools. Areas of thin mobile sand layers are likely to require burial into bedrock, as the target DoL is measured ffrom the stable seabed level.<br><br>Alternative protection methods such as rock dumping or mattressing might be required. | 2 | C | M |
| 2 | Hard Soils Within Burial Profile | Presence of hard soils can cause issues to cable installation.<br><br>Trenchability along those areas is highly dependable on the geotechnical parameters of the soils and cables might be not sufficiently protected if targeted burial depths are not achieved.<br><br>Exposed cables have increased risks to internal and external threats. | 3 | D | M | Detail assessment of the geotechnical parameters of the tertiary soil units is recommended, in order to understand the burial feasibility.<br>The recommended burial strategy already limits exposure, in so far as possible, with use of a mechanical trencher capable of excavating the stiffer clays and Glacial Till.<br>Alternative protection methods such as rock dumping or mattressing might be required. | 2 | D | M |
| 3 | Boulders at and within Seabed | Boulders of indurated and cemented material derived from the underlying geological units.<br><br>Boulders create obstructions for trenching and installation activities.<br><br>Buried boulders can cause reduced burial. | 4 | E | H | Detailed, high resolution bathymetric and side scan sonar survey.<br><br>Sympathetic routing design, resilient trenching methods, boulder clearance campaigns ahead of or simultaneous with trenching. | 2 | C | M |
| 4 | Soft Soils at and within Seabed | Presence of soft, unconsolidated soils can cause issues to cable installation.<br><br>Soft soils can cause trencher sinkage and less efficient trenching if not planned for. | 3 | D | M | Detailed installation engineering examining trencher types, bearing pressures and means of reducing bearing pressure if necessary. | 1 | B | L |

## GEOHAZARD & GEOTECHNICAL RISK Register (GRR) - Cables

| Project Number: | PRJ111361 | | | | Project Name: | Dogger Bank South Offshore Wind Farm Export Cables | | | |
|---|---|---|---|---|---|---|---|---|---|
| GRR Review Date: | 22/06/2022 | | | | Project Manager: | Matthew Laing | | | |
| | | | Risk Evaluation | | | | Risk Evaluation | | |
| Ref. | | Hazard Details | Inherent Risk Severity | Inherent Risk Probability | Inherent Risk Level | Control Measures | Residual Risk Severity | Residual Risk Probability | Residual Risk Level |
| 5 | Irregular Seabed | Presence of irregular seabed can cause issues with trencher traction and progress, also reduced burial where trencher tools pull out of seabed. | 3 | E | H | Detailed installation engineering examining trencher types, utilise suitable trencher.<br><br>Possible requirement for CFE to reduce gradients and burial depth required to achieve DoL. | 3 | C | M |
| 6 | Gravel Reduces Depth of Lowering | Gravels present within seabed soils, or even flints within chalk, may not be fully removed from trench, limiting the depth to which lowering can occur. | 3 | C | M | Evaluate detailed geotechnical and geophysical survey. Account for risk with increased trench depth and trenching methods to maximise suspension and eduction. | 3 | B | M |
| 7 | Peat or Organic Material within Burial Profile | Organic materials in soil can reduce jettability | 3 | B | M | Interrogation of geotechncial samples, surficial sediments and sub-bottom data to ensure avoidance of any peat depositis within the corridor. | 3 | A | L |
| 8 | Shells and shell fragments reducing Depth of Lowering | Shells and shell fragments, may behave similarly to gravel, limiting the depth to which lowering can occur | 3 | C | M | Acquire and evaluate geotechncial data to assess the shell content in the seabed and how likely it will affect jetting. Account for risk with increased trench depth and trenching methods to maximise suspension and eduction. | 3 | B | M |
| **Cable Operation** | | | | | | | | | |
| 1 | Shipping | Ships can cause direct damage to exposed or insufficiently buried cables by deploying anchors either deliberately (in case of anchorages) or accidentally over / next to a cable. Direct cable strike or more likely snagging of cable can cause damage to cable (and potentially the vessel). | 2 | E | H | Probabilistic assessment of shipping and estimation of likely anchor penetration depth relative to seabed geology and shipping activity. Conservative approach to be taken with regard to unknown factors (e.g. number of smaller vessels without AIS).<br><br>Determination of appropriate cable burial depths to provide adequate protection. | 1 | E | L |

## GEOHAZARD & GEOTECHNICAL RISK Register (GRR) - Cables

| Project Number: | PRJ111361 | Project Name: | Dogger Bank South Offshore Wind Farm Export Cables |
|---|---|---|---|
| GRR Review Date: | 22/06/2022 | Project Manager: | Matthew Laing |

