# ENERGINET - DANISH OFFSHORE WIND 2030

## Cable Burial Risk Assessment

**North Sea I - Nymindegab South Export Cable Route**

P2719_R6452_Rev1 | 25 June 2024

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# DOCUMENT RELEASE FORM

## Energinet - Danish Offshore Wind 2030

**P2719_R6452_Rev1**

Cable Burial Risk Assessment

North Sea I - Nymindegab South Export Cable Route

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# SUMMARY

Intertek Energy & Water (Intertek) has been appointed by Energinet to conduct a Cable Burial Risk Assessment (CBRA) study for the marine sections of the North Sea Nymindegab South cable route.

**Sediment Mobility**

Sediment mobility in itself does not pose a threat to a submarine cable, but it can lead to issues with the thermal conductivity of cables (over burial), and exposure of cables (scour); Over burial should be accounted for in the design phase of the cables and is usually dealt with by increasing, universally or locally, the cross-sectional area of the cables. Burial under excess soil can change the thermal properties of the soil and cause hotspots along the cable, while exposure increases the risk of damage due to external aggressors such as trawling and anchoring and potentially mechanical damage from free spans.

There are no areas within cable corridor where there are bedforms present. For the purposes of depth of lowering all depths recommended in this report are assumed to be measured against a horizontal plane which has been determined to be non-mobile and after any required route engineering has been undertaken to flatten mobile sediments.

**Fishing Risk**

The review of the fishing indicated areas of mobile and static fishing gear along the entire cable route. No fishing protection or exclusion areas from fishing activity were reported.

Moreover, as the entire route is within water depth ranges in which mobile gear fishing could take place, we recommend the cables are given sufficient protection from fishing gear interaction in all sections of the route. The Carbon Trust's guidance indicates that penetration of fishing gear into the seabed is limited to a maximum of 0.3 m penetration even in soft sediment based on previous literature research. Allowing for a Factor of Safety (FoS) of 2 means Recommended Minimum Depth of Lowering (RMDOL) based on fishing risk only would result in a value of 0.60m.

**Anchoring Risk**

Vessel Automatic Identification System (AIS) data has been used to determine the size and quantity of vessels which operate in the vicinity of the cable route. Vessels are grouped into size categories based on their deadweight tonnage (DWT) from Band A (0-100 DWT) to Band I (150K-200K DWT) and an appropriate associated anchor size is assigned to each band. Analysis of this data determines the probability of anchor-cable interactions for each vessel banding and thus the size of anchor which must be protected against in order to reduce risk to the cable to (As Low as Reasonably Practicable) ALARP.

The probabilistic assessment calculates the annual failure probability of 13% for the entire route (based on anchor risk alone) if surface laid. This value equates to a return period of 7.99 years and a failure probability over the (40 year) lifetime of 99.52%. This is not an acceptable level of risk.

Areas with the highest risk of Annual Failure include zones 1, 7,8 and, 10 These zones are areas of high vessel traffic and soft geology thus; increased anchor drag risk. The lowest zone of risk is zones 12, 14 and 15 given the low vessel traffic reducing all risk of anchor strike.

Note, the key reasons why anchor risk is not the key determinant in most zones is due to both the relatively light vessel densities and also the prevalent presence of soils which prevent anchors from penetrating very deeply.

**Recommended Minimum Depth of Lowering (RMDOL)**

The above approach results in a RMDOL varying from 0.65m to 1.7m. If these RMDOL values are achieved and maintained over the course of the cable lifetime then this would result in an annual failure rate of 0.00836% which equates to a return period of ~11,957 years and a failure probability over the (40 year) lifetime of 0.33% - i.e. "Event rarely expected to occur.".

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# GLOSSARY

**AIS**
Automatic Identification System

**ALARP**
As Low As Reasonably Practical

**BGS**
British Geological Survey

**CBRA**
Cable Burial Risk Assessment

**CPT**
Cone Penetration Test

**DMA**
Danish Maritime Authority

**DNV**
Det Norske Veritas

**DoL**
Depth of Lowering

**DoC**
Depth of Cover

**DTM**
Digital Terrain Model

**DWT**
Deadweight Tonnage

**EMODnet**
European Marine Observation and Data Network

**EU**
European Union

**F&S**
Fishing and Shipping

**FoS**
Factor of Safety

**GS**
Grab Sample

**hr**
Hour

**ICES**
International Council for the Exploration of the Sea

**IACS**
International Association of Classification Societies

**IMO**
International Maritime Organisation

**Intertek**
Intertek Energy and Water

**kg**
Kilogram

**KP**
Kilometre Positions

**kPa**
Kilopascal

**m**
Metre

**MAIB**
Marine Accident Investigation Branch

**MBES**
Multi-Beam Echo Sounder

**MMO**
Marine Management Organisation

**MPa**
Megapascal

**MPA**
Marine Protected Area

**MSFD**
Marine Strategy Framework Directive

**MTTF**
Mean Time of Failure

**nm**
Nautical Miles

**NTZ**
No-Take Zone

**O&M**
Operation and Maintenance

**PPA**
Partially Protected Area

**PCI**
Project of Common Interest

**RMDOL**
Recommended Minimum Depth of Lowering

**SAR**
Swept Area Ratio

**SBP**
Sub-Bottom Profiler

**SI**
Seabed Index

**SSS**
Side Scan Sonar

**TAC**
Total Allowable Catch

**TDOL**
Target Depth of Lowering

**ToP**
Top of the Product

**VC**
Vibro-Core

**yr**
Year

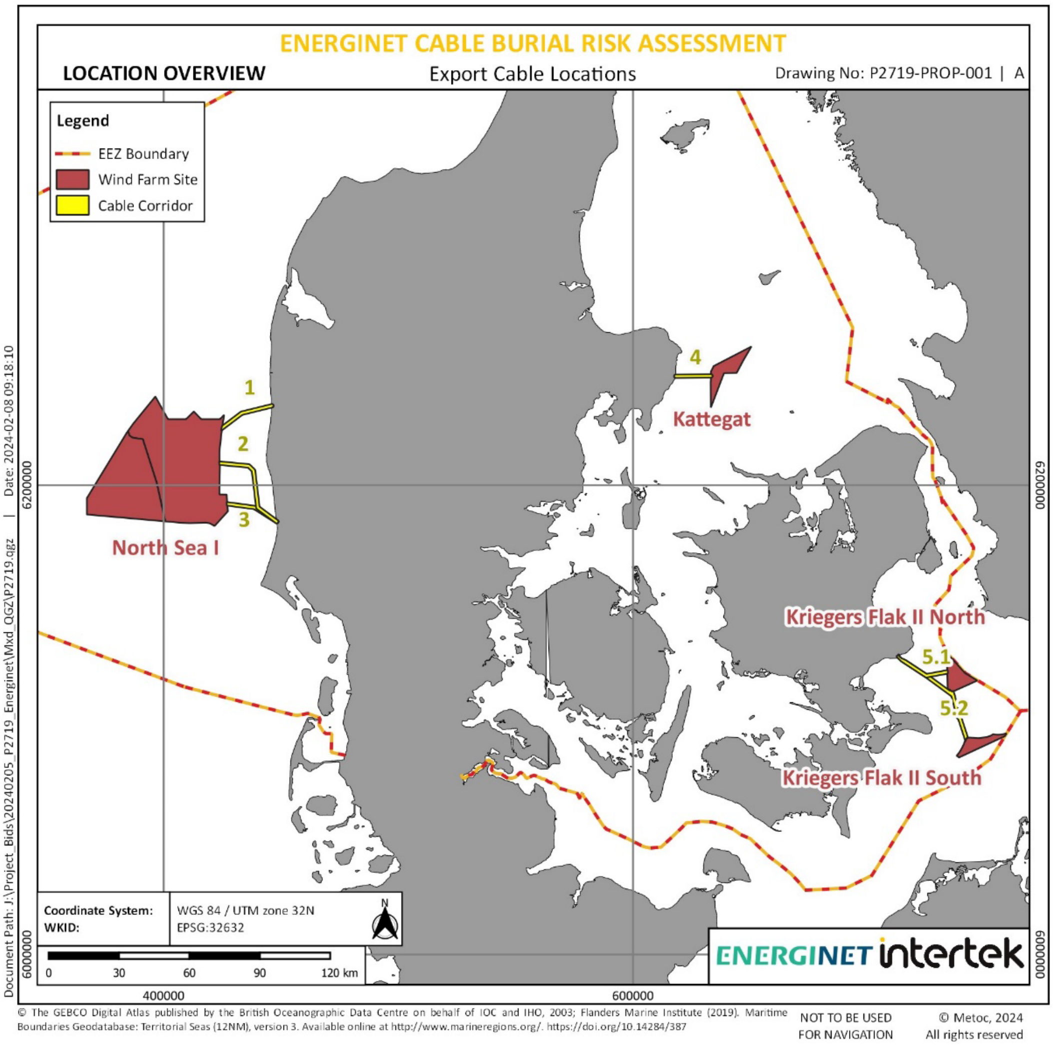
# 1. INTRODUCTION

**Intertek Energy & Water (Intertek) has been appointed by Energinet to conduct a Cable Burial Risk Assessment (CBRA) study for the marine sections of the North Sea Nymindegab South cable route.**

## 1.1 Project Background

Denmark is developing further offshore wind energy areas and related infrastructure in the Danish North Sea, the inner Danish Waters, and the Danish Baltic Sea as per a decision made by the Danish Parliament in 2022. It is understood that five main subsea cable connections will connect the offshore wind energy in the areas of North Sea I, Kattegat, and Kriegers Flak to the Danish mainland. There will be three cable routes from North Sea I, one from Kattegat, and one from Kriegers Flak as illustrated in the below overview map **Figure 1-1.**

Figure 1-1 Danish Offshore Wind 2030 Investigated Offshore Wind Farm Areas and the Associated Export Cable Corridors (1500m wide)




It is understood that the width of the corridors for the route survey is 1500 m. Energinet anticipates that at least two cables are planned for each corridor. The length of the routes is detailed below in **Table 1-1.**

**Table 1-1 North Sea Nymindegab South Export Cable Route**

| No. | Cable Route | Length [km] |
|---|---|---|
| 3 | NS I – Nymindegab South | Ca. 23 km |

## 1.2 Revision List

This is second issue based on comments received from Energinet – Revision 1

## 1.3 Scope of Work

Intertek has undertaken a thorough analysis and assessment of threats and risks concerning the integrity of the subsea cable throughout its lifetime. We have utilised the geophysical and geotechnical route survey data provided, along with available archive data. We have combined various elements detailed below such as threat identification, frequency analysis, failure assessment, risk assessment, to determine our recommendation for sufficient depth of lowering for installation and operation.

The purpose of this report is to identify any potential areas where activities, such as shipping and fishing, may pose a risk to the integrity of the installed cable and thus derive recommended depth of lowering along the route based on these threats.

The probabilistic method described by the Carbon Trust and used within this report relates to amount of time a vessel spends within a critical distance of the cable and the probability that a vessel might have an incident where the deployment of an anchor is necessary. When an event is certain to occur, its probability is 1.

Assumptions used are considered conservative and 'realistic worst case' which produces higher probabilities than would likely be the case. This enables the route and installation methods to be considered with a higher margin of safety.

**Threat Identification:**
Intertek completed the identification of an array of potential threats, including but not limited to foundering vessels, dropped objects, anchors, grounding ships, fishing activities, construction undertakings from neighbouring projects, and extraction of raw materials.

**Frequency Analysis:**
Following the threat identification process, a frequency analysis to evaluate the probability of events associated with identified threats, segmenting the analysis into 100-meter cable sections, was completed. The outcome presented through a series of detailed charts and tables for each individually identified threat, providing a clear understanding of the associated risks.

**Failure Assessment:**
Based on the frequency analysis and assessment the probability of failure in the event of any encountered threats was calculated. This assessment took into account factors such as the amount of cover on top of the asset and the likelihood of cable failure relative to the frequency of encounters with each identified threat type, ensuring a comprehensive evaluation of potential failure scenarios.

**Risk Assessment:**
A comprehensive risk assessment, quantifying the total probability of failure (PoF) along the cable route was undertaken.

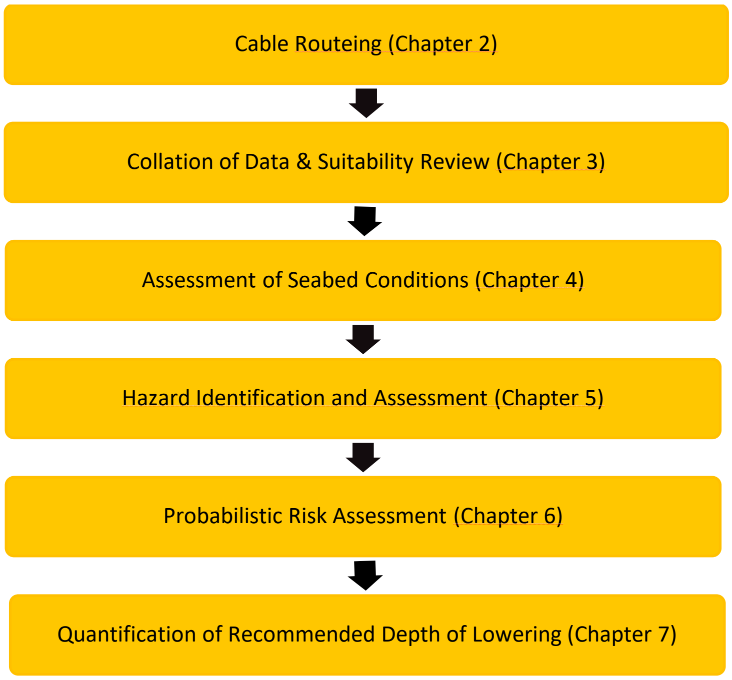
PoF at intervals of 1 failure per 10,000 years was discussed, determined and agreed by Energinet on the 19/03/2024 as a target failure that provides a robust level of protection. As per Energinet's suggestion, Intertek has used the DNV risk assessment guidelines (see Table 6-6) aiming for a Category 2 risk " Event rarely expected to occur" that encompasses a 1 in 10,000 PoF.

Additionally, Intertek have provided a representation illustrating how PoF varies with cable depth of lowering. This facilitates informed decision-making regarding risk mitigation strategies.

**Recommended Depth of Lowering:**
Drawing insights from the risk assessment, Intertek propose a recommended depth of lowering tailored to mitigate the identified risks posed by external threats. This depth of lowering (DOL) varies along the cable route to account for specific risk profiles, ensuring optimal protection of the asset throughout its operational lifespan.

The CBRA study presented in this report has been undertaken following the Carbon Trust's proposed methodology (Carbon Trust, Feb 2015) and steps (see **Figure 1-2**).

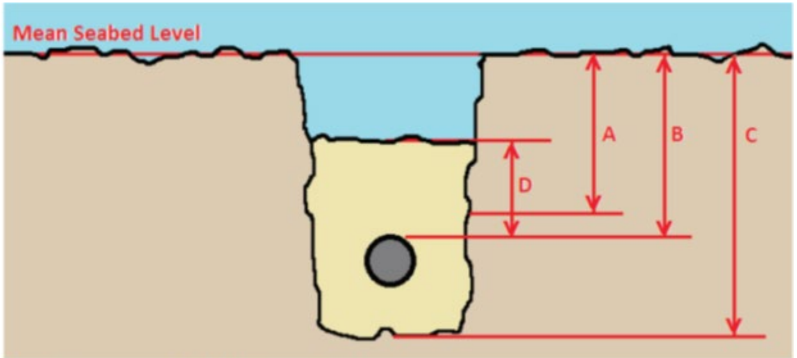
**Figure 1-2 Burial Risk Assessment Method Flowchart in Line with Carbon Trust CTC835 Guideline**



## 1.4 Definition of Trenching Parameter

Intertek has used the Carbon Trust's definition of Depth of Lowering (DOL) for this study. This is illustrated in **Figure 1-3.**

### Figure 1-3 Definition of Burial Terms used in Report




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

**Recommended Minimum Depth of Lowering (RMDOL)**
This is the minimum DOL recommended for protection from the external threats. It is the direct output of the fishing risk assessment and the probabilistic anchor risk assessment and includes a factor of safety (FoS).

**Target Depth of Lowering (TDOL)**
This is the depth that will be specified as the target depth to the cable installation contractor. TDOL is a depth which makes best use of what is achievable by industry standard burial tools to gain additional depth beyond RMDOL without incurring a step change in costs. Target DOL is also a practical application of depth which considers the effect burial depth has on tool stability.

**Target Trench Depth**
This is the trench depth cable installation contractors determine is required to meet TDOL. This is driven by cable properties and the selected trenching tool and is usually the diameter of the cable plus between 0.1 m and 0.4 m beyond the TDOL.

**Depth of Cover**
The thickness of material on top of the cable after trenching. DOC can vary depending on the sediment type and tidal cycles I.E in areas of fine sand or in stormy locations.

## 1.5 Relevant Data

Data obtained from the geophysical and geotechnical campaigns and other relevant data sources used in the CBRA are presented in **Table 1-2** below.