| | | | Risk Evaluation | | | | Risk Evaluation | | |
|---|---|---|---|---|---|---|---|---|---|
| **Ref.** | | **Hazard Details** | **Inherent Risk Severity** | **Inherent Risk Probability** | **Inherent Risk Level** | **Control Measures** | **Residual Risk Severity** | **Residual Risk Probability** | **Residual Risk Level** |
| 2 | Fishing | Fishing activities can result in direct damage to exposed or insufficiently buried cables by fishing gear snagging on the cable. Also (greater) risk to the fishing vessel in the event of a snagging incident.<br><br>Fishing vessels account for a proportion of the traffic in the area. | 2 | C | M | Assessment of likely fishing gear penetration based on identified fishing types relative to seabed geology and recommendation of burial to sufficient depth to afford adequate protection.<br><br>Ongoing monitoring of fishing activity and methods as part of IMR regime.<br><br>Identification of new cables on nautical charts / fishermen awareness initiatives. | 2 | B | L |
| 3 | Fishing - future variations in equipment | Fishing methods and equipment could vary with time resulting in increased risk to the cables. | 2 | E | H | Ongoing monitoring of fishing activity and methods as part of IMR regime.<br><br>The risk to the cables should be reassessed if there is a significant change in fishing activities which results in greater penetration of fishing equipment into the seabed. If necessary, mitigation actions to be taken (deeper burial, rock dump, fishing exclusion zones, etc.).<br><br>Given the increased vessel running costs of deeper penetrating fishing gear (higher towing force), increase in this factor is considered unlikely, however it is possible that the locations of fishing grounds will change in future. | 2 | B | L |
| 4 | On-bottom Stability | Water depth and metocean conditions influence cable on bottom stability (abrasion / fatigue effects on surface laid cables, which could be exacerbated by the uneven seabed surface in areas of outcropping rock or sand waves). | 2 | E | H | Cables are planned to be buried for the entirety of the route. Where burial may not be possible, and alternative method of cable protection is to be considered. | 2 | A | L |

# GEOHAZARD & GEOTECHNICAL RISK Register (GRR) - Cables

| **Project Number:** | **PRJ111361** | | | **Project Name:** | **Dogger Bank South Offshore Wind Farm Export Cables** | | |
|---|---|---|---|---|---|---|---|
| **GRR Review Date:** | **22/06/2022** | | | **Project Manager:** | **Matthew Laing** | | |

| | | | **Risk Evaluation** | | | | **Risk Evaluation** | | |
|---|---|---|---|---|---|---|---|---|---|
| **Ref.** | | **Hazard Details** | **Inherent Risk Severity** | **Inherent Risk Probability** | **Inherent Risk Level** | **Control Measures** | **Residual Risk Severity** | **Residual Risk Probability** | **Residual Risk Level** |
| 5 | Dredging / Dumping | Dredging activity can result in direct damage to cables as well as exposure of buried cables or reduction in burial, increasing risk to primary hazards such as shipping or fishing. Over-burial by dumping, can result in exceeding cable thermal / physical design parameters. | 2 | B | L | Consultation with dredging licence holders, as required.<br><br>Identification of new cables on nautical charts / implementation of exclusion zones for dredging / dumping activity. | 2 | A | L |
| 6 | Mobile Sediment / Seabed Mobility | Highly mobile seabed may overtime expose the cable and potentially cause freespans if cable not buried to a sufficient depth.<br><br>Cable exposure increases risk of impact damage. Freespans can cause fatigue damage over time. | 4 | D | H | Detailed seabed mobility study findings provided by the client has been utilised when defining CBRA results.<br><br>Survey prior to the cable lay to confirm assessment of site / RPL(s). Regular survey of cables as part of IMR regime - with emphasis on areas anticipated to be mobile.<br><br>Reassessment of cable risks and mitigation works as required if cable becomes over-buried or exposed. | 2 | D | M |
| 7 | Soils with Insulative properties | Clays/till and peat can have insulating properties and increase the risk of overheating, which is exacerbated by deeper burial | 4 | C | M | Thermal resistivity tests of the Clay-rich till and potential peat deposits should be consulted, and burial depth reduced if required. Should burial depths need reducing, CBRA calculation should be run for route section to determine if the resultant pstrike and return period are acceptable | 2 | C | M |