### Table 1-2 Data Used in the CBRA

| Data Type | Name | Information |
|---|---|---|
| Survey Bathymetry | NS_ECR1_MBES_XYZ_025m.xyz | 0.5m resolution bathymetry over a 1500m survey corridor |
| | NS_ECR1_CONTOURS_LIN.shp | 0.5m bathymetry contours over the extent of the survey corridor |
| Open-Source Bathymetry | EMODnet Bathymetry | EMODnet Digital Terrain Model (DTM) is generated for European sea regions from selected bathy survey data sets (1975 to 2013 using SBES & MBES) and composite DTMs, while gaps with no data coverage are completed by integrating the GEBCO Digital Bathymetry. 200m Resolution |
| AIS Data | Intertek_P2671_AIS_Data | 5-minute time series data of shipping from 07/02/2023 to 06/02/2024 +/- 5NM either side of the route centreline provided by Exmile Solutions Ltd |
| Geology | Shallow Geological Isopach | Draft shallow geological isopach interpreted from sub-bottom profiler data and correlated with side scan sonar imagery and bathymetric digital terrain model data |
| Geotechnical Samples | Vibrocore, Cone Penetrometer Tests and grab sample logs | Draft geotechnical sample logs from Vibrocore (VC), Cone Penetration Test (CPT) and Grab Sample (GS) |
| Desktop Study | Screening of seabed geological conditions for the offshore wind farm area North Sea and the adjacent cable corridor area | Geological desktop study of the area undertaken by GEUS |
| Fishing Intensity | EMODnet | Datasets on fishing intensity in the EU waters by sea basin, created every year by the International Council for the Exploration of the Sea (ICES). In the 2020 Cogea started to collect and harmonize them according to the EMOdnet Human Activities dataset schema. This dataset is updated yearly. The fisheries overview data concern the spatial distribution of average annual fishing effort (mW fishing hours) by ecoregion and by gear type. Fishing effort data are only shown for vessels >12 m having VMS. |
| Registry information on fishing vessels | Danish Ship Register (DAS) | General registry of the Danish fishing fleet including information on registered vessels by fishing area, method, base port, length, power, etc. |
| Annual Report on Danish Fisheries | Danish Fisheries Agency | Annual statistics for marine fisheries for 2022 including information on FAO area of catch and species. |

## 1.6 Limitations

The Cable Burial Risk Assessment analysis presented herein has been undertaken using the data listed in **Table 1-2** provided at the time of analysis. It is important to note that, as of the completion of this analysis and the writing of this report, the geophysical interpretation, geotechnical factual and integrated reports were not available from the survey contractor. Additionally, no alignment charts were available. Intertek's analysis of the soils conditions along the route is based solely on the analysis of the draft geotechnical coring and cone penetrometer logs.

This report reflects the most current understanding of the site conditions. It should be noted that the analysis does not take into account future shipping patterns that will result from the construction of the windfarm since to many variables will be assumed for this verification and was not part of the initial methodology. Future revisions of this report may be necessary once the completed geophysical and geotechnical interpretation becomes available for review and integration into the analysis, and as shipping patterns evolve.

# 2. CABLE ROUTEING

Export cable route was received from Energinet as part of the data package. The export cable route extends from landfall location to the planned offshore wind location, shown below in **Figure 1-2**.

Kilometre Positions (KP) were calculated using a tool in ArcGIS using the provided survey centreline shapefile.

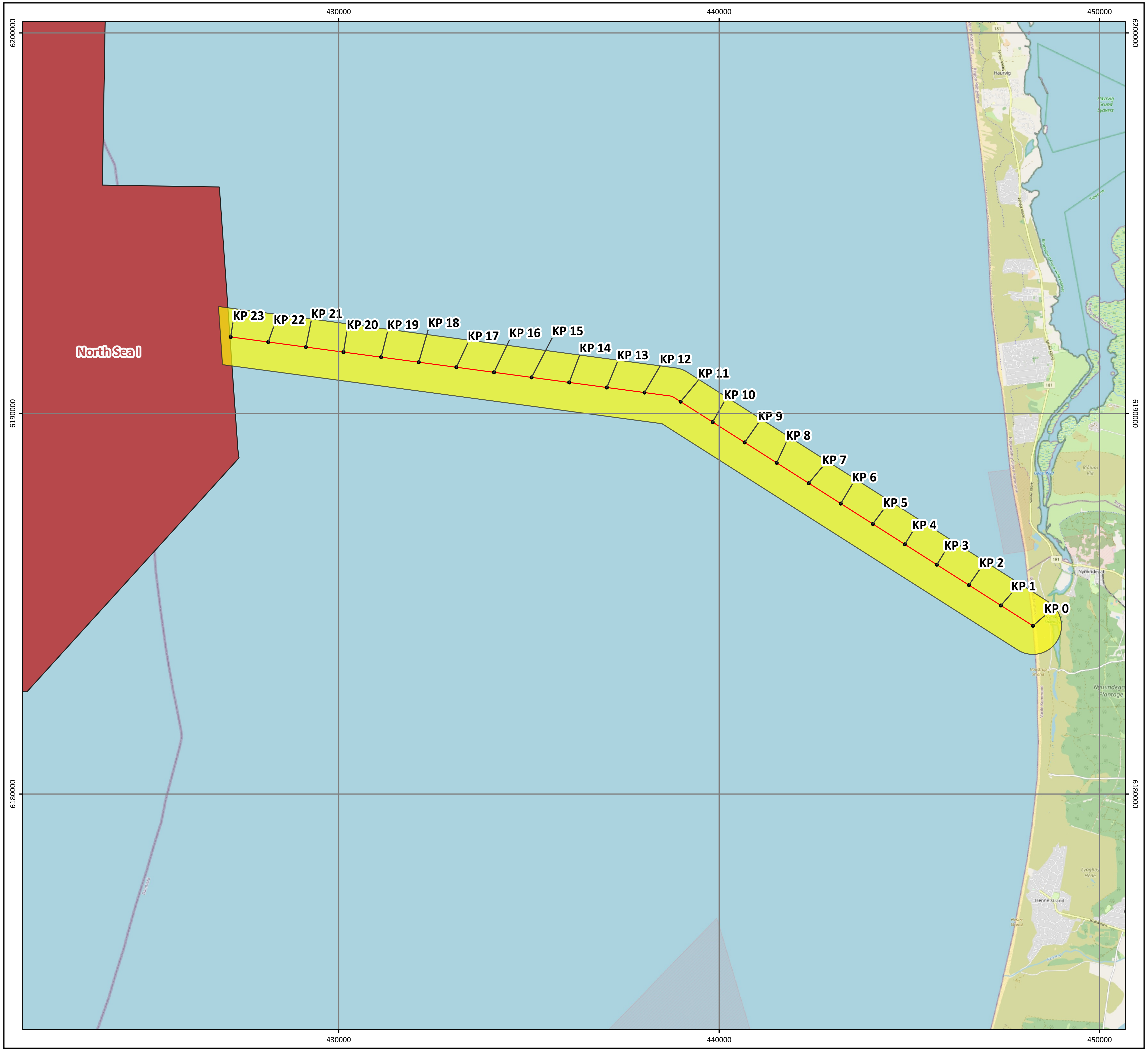
The cable corridor surveyed was 1500m.

# CABLE BURIAL RISK ASSESSMENT
# NORTH SEA I - NYMINDEGAB SOUTH

## LOCATION OVERVIEW

Cable Route

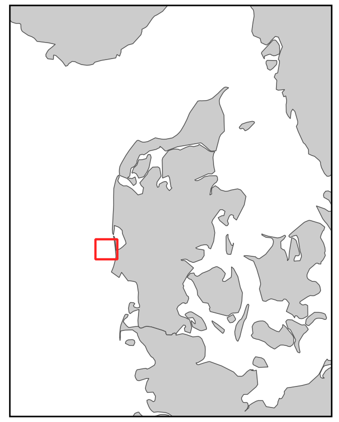
| Drawing No: P2719D-LOC-001 | B |
|---|---|




Legend

- KP
- Cable Route
- Cable Corridor (1.5km)
- Wind Farm Site

N



NOT TO BE USED FOR NAVIGATION

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| **WKID** | EPSG:25832 |
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| **Data Sources** | ENERGINET; NUTS |
| **File Reference** | J:\P2719\Mxd_QGZ\P2719D\01_LOC \P2719D_LOC.qgz |
| **Created By** | Lewis Castle |
| **Reviewed By** | Emma Langley |
| **Approved By** | Stephane Theurich |

0 1 2 3 4 km

# 3. COLLATION OF DATA AND SUITABILITY REVIEW

This section provides an overview of the bathymetrical and geological data along the surveyed corridor, based on the interpretation of the geophysical and geotechnical data. All data obtained from the geophysical and geotechnical survey has been correlated with each other, and the output from this has been compared to the existing data sources.

## 3.1 Bathymetric Data

The seabed topography along the route is characterised by the presence of areas of mobile sediments, outcrop of bedrock, boulders, linear features such as furrows or striations of coarser sediment and varying relief. The knowledge of these features is critical to any cable installation feasibility study. This section describes the existing bathymetry data in the study area and the resolution and quality of each dataset.

Sources for the bathymetry datasets can be found in Section 1.5 and is summarised below:

- EMODnet Bathymetry – 100m resolution
- Survey Data – 0.5m resolution bathymetric soundings
- Survey Data – 0.5m bathymetry contours

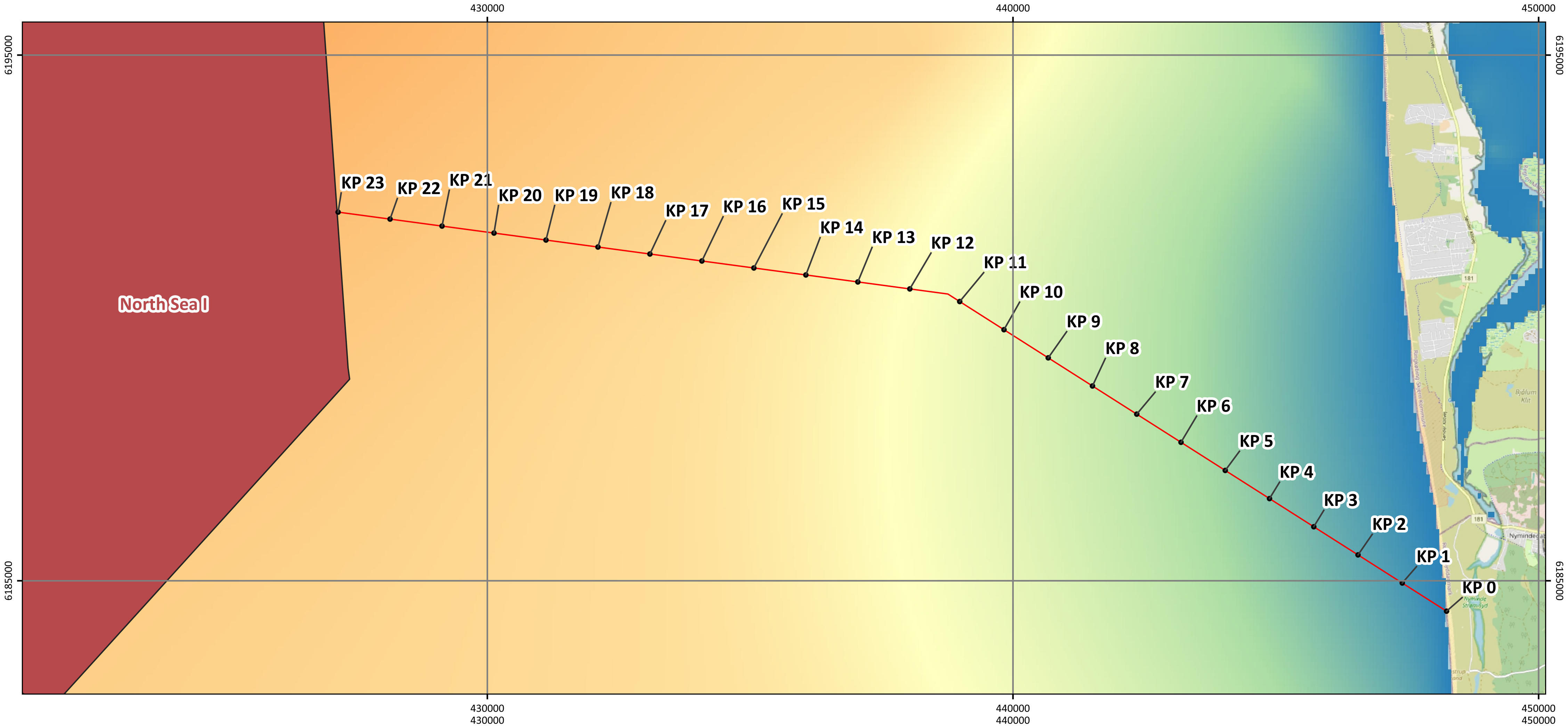
The open-source data (EMODnet Bathymetry) was used to define the route centreline for survey. These sources provide a good overview of the surrounding area and highlight large features such as sandwaves. There is good overall correlation between the open-source data and the acquired high resolution survey data.

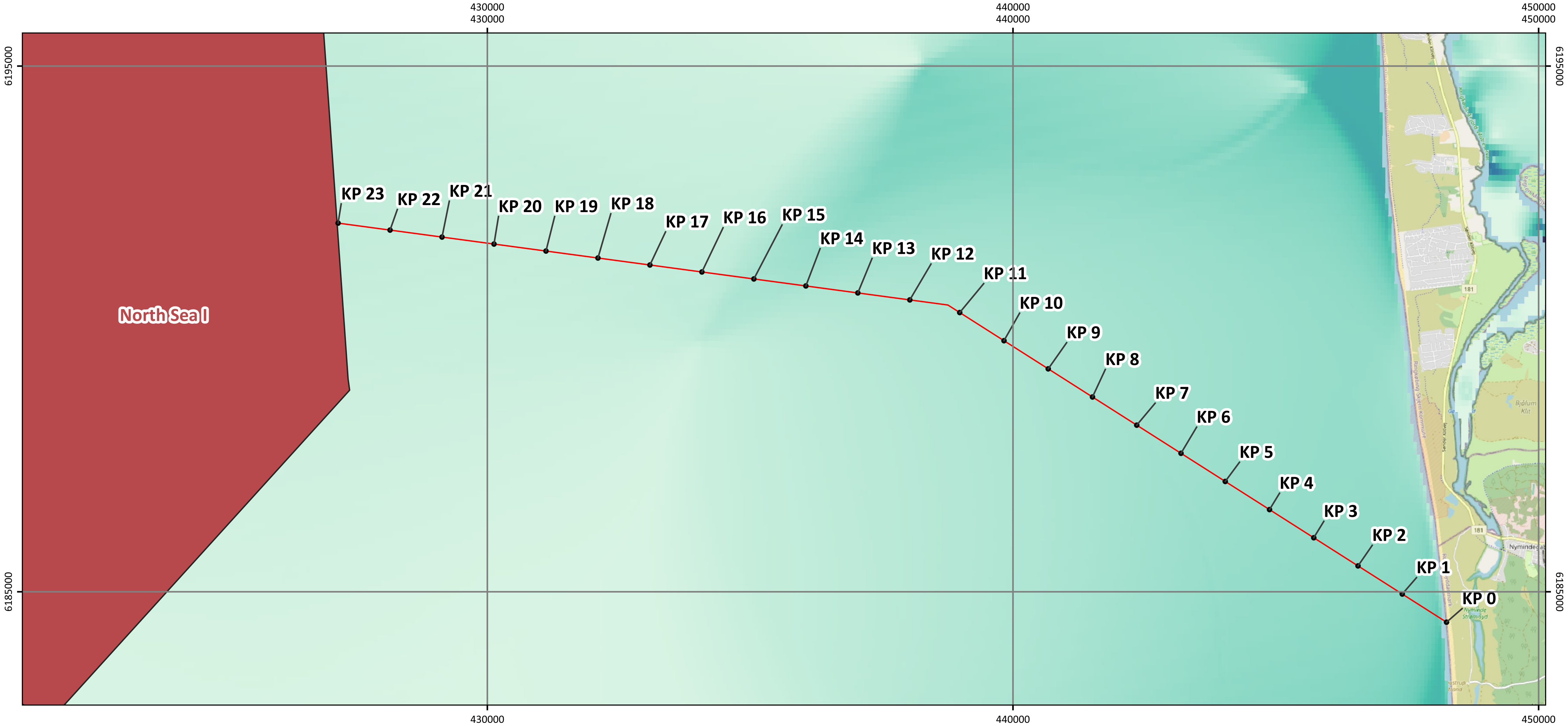
### 3.1.1 Suitability of Data

The bathymetric soundings obtained for this study is of very high quality and processed to a high resolution (0.5m). It has highlighted areas of shoaling, potential areas of sediment mobility, areas of outcrop and in some cases confirmed the presence of wrecks and obstructions.

The offshore dataset provided by EMODnet is a dataset suitable to show water depths, areas of shoaling and bathymetric lows. The low-resolution dataset confirms the presence of larger features in the study area, but its resolution is too low to determine any migration rate of mobile bedforms. The acquired, bathymetric data could be used to provide this insight, if compared to a similar, but temporally different data set.

An example of the typical slopes encountered within the survey corridor has been provided by the survey contractor and shown in **Figure 3-1**. The zones were derived from the geological zonation and then refined taking into account the shipping patterns. The bathymetry profile of the cable route is displayed in **Figure 3-2.**




The bathymetric metadata and Digital Terrain Model data products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu.; © EuroGeographics, © TurkStat.; © Energinet;

# CABLE BURIAL RISK ASSESSMENT NORTH SEA I - NYMINDEGAB SOUTH

## BATHYMETRY

Bathymetry Along Cable Route

| Drawing No: P2719D-BATH-001 | B |
|---|---|

**Legend**

- KP
- Cable Route
- Wind Farm Site

**Bathymetry (m below LAT)**

0

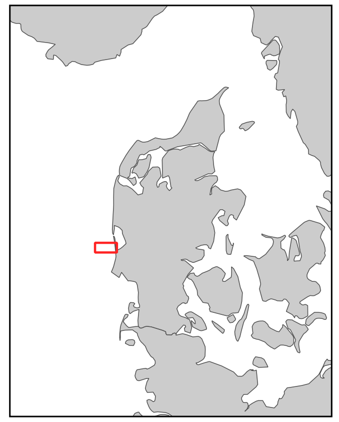
-30

**Seabed Slope (Degrees)**

0

0.5

N



NOT TO BE USED FOR NAVIGATION

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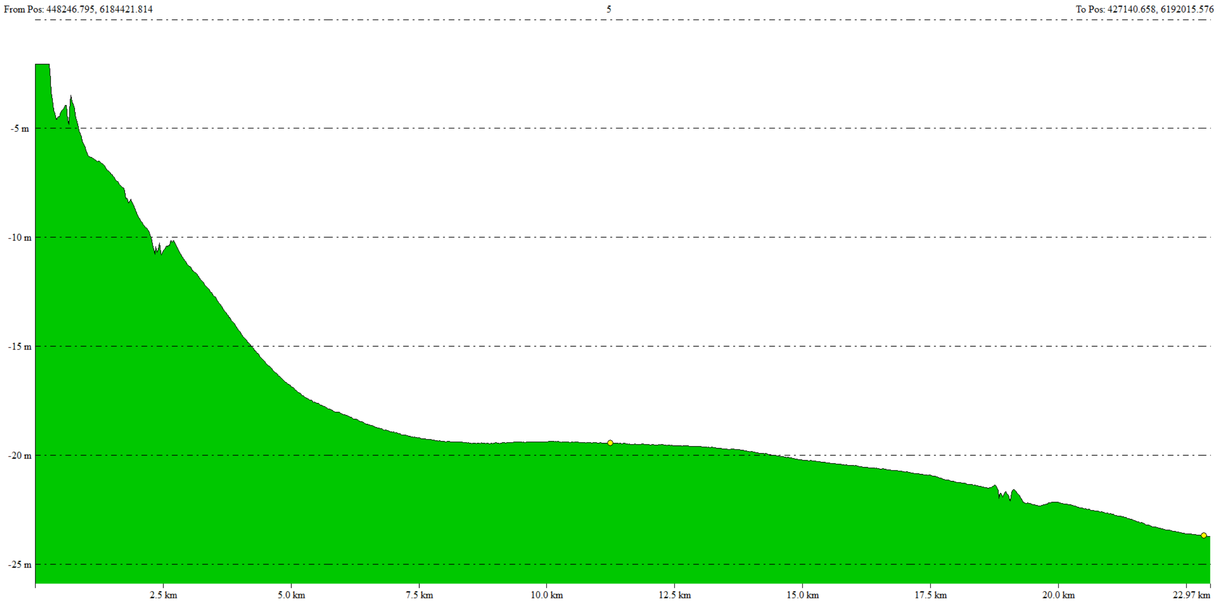
| **File Reference** | J:\P2719\Mxd_QGZ\P2719D\01_LOC \P2719D_LOC.qgz |
| **Created By** | Lewis Castle |
| **Reviewed By** | Emma Langley |
| **Approved By** | Stephane Theurich |

ENERGINET intertek

0 1 2 3 4 km

**Figure 3-2 Bathymetric Profile along the Cable Route Centreline (East to West)**




## 3.2 Geophysical Data

The geophysical data was surveyed by GEOxyz, producing the following results. Side scan sonar (SSS) data has been used for interpretation of surficial geology, identification of seabed features, and to select contacts. Sediment classes distinguished from SSS imagery are correlated with grab sample, vibrocore (VC) and cone penetration test (CPT) results. Topographical features identified from SSS records have been correlated with bathymetric digital terrain models processed from the bathymetric sounds acquired using the multibeam echo sounder (MBES). Shallow geology interpretations are based on sub-bottom profiler (SBP) data correlated with the geotechnical sampling results. SSS and MBES data is also used to corroborate the SBP data interpretation in the uppermost layers. Magnetometer records collected during the survey are used to identify cables and ferrous objects on the seafloor within the survey corridor.

It should be noted that Intertek did not do the initial geophysical interpretation. Furthermore, not all the data was available at the time of writing this CBRA (see section 3.2.2).

### 3.2.1 Geophysical Survey

#### 3.2.1.1 Bathymetry and Seabed Morphology

The route is generally characterised by gradually sloping seabed from the landfall to the end of the route. The maximum depth along the route is 23m at KP23.0. Moderate gradients are generally associated with areas of sand and till. No mobile bedforms are present along the route.

#### 3.2.1.2 Seabed Sediments and Features

The surficial sediments vary mainly between very loose SAND to low strength CLAY.

The interpretation of surficial sediment types was derived from the acoustic character of the SSS data, and the interpretations were aided by MBES bathymetric 3D surfaces and SBP data. During the review of the SSS survey data, higher intensity sonar returns (darker grey to black colours) were interpreted as relatively coarser grained sediments, and lower intensity sonar returns (lighter grey colours) were interpreted as relatively finer grained sediments. Bathymetric data was used to correct the interpretation for the effects of seabed slope on sonar returns. The correlation with the geotechnical results was initially based on the field logs and further verified with the final geotechnical results.

Seabed sediment classifications are as follows:

### Table 3-1 Seabed Sediment Classification from SSS data

| Acoustic Description | Interpretation |
|---|---|
| Low to medium acoustic reflectivity.<br>Slightly grainy texture. | SILT and SAND<br>The ratio between sand and silt can vary within this sediment type. The sediment often has a patchy appearance due to variation of the dominating sediment fraction. |
| Low to medium acoustic reflectivity. Slightly grainy to grainy texture with point source reflectors. | SILT<br>Predominantly silt, may have minor fractions of clay, sand and/or gravel. |
| Medium acoustic reflectivity, slightly grainy texture. | SAND<br>Predominantly sand, may have minor fractions of clay, silt and/or gravel. |
| Medium to high acoustic reflectivity. Slightly grainy to grainy texture, coarse texture in places. | Gravelly SAND to sandy GRAVEL<br>The ratio between SAND and GRAVEL can vary within this sediment type. |
| High acoustic reflectivity.<br>Grainy to coarse texture. | GRAVEL<br>Predominantly gravel, may have minor fractions of clay, silt and/or sand. |
| Medium to high acoustic reflectivity.<br>Exhibits relief and texture. | BEDROCK<br>Comprises outcrops of crystalline bedrock |

Seabed Feature Classifications are as follows:

### Table 3-2 Seabed Feature Classification

| Interpreted Seabed Feature | Criteria[1] |
|---|---|
| Ripples | Wave length <15 m, Height <1.0 m |
| Megaripples | Wave length 15-25 m, Height 1-3 m |
| Sandwaves | Wave length 25-200 m, Height >3 m |
| Boulder Field<br>Occasional boulders<br>All >0.5 m | Concentration of 10 to 20 boulders within a maximum area of 100 x 100 m |
| Boulder Field<br>Numerous boulders<br>All >0.5 m | Concentration of >20 boulders within a maximum area of 100 x 100 m |
| Trawl Mark Area | Concentration of numerous trawl marks |
| Current Lineation | Current lineation |

[1] Note, there is no standard for bedform descriptions. Criteria presented in **Table 3-2** are as defined by route survey contractor. Alternative criteria are also common.

#### 3.2.1.3 Shallow Geological Features

The shallow geology along the route is characterised by variations of units of, CLAY, CLAY overlying SAND , SAND overlying CLAY and SAND units. No subcropping or outcropping bedrock was noted from the analysis of the geotechnical information provided.

The classifications of the shallow geology have been derived through a combination of analysis and interpretation of the acoustic character of the SBP data and was modified according to the geotechnical results. A comparison with available background information was made and broken down into major sediment types along the route (**Table 3-3**).

**Table 3-3 Shallow Geology Soil Types and Lithology**

| Sediment Type | Acoustic Characters | Lithological Variation |
|---|---|---|
| Veneer | - | Veneer of mobile sediments not resolved in seismic data (generally <0.5 m). SAND Occasionally SILT. Veneer of reworked sediment by winnowing of fines often present of top of TILL. |
| Sand | Acoustically homogeneous to layered, low to medium amplitude recent sediments present at seabed. Base often medium to high amplitude indicating presence of coarser sediment | Fine to coarse SAND. May locally contain shells, pebbles, cobbles and pockets of SILT, CLAY and GRAVEL. Commonly forming mobile sediment. |
| Till | Either heterogeneous with acoustic character indicating the presence clay with sand layers and possible coarser sediments, and boulders or Limited or no acoustic penetration. | Possible glacial deposit / till or diamicton. Unsorted sediment, soft to stiff clay with interbeds of sand, and layers/lenses of coarse sand and gravel. May contain pebbles, cobbles, and boulders. |

### 3.2.2 Suitablility of Geophysical Data

It is understood that the client requested early delivery of CBRA before the full geophysical survey data and reports are/were available therefore, they were not used in this project. Therefore, the geophysical data provided for this study is mixture of suitable and not usable;

Seabed features were provided in the form of a shapefiles that were of medium quality highlighting some of the seabed features present. Similarly, surficial deposits and SBP isopach's were deemed of good quality and were useable for this project. However, SSS mosaics were not provided and the RAW SBP was unusable with no TIFS provided.

The final geophysical survey report was not provided

## 3.3 Geotechnical Data

The geotechnical survey, undertaken by GEO, consisted of vibrocore samples (VC) and cone penetration tests (CPT).

In total, 21 CPT locations were carried out, with 2 re-attempts required.

For the vibrocores, a total of 21 locations were carried out with 2 re-attempts required.

### 3.3.1 Vibrocores

The vibrocores were recovered using electrically powered vibrocoring units. The corers were fitted with 6m long core barrel and used clear PVC 100mm OD liner. A 'basket-spring type' core catcher was fitted above the cutting shoe, in the base of the vibrocore barrel, to maximise retention of the penetrated sediment during retraction from the seabed and subsequent retrieval of the unit to the vessel deck.

During VC operations, there were instances of re-attempts being required largely due to initial poor recovery. Poor penetration and subsequent low material recovery were generally a function of dense to very dense coarse granular material or high strength cohesive material being encountered.

### 3.3.2 Cone Penetration Testing

CPTs were carried out to a maximum depth of 5.5m using 10cm2 electric piezocones operated from a seabed CPT unit,

The aim at each CPT location was to reach the target penetration depth of 6m. Re-attempts were required due to either initial failure to reach the required depth, concern with the overall test application class, or due to electrical power and/or communication issues with the seabed CPT unit.

### 3.3.3 Suitability of Geotechnical Data

Each VC and CPT log are clearly presented and provided the relevant geological information at each location.

## 3.4 Installation Constraints Identified from Available Data

- No surficial boulder fields were identified by Intertek from the bathymetric data.
- No bedrock outcrops/subcrops were identified from the geotechnical logs.
- No third-party infrastructure to cross.
- No Mobile sediments were identified from the bathymetric data.

## 3.5 AIS Shipping Data

### 3.5.1 Methodology

AIS (Automatic Identification System) is an automatic tracking system used on ships for identifying and locating vessels by electronically exchanging data with other nearby ships and AIS base stations and satellites. The International Maritime Organisation (IMO) requires AIS to be fitted aboard international voyaging ships with gross tonnage of 300 or more tons, and all passenger ships regardless of size. This would cover almost all commercial vessels and most private vessels that would be of risk to the cable; however, some smaller fishing vessels could be missing from the AIS dataset.

Information provided by the AIS equipment usually consists of unique identification number for each vessel, vessel name, vessel type, vessel position, course, and speed. Other attributes like vessel deadweight tonnage and draught may be completed by the AIS supplier.

To quantify the anchoring risk to the cable, Intertek procured historical AIS data for a 12-month period (Exmile Solutions, 2024) between February 2023 and February 2024. Data were comprised of both terrestrial (AIS-T) and satellite derived (AIS-S) sources. Each record included a series of standardised attributes, as detailed in **Table 3-4**. This wide study area allows a clear insight into vessel movements by vessel type/size in the surrounding geography.

**Table 3-4 Standard Attributes used During Data Processing**

| Parameter | Format | Description |
|---|---|---|
| MMSI | Numerical | Maritime Mobile Service Identify number, unique to each vessel |
| Vessel Name | Text | Name given to the vessel |
| Vessel Type | Text | Category assigned to the type of ship (e.g. Fishing, Cargo, Tanker, Pleasure craft) |
| Status | Numerical | Code given |
| Speed | Numerical | Travelling speed (knots) |
| Longitude | Numerical | Longitude of the ship's position |
| Latitude | Numerical | Latitude of the ship's position |
| Course | Numerical | Direction the ship is travelling |
| Heading | Numerical | Direction the ship is facing |
| Timestamp (UTC) | Date and time | Time and date of the ship's location |
| Length | Numerical | Length of the vessel (meters) |
| Draught (mx10) | Numerical | Distance between the sea level and keel of the vessel |
| SWT | Numerical | Carrying capacity of the vessel (tonnes) |

### 3.5.2 Data Sources, Gaps and Omissions

The data sources for this section are shown below in **Table 3-5**.

**Table 3-5 AIS Data Sources**

| Type of Data | Source | Description |
|---|---|---|
| Automatic Identification system (AIS) | Exmile Solutions | Information of individual ship locations from land and satellite-based receivers from 7/2/23 to 6/2/24. |

As an initial quality control measure, a gap analysis was undertaken removing duplicated entries of a ship’s position where the same timestamp was reported. The procedure also involved using public databases to fill in missing attributes including vessel length, vessel type and deadweight tonnage. Although a significant portion of the vessels had missing DWT values, these were accounted for by aggregating vessel types into broader and more meaningful categories, reducing the number of classes from 60 to 13. The broad categories were selected to be consistent with the classes reported on the EMODnet Human Activities portal (European Comission, 2024).

Once aggregated, an empirical relationship was established between vessel length and deadweight tonnage for each new vessel type (see section 6.2). From here, records that were missing information on a vessel’s deadweight tonnage could be inferred by applying the formula to the vessel length. Records where key attributes could not be sourced from public databases or inferred through empirical formulae were omitted from the analysis as they would not be successfully sorted into anchor band categories for the CBRA.

To ensure the best resolution for the data and future CBRA, data was interpolated from a 5-minute time step to a 1-minute time step using an in-house application. The interpolation process produced regular points between vessel pings with time intervals exceeding 1 minute. Vessel density grids for the area were produced by overlaying a square grid comprising 0.5 $km^2$ cells to determine the density of track lines on an overall, yearly/seasonal basis.

### 3.5.3 AIS Analysis

#### 3.5.3.1 Vessel Traffic

The main vessel traffic crossing the proposed cable route is in the form of tanker, tug, passenger, pleasure crafts, sailing, cargo, fishing vessels, and service. **Figure 3-3** below shows the total vessel density for 12 months.

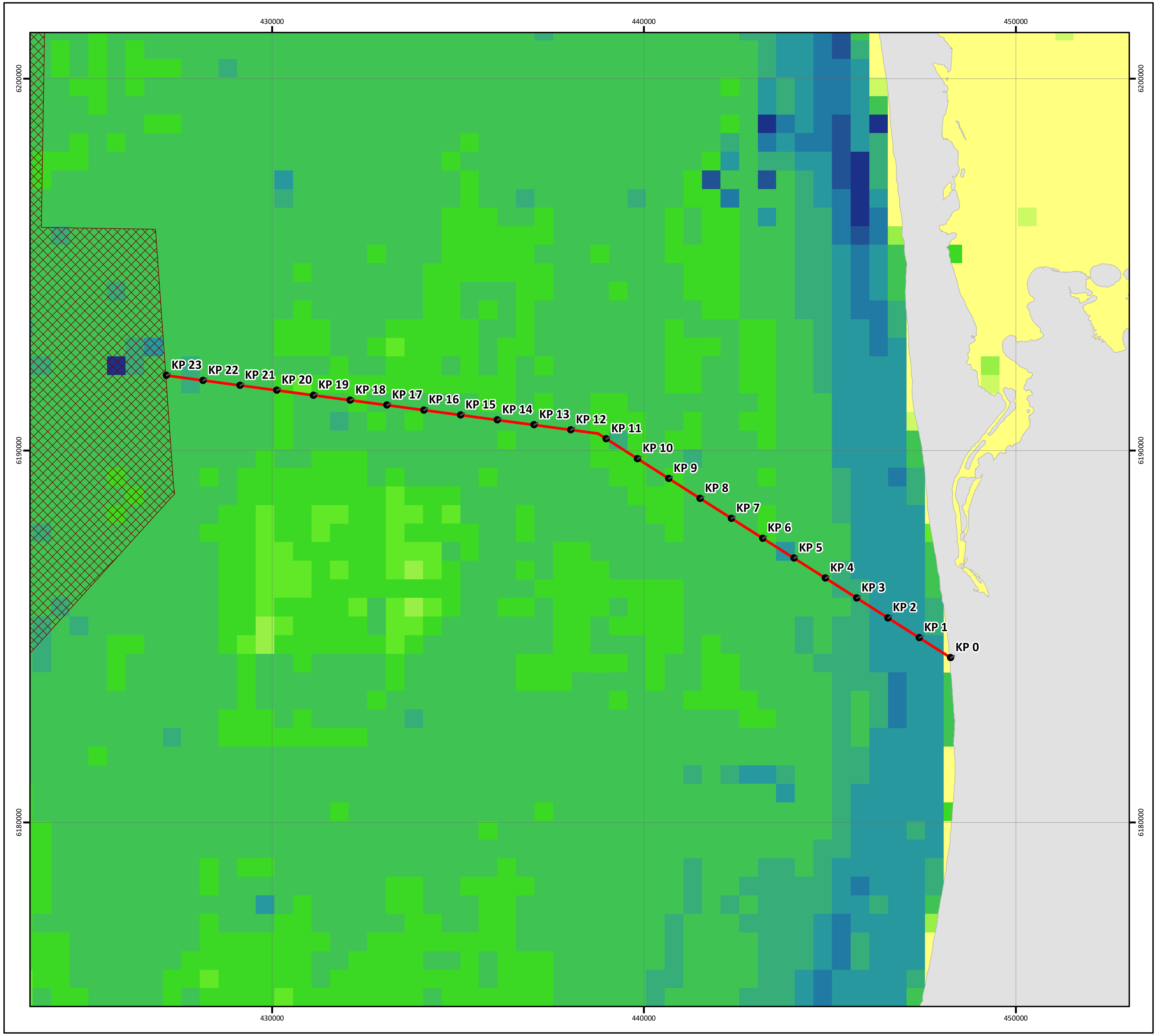
Seasonal variations show the highest months of vessel traffic are present in Winter (Jan – Mar). The lowest months are in the Autumn (Oct – Dec). The seasonal and vessel heat maps are presented in **Appendix D**

#### 3.5.3.2 Anchorages

No anchorages were identified in the vicinity of the cable route.