# APPENDIX B DRAWINGS

# APPENDIX C CBRA ALIGNMENT CHARTS

# APPENDIX D BAS TABLES

| Route Option | KP Start | KP End | Water Depth (mLAT) | | Target Depth of Lowering (m) | Seabed Composition At Target Depth of Lowering | Burial Method Suitability | | | Burial Class | Remedial Protection | Key Risks in Zone | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Max | | | Jetting | Ploughing | Mechanical Cutting | | | | |
| A | 0.000 | 2.500 | 0 | 12 | 0.75 | SAND over CLAY (till). Some CHALK bedrock within 5m BSF | Possible | Suitable | Suitable | B | KP0.000 to KP2.250 | Subcropping CHALK between KP0.7 and KP2.5 may reduce achievable burial with Jetting or Ploughing | Shallow burial likely due to potential subcropping CHALK in nearshore, however the strike probability is very low in this section so shallow burial alone may be sufficient protection. |
| | 2.500 | 14.400 | 8 | 23 | 0.75 | SAND over CLAY (till) | Suitable | Possible | Not Suitable | A | | Shallow bank at KP5.6 will limit tidal and/or weather operational windows | |
| | 14.400 | 19.700 | 23 | 42 | 1 | SAND over CLAY (till) | Suitable | Possible | Not Suitable | A | | Subcropping till may limit jettability | |
| | 19.700 | 29.250 | 42 | 51 | 1 | SAND over CLAY (till) LIMESTONE and MUDSTONE Bedrock with overlying mobile SAND layer | Not Suitable | Possible | Suitable | C | | Jetting would allow burial in mobile sands, but underlying till will limit jettability | Mobile SAND varies in thickness from 0-3m |
| | 29.250 | 43.400 | 51 | 58 | 0.5 | CLAY (till) over SAND and CLAY CLAY (till) over Limestone and Mudstone Bedrock | Not Suitable | Possible | Suitable | C | | Clays of too high strength for jetting. Mobile sand present in some areas | Mobile SAND varies in thickness from 0-3m |
| | 43.400 | 59.700 | 53 | 61 | 0.5 | Mobile SAND over loose SAND and CLAY (till) | Suitable | Possible | Not Suitable | B | KP50.700 to KP50.900 | Potential subcropping CHALK bedrock. Langeled Pipeline crossing may require remedial protection for unburied crossing section. | Mobile SAND of 1.5m average thickness. Remedial Protection length will depend on Pipeline owner's requirement and burial tool's ability to get in close proximity with the pipeline. This will determine how close to the pipeline the trencher will have to grade-out and grade-in before and after the crossing. |
| | 59.700 | 62.500 | 59 | 60 | 0.5 | LIMESTONE and MUDSTONE Bedrock with overlying mobile SAND layer | Possible | Possible | Suitable | B | | Underlying bedrock will limit jettability. Large mobile sandwaves may require dredging to enable mechanical trenching. | Mobile SAND varies in thickness from 0-4.4m |
| | 62.500 | 100.500 | 55 | 59 | 0.5 | Mobile SAND over CLAY (till) Some CHALK bedrock within 5m BSF | Suitable | Possible | Not Suitable | B | | Potential subcropping CHALK bedrock. Mobile SAND of 1.5m average thickness | Mobile SAND varies in thickness from 1-2m |
| | 100.500 | 102.500 | 56 | 57 | 1 | Mobile SAND over Loose SAND | Suitable | Possible | Not Suitable | A | | Large mobile sandwaves may require dredging to enable jetting to DOL in non-mobile layer. Trench collapse in loose sands. | Mobile SAND varies in thickness from 0-5m |
| | 102.500 | 109.500 | 48 | 69 | 0.5 | Mobile SAND over Loose SAND Mobile SAND over CLAY Mobile SAND over CLAY (till) | Suitable | Possible | Not Suitable | A | KP108.880 to KP108.915 | Large mobile sandwaves may require dredging to enable jetting to DOL in non-mobile layer. Trench collapse in loose sands. | Mobile SAND varies in thickness from 0-5m. Remedial protection may be required in sections for potential intermittent outcropping till if jetting passes fail to achieve DoL. |
| | 109.500 | 123.940 | 22 | 50 | 1 | Mobile SAND over Loose SAND Mobile SAND over CLAY Mobile SAND over CLAY (till) | Suitable | Possible | Not Suitable | A | | Large mobile sandwaves may require dredging to enable jetting to DOL in non-mobile layer. Trench collapse in loose sands. | Mobile SAND varies in thickness from 0-5m |

| Route Option | KP Start | KP End | Water Depth (mLAT) | | Target Depth of Lowering (m) | Seabed Composition At Target Depth of Lowering | Burial Method Suitability | | | Burial Class | Remedial Protection | Key Risks in Zone | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Max | | | Jetting | Ploughing | Mechanical Cutting | | | | |
| A1 | 0.000 | 2.500 | 0 | 12 | 0.75 | SAND over CLAY (till). Some CHALK bedrock within 5m BSF | Possible | Suitable | Suitable | B | | Subcropping CHALK between KP0.7 and KP2.5 may reduce achievable burial with Jetting or Ploughing | Shallow burial likely due to potential subcropping CHALK in nearshore, however the strike probability is very low in this section so shallow burial alone may be sufficient protection. |
| | 2.500 | 14.400 | 8 | 23 | 0.75 | SAND over CLAY (till) | Suitable | Possible | Not Suitable | A | | Shallow bank at KP5.6 will limit tidal and/or weather operational windows | |
| | 14.400 | 19.700 | 23 | 42 | 1 | SAND over CLAY (till) | Suitable | Possible | Not Suitable | A | | Areas with shallow till could limit jetting to DOL | |
| | 19.700 | 29.250 | 42 | 51 | 1 | SAND over CLAY (till) LIMESTONE and MUDSTONE Bedrock with overlying mobile SAND layer | Not Suitable | Possible | Suitable | C | | Jetting would allow burial in mobile sands, but underlying till will limit jettability | Mobile SAND varies in thickness from 0-3m |
| | 29.250 | 43.400 | 51 | 58 | 0.5 | CLAY (till) over SAND and CLAY CLAY (till) over Limestone and Mudstone Bedrock | Not Suitable | Possible | Suitable | C | | Clays of too high strength for jetting. Mobile sand present in some areas | Mobile SAND varies in thickness from 0-3m |
| | 43.400 | 59.700 | 53 | 61 | 0.5 | Mobile SAND over loose SAND and CLAY (till) | Suitable | Possible | Not Suitable | B | | Potential subcropping CHALK bedrock. Langeled Pipeline crossing may require remedial protection for unburied crossing section. | Mobile SAND of 1.5m average thickness. Remedial Protection length will depend on Pipeline owner's requirement and burial tool's ability to get in close proximity with the pipeline. This will determine how close to the pipeline the trencher will have to grade-out and grade-in before and after the crossing. |
| | 59.700 | 62.500 | 59 | 60 | 0.5 | LIMESTONE and MUDSTONE Bedrock with overlying mobile SAND layer | Possible | Possible | Suitable | B | | Underlying bedrock will limit jettability. Large mobile sandwaves may require dredging to enable mechanical trenching. | Mobile SAND varies in thickness from 0-4.4m |
| | 62.500 | 100.500 | 55 | 59 | 0.5 | Mobile SAND over CLAY (till) Some CHALK bedrock within 5m BSF | Suitable | Possible | Not Suitable | B | | Potential subcropping CHALK bedrock. Mobile SAND of 1.5m average thickness | Mobile SAND varies in thickness from 1-2m |
| | 100.500 | 102.500 | 56 | 57 | 1 | Mobile SAND over Loose SAND | Suitable | Possible | Not Suitable | A | | Large mobile sandwaves may require dredging to enable jetting to DOL in non-mobile layer. Trench collapse in loose sands. | Mobile SAND varies in thickness from 0-5m |
| | 102.500 | 109.500 | 48 | 69 | 0.5 | Mobile SAND over Loose SAND Mobile SAND over CLAY Mobile SAND over CLAY (till) | Suitable | Possible | Not Suitable | A | KP105.259 to KP105.339 | Large mobile sandwaves may require dredging to enable jetting to DOL in non-mobile layer. Trench collapse in loose sands. | Mobile SAND varies in thickness from 0-5m. Remedial protection may be required in sections for potential intermittent outcropping till if jetting passes fail to achieve DoL. |
| | 109.500 | 124.600 | 22 | 50 | 1 | Mobile SAND over Loose SAND Mobile SAND over CLAY Mobile SAND over CLAY (till) | Suitable | Possible | Not Suitable | A | | Large mobile sandwaves may require dredging to enable jetting to DOL in non-mobile layer. Trench collapse in loose sands. | Mobile SAND varies in thickness from 0-5m |
| | 124.600 | 158.000 | 16 | 37 | 1 | SAND over SAND and CLAY (till) | Suitable | Possible | Not Suitable | A | | Subcropping till may limit jettability | Undetermined Region - designated as equivalent to Zone 8 in Fugro ECR Ground Model Report. |