## 3.6 Vessel Incident Data

For this study, Intertek has reviewed information from the Danish Maritime Accident Investigation Board available on Home (dmaib.com). No investigations or accidents were reported in 2024 near the North Sea 1 NS cable corridor.






# CABLE BURIAL RISK ASSESSMENT
# NORTH SEA I - NYMINDEGAB SOUTH

## AUTOMATIC IDENTIFICATION SYSTEM (AIS) Vessel Density (February 2023 - February 2024)

| Drawing No: P2719D-AIS-001 | B |
| --- | --- |

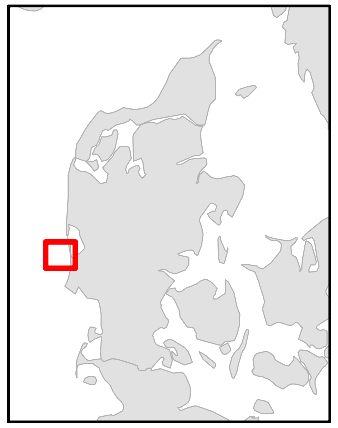
**Legend**

- KP
- Cable Route
- Wind Farm Site

**Vessel Density (Duration per Year)**

- < 15 minutes
- 15 - 30 minutes
- 30 - 45 minutes
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

N W E S



NOTE: Not to be used for Navigation

| | |
| --- | --- |
| Date | 19 June 2024 |
| Coordinate System | ETRS 1989 UTM Zone 32N |
| Projection | Transverse Mercator |
| Datum | ETRS 1989 |
| Data Source | ESRI; NUTS; ENERGINET |
| File Reference | J:\P2719\Mxd_QGZ\P2719D\02_AIS\ P2719D-AIS-001.mxd |
| Created By | Lewis Castle |
| Reviewed By | Emma Langley |
| Approved By | Stephane Theurich |

[redacted] [redacted]

0 1 2 3 4 km

# 4. ASSESSMENT OF SEABED CONDITIONS

This section presents the breakdown of the North Sea Nymindegab South cable route based on distinct seabed conditions based on our review of the available geotechnical and regional geological data.

Intertek reviewed the provided cone penetrometer test (CPT) logs and the associated core logs to interpret a ground model along the route centreline. The following shear strength classification for cohesive soils and the relative densities classifications for non-cohesive soils. If a unit comprised of CLAY with thin band of SAND then this band was omitted. This creates conservatism in our analysis of the potential anchor penetration. In the absence of isopachs indicating a change of unit (e.g. unit pinching out) transition was made at an equal distance between the geotechnical samples.

### Table 4-1 Interpreted Undrained Shear Strength Parameter and Classification

| Descriptive Term | Shear Strength Range (kPa) |
|---|---|
| extremely low | <10 |
| very low | 10 to 20 |
| low | 20 to 40 |
| medium | 40 to 75 |
| high | 75 to 150 |
| very high | 150 to 300 |

### Table 4-2 Interpreted Relative Density Parameter and Classification

| Descriptive Term (Relative Density) | Cone Resistance Range (MPa) |
|---|---|
| very loose | <2.5 |
| loose | 2.5 to 5 |
| medium dense | 5 to 10 |
| dense | 10 to 20 |
| very dense | >20 |

### Table 4-3 Geotechnical Zones

| Zone | Comments/Assumptions | Start KP | End KP |
|---|---|---|---|
| 1 | 0.1 of Extremely Low Strength clay overlying Medium Dense Sand | 0.00 | 4.00 |
| 2 | 0.1 of Extremely Low Strength clay, 0.9 of low strength clay overlying Medium Dense Sand | 4.00 | 7.16 |
| 3 | 0.1 of Extremely Low Strength Clay, 1 of Low Strength Clay overlying Very Loose Sand | 7.16 | 8.72 |
| 4 | 0.1 of Extremely Low Strength Clay, 1.3 of Low Strength Clay overlying Loose Sand | 8.72 | 10.15 |
| 5 | 0.1 of Extremely Low Strength Clay, 1.5 of Low Strength Clay overlying Medium Dense Sand | 10.15 | 11.24 |

| Zone | Comments/Assumptions | Start KP | End KP |
|---|---|---|---|
| 6 | 0.1 of Extremely Low Strength clay, 1.2 of meidum dense sands overlying low strength clay | 11.24 | 13.36 |
| 7 | 0.1 of Extremely Low Strength clay, 1 of Loose Sand, overlying low strength clay | 13.36 | 14.55 |
| 8 | 0.5 of Extremely Low Strength Clay, 0.7 of Loose Sand overlying medium dense sand | 14.55 | 16.35 |
| 9 | 0.1 of Extremely Low Strength Clay, 0.4 of low strength clay overlying loose sand | 16.35 | 16.86 |
| 10 | 0.1 of very loose sand, 1.5 of medium dense sand overlying low strength clay | 16.86 | 17.59 |
| 11 | 0.5 of Extremely Low Strength Clay, overlying medium dense sand | 17.59 | 18.64 |
| 12 | 0.1 of very loose Sand, 0.6 of medium dense sand, overlying medium strength clay | 18.64 | 19.70 |
| 13 | 0.2 of very loose sand, 1.4 of medium dense sand, overlying high strength clay | 19.70 | 20.76 |
| 14 | 0.15 of Extremely low strength clay, 1 of medium dense sand, overlying medium strength clay | 20.76 | 21.82 |
| 15 | 0.2 of low strength clay, 0.6 of medium strength clay overlying medium dense sand | 21.82 | 23.00 |

# 5. RISK IDENTIFICATION AND ASSESSMENT

To specify an appropriate DOL for the North Sea Nymindegab South cable, Intertek conducted a risk identification and assessment considering both the likelihood and severity of the most common external threats to the cable.

Risks that pose a threat to installed marine cables can be classified as either natural or anthropogenic risks. The following sections describe the most common risks affecting marine cables.

The completed Risk Register is provided in **Appendix B**.

## 5.1 Natural Hazards

### 5.1.1 Sediment Mobility

Sediment mobility in itself does not pose a threat to a submarine cable, but it can lead to issues with the thermal conductivity of cables (over burial), and exposure of cables (scour); Over burial should be accounted for in the design phase of the cables and is usually dealt with by increasing, universally or locally, the cross-sectional area of the cables. Burial under excess soil can change the thermal properties of the soil and cause hotspots along the cable, while exposure increases the risk of damage due to external aggressors such as trawling and anchoring and potentially mechanical damage from free spans.

There are no areas within cable corridor where there are bedforms present. For the purposes of depth of lowering all depths recommended in this report are assumed to be measured against a horizontal plane which has been determined to be non-mobile and after any required route engineering has been undertaken to flatten mobile sediments.

### 5.1.2 Waves and Currents

Waves and currents may cause abrasion and stress to an exposed cable where it crosses over rock or rough terrain. Sufficient burial and protection of a subsea cable will reduce the risk of waves and currents to a negligible level.

In addition, wave/currents can mobilise sediment which may lead to increase in the thermal environment for cables if burial depth increases. Sediment mobilisation can also lead to exposure of the cable through de-burial, causing loss of protection against external aggressors.

### 5.1.3 Extreme Weather

Extreme weather is unexpected, unusual, unpredictable, severe or unseasonal weather and involves weather at the extremes of the historical distribution. While the North Sea Nymindegab South cable is geographically in a relatively weather-stable area, sufficient depth of lowering and protection will be required to deal with the effects of extreme weather such as excessive scour and extensive movement of mobile sediments. For the purposes of burial targets all depths recommended in this report are assumed to be measured against a horizontal plane which has been determined to be non-mobile and after any required mobile bedform engineering has been undertaken to flatten mobile sediments.

### 5.1.4 Outcropping Bedrock

Bedrock and hard sediment are considered an issue when the seabed proves to have properties that affect, and effectively inhibit, the use of the common trenching methods.

Bedrock and hard sediment may cause problems with reaching the required burial depth. In addition, topographical irregularities in bedrock or hard sediment may cause freespan, point load, and abrasion.

Methods to avoid problems with bedrock or hard sediment include appropriate micro-routing, deployment of heavier trenching machines, or the installation of additional cable protection.

There was no evidence of outcropping bedrock within the cable route corridor in the data provided.

### 5.1.5 Other Geohazards

Geohazards are geological states that may lead to risk and damage, induced by natural processes or human activity. Marine geohazards include any feature or process that could harm, endanger, or affect seafloor facilities, cables, pipelines etc. Marine geohazards can be a local and / or regional site and soil conditions having a potential to develop into seafloor failure events, which cause losses of life or damage to health, environment or field installations (Camargo *et al.*, Feb 2019).

Various geological processes and features can induce hazards. Some of the more well known, due to their high destructive power are earthquakes, volcanoes, landslides, and associated tsunamis. Others generally do not cause direct damage to societies but can affect engineered structures. These include pockmarks, mud volcanoes, and mobile bedforms. Some manifest themselves on the surface of the seafloor, while others occur in the subsurface.

No evidence of volcanos or landslides were identified in the literature or the provided survey data. Minor earthquakes have been identified within the wider region (Gregersen *et al*.,1998).

## 5.2 Anthropogenic Hazards

### 5.2.1 Shipping

Shipping represents an anchoring hazard to a cable on or in the seabed. Vessels that drop their anchors have the potential to interact with the cables if the anchor is dragged along the cable route or dropped directly on the cable. Ships in transit do not typically anchor under normal conditions and planned anchoring normally takes place within a designated area. Contact with an anchor is often catastrophic for the cable as the forces applied by a moving anchor can be extremely large. The anchoring hazard may result from:

- Insufficient protection.
- Emergency anchoring (where an anchor is deployed to prevent collision or grounding).
- Accidental anchoring (where an anchor falls unexpectedly from a vessel due to equipment impact or operator error). Accidental anchoring is accentuated by proximity to a port where, for navigational reasons such as the traffic density, proximity of obstructions, shallow waters and other vessels, anchors are more likely to be readied for deployment.
- A vessel being anchored inadequately (where an anchor is deployed but drags longer than necessary along the seabed prior to embedment).

All charted anchorage areas were identified and avoided as part of the routing study hence accidental anchoring and inadequate anchoring are not relevant to this study. Please refer to **Appendix F** for additional information on Navigation and Shipping in the vicinity of the cable route.

#### 5.2.1.1 Unintentional anchor drags

Intertek is aware that in some cases, unintentional anchor drags are feasible as a potential hazard. However, Intertek has not investigated these deployments, especially for large commercials vessel.

The unintentional anchoring risk for large commercial vessels carrying anchors capable of causing significant damage to a buried cable is considered extremely low. Vessels of this size are usually fitted with secure anchor mechanisms and the redundancy of machinery installed to prevent such a mechanical failure accusing is high (DNV, 2010).

Similarly, the impact of unintentional deployment on smaller leisure vessels is harder to quantify given smaller sizes of anchors and different mechanisms to secure anchors during transit.

Intertek has reviewed literature on this topic and has not been able to determine the likely hood of intentional anchor drop and drag risk. Therefore, the risk of accidental anchor deployment for these vessels is not considered probable enough to include in our assessment

#### 5.2.1.2 Ports and Harbours

There is one port within 30km of the study area this is Hivde Sande, however there are numerous ports and harbours north and south of the study area , ranging from large ferry and goods ports to small fishing and recreational harbours. There are two major ports which have more of an influence on the Project area these are located both northeast and south east of the North Sea 1 study area, there are also various small harbours and marinas located further south of the study area;

- Port of Esbjerg
- Port of Thyboron
- Port of Romo
- Nordby Havn, Fanø
- Hvide Sande
- Ringkobing
- Sylt Marina

### 5.2.2 Summary of Shipping Related Features

Shipping related features within the study area are outlined below.

#### 5.2.2.1 Wrecks

According to UKHO and Navionics data sets, there are nine known Shipwrecks within the study area.

#### 5.2.2.2 Dredging and Waste Disposal

Within the study area there are no waste disposal sites located within the study area or within the vicinity of the study area. There are three dredge site locations which are located within 6 km of the study area (Emodenet, 2023).

#### 5.2.2.3 Lighthouses

There are five lighthouses within study area, four of these are located in the Hvide Sande region in Denmark, and the fifth lighthouse is located Lyngvig.

#### 5.2.2.4 Anchorage

There are no anchorages present within the study area, however the main anchorages outside the study area are;

- Port of Esbjerg
- Port of Thyboron

#### 5.2.2.5 Energy

At the time of writing no offshore wind farms, oil and gas/hydrocarbon platforms or nuclear energy plants are within the study area. Furthermore, one power cable crosses the study area, this is Viking Link interconnector, which runs from Lincolnshire, UK to southern Jutland, Denmark, this is a 1400 MW which cable measures approximately 765km.

There are three active pipelines within the study area, PL1014_PR is operated by Dong Efterforskning og Produktion A/S and is used for gas transportation and measures 0.25 km. PL1017_PR is operated by Maersk Oil and is an active gas pipeline measuring 0.21km. PL1007_PR is an active oil pipeline which measures 0.21m and is operated by Maersk Oil.

### 5.2.3 Fishing Gear Interaction

Fishing is a risk to the cable as certain fishing activities and gear are in contact with and/or penetrate the seabed. Literature review and analysis of data has shown that there are benthic fishing activities (dredging, trawling, netting) in proximity to the cable route. It is difficult to determine specific types of gear used so the depth of lowering and protection methods are derived from the maximum depth of penetration from fishing.

Further information on the fishing gear and activities in the vicinity of the cable route are provided in **Appendix G.**

#### 5.2.3.1 Overview

There are over 2700 fishing vessels containing 1900 crew and supporting approximately 8000 jobs in Denmark (Ministry of Food, Agriculture and Fisheries, 2024). The fishing study has been carried out without consultation, however the following key European and Danish Sea fishing organisations were identified as being relevant to the area:

- Baltic Fishermen's Association
- European Association of Fish Producers Organisations (EAPO)
- The Pelagic Advisory Council (AC)
- North Sea AC
- European Bottom Fisheries Alliance (EBFA)
- Association of Sustainable Fisheries (ASF)
- International Coalition of Fisheries Association (ICFA)
- European Fisheries Alliance (EUFA)
- Ministry of Environment and Food
- Ministry for Business
- Danish Fisheries Association (DFA)

#### 5.2.3.2 Data Sources

The principal sources of data and information used in the complication of the fishing section are outlined in **Table 5-1** below.

**Table 5-1 Fishing Study Principal Data Sources and Information**

| Type of Data | Source | Description |
|---|---|---|
| AIS (Automative Identification System) | Danish Maritime Authority (DMA) | Data with information on the position of fishing vessels 15 m and over in total length collected by the Danish Maritime Authority. |
| Fishing Intensity | EMODnet | Datasets on fishing intensity in the EU waters by sea basin, created every year by the International Council for the Exploration of the Sea (ICES). In the |

| Type of Data | Source | Description |
|---|---|---|
| | | 2020 Cogea started to collect and harmonize them according to the EMOdnet Human Activities dataset schema. This dataset is updated yearly. The fisheries overview data concern the spatial distribution of average annual fishing effort (mW fishing hours) by ecoregion and by gear type. Fishing effort data are only shown for vessels >12 m having VMS. |
| Fishing Effort (Total Swept Area Ratio) | Technical University of Denmark | Annual Swept Area Ratio (SAR) and the Percentage Unfished Area (PUA) for various fishing gears and selected areas. |

#### 5.2.3.3 Data Gaps

Vessels under 12 meters are not included in the AIS data (positional records) that has been used to inform this study. Although these smaller vessels must be taken into account for Navigational Risk Assessment (NRA) and the impact on other sea users, they are not seen as a major risk factor to the assets. The majority of fishing vessels potentially active in area of relevance to the Project that are less than 12 m in length are minor artisanal vessels and to a lesser extent longliners and purse seiners. The fishing gear used by these vessels have limited potential to cause negative interactions with subsea cables. Therefore, this lack of data is not seen as a hindrance to the conclusions of the report with regard to risks to the Project during its operational phase.

The presence of fishing vessels under 12 m in length, particularly those that operate static gears, may result in conflict with the Project during early surveys and installation works. It is recommended that local fisheries organisations are consulted with to gather information on vessels not captured in the AIS dataset that are potentially active in the area of the Project.

### 5.2.4 Dredging/Aggregate Extraction/Subsea Mining/Dumping

No dredging, aggregate extraction, subsea mining or dumping areas were observed in the vicinity of the cable corridor.

### 5.2.5 Telecommunication Cables

According to EMODnet, 2024 there at five telecommunication cable that transit through the study area, these cables all make landfall in Denmark. The telecommunication cables include:

- ODIN 2
- TAT14 Segment k(1)
- TAT14 Segment N
- CANTAT 3
- UK – DK 4

### 5.2.6 Other Cables

No third-party assets were identified from the survey data provided or within the cable corridor.

## 5.3 Risk Assessment and Evaluation Criteria

In this section, the risk acceptance criteria are discussed to allow implementation of the results of the probability of failure and consequence of failure assessment. The key output of this risk register being a probabilistic assessment of the risk to the cable after burial options are completed to a specified depth of lowering.

**Table 5-2** shows the risk matrix that we developed for the purpose of this project. The generic meaning of the colour code is indicated in the legend below the Figure. The principle works as follows: an event, such as a cable failure, has a probability of happening, and has a severity. The combination gives a location in the risk matrix and from that follows required next steps.

### Table 5-2 Risk Matrix

| | | Likelihood | | | | |
|---|---|---|---|---|---|---|
| | | **Rare (1)** | **Unlikely (2)** | **Possible (3)** | **Likely (4)** | **Almost Certain (5)** |
| **Severity** | **Insignificant (1)** | 1 | 2 | 3 | 4 | 5 |
| | **Minor (2)** | 2 | 4 | 6 | 8 | 10 |
| | **Moderate (3)** | 3 | 6 | 9 | 12 | 15 |
| | **Major (4)** | 4 | 8 | 12 | 16 | 20 |
| | **Severe (5)** | 5 | 10 | 15 | 20 | 25 |

| | |
|---|---|
| Dark green | Broadly acceptable |
| Light green | ALARP low |
| Yellow | ALARP medium |
| Orange | ALARP high |
| Red | Intolerable |

The severities are defined for two different categories, cost and performance, as shown in **Table 5-3**, while the definition of the likelihood is shown in **Table 5-4**.

### Table 5-3 Severity Definition

| | | | Severity | | | | |
|---|---|---|---|---|---|---|---|
| **Category** | **Cost** | | **Insignificant (1)** | **Minor (2)** | **Moderate (3)** | **Major (4)** | **Severe (5)** |
| | | | **Less than €59K** | **€59k - €590K** | **€590K - €11.82M** | **€11.82M – €236.45M** | **10% CAPEX (>€236.45M)** |
| | **Performance** | **Availability** | Increased surveillance | Increased maintenance<br><br>Occasional duration limits (days) at peak | One substantial outage +major intervention<br><br>Regular duration limits (hours) at peak capacity | Between one and eight 6-month outages Between 1 and 10% capacity loss | 10% availability drop through project lifetime (eg > eight 6-month outages in 40 years) > 10% max capacity loss |
| | | **Derating** | Rare minor derating in a short period of time. | Routine minor derating for short period of time. | Minor derating for extended period. | Substantial derating for significant period of time. | Significant permanent derating. |

Euros have been converted where £1=€1.18 at 16:34 on 18/02/2024.

**Table 5-4 Likelihood Definition**

| | Description | Probability of Event in the Lifetime (40 years) | Probability of Event per Year Range |
|---|---|---|---|
| **Rare (1)** | Although they are conceivable, not expected to occur. “Plausible but not known occurrences in industry”. | 0% - 2% | 0.00% - 0.05% |
| **Unlikely (2)** | Incidents of this nature are uncommon but there is a chance that they may occur. | 2%-10% | 0.05% - 0.26% |
| **Possible (3)** | This may happen. | 10%- 25% | 0.26% - 0.72% |
| **Likely (4)** | Likely to experience in the near-future. | 25%- 75% | 0.72% - 3.41% |
| **Almost Certain (5)** | Will occur or is already occurring. “Probability within the life time of the project (i.e. several known occurrences per year).” | 75%-100% | 3.41% - 100.00% |

## 5.4 Risk Mitigation

There are several remedial methods of protection that can be considered to reduce the risk to the cable. The principal method of protection for most modern cable systems is burial into the seabed. In general, an activity must penetrate through the material above the burial to interact with the cable.

It may be noted that there are instances in which utility crossings, joints, HDD exits or extremely hard soil conditions (e.g., bedrock) preclude burial or reduce the depth achievable. In such instances, there are three primary means of remedial protection which can be used:

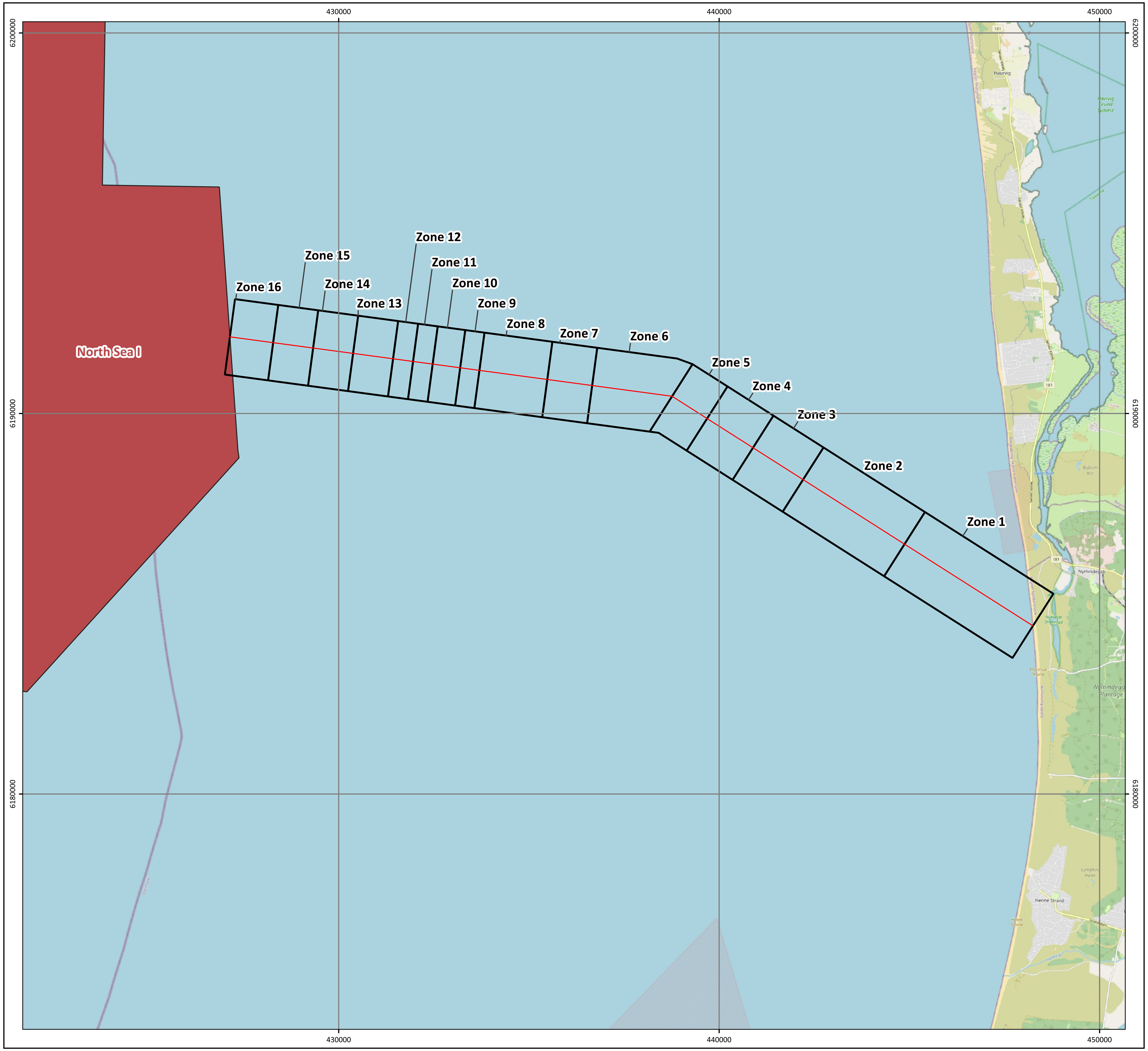
- Concrete mattresses
- Rock placement
- Articulated shell

## 5.5 Final Route Zonation

The final route segmentation used for the probabilistic assessment was segmented according to changes in risk profile resulting from changes in:

- Seabed geology
- External risk factors (e.g. Anchoring risk variation by location and water depth)

The final cable segmentation for the cable route is presented in the Cable Burial Risk Assessment (CBRA) Summary Table **(Section 7**) and is shown below in **Figure 5-1**






# CABLE BURIAL RISK ASSESSMENT NORTH SEA I - VEDERSØ KLIT

## LOCATION OVERVIEW

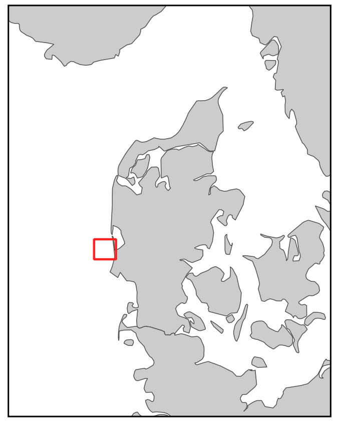
CBRA Zones

Drawing No: P2719D-LOC-003 | A

Legend

- Cable Route
- CBRA Zone
- Wind Farm Site

N



NOT TO BE USED FOR NAVIGATION

| | |
|---|---|
| Date | 2024-06-20 16:03:26 |
| Coordinate System | ETRS89 / UTM zone 32N |
| WKID | EPSG:25832 |
| Scale @A3 | 1:100,000 |
| Data Sources | ENERGINET |
| File Reference | J:\P2719\Mxd_QGZ\P2719D\01_LOC \P2719D_LOC.qgz |
| Created By | Lewis Castle |
| Reviewed By | Emma Langley |
| Approved By | Stephane Theurich |

ENERGINET intertek

0 1 2 3 4 km

# 6. PROBABILISTIC RISK ASSESSMENT

This section describes the methodology and results used to assess the fishing and anchoring risk the North Sea Nymindegab South cable system.

All relevant factors are assessed for a cable route on a section-by-section basis.

## 6.1 Fishing Risk Assessment Methodology

The review of the fishing assessment indicated mobile and static fishing areas present along the entire cable route. No fishing protection or areas excluded from fishing activity were reported.

Moreover, as the entire route is within water depth range in which mobile gear fishing could take place, we recommend the cable is given sufficient protection from potential fishing gear interaction along the entire route.

The Carbon Trust' guidance indicates that penetration of fishing gear into the seabed is limited to a maximum of 0.3 m penetration even in soft sediment based on previous literature research.

Adding a FoS of 2 to account for measurement errors and deformation of soil beneath fishing gear gives a RMDOL of 0.60m for fishing risk alone.

## 6.2 Vessel and Anchors Bands

To facilitate easier analysis of the vessel traffic, the vessels were grouped into seven deadweight tonnage bands. This allowed a set range of anchor sizes to be used to characterise those carried by shipping fleets in the tonnage bands. This is shown below in **Table 6-1**

The vessels' DWT were calculated from the vessel length data supplied in the AIS data. The methodology to calculate the vessels' DWT is as follows:

1. Create a list of all unique vessels present in the AIS data set.

For each vessel category (Cargo, Tanker, Passenger, etc) research the DWT information online (https://www.marinetraffic.com/) using vessel MMSI number for a sufficient set of vessels per category (30 to 50 vessels' DWT were researched online per category).

2. For each vessel category, plot the DWT vs Length and derive a conservative power trendline that fits the distribution of data points.

Based on the above process, the following empirical formulas were derived by Intertek and used to calculate the vessels' DWT:

$$DWT_{cargo} = 0.0017 \times L^{3.2551}$$

$$DWT_{Tanker} = 0.0025 \times L^{3.175}$$

$$DWT_{Passenger}{}^{2} = 0.0583 \times L^{2.1278}$$

$$DWT_{Vessel<70m} = 0.0009 \times L^{3.3717}$$

Where:

DWT = Vessel deadweight tonnage (tonnes)

L = Vessel length (m)

Once the vessel deadweight tonnage is known, the theoretical anchor mass can be calculated by the following empirical formula proposed by Luger as referenced in the Submarine Power Cables book by Worzyk, (this is recognised as an acceptable approach by the Carbon Trust's CTC-835):

$$y = 7 \times 10^{-13}x^3 - 6 \times 10^{-7}x^2 + 0.1635x + 2162.2$$

Where:

y = Anchor mass (kg)

x = Vessel deadweight tonnage (upper DWT boundary of each band) (tonnes)

The Carbon Trust's guidance shows the Luger formula to be a good fit with the International Association of Classification Societies (IACS) rules for vessel DWT between 10,000 and at least up to 100,000. Thus, for the vessel Band with a DWT up to 10,000 (Bands A & B), Intertek has used the estimated anchor size from Table 9 of Ref 1, for Bands C-E we have used Luger's formula and for Bands F-G we have used a chart from a presentation given by Luger.

We then used an anchor catalogue to select realistic stockless anchor dimensions based on the theoretical anchor mass calculated. The "Hall" pattern anchor is used for Bands A-E and "Spek" is used for Bands F and G as these are typical stockless anchors in common use, especially on older vessels. These types of anchors have a relatively long fluke length for its unit mass and a large opening angle, which equates to more penetration for a given fluke length.

[2] The relationship between DWT and vessel length would normally be expected to be closer to the cube of the length than the square. However, as demonstrated in the **Appendix D**, the formula is a good fit to the data set obtained from research.

**Table 6-1 Vessel and Anchor Size Bands**

| Band Name | Vessel DWT [Tonnes] | Vessel DWT [Tonnes] | Calculated Theoretical Anchor Mass [kg] | Selected Anchor Mass [kg] |
|---|---|---|---|---|
| Band A[3] | 0.00 | 100.00 | 335 | 300 |
| Band B | 100.00 | 1,000.00 | 524 | 570 |
| Band C | 1,000.00 | 3,500.00 | 1,302 | 1,290 |
| Band D | 3,500.00 | 10,000.00 | 2,388 | 2,460 |
| Band E | 10,000.00 | 30,000.00 | 6,546 | 6,900 |
| Band F | 30,000.00 | 60,000.00 | 9,963 | 9,900 |
| Band G | 60,000.00 | 100,000.00 | 13,212 | 13,500 |
| Band H | 100,000.00 | 150,000.00 | 16,917 | 17,800 |
| Band I | 150,000.00 | 200,000.00 | 18,583 | 20,000 |

## 6.3 Probabilistic Model

Intertek have developed a robust probabilistic assessment to determine the probability of interaction between an anchor and an installed cable based on local data for shipping traffic intensities, derived from historical AIS data. The model predicts the probability of a buried cable being struck because of anchoring. The probability of cable-anchor interaction decreases as DoL is increased beyond the maximum penetration depth of each anchor size.

The method takes account of:

- Shipping traffic intensity by vessel size;
- Probability of engine failure;
- Probability of an emergency anchor deployment;
- Dragging distance of an anchor; and
- Protection factor provided by soils.

The assessment provides the annual probability of a failure, which can in turn be used to calculate the mean time to failure (MTTF) due to anchoring. It should be recognised that it does not predict a failure time and that failure in year one is equally as likely as in any subsequent year.

The probabilities are calculated for a range of vessel and anchor sizes. The anchor size for the upper end of the vessel tonnage band is used, as indicated in **Table 6-1.**

The probability of failure of the cable because of damage caused by emergency anchoring is calculated using the following equation:

[3] Within this band there are a significant number of vessels present that are too small to carry an anchor of this mass. As such, the selected anchor mass represents a conservative approach

$$P_{anchor\ damage\ per\ km} = K \times P_{loss} \times P_{deploy} \times P_{fa}$$

Where:

| | |
|---|---|
| $P_{anchor\ damage\ per\ km}$ | = probability of anchor damage on cable (-/year.km$^{-1}$) |
| K | = total number of ship hours in sample box (hr/year.km$^{-2}$) |
| $P_{loss}$ | = probability of engine failure (-/engine hour) |
| $P_{deploy}$ | = probability of anchor operation (-) |
| $P_{fa}$ | = protection factor (-) |

**Zones of Interest**

A vessel does not immediately drop an anchor when it encounters engine problems. It drifts for a period while trying to recover from the engine problem. If unrecoverable, it slows down to below approximately 1 knot before dropping an anchor. Anchoring at speeds above 1 knot will most likely lead to vessel structural damage. Defining a Zone of Interest which is greater than just directly adjacent to the cable route allows for a potential period spent drifting while trying to recover the engine and/or slow down sufficiently to allow anchoring to take place. This means that the cables will not only be affected by vessels that are directly above it.

The Zones of Interest for the cable routes for each individual cable segments are defined as a 2km buffer around each segment. **Figure 5-1** shows the cable route segments and associated Zones of Interest used.

**K - Total number of ship hours in sample box**

This can be obtained by interrogating the historical AIS data. The AIS data has been interpolated to provide a location every 1 minute.

A fishnet grid at 0.5 $km^2$ resolution was created and intersected with the interpolated points. The sum of vessel hours was represented within each grid cell. Each zone of the cable route was intersected with the 0.5$km^2$ grid cells and all these values were used to represent each the vessel/hours/year/$km^2$ for the route within that zone. This value is then multiplied by the drag distance(m)/1000m. The fishnet grid is shown below in **Figure 6-1**

The Drag distance ($D_{ship}$) is defined by the following equation derived from the carbon trust (Carbon Trust, 2015).