| Route Option | KP Start | KP End | Water Depth (mLAT) | | Target Depth of Lowering (m) | Seabed Composition At Target Depth of Lowering | Burial Method Suitability | | | Burial Class | Remedial Protection | Key Risks in Zone | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Max | | | Jetting | Ploughing | Mechanical Cutting | | | | |
| | 0.000 | 2.500 | 0 | 12 | 0.75 | SAND over CLAY (till). Some CHALK bedrock within 5m BSF | Possible | Suitable | Suitable | B | KP0.000 to KP2.250 | Subcropping CHALK between KP0.7 and KP2.5 may reduce achievable burial with Jetting or Ploughing | Shallow burial likely due to potential subcropping CHALK in nearshore, however the strike probability is very low in this section so shallow burial alone may be sufficient protection. |
| | 2.500 | 14.400 | 8 | 23 | 0.75 | SAND over CLAY (till) | Suitable | Possible | Not Suitable | A | | Shallow bank at KP5.6 will limit tidal and/or weather operational windows | |
| | 14.400 | 19.700 | 23 | 42 | 1 | SAND over CLAY (till) | Suitable | Possible | Not Suitable | A | | Areas with shallow till could limit jetting to DOL | |
| | 19.700 | 29.250 | 42 | 51 | 1 | SAND over CLAY (till) LIMESTONE and MUDSTONE Bedrock with overlying mobile SAND layer | Not Suitable | Possible | Suitable | C | | Jetting would allow burial in mobile sands, but underlying till will limit jettability | Mobile SAND varies in thickness from 0-3m |
| | 29.250 | 43.400 | 51 | 58 | 0.5 | CLAY (till) over SAND and CLAY CLAY (till) over Limestone and Mudstone Bedrock | Not Suitable | Possible | Suitable | C | | Clays of too high strength for jetting. Mobile sand present in some areas | Mobile SAND varies in thickness from 0-3m |
| | 43.400 | 59.700 | 53 | 61 | 0.5 | Mobile SAND over loose SAND and CLAY (till) | Suitable | Possible | Not Suitable | B | KP50.700 to KP50.900 | Potential subcropping CHALK bedrock. Langeled Pipeline crossing may require remedial protection for unburied crossing section. | Mobile SAND of 1.5m average thickness. Remedial Protection length will depend on Pipeline owner's requirement and burial tool's ability to get in close proximity with the pipeline. This will determine how close to the pipeline the trencher will have to grade-out and grade-in before and after the crossing. |
| A2 | 59.700 | 62.500 | 59 | 60 | 0.5 | LIMESTONE and MUDSTONE Bedrock with overlying mobile SAND layer | Possible | Possible | Suitable | B | | Underlying bedrock will limit jettability. Large mobile sandwaves may require dredging to enable mechanical trenching. | Mobile SAND varies in thickness from 0-4.4m |
| | 62.500 | 100.500 | 55 | 59 | 0.5 | Mobile SAND over CLAY (till) Some CHALK bedrock within 5m BSF | Suitable | Possible | Not Suitable | B | | Potential subcropping CHALK bedrock. Mobile SAND of 1.5m average thickness | Mobile SAND varies in thickness from 1-2m. KP86.450 to KP96.750 lacking full survey data coverage. |
| | 100.500 | 102.500 | 56 | 57 | 1 | Mobile SAND over Loose SAND | Suitable | Possible | Not Suitable | A | | Large mobile sandwaves may require dredging to enable jetting to DOL in non-mobile layer. Trench collapse in loose sands. | Mobile SAND varies in thickness from 0-5m |
| | 102.500 | 113.500 | 35 | 67 | 0.5 | Mobile SAND over Loose SAND Mobile SAND over CLAY Mobile SAND over CLAY (till) | Suitable | Possible | Not Suitable | A | KP107.419 to KP107.474 KP108.880 to KP108.915 | Large mobile sandwaves may require dredging to enable jetting to DOL in non-mobile layer. Subcropping till may limit jettability | Mobile SAND varies in thickness from 0-5m. Remedial protection may be required in sections for potential intermittent outcropping till if jetting passes fail to achieve DoL.. |
| | 113.500 | 117.500 | 37 | 57 | 1 | Mobile SAND over SAND and CLAY | Suitable | Possible | Not Suitable | A | | Large mobile sandwaves may require dredging to enable jetting to DOL in non-mobile layer | Mobile SAND varies in thickness from 0-3m |
| | 117.500 | 123.200 | 22 | 54 | 1.5 | Mobile SAND over SAND and CLAY Mobile SAND over Loose SAND Mobile SAND over CLAY | Suitable | Possible | Not Suitable | A | | Large mobile sandwaves may require dredging to enable jetting to DOL in non-mobile layer | Mobile SAND varies in thickness from 0-5m |