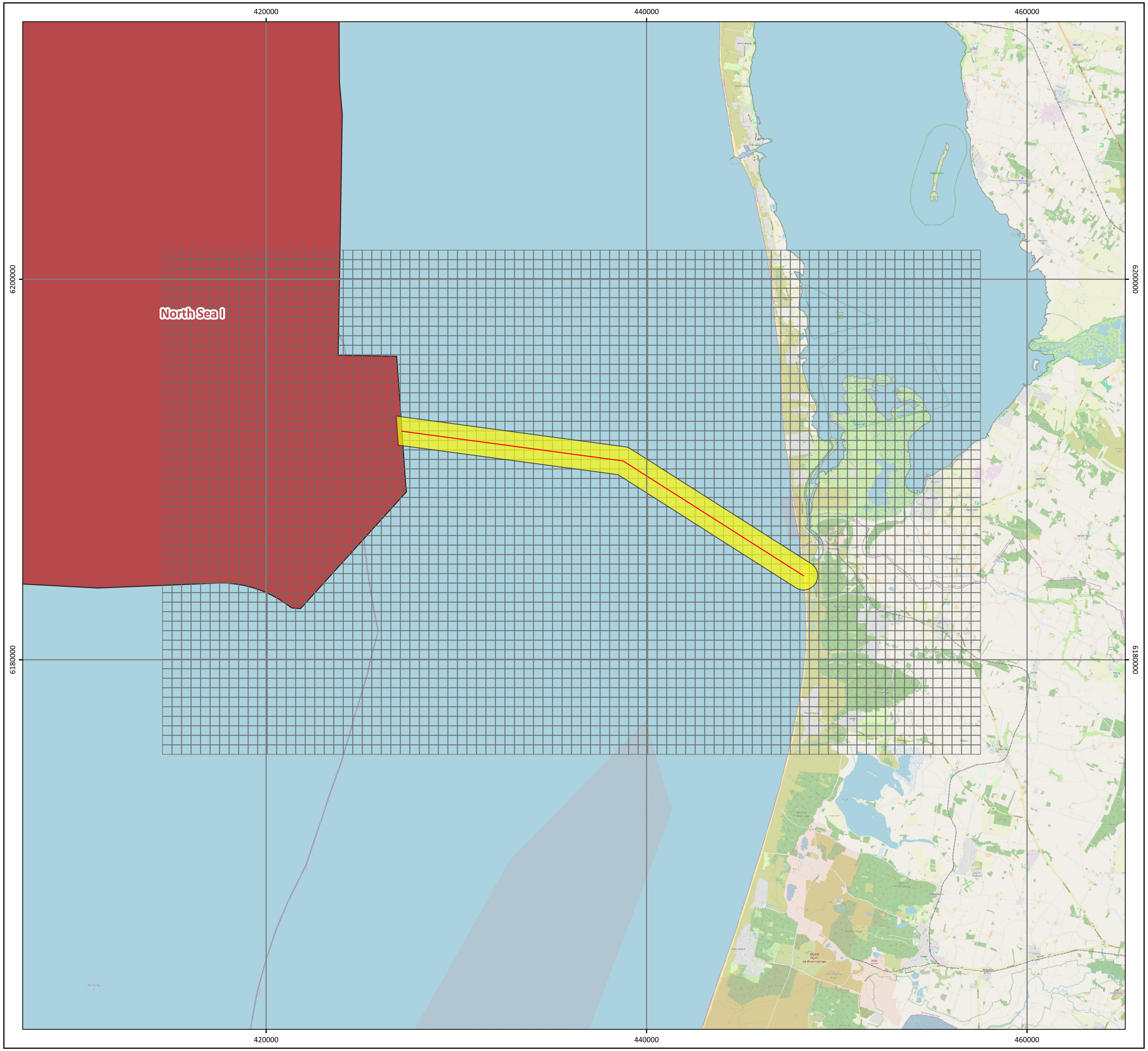
$$D_{ship} = \frac{m * V_{ship}^2}{4 * UHC}$$

Where:

| | |
|---|---|
| $D_{ship}$ | = Distance Travelled by the anchor in order to be a threat to the cable (m) |
| m | = Vessel mass as displacement (tons) |
| $V_{ship}$ | = Ship speed when anchor is deployed (m/s) |
| UHC | = Ultimate Holding Capacity of the Anchor (tons) |

In this case, displacement has been derived from the Carbon Trusts (Carbon Trust, 2015) methodology and vessel speed is assumed to be 2 knots based on industry standards. Intertek is aware the 4 knots is recorded as per the Carbon Trust's guidelines if vessel speed is not known, however 2 knots is used as a very conservative approach, since slower vessels are more likely to drop anchor.

UHC has been derived from Sotra's Anchor and chain handbook (Sorta, 2021). The handbook used provides three different UHC equations for different Seabed types (Sand and Clay, Medium Clay and Very soft clay and Mud), therefore three different UHC values have been used based on seabed geology. UHC and $D_{ship}$ values per vessel bands are presented in **Table 6-2**.




# CABLE BURIAL RISK ASSESSMENT
# NORTH SEA I - VEDERSØ KLIT

## LOCATION OVERVIEW

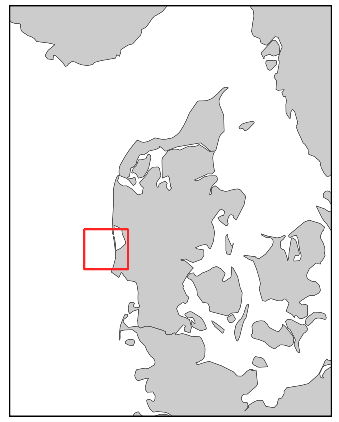
Fishnet Grid Extent

| Drawing No: P2719D-LOC-002 | A |
|---|---|

Legend

- Cable Route
- Fishnet Grid (0.5km²)
- Cable Corridor (1.5km)
- Wind Farm Site

N



NOT TO BE USED FOR NAVIGATION

| | |
|---|---|
| **Date** | 2024-06-21 16:25:04 |
| **Coordinate System** | ETRS89 / UTM zone 32N |
| **WKID** | EPSG:25832 |
| **Scale @A3** | 1:200,000 |
| **Data Sources** | ENERGINET |
| **File Reference** | J:\P2719\Mxd_QGZ\P2719D\01_LOC \P2719D_LOC.qgz |
| **Created By** | Lewis Castle |
| **Reviewed By** | Emma Langley |
| **Approved By** | Stephane Theurich |

ENERGINET intertek

0 2 4 6 8 km

### Table 6-2 UHC and $D_{ship}$ Values per Vessel Band

| Band Name | Vessel DWT [Tonnes] | | Displacement of Vessels [T] | UHC - SAND and Clay [mT] | UHC - Medium Clay [mT] | UHC Very soft Clay and Mud [mT] | Dship SAND and Clay [m] | Dship Medium Clay [m] | Dship Soft Clay and Mud [m] |
|---|---|---|---|---|---|---|---|---|---|
| Band A | 0.00 | 100.00 | 170.00 | 26.33 | 20.48 | 6.46 | 8.30 | 11.62 | 11.62 |
| Band B | 100.00 | 1,000.00 | 1,700.00 | 34.71 | 30.90 | 48.98 | 55.01 | 77.02 | 77.02 |
| Band C | 1,000.00 | 3,500.00 | 5,100.00 | 86.24 | 71.39 | 59.13 | 71.44 | 100.02 | 100.02 |
| Band D | 3,500.00 | 10,000.00 | 17,000.00 | 158.18 | 124.73 | 107.47 | 136.29 | 190.81 | 190.81 |
| Band E | 10,000.00 | 30,000.00 | 51,000.00 | 433.61 | 315.42 | 117.62 | 161.69 | 226.36 | 226.36 |
| Band F | 30,000.00 | 60,000.00 | 102,000.00 | 659.98 | 464.22 | 154.55 | 219.72 | 307.61 | 307.61 |
| Band G | 60,000.00 | 100,000.00 | 170,000.00 | 875.18 | 601.85 | 194.25 | 282.46 | 395.45 | 395.45 |
| Band H | 100,000.00 | 150,000.00 | 255,000.00 | 1120.58 | 755.52 | 227.56 | 337.52 | 472.52 | 472.52 |
| Band I | 150,000.00 | 200,000.00 | 340,000.00 | 1230.94 | 823.71 | 276.21 | 412.77 | 577.87 | 577.87 |

Vessel density numbers are provided in **Appendix D**.

**$P_{loss}$ - Probability of engine failure**
This is taken from a report compiled by DNV (Det Norske Veritas) for the Marine & Coastguard Agency for coastal waters around the UK. The value used in the calculations is 0.00015 / hr (equivalent to an average of 1.3 / yr of continuous vessel operation). In general, this figure is probably somewhat conservative.

**$P_{deploy}$ - Probability of anchor operation:**
The anchor will not be dropped in every emergency situation. This depends on the local geography, local bathymetry and the Vessel Master's knowledge.

**Table 6-3** provides the $P_{deploy}$ factors which have been applied in this CBRA.

### Table 6-3 $P_{deploy}$ Values by Vessel Band and Water Depth

| Water Depth (m) | $P_{deploy}$ | | | | | | |
|---|---|---|---|---|---|---|---|
| | Band A | Band B | Band C | Band D | Band E | Band F | Band G |
| 0-50 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 50-75 | 0.05 | 0.05 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| 75-100 | 0 | 0 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| >100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**$P_{fa}$ - Protection factor:**
This considers the protection offered by soil cover. $P_{fa}$ is a combination between the anchor penetration depth in different soil condition and the actual cable DOL and is either 0 or 1. If the cable DoL is greater than the maximum anchor penetration depth (including FoS) for a given anchor size then $P_{fa}$ equals to 0 for that anchor size. Conversely, if cable DoL is less than or equals to the anchor penetration depth (including FoS) for a given anchor size then $P_{fa}$ equals to 1 for that anchor size.

Anchor penetration depths for SANDS and CLAYS (or SAND/CLAY mixes) are typically calculated by taking the sine of the fluke opening angle and multiplying by the fluke length (for Hall anchors this is 45°). This is due to observations that anchor shanks are typically supported by the soil as they are dragged over it. However, EXTREMELY LOW STRENGTH SILTS and CLAYS (i.e. with shear strength <10kPa) are unable to support the shank and as such penetration can be significantly deeper – 3 times the sine 45° of fluke length is typically used in the industry (note these soils are not present on the route). In addition, industry understanding is that HIGH STRENGTH CLAYS (≥100kPa) prevent flukes penetrating at all and where soils with shear strength of this level or above are present on the route in underlying layers we have designated the depth they are at as the maximum depth any anchor will penetrate to.

As above, the industry typically applies Sin 45° of fluke length to calculate anchor penetration in SANDS. However, trials in the German Bight in 2013 suggest that in SANDS anchor penetration are less than previously thought. This report concluded that a 11.5t Hall anchor would have a maximum depth of penetration of 1m in VERY LOOSE SAND, 0.79m in LOOSE SAND and 0.40m in a MEDIUM DENSE SAND which are less than the theoretical value of 1.17m calculated by Sin 45° of fluke length. In addition, the report indicates extrapolation of results to anchors of different size using a scaling factor is valid.

Normally the fluke angle is fixed between 30° to 50°, the lower angle, i.e. less penetration is used in areas of sand or hard or stiff clays, the higher fluke angle, more penetration, is used for holding in softer consolidated clays and provides a greater resistance force (DNV, 2015).

Thus, for each anchor size defined in **Table 6-1**, Intertek calculated the theoretical anchor penetration depth and used the results outlined in the German Bight Anchor Penetration Trials report to scale these anchor penetration depths to more realistic values for areas of SAND sediment type. Areas of SAND sediment type which were dense or very dense were considered as medium dense for the purposes of calculating anchor penetration depths.

A Factor of Safety of 1.5 has been applied on the anchor penetration depths to consider:

- Uncertainty in anchor sizing;
- Uncertainty of soil type; and
- Deformation of the soil beneath the maximum penetration depth.

In addition, all final maximum penetration depths have been rounded up to the closet 5cm to avoid implying a level of accuracy which is not justified. Results of anchor penetration calculations by soil category, without and with the Factor of Safety are provided in **Table 6-4** and **Table 6-5** respectively.

In addition (and as can be expected), there are a number of zones in which there is a surficial sediment layer which has soil properties which vary significantly from the underlying layers. To account for this, we have defined all layers which are present within the soils depths which are relevant to the burial of the cable. Anchor penetration has then been first calculated for the top layer (Layer 1) and if the anchor penetrates through this layer into the underlying layer, then a second calculation has been undertaken to determine penetration depth in Layer 2. The method for calculating Layer 2 penetration is as follows:

- Calculate the remaining anchor penetration potential (in percentage terms) for each anchor size after it has penetrated Layer 1 (e.g. in LOOSE SAND a Band C anchor will penetrate 0.75m, if the top layer is 0.50m then the anchor has ~33% of its penetrating potential remaining after penetrating through Layer 1).
- Multiply the remaining anchor penetration by the maximum anchor penetration in Layer 2 to derive the Layer 2 penetration depth (e.g. in MEDIUM DENSE SAND a Band C anchor will penetrate 0.40m. If only ~33% of its penetrating potential remains after penetrating through Layer 1 then this equates to ~0.13cm penetration into Layer 2).
- The same method is used for Layer 3.

Thus, total penetration is calculated by adding the penetration thicknesses for Layer 1 and (where applicable) Layer 2 together.

**Table 6-4 Anchor Sizes and Anchor Penetration Depth by Soil Category**

| Band Name | Selected Anchor Mass [kg] | Theoretical Anchor Penetration Value [m] | Scaled Anchor Penetration by Soil Category [m] | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | VERY LOOSE SAND | LOOSE SAND | MEDIUM DENSE SAND | EXTREMELY LOW STRENGTH CLAY (<10 kPa) | MEDIUM STRENGTH CLAY (≥10 to <75 kPa) | HIGH STRENGTH CLAY (≥75 kPa) |
| Band A | 300 | 0.35 | 0.30 | 0.24 | 0.12 | 1.05 | 0.35 | 0.18 |
| Band B | 570 | 0.44 | 0.38 | 0.30 | 0.15 | 1.33 | 0.44 | 0.22 |
| Band C | 1,290 | 0.57 | 0.49 | 0.39 | 0.20 | 1.72 | 0.57 | 0.29 |
| Band D | 2,460 | 0.71 | 0.61 | 0.48 | 0.24 | 2.14 | 0.71 | 0.36 |
| Band E | 6,900 | 1.00 | 0.85 | 0.68 | 0.34 | 3.01 | 1.00 | 0.50 |
| Band F | 9,900 | 1.13 | 0.96 | 0.76 | 0.38 | 3.39 | 1.13 | 0.57 |
| Band G | 13,500 | 1.13 | 0.96 | 0.76 | 0.39 | 3.40 | 1.13 | 0.57 |
| Band H | 17,800 | 1.25 | 1.06 | 0.84 | 0.43 | 3.75 | 1.25 | 0.63 |
| Band I | 20,000 | 1.28 | 1.09 | 0.86 | 0.44 | 3.84 | 1.28 | 0.64 |

### Table 6-5 Anchor Sizes and Anchor Penetration Depth by Soil Category Including a Factor of Safety of 1.5

| Band Name | Selected Anchor Mass [kg] | Theoretical Anchor Penetration Value [m] | Scaled Anchor Penetration by Soil Category (incl. FoS of 1.5 & rounded up to nearest 0.05m) [m] | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | VERY LOOSE SAND | LOOSE SAND | MEDIUM DENSE SAND | EXTREMELY LOW STRENGTH CLAY (<10 kPa) | MEDIUM STRENGTH CLAY (≥10 to <75 kPa) | HIGH STRENGTH CLAY (≥75 kPa) |
| Band A | 300 | 0.35 | 0.45 | 0.40 | 0.20 | 1.60 | 0.55 | 0.30 |
| Band B | 570 | 0.44 | 0.60 | 0.45 | 0.25 | 2.00 | 0.70 | 0.35 |
| Band C | 1,290 | 0.57 | 0.75 | 0.60 | 0.30 | 2.60 | 0.90 | 0.45 |
| Band D | 2,460 | 0.71 | 0.95 | 0.75 | 0.40 | 3.25 | 1.10 | 0.55 |
| Band E | 6,900 | 1.00 | 1.30 | 1.05 | 0.55 | 4.55 | 1.55 | 0.80 |
| Band F | 9,900 | 1.13 | 1.45 | 1.15 | 0.60 | 5.10 | 1.70 | 0.85 |
| Band G | 13,500 | 1.13 | 1.45 | 1.15 | 0.60 | 5.10 | 1.70 | 0.85 |
| Band H | 17,800 | 1.25 | 1.60 | 1.30 | 0.65 | 5.65 | 1.90 | 0.95 |
| Band I | 20,000 | 1.28 | 1.65 | 1.30 | 0.70 | 5.80 | 1.95 | 1.00 |

## 6.4 Identification of the Acceptable Risk

### 6.4.1 Project Requirement

Quantify the depth of lowering to achieve a total probability of failure (PoF) along the cable route of 1 failure per 10,000 years.

### 6.4.2 Calculations of Probability

The calculation for probability of a cable strike for the entire cable system is given by:

$$P_{anchor\ damage,total\ system} = \sum P_{anchor\ damage\ per\ km}$$

Where:

$P_{anchor\ damage,total\ system}$ = probability of anchor damage for the entire cable route (-/year)

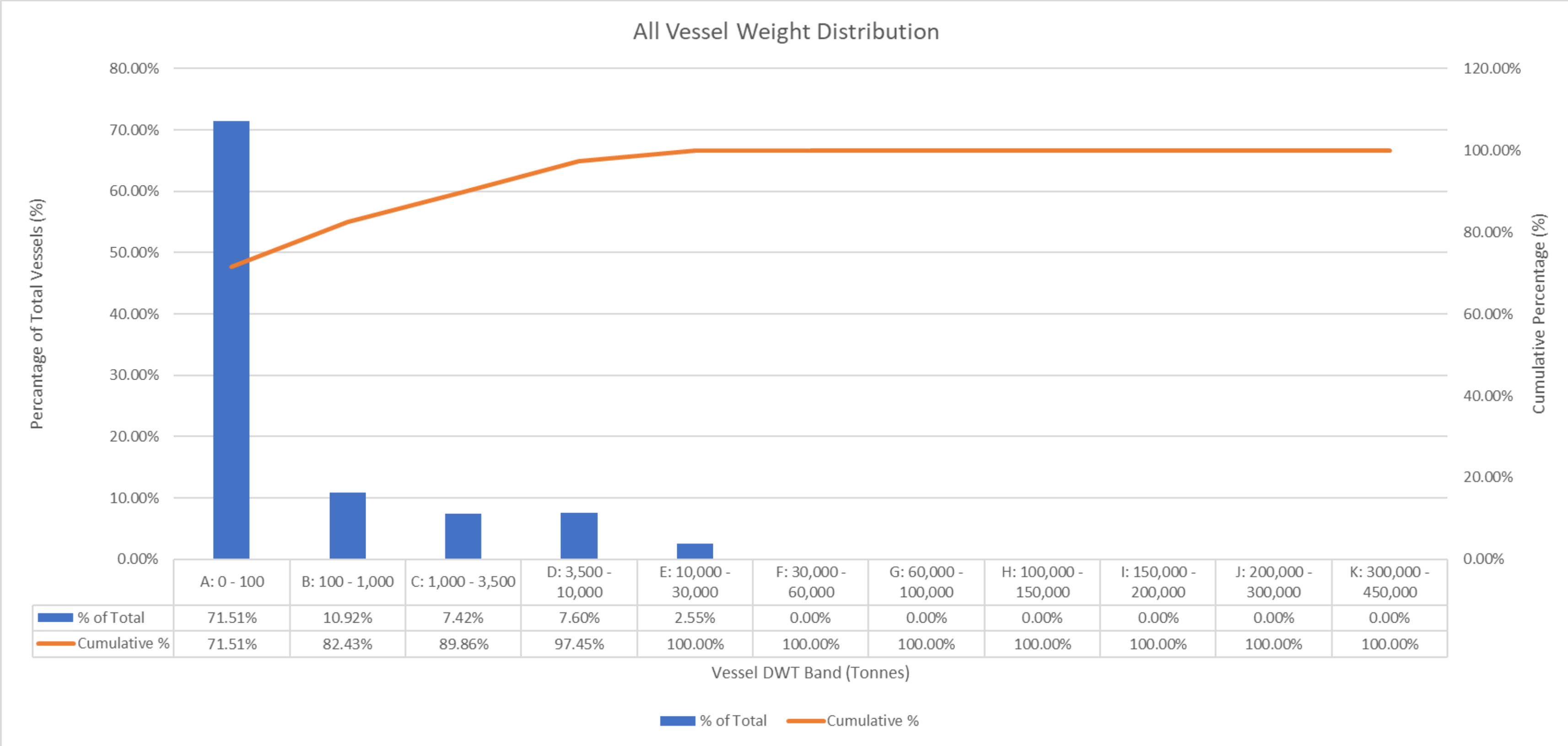
As recommended by the Carbon Trust’s guideline, Intertek used an iterative approach to identify a burial depth which results in a “target” residual risk to overall cable system.