| Route Option | KP Start | KP End | Water Depth (mLAT) | | Target Depth of Lowering (m) | Seabed Composition At Target Depth of Lowering | Burial Method Suitability | | | Burial Class | Remedial Protection | Key Risks in Zone | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Max | | | Jetting | Ploughing | Mechanical Cutting | | | | |
| B | 0.000 | 2.500 | 0 | 12 | 0.75 | SAND over CLAY (till). Some CHALK bedrock within 5m BSF | Possible | Suitable | Suitable | B | KP0.000 to KP2.250 | Subcropping CHALK between KP0.7 and KP2.5 may reduce achievable burial with Jetting or Ploughing | Shallow burial likely due to potential subcropping CHALK in nearshore, however the strike probability is very low in this section so shallow burial alone may be sufficient protection. |
| | 2.500 | 14.400 | 8 | 23 | 0.75 | SAND over CLAY (till) | Suitable | Possible | Not Suitable | A | | Shallow bank at KP5.6 will limit tidal and/or weather operational windows | |
| | 14.400 | 19.700 | 23 | 42 | 1 | SAND over CLAY (till) | Suitable | Possible | Not Suitable | A | | Areas with shallow till could limit jetting to DOL | |
| | 19.700 | 29.250 | 42 | 51 | 1 | SAND over CLAY (till) LIMESTONE and MUDSTONE Bedrock with overlying mobile SAND layer | Not Suitable | Possible | Suitable | C | | Jetting would allow burial in mobile sands, but underlying till will limit jettability | Mobile SAND varies in thickness from 0-3m |
| | 29.250 | 43.400 | 51 | 58 | 0.5 | CLAY (till) over SAND and CLAY CLAY (till) over Limestone and Mudstone Bedrock | Not Suitable | Possible | Suitable | C | | Clays of too high strength for jetting. Mobile sand present in some areas | Mobile SAND varies in thickness from 0-3m |
| | 43.400 | 59.700 | 53 | 61 | 0.5 | Mobile SAND over loose SAND and CLAY (till) | Suitable | Possible | Not Suitable | B | KP50.700 to KP50.900 | Potential subcropping CHALK bedrock. Langeled Pipeline crossing may require remedial protection for unburied crossing section. | Mobile SAND of 1.5m average thickness. Remedial Protection length will depend on Pipeline owner's requirement and burial tool's ability to get in close proximity with the pipeline. This will determine how close to the pipeline the trencher will have to grade-out and grade-in before and after the crossing. |
| | 59.700 | 62.500 | 59 | 60 | 0.5 | LIMESTONE and MUDSTONE Bedrock with overlying mobile SAND layer | Possible | Possible | Suitable | B | | Underlying bedrock will limit jettability. Large mobile sandwaves may require dredging to enable mechanical trenching. | Mobile SAND varies in thickness from 0-4.4m |
| | 62.500 | 79.000 | 55 | 59 | 0.5 | Mobile SAND over CLAY (till) Some CHALK bedrock within 5m BSF | Suitable | Possible | Not Suitable | A | | Potential subcropping CHALK bedrock. Mobile SAND of 1.5m average thickness | Mobile SAND varies in thickness from 1-2m |
| | 79.000 | 88.000 | 34 | 51 | 1 | Mobile SAND over Loose SAND | Suitable | Possible | Not Suitable | A | | Large mobile sandwaves may require dredging to enable jetting. | Mobile SAND varies in thickness from 0-5m |
| | 88.000 | 108.000 | 49 | 67 | 0.5 | Mobile SAND over Loose SAND Mobile SAND over Loose SAND and CLAY (till) | Suitable | Possible | Not Suitable | A | KP102.897 to KP102.951 KP104.358 to KP104.392 | Large mobile sandwaves may require dredging to enable jetting. Subcropping till may limit jettability | Mobile SAND varies in thickness from 0-5m. Remedial protection may be required in sections for potential intermittent outcropping till if jetting passes fail to achieve DoL. |
| | 108.000 | 114.000 | 38 | 60 | 1 | Mobile SAND over SAND and CLAY | Suitable | Possible | Not Suitable | A | | Large mobile sandwaves may require dredging to enable jetting. | Mobile SAND varies in thickness from 0-3m |
| | 114.000 | 118.677 | 22 | 50 | 1.5 | Mobile SAND over Loose SAND Mobile SAND over CLAY and CLAY (till) | Suitable | Possible | Not Suitable | A | | Large mobile sandwaves may require dredging to enable jetting. Subcropping till may limit jettability | Mobile SAND varies in thickness from 0-5m |