The iterative step can be described as follows:

3. Calculate the value of $P_{anchor\ damage,total\ system}$ for all vessels with a surface-laid cable.
4. Identify the value of $P_{anchor\ damage,total\ system}$ that would be acceptable to the stakeholders.
5. Goal-seek RMDOL which achieves this tolerable level.
6. If the RMDOL is considered impractical the acceptable level of risk should be re-considered.

**Figure 6-2** shows vessel size distribution by DWT. Naturally, vessel densities are overwhelmingly composed of smaller vessels, so risk reduces significantly as DOL increases over and above the penetration depths of anchor sizes associated with smaller vessels.

## Figure 6-2 Overview of Vessel Size Distribution



## 6.5 Probabilistic Risk Assessment Results

For this risk assessment the DNV 2005 risk levels were assigned to the probabilities. **Table 6-6** provides the DNV risk classification (DNV, 2005).

### Table 6-6 DNV Risk Classification Used

| DNV Risk Classification | Description | Return Periods (Years) |
|---|---|---|
| Cat 1 | Low frequency that event considered negligible | >1 in 100,000 |
| Cat 2 | Event rarely expected to occur | 1 in 10,000 to 1 in 100,000 |
| Cat 3 | Event individually not expected to happen, but when summarised over a large number of assets have the credibility to happen once a year | 1 in 1,000 to 1 in 10,000 |
| Cat 4 | Event individually may be expected to occur during the lifetime of the cable | 1 in 100 to 1 in 1,000 |
| Cat 5 | Event individually may be expected to occur more than once during lifetime | <1 in 100 |

### 6.5.2 Results of Surface Laid Cable

**Table 6-7** presents segment annual failure for a surface laid cable.

### Table 6-7 Zone Annual Failure for Surface Laid Cable

| Zone | $P_{anchor\ damage}$ |
|---|---|
| 1 | 2.06E-02 |
| 2 | 4.81E-03 |
| 3 | 4.27E-03 |
| 4 | 6.82E-03 |
| 5 | 9.73E-03 |
| 6 | 7.48E-03 |
| 7 | 1.80E-02 |
| 8 | 1.43E-02 |
| 9 | 9.22E-03 |
| 10 | 1.18E-02 |
| 11 | 3.30E-03 |
| 12 | 1.16E-03 |
| 13 | 8.95E-03 |
| 14 | 1.47E-03 |
| 15 | 1.17E-03 |
| 16 | 2.07E-03 |
| Annual Failure Probability for Entire route | 13% |

| Zone | $P_{anchor\ damage}$ |
|---|---|
| Return Period (years) | 7.99 |
| Failure Probability in the lifetime (40 years) | 99.52% |

The probabilistic assessment calculates the annual failure probability of 13% for the entire route (based on anchor risk alone) if surface laid. This value equates to a return period of 7.99 years and a failure probability over the (40 year) lifetime of 13%.

Areas with the highest risk of Annual Failure include zones 1, 7,8 and, 10 These zones are areas of high vessel traffic and soft geology thus; increased anchor drag risk.

The lowest zone of risk is zones 12, 14 and 15 given the low vessel traffic reducing all risk of anchor strike.

### 6.5.3 Results for Recommended Minimum DOL

A RMDOL was derived on a zone basis to mitigate the risk from anchoring from the selected vessel band in order to achieve an overall acceptable risk of 1 failure per 10,000 years. The tables below present the RMDOL and associated annual failure probability for the following 10 scenarios:

1. Scenario 1: Protection against vessels in Band A
2. Scenario 2: Protection against vessels in Bands A to B
3. Scenario 3: Protection against vessels in Bands A to C
4. Scenario 4: Protection against vessels in Bands A to D
5. Scenario 5: Protection against vessels in Bands A to E
6. Scenario 6: Protection against vessels in Bands A to F
7. Scenario 7: Protection against vessels in Bands A to G
8. Scenario 8: Protection against vessels in Bands A to H
9. Scenario 9: Protection against vessels in Bands A to I
10. Scenario 10: Selected protection section by section

As can be seen in the provided scenarios, anchoring risk is concentrated in Zone 9, both in terms of vessel traffic density and also size of associated vessels. This is followed by Zone 6 and Zone 1.

Note, the key reasons why anchor risk is not the key determinant in most zones is due to both the relatively light vessel densities and the prevalent presence of soils which prevent anchors from penetrating very deeply.

The above approach results in a RMDOL varying from 0.60m to 1.7m. If these RMDOL values are achieved and maintained over the course of the cable lifetime then this would result in an annual failure rate of 0.00836% which equates to a return period of ~11,957 years and a failure probability over the (40 year) lifetime of 0.33% - i.e. “Event rarely expected to occur.”.

# 7. CBRA ASSESSMENT

| Zone ID, KP and length | | | | | Water Depth (m below LAT) | | | Known Co-Located Infrastructure/ Obstacles | Geophysical/Geotechnical Data | | | | | | | | | | | | | Shipping Data (Anchoring Assessment) | | | Fishing Data | | Recommended Minimum Depth of Lowering (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | | | Geotechnical data used | | | | | | | | |
| GIS ID | Zone ID | Start KP | End KP | Length KM | MAX | MIN | Mean | | Layer 1 Dominant Sediment Type | Layer 1 Thickness (m) | Layer 1 Categorisation for Anchor Penetration Calculation | Layer 2 Dominant Sediment Type | Layer 2 Thickness (m) | Layer 2 Categorisation for Anchor Penetration Calculation | Layer 3 Dominant Sediment Type | Layer 3 Thickness (m) | Layer 3 Categorisation for Anchor Penetration Calculation | Mobile Features (where applicable) | CPTS | VC | Grab Samples | Risk from Anchoring (Vessel Bands Present) | Shipping Buffer Size (m) | Recommended DoL for Protection against Anchor Strike (including Factor of Safety of 1.5 & rounded up to nearest 0.05m) (m) | Presence of Fishing | Recommended DoL for Protection against Fishing Gear (including Factor of Safety of 2) (m) | |
| 1 | 1 | 0.00 | 3.31 | 3.31 | 6.6 | 0.0 | 3.0 | None Present | CLAY/TILL/SILT | 0.1 | EXTREMELY LOW STRENGTH CLAY (<10 kPa) | SAND | 2 | MEDIUM DENSE SAND | | | | None | GT_CPT_021<br>GT_CPT_062 | | | Yes | 2,000 | 0.50 | Yes | 0.60 | 0.60 |
| 2 | 2 | 3.31 | 4.13 | 0.82 | 10.1 | 4.3 | 7.0 | None Present | CLAY/TILL/SILT | 0.1 | EXTREMELY LOW STRENGTH CLAY (<10 kPa) | CLAY/TILL/SILT | 0.9 | MEDIUM STRENGTH CLAY (≥10 to <75 kPa) | SAND | 2 | MEDIUM DENSE SAND | None | GT_CPT_022<br>GT_CPT_063B<br>GT_CPT_023 | | | Yes | 2,000 | 1.10 | Yes | 0.60 | 1.10 |
| 3 | 3 | 4.13 | 6.46 | 2.33 | 11.8 | 8.5 | 10.0 | None Present | CLAY/TILL/SILT | 0.1 | EXTREMELY LOW STRENGTH CLAY (<10 kPa) | CLAY/TILL/SILT | 0.9 | MEDIUM STRENGTH CLAY (≥10 to <75 kPa) | SAND | 2 | MEDIUM DENSE SAND | None | GT_CPT_022<br>GT_CPT_063B<br>GT_CPT_023 | | | Yes | 2,000 | 1.10 | Yes | 0.60 | 1.10 |
| 4 | 4 | 6.46 | 7.85 | 1.39 | 13.3 | 10.4 | 12.0 | None Present | CLAY/TILL/SILT | 0.1 | EXTREMELY LOW STRENGTH CLAY (<10 kPa) | CLAY/TILL/SILT | 1 | MEDIUM STRENGTH CLAY (≥10 to <75 kPa) | SAND | 1.2 | VERY LOOSE SAND | None | GT _CPT_064 | ` | | Yes | 2,000 | 1.55 | Yes | 0.60 | 1.55 |
| 5 | 5 | 7.85 | 10.71 | 2.86 | 14.4 | 12.3 | 13.0 | None Present | CLAY/TILL/SILT | 0.1 | EXTREMELY LOW STRENGTH CLAY (<10 kPa) | CLAY/TILL/SILT | 1.3 | MEDIUM STRENGTH CLAY (≥10 to <75 kPa) | SAND | 0.5 | LOOSE SAND | None | GT _CPT_065 | | | Yes | 2,000 | 1.65 | Yes | 0.60 | 1.65 |
| 6 | 6 | 10.71 | 11.77 | 1.06 | 16.8 | 13.7 | 15.0 | None Present | CLAY/TILL/SILT | 0.1 | EXTREMELY LOW STRENGTH CLAY (<10 kPa) | CLAY/TILL/SILT | 1.5 | MEDIUM STRENGTH CLAY (≥10 to <75 kPa) | SAND | 1 | MEDIUM DENSE SAND | None | GT _CPT_066a | | | Yes | 2,000 | 1.70 | Yes | 0.60 | 1.70 |
| 7 | 7 | 11.77 | 13.88 | 2.11 | 18.0 | 16.2 | 17.0 | None Present | CLAY/TILL/SILT | 0.1 | EXTREMELY LOW STRENGTH CLAY (<10 kPa) | CLAY/TILL/SILT | 1.2 | MEDIUM STRENGTH CLAY (≥10 to <75 kPa) | CLAY/TILL/SILT | 1.2 | MEDIUM STRENGTH CLAY (≥10 to <75 kPa) | None | GT _CPT_067<br>GT _CPT_068 | | | Yes | 2,000 | 0.80 | Yes | 0.60 | 0.80 |
| 8 | 8 | 13.88 | 14.94 | 1.06 | 18.8 | 17.1 | 19.0 | None Present | CLAY/TILL/SILT | 0.1 | EXTREMELY LOW STRENGTH CLAY (<10 kPa) | CLAY/TILL/SILT | 1 | MEDIUM STRENGTH CLAY (≥10 to <75 kPa) | CLAY/TILL/SILT | 0.3 | MEDIUM STRENGTH CLAY (≥10 to <75 kPa) | None | GT_CPT_69<br>GT_CPT_70 | | | Yes | 2,000 | 1.55 | Yes | 0.60 | 1.55 |
| 9 | 9 | 14.94 | 16.04 | 1.10 | 19.0 | 18.2 | 19.0 | None Present | CLAY/TILL/SILT | 0.5 | EXTREMELY LOW STRENGTH CLAY (<10 kPa) | CLAY/TILL/SILT | 0.7 | MEDIUM STRENGTH CLAY (≥10 to <75 kPa) | SAND | 2 | MEDIUM DENSE SAND | None | GT_CPT_71<br>GT_CPT_72 | | | Yes | 2,000 | 1.50 | Yes | 0.60 | 1.50 |
| 10 | 10 | 16.04 | 16.66 | 0.62 | 19.2 | 18.4 | 19.0 | None Present | CLAY/TILL/SILT | 0.1 | EXTREMELY LOW STRENGTH CLAY (<10 kPa) | CLAY/TILL/SILT | 0.4 | MEDIUM STRENGTH CLAY (≥10 to <75 kPa) | SAND | 2 | LOOSE SAND | None | GT_CPT_73 | | | Yes | 2,000 | 1.55 | Yes | 0.60 | 1.55 |
| 11 | 11 | 16.66 | 17.06 | 0.40 | 19.4 | 18.6 | 19.0 | None Present | SAND | 0.1 | VERY LOOSE SAND | CLAY/TILL/SILT | 1.5 | MEDIUM DENSE SAND | SAND | 0.3 | MEDIUM STRENGTH CLAY (≥10 to <75 kPa) | None | GT_CPT_74 | | | Yes | 2,000 | 0.80 | Yes | 0.60 | 0.80 |
| 12 | 12 | 17.06 | 18.11 | 1.05 | 19.6 | 18.8 | 19.0 | None Present | CLAY/TILL/SILT | 0.5 | EXTREMELY LOW STRENGTH CLAY (<10 kPa) | CLAY/TILL/SILT | 2.5 | MEDIUM STRENGTH CLAY (≥10 to <75 kPa) | | | | None | GT_CPT_75 | | | Yes | 2,000 | 1.15 | Yes | 0.60 | 1.15 |
| 13 | 13 | 18.11 | 19.17 | 1.06 | 19.9 | 19.0 | 19.0 | None Present | SAND | 0.1 | VERY LOOSE SAND | CLAY/TILL/SILT | 0.6 | MEDIUM STRENGTH CLAY (≥10 to <75 kPa) | CLAY/TILL/SILT | 1.1 | MEDIUM STRENGTH CLAY (≥10 to <75 kPa) | None | GT_CPT_76 | | | Yes | 2,000 | 0.90 | Yes | 0.60 | 0.90 |
| 14 | 14 | 19.17 | 20.23 | 1.06 | 20.3 | 19.4 | 20.0 | None Present | SAND | 0.2 | LOOSE SAND | CLAY/TILL/SILT | 1.4 | MEDIUM STRENGTH CLAY (≥10 to <75 kPa) | CLAY/TILL/SILT | 0.6 | HIGH STRENGTH CLAY (≥75 kPa) | None | GT_CPT_77 | | | Yes | 2,000 | 0.70 | Yes | 0.60 | 0.70 |
| 15 | 15 | 20.23 | 21.28 | 1.05 | 20.6 | 19.8 | 20.0 | None Present | CLAY/TILL/SILT | 0.15 | EXTREMELY LOW STRENGTH CLAY (<10 kPa) | CLAY/TILL/SILT | 1 | MEDIUM STRENGTH CLAY (≥10 to <75 kPa) | CLAY/TILL/SILT | 0.25 | MEDIUM STRENGTH CLAY (≥10 to <75 kPa) | None | GT_CPT_78 | | | Yes | 2,000 | 0.70 | Yes | 0.60 | 0.70 |
| 16 | 16 | 21.28 | 23.00 | 1.72 | 21.0 | 20.1 | 21.0 | None Present | CLAY/TILL/SILT | 0.2 | MEDIUM STRENGTH CLAY (≥10 to <75 kPa) | CLAY/TILL/SILT | 0.6 | MEDIUM STRENGTH CLAY (≥10 to <75 kPa) | SAND | 0.5 | MEDIUM DENSE SAND | None | GT_CPT_79 | | | Yes | 2,000 | 0.95 | Yes | 0.60 | 0.95 |

# 8. CONCLUSION AND RECOMMENDATIONS

The cable burial risk assessment has shown that the following hazards are present along the North Sea Nymindegab South cable route:

**Sediment Mobility**

Sediment mobility in itself does not pose a threat to a submarine cable, but it can lead to issues with the thermal conductivity of cables (over burial), and exposure of cables (scour); Over burial should be accounted for in the design phase of the cables and is usually dealt with by increasing, universally or locally, the cross-sectional area of the cables. Burial under excess soil can change the thermal properties of the soil and cause hotspots along the cable, while exposure increases the risk of damage due to external aggressors such as trawling and anchoring and potentially mechanical damage from free spans.

There are no areas within cable corridor where there are bedforms present. For the purposes of depth of lowering all depths recommended in this report are assumed to be measured against a horizontal plane which has been determined to be non-mobile and after any required route engineering has been undertaken to flatten mobile sediments.

**Fishing Risk**

The review of the fishing indicated areas of mobile and static fishing gear along the entire cable route. No fishing protection or exclusion areas from fishing activity were reported.

Moreover, as the entire route is within water depth ranges in which mobile gear fishing could take place, we recommend the cables are given sufficient protection from fishing gear interaction in all sections of the route. The Carbon Trust's guidance indicates that penetration of fishing gear into the seabed is limited to a maximum of 0.3 m penetration even in soft sediment based on previous literature research. Allowing for a FoS of 2 means RMDOL based on fishing risk only would result in a value of 0.60m.

**Anchoring Risk**

Vessel Automatic Identification System (AIS) data has been used to determine the size and quantity of vessels which operate in the vicinity of the cable route. Vessels are grouped into size categories based on their deadweight tonnage (DWT) from Band A (0-100 DWT) to Band I (150K-200K DWT) and an appropriate associated anchor size is assigned to each band. Analysis of this data determines the probability of anchor-cable interactions for each vessel banding and thus the size of anchor which must be protected against in order to reduce risk to the cable to ALARP.

The probabilistic assessment calculates the annual failure probability of 13% for the entire route (based on anchor risk alone) if surface laid. This value equates to a return period of 7.99 years and a failure probability over the (40 year) lifetime of 99.52%. This is not an acceptable level of risk.

Areas with the highest risk of Annual Failure include zones 1, 7, 8 and, 10 These zones are areas of high vessel traffic and soft geology; thus, increased anchor drag risk. The lowest zone of risk is zones 12, 14 and 15 given the low vessel traffic reducing all risk of anchor strike.

Note, the key reasons why anchor risk is not the key determinant in most zones is due to both the relatively light vessel densities and also the prevalent presence of soils which prevent anchors from penetrating very deeply.

**Recommended Minimum Depth of Lowering (RMDOL)**

The above approach results in a RMDOL varying from 0.60m to 1.7m. If these RMDOL values are achieved and maintained over the course of the cable lifetime then this would result in an annual failure rate of 0.00836% which equates to a return period of ~11,957 years and a failure probability over the (40 year) lifetime of 0.33% - i.e. "Event rarely expected to occur".

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# APPENDIX A Sr

## Geotechnical Boundaries

## Table A-1 Geotechnical Boundaries

| Zone | Comments/Assumptions | Start KP | End KP | Segment Distance (km) |
|---|---|---|---|---|
| 1 | 0.1 of Extremely Low Strength clay overlying Medium Dense Sand | 0.00 | 4.00 | 4.00 |
| 2 | 0.1 of Extremely Low Strength clay, 0.9 of low strength clay overlying Medium Dense Sand | 4.00 | 7.16 | 3.16 |
| 3 | 0.1 of Extremely Low Strength Clay, 1 of Low Strength Clay overlying Very Loose Sand | 7.16 | 8.72 | 1.56 |
| 4 | 0.1 of Extremely Low Strength Clay, 1.3 of Low Strength Clay overlying Loose Sand | 8.72 | 10.15 | 1.43 |
| 5 | 0.1 of Extremely Low Strength Clay, 1.5 of Low Strength Clay overlying Medium Dense Sand | 10.15 | 11.24 | 1.10 |
| 6 | 0.1 of Extremely Low Strength clay, 1.2 of medium dense sands overlying low strength clay | 11.24 | 13.36 | 2.12 |
| 7 | 0.1 of Extremely Low Strength clay, 1 of Loose Sand, overlying low strength clay | 13.36 | 14.55 | 1.19 |
| 8 | 0.5 of Extremely Low Strength Clay, 0.7 of Loose Sand overlying medium dense sand | 14.55 | 16.35 | 1.81 |
| 9 | 0.1 of Extremely Low Strength Clay, 0.4 of low strength clay overlying loose sand | 16.35 | 16.86 | 0.51 |
| 10 | 0.1 of very loose sand, 1.5 of medium dense sand overlying low strength clay | 16.86 | 17.59 | 0.73 |
| 11 | 0.5 of Extremely Low Strength Clay, overlying medium dense sand | 17.59 | 18.64 | 1.06 |
| 12 | 0.1 of very loose Sand, 0.6 of medium dense sand, overlying medium strength clay | 18.64 | 19.70 | 1.06 |
| 13 | 0.2 of very loose sand, 1.4 of medium dense sand, overlying high strength clay | 19.70 | 20.76 | 1.06 |
| 14 | 0.15 of Extremely low strength clay, 1 of medium dense sand, overlying medium strength clay | 20.76 | 21.82 | 1.06 |
| 15 | 0.2 of low strength clay, 0.6 of medium strength clay overlying medium dense sand | 21.82 | 23.00 | 1.19 |

# APPENDIX B

## Risk Register

## Table B-1 Risk Register

| Hazard Log Ref No. | Hazard Class | Hazard Description (Potential) | Risk Description | Initial Risk Rating | | | Mitigation | Residual Risk Rating | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Likelihood | Severity | Risk Rating | | Likelihood | Severity | Risk Rating |
| **Natural** | | | | | | | | | | |
| 1.A | Bathymetry | Sandwaves sections are present along the cable route which present extreme slopes. | Risk to trencher operation during installation. Not applicable as installation risk not considered here. **Not Scored.** | | | | | | | |
| 1.B | | Sandwaves sections are present along the cable route. | Sandwave sections are mobile which risks long-term asset protection (i.e. from vortex induced vibration and/or exposure to external aggressors) should free-spans develop or burial reduce to insufficient levels. **Assessed under 11. Mobile Sediment.** | | | | | | | |
| 2 | Seabed topography | Uneven seabed topography may lead to more variable burial requirements. | Local burial depth may be adjusted upwards by sandwaves that return after installation resulting in degraded thermal performance leading to potential derating. | 4 | 2 | 8 | Ensure cable's design can tolerate increased burial depths from returning sandwaves after installation. | 1 | 2 | 2 |
| 3 | Seabed obstructions | Obstruction will result in section out of burial specification. | Not applicable, only applicable to as-built cable. **Not scored** | | | | | | | |
| 4 | Shallow gas | Represent a danger to vessels / personnel. | Applicable to installation and as-built cable but not to present CBRA. **Not scored.** | | | | | | | |

| Hazard Log Ref No. | Hazard Class | Hazard Description (Potential) | Risk Description | Initial Risk Rating | | | Mitigation | Residual Risk Rating | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Likelihood | Severity | Risk Rating | | Likelihood | Severity | Risk Rating |
| 5 | Currents / waves | Abrasion, stress and fatigue where cable crosses rock/rough terrain. Can induce loading on cable connectors.<br><br>Can mobilise sediment exposing cables to further primary hazards. Metocean conditions likely to impact on surface laid cable and also influence sediment mobility. | Risk associated with protection for rocky terrain is design specific, thus outside CBRA scope. **Not scored.**<br><br>See hazard No.13 for risk from Mobile Sediment.<br><br>For surface laid there would be potential for damage from wave/current actions, predominantly in shallow waters. | 2 | 3 | 6 | CBRA to include consideration of wave/current action should surface laid be acceptable from anthropogenic threats.<br><br>For protection in rocky areas, a design risk assessment would be required.<br><br>Hydro-sedimentary study to be undertaken to determine risk of sediment accretion or erosion along the route. Vertical reference level to be revised if required by results of study. | 1 | 2 | 2 |
| 6 | Fish bites | Can damage insulation: historically mainly occurred with telegraph cables but recent occurrences have been noted occasionally. | Only applicable to subsea telecom cables. Not plausible threat to a power cable. | | | | | | | |
| 7.A | Hurricane / Storm surge / Extreme Weather | Can cause a shallow buried asset to be unburied due to hydrostatic forces or erosion of the seabed / formation of depressions; alternatively can lead to over burial through accretion. | Asset becomes vulnerable to risks such as fish and shipping. Additionally deburial may cause damage (strains and stresses) to the asset.<br><br>See hazard No.13 for risk from increased burial depth (Mobile Sediment). | 3 | 3 | 9 | Recommended to undertake a Hydro-Sedimentary Study to determine risk of erosion or accretion on the route due to strong waves or currents. Outputs of this study should feed into the calculation of the vertical reference level which Recommend Minimum and Target Depth of Lowering is measured against.<br><br>Cable designed to accommodate for greater levels of burial than level buried to, to accommodate more onerous thermal environment caused by either sandwave movement or accretion. | 3 | 2 | 6 |

| Hazard Log Ref No. | Hazard Class | Hazard Description (Potential) | Risk Description | Initial Risk Rating | | | Mitigation | Residual Risk Rating | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Likelihood | Severity | Risk Rating | | Likelihood | Severity | Risk Rating |
| 7.B | | Soil liquefaction | Risk of mechanical stress for cable on interface locations with structures (HDD entry point, j-tube bellmouth).<br><br>Risk of overheating if cable sinks deeper than design allows for.<br><br>Risk of free-spanning cable if depressions form. | 2 | 3 | 6 | Recommended to undertake detailed Hydro-sedimentary Study to determine potential for wave-induced soil liquefaction.<br><br>Consider use of bend restrictors in accordance with risk as identified by details engineering design.<br><br>Cable designed to accommodate for greater levels of burial than level buried to, to accommodate more onerous thermal environment caused by either sandwave movement, accretion, or else greater burial through liquefaction.<br><br>Cables monitored by Distributed Temperature Sensing (DTS)/Distributed Acoustic Sensing (DAS) and regular condition surveys to give early warning of reduction in sediment cover.<br><br>Ensuring cable specific gravity is as close as possible to that of liquefied soils. | 2 | 1 | 2 |
| 7.C | | Cause submarine landslides or turbidity currents reducing sediment cover exposing cables to primary risk. | Review of literature and the results of the seabed survey indicates that significant hazards of this nature are not expected along the cable's route though this should be confirmed by a detailed Geohazard Study. | 1 | 3 | 3 | Recommended to undertake detailed Geohazard Study. | 1 | 3 | 3 |

| Hazard Log Ref No. | Hazard Class | Hazard Description (Potential) | Risk Description | Initial Risk Rating | | | Mitigation | Residual Risk Rating | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Likelihood | Severity | Risk Rating | | Likelihood | Severity | Risk Rating |
| 8.A | Submarine earthquakes | Cause submarine landslides or turbidity currents reducing sediment cover exposing cables to primary risk. | Review of literature and the results of the seabed survey indicates that significant hazards of this nature are not expected along the cable's route though this should be confirmed by a detailed Geohazard Study. | 1 | 3 | 3 | Recommended to undertake detailed Geohazard Study. | 1 | 3 | 3 |
| 8.B | | Shifting geological layers along a fault line | Damage to asset caused by strains and stresses | 1 | 4 | 4 | Risk is at ALARP as there is no evidence of faults along the export cable route. | 1 | 3 | 3 |
| 8.C | | Soil liquefaction | Risk of mechanical stress for cable on interface locations with structures (j-tube bellmouth).<br><br>Risk of overheating if cable sinks deeper than design allows for.<br><br>Risk of free-spanning cable if depressions form. | 2 | 3 | 6 | Undertake detailed Geohazard Study to determine potential for earthquake-induced soil liquefaction (note, study has been undertaken).<br><br>Consider use of bend restrictors in accordance with risk as identified by details engineering design.<br><br>Cable designed to accommodate for greater levels of burial than level buried to, to accommodate more onerous thermal environment caused by either sandwave movement, accretion, or else greater burial through liquefaction.<br><br>Cables monitored by Distributed Temperature Sensing (DTS)/Distributed Acoustic Sensing (DAS) and regular condition surveys to give early warning of reduction in sediment cover.<br><br>Ensuring cable specific gravity is as close as possible to that of liquefied soils. | 2 | 1 | 2 |
| 9 | Submarine volcanoes | Directly impact cables through contact or trigger submarine landslides (see above). | None present at site. **Not scored.** | | | | | | | |

| Hazard Log Ref No. | Hazard Class | Hazard Description (Potential) | Risk Description | Initial Risk Rating | | | Mitigation | Residual Risk Rating | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Likelihood | Severity | Risk Rating | | Likelihood | Severity | Risk Rating |
| 10 | Icebergs | Can directly impact on cables in shallow water depth as they scour the seabed. Not anticipated along the cable's route. | Not plausible. **Not scored.** | | | | | | | |
| **Soil Conditions** | | | | | | | | | | |
| 11 | Mobile Sediment | Sand Wave or megaripple mobility could cause deburial or increased burial of the cable. | Potential mobile sediments identified from review of data for leading to uncertainties to actual burial depth at any time.<br><br>The risk is that information gaps concerning the extent of sediment mobility means that the recommended DOL contingency is either too low or too high. The consequence is either lower protection or higher CAPEX. | 3 | 3 | 9 | Determination of accurate vertical reference level and DOL to reduce risk to ALARP.<br><br>Cable designed to accommodate for greater levels of burial than level buried to, to accommodate more onerous thermal environment caused by either sandwave movement, accretion, or else greater burial through liquefaction.<br><br>Cables monitored by Distributed Temperature Sensing (DTS)/Distributed Acoustic Sensing (DAS) and regular condition surveys to give early warning of reduction in sediment cover. | 2 | 3 | 6 |
| 12 | Variable ground conditions | Outcropping or subcropping rock, cemented / over consolidated soils, coral reef, weak layers, sapropels, very low strength soils, salt piercements, shallow gas, supersaturated soils, aggressive soils or soils with pyrite formation can affect the degree of burial or the ease of burial of a cable. | Very Low Strength CLAY as a top layer of various thicknesses is present on the route may present a risk during trenching due to sinkage or loss of traction during installation. | 3 | 2 | 6 | Undertake capacity bearing assessment of soil and select appropriate burial tool. | 2 | 2 | 4 |

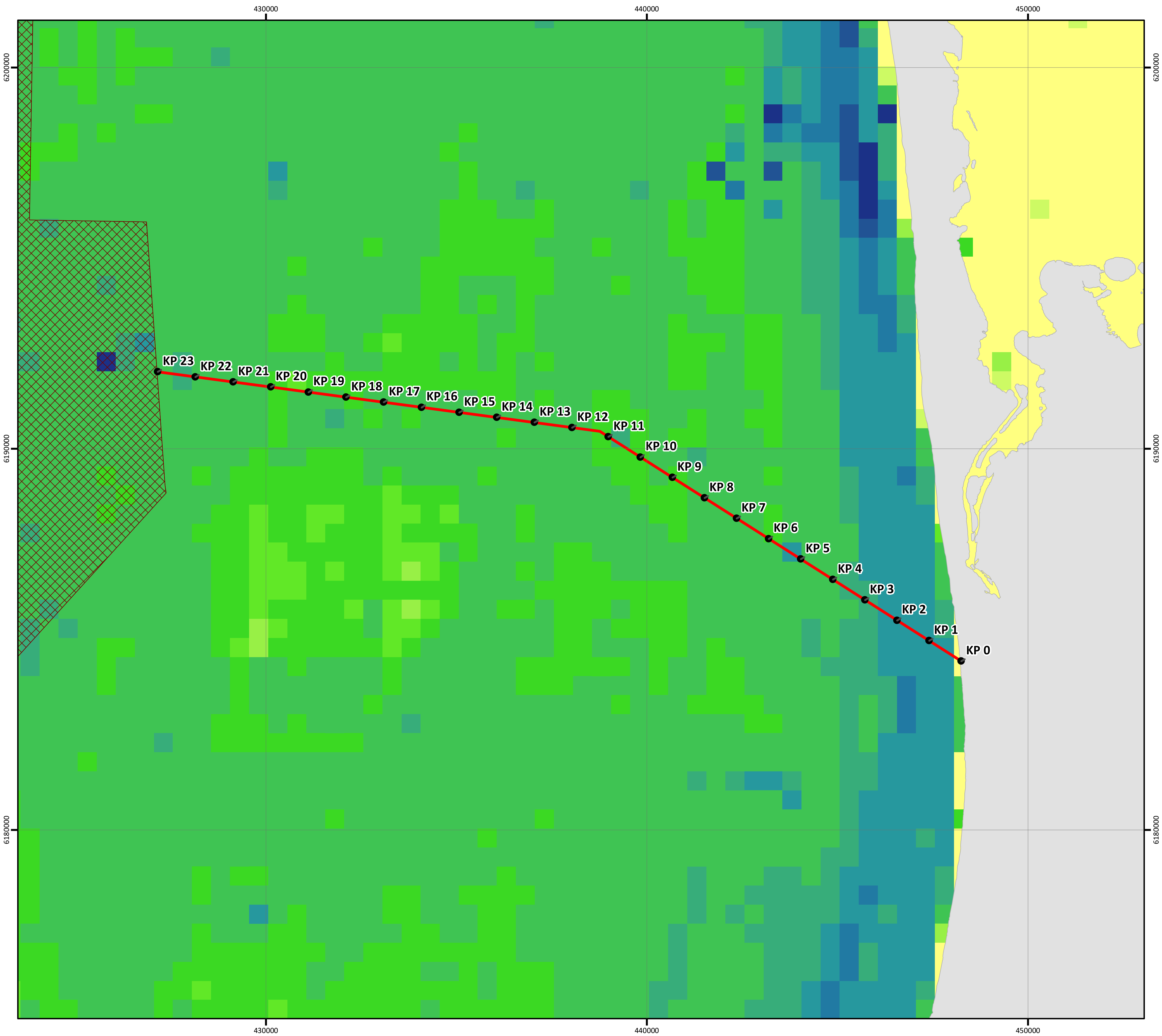
| Hazard Log Ref No. | Hazard Class | Hazard Description (Potential) | Risk Description | Initial Risk Rating | | | Mitigation | Residual Risk Rating | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Likelihood | Severity | Risk Rating | | Likelihood | Severity | Risk Rating |
| 13 | Thermal Variability | Soils which have a significant difference in thermal properties compared with surrounding soils. | Cable thermal environment as determined by geotechnical site investigation campaign is not accurate leading to either oversizing or under-sizing of cable core. | 3 | 3 | 9 | Close work and information exchange between site survey lead and cable design lead to ensure risk of thermal variability in soils from received figures is understood and accounted for in cable design.<br><br>Use of competent personnel and rigorous internal QC process before each decision point in project lifecycle. | 2 | 3 | 6 |
| **Anthropogenic** | | | | | | | | | | |
| 14a | Fishing | Snagging of cables with fishing gear and damage during retrieval of gear. Seabed interacting gear reducing sediment coverage above cable. | Due