| Route Option | KP Start | KP End | Water Depth (mLAT) | | Target Depth of Lowering (m) | Seabed Composition At Target Depth of Lowering | Burial Method Suitability | | | Burial Class | Remedial Protection | Key Risks in Zone | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Max | | | Jetting | Ploughing | Mechanical Cutting | | | | |
| C | 0.000 | 2.500 | 0 | 12 | 0.75 | SAND over CLAY (till). Some CHALK bedrock within 5m BSF | Possible | Suitable | Suitable | B | KP0.000 to KP2.250 | Subcropping CHALK between KP0.7 and KP2.5 may reduce achievable burial with Jetting or Ploughing | Shallow burial likely due to potential subcropping CHALK in nearshore, however the strike probability is very low in this section so shallow burial alone may be sufficient protection. |
| | 2.500 | 14.400 | 8 | 23 | 0.75 | SAND over CLAY (till) | Suitable | Possible | Not Suitable | A | | Shallow bank at KP5.6 will limit tidal and/or weather operational windows | |
| | 14.400 | 19.700 | 23 | 42 | 1 | SAND over CLAY (till) | Suitable | Possible | Not Suitable | A | | Areas with shallow till could limit jetting to DOL | |
| | 19.700 | 29.250 | 42 | 51 | 1 | SAND over CLAY (till)<br>LIMESTONE and MUDSTONE Bedrock with overlying mobile SAND layer | Not Suitable | Possible | Suitable | C | | Jetting would allow burial in mobile sands, but underlying till will limit jettability | Mobile SAND varies in thickness from 0-3m |
| | 29.250 | 43.400 | 51 | 58 | 0.5 | CLAY (till) over SAND and CLAY<br>CLAY (till) over Limestone and Mudstone Bedrock | Not Suitable | Possible | Suitable | C | | Clays of too high strength for jetting. Mobile sand present in some areas | Mobile SAND varies in thickness from 0-3m |
| | 43.400 | 59.700 | 53 | 61 | 0.5 | Mobile SAND over loose SAND and CLAY (till) | Suitable | Possible | Not Suitable | B | KP50.700 to KP50.900 | Potential subcropping CHALK bedrock. Langeled Pipeline crossing may require remedial protection for unburied crossing section. | Mobile SAND of 1.5m average thickness. Remedial Protection length will depend on Pipeline owner's requirement and burial tool's ability to get in close proximity with the pipeline. This will determine how close to the pipeline the trencher will have to grade-out and grade-in before and after the crossing. |
| | 59.700 | 62.500 | 59 | 60 | 0.5 | LIMESTONE and MUDSTONE Bedrock with overlying mobile SAND layer | Possible | Possible | Suitable | B | | Underlying bedrock will limit jettability. Large mobile sandwaves may require dredging to enable mechanical trenching. | Mobile SAND varies in thickness from 0-4.4m |
| | 62.500 | 65.500 | 55 | 59 | 0.5 | Mobile SAND over CLAY (till)<br>Some CHALK bedrock within 5m BSF | Suitable | Possible | Not Suitable | A | | Potential subcropping CHALK bedrock. Mobile SAND of 1.5m average thickness | Mobile SAND varies in thickness from 1-2m |
| | 65.500 | 92.000 | 33 | 63 | 1 | Mobile SAND over loose SAND | Suitable | Possible | Not Suitable | A | | Large mobile sandwaves may require dredging to enable jetting | Mobile SAND varies in thickness from 0-5m |
| | 92.000 | 150.221 | 16 | 61 | 0.5 | Mobile SAND over loose SAND<br>Mobile SAND over SAND and CLAY (till)<br>Mobile SAND over SAND and CLAY | Suitable | Possible | Not Suitable | A | KP102.412 to KP102.476<br>KP112.216 to KP115.475<br>KP117.344 to KP117.393 | Large mobile sandwaves may require dredging to enable jetting. Subcropping till may limit jettability | Mobile SAND varies in thickness from 0-5m. Remedial protection may be required in sections for potential intermittent outcropping till if jetting passes fail to achieve DoL. |

| Route Option | KP Start | KP End | Length | % of Total | Tooling | Target Depth of Lowering (m) |
|---|---|---|---|---|---|---|
| A | 0 | 2.5 | 2.5 | 2.01 | Jetting | 0.75 |
| | 2.5 | 14.4 | 11.9 | 9.57 | Jetting | 0.75 |
| | 14 | 19.7 | 5.7 | 4.58 | Jetting | 1 |
| | 19.7 | 29.25 | 9.55 | 7.68 | Mechanical Trenching | 1 |
| | 29.25 | 43.4 | 14.15 | 11.38 | Mechanical Trenching | 0.5 |
| | 43.4 | 59.7 | 16.3 | 13.11 | Jetting | 0.5 |
| | 59.7 | 62.5 | 2.8 | 2.25 | Mechanical Trenching | 0.5 |
| | 62.5 | 100.5 | 38 | 30.56 | Jetting | 0.5 |
| | 100.5 | 102.5 | 2 | 1.61 | Jetting | 1 |
| | 102.5 | 109.5 | 7 | 5.63 | Jetting | 0.5 |
| | 109.5 | 123.94 | 14.44 | 11.61 | Jetting | 1 |

**Totals:**

| Tooling | Length (km) | Length (%) |
|---|---|---|
| Jetting | 97.84 | 78.69 |
| Mechanical Trenching | 26.5 | 21.31 |

| Burial Depth | Length (km) | Length (%) |
|---|---|---|
| 0.5m | 78.25 | 62.93 |
| 0.75m | 14.4 | 11.58 |
| 1.0m | 31.69 | 25.49 |
| 1.5m | 0 | 0.00 |

| Route Option | KP Start | KP End | Length | % of Total | Tooling | Target Depth of Lowering (m) |
|---|---|---|---|---|---|---|
| A1 | 0 | 2.5 | 2.5 | 1.58 | Jetting | 0.75 |
| | 2.5 | 14.4 | 11.9 | 7.51 | Jetting | 0.75 |
| | 14 | 19.7 | 5.7 | 3.60 | Jetting | 1 |
| | 19.7 | 29.25 | 9.55 | 6.03 | Mechanical Trenching | 1 |
| | 29.25 | 43.4 | 14.15 | 8.93 | Mechanical Trenching | 0.5 |
| | 43.4 | 59.7 | 16.3 | 10.29 | Jetting | 0.5 |
| | 59.7 | 62.5 | 2.8 | 1.77 | Mechanical Trenching | 0.5 |
| | 62.5 | 100.5 | 38 | 23.99 | Jetting | 0.5 |
| | 100.5 | 102.5 | 2 | 1.26 | Jetting | 1 |
| | 102.5 | 109.5 | 7 | 4.42 | Jetting | 0.5 |
| | 109.5 | 124.6 | 15.1 | 9.53 | Jetting | 1 |
| | 124.6 | 158 | 33.4 | 21.09 | Jetting | 1 |

**Totals:**

| Tooling | Length (km) | Length (%) |
|---|---|---|
| Jetting | 131.90 | 83.27 |
| Mechanical Trenching | 26.50 | 16.73 |

| Burial Depth | Length (km) | Length (%) |
|---|---|---|
| 0.5m | 78.25 | 49.40 |
| 0.75m | 14.40 | 9.09 |
| 1.0m | 65.75 | 41.51 |
| 1.5m | 0.00 | 0.00 |

| Route Option | KP Start | KP End | Length | % of Total | Tooling | Target Depth of Lowering (m) |
|---|---|---|---|---|---|---|
| A2 | 0 | 2.5 | 2.5 | 2.02 | Jetting | 0.75 |
| | 2.5 | 14.4 | 11.9 | 9.63 | Jetting | 0.75 |
| | 14 | 19.7 | 5.7 | 4.61 | Jetting | 1 |
| | 19.7 | 29.25 | 9.55 | 7.73 | Mechanical Trenching | 1 |
| | 29.25 | 43.4 | 14.15 | 11.45 | Mechanical Trenching | 0.5 |
| | 43.4 | 59.7 | 16.3 | 13.19 | Jetting | 0.5 |
| | 59.7 | 62.5 | 2.8 | 2.27 | Mechanical Trenching | 0.5 |
| | 62.5 | 100.5 | 38 | 30.74 | Jetting | 0.5 |
| | 100.5 | 102.5 | 2 | 1.62 | Jetting | 1 |
| | 102.5 | 113.5 | 11 | 8.90 | Jetting | 0.5 |
| | 113.5 | 117.5 | 4 | 3.24 | Jetting | 1 |
| | 117.5 | 123.2 | 5.7 | 4.61 | Jetting | 1.5 |

**Totals:**

| Tooling | Length (km) | Length (%) |
|---|---|---|
| Jetting | 97.10 | 78.56 |
| Mechanical Trenching | 26.50 | 21.44 |

| Burial Depth | Length (km) | Length (%) |
|---|---|---|
| 0.5m | 82.25 | 66.55 |
| 0.75m | 14.40 | 11.65 |
| 1.0m | 21.25 | 17.19 |
| 1.5m | 5.70 | 4.61 |

| Route Option | KP Start | KP End | Length | % of Total | Tooling | Target Depth of Lowering (m) |
|---|---|---|---|---|---|---|
| B | 0 | 2.5 | 2.5 | 2.10 | Jetting | 0.75 |
| | 2.5 | 14.4 | 11.9 | 9.99 | Jetting | 0.75 |
| | 14 | 19.7 | 5.7 | 4.79 | Jetting | 1 |
| | 19.7 | 29.25 | 9.55 | 8.02 | Mechanical Trenching | 1 |
| | 29.25 | 43.4 | 14.15 | 11.88 | Mechanical Trenching | 0.5 |
| | 43.4 | 59.7 | 16.3 | 13.69 | Jetting | 0.5 |
| | 59.7 | 62.5 | 2.8 | 2.35 | Mechanical Trenching | 0.5 |
| | 62.5 | 79 | 16.5 | 13.86 | Jetting | 0.5 |
| | 79 | 88 | 9 | 7.56 | Jetting | 1 |
| | 88 | 108 | 20 | 16.80 | Jetting | 0.5 |
| | 108 | 114 | 6 | 5.04 | Jetting | 1 |
| | 114 | 118.677 | 4.677 | 3.93 | Jetting | 1.5 |

**Totals:**

| Tooling | Length (km) | Length (%) |
|---|---|---|
| Jetting | 92.58 | 77.75 |
| Mechanical Trenching | 26.50 | 22.25 |

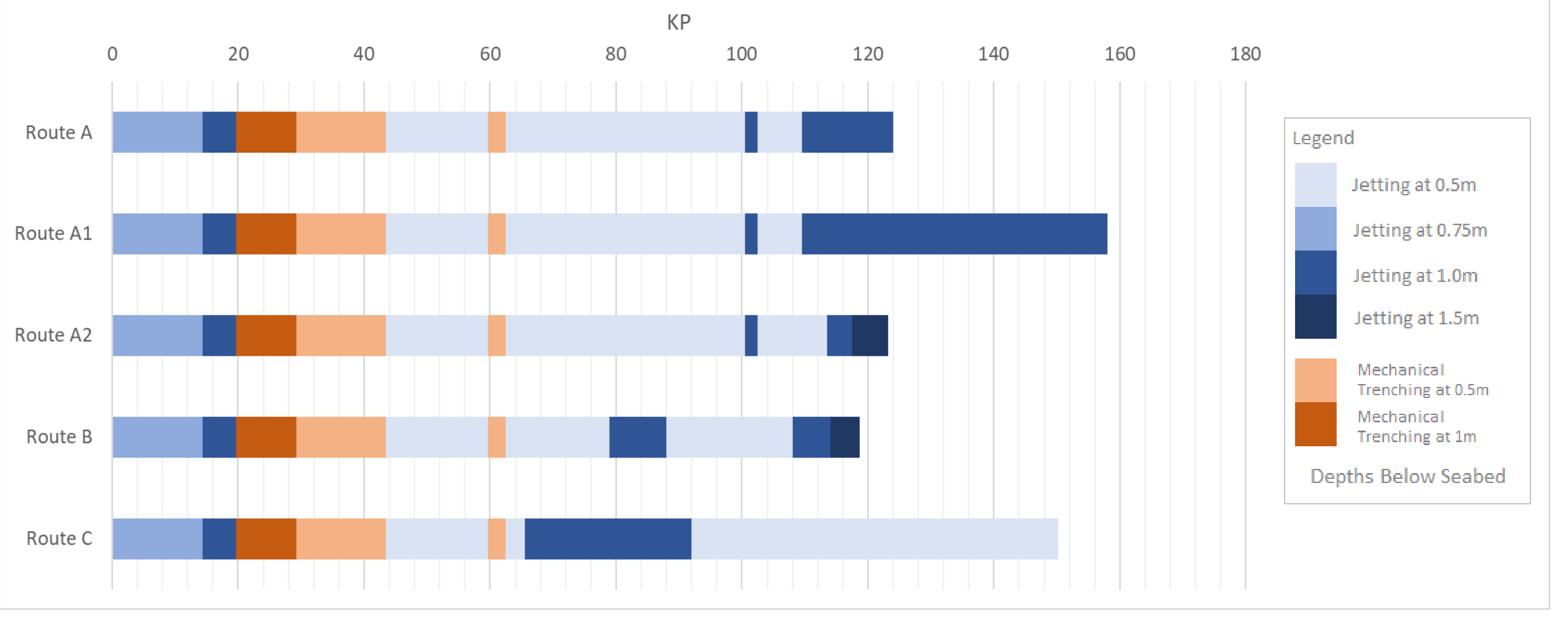
| Burial Depth | Length (km) | Length (%) |
|---|---|---|
| 0.5m | 69.75 | 58.58 |
| 0.75m | 14.40 | 12.09 |
| 1.0m | 30.25 | 25.40 |
| 1.5m | 4.68 | 3.93 |

| Route Option | KP Start | KP End | Length | % of Total | Tooling | Target Depth of Lowering (m) |
|---|---|---|---|---|---|---|
| C | 0 | 2.5 | 2.5 | 1.66 | Jetting | 0.75 |
| | 2.5 | 14.4 | 11.9 | 7.90 | Jetting | 0.75 |
| | 14 | 19.7 | 5.7 | 3.78 | Jetting | 1 |
| | 19.7 | 29.25 | 9.55 | 6.34 | Mechanical Trenching | 1 |
| | 29.25 | 43.4 | 14.15 | 9.39 | Mechanical Trenching | 0.5 |
| | 43.4 | 59.7 | 16.3 | 10.82 | Jetting | 0.5 |
| | 59.7 | 62.5 | 2.8 | 1.86 | Mechanical Trenching | 0.5 |
| | 62.5 | 65.5 | 3 | 1.99 | Jetting | 0.5 |
| | 65.5 | 92 | 26.5 | 17.59 | Jetting | 1 |
| | 92 | 150.221 | 58.221 | 38.65 | Jetting | 0.5 |

**Totals:**

| Tooling | Length (km) | Length (%) |
|---|---|---|
| Jetting | 124.12 | 82.41 |
| Mechanical Trenching | 26.50 | 17.59 |

| Burial Depth | Length (km) | Length (%) |
|---|---|---|
| 0.5m | 94.47 | 62.72 |
| 0.75m | 14.40 | 9.56 |
| 1.0m | 41.75 | 27.72 |
| 1.5m | 0.00 | 0.00 |



# APPENDIX E BAS RESULTS - SHAPEFILE

**RWE Renewables UK Dogger Bank South (West) Limited**

**RWE Renewables UK Dogger Bank South (East) Limited**

**Windmill Hill Business Park**
**Whitehill Way**
**Swindon**
**Wiltshire, SN5 6PB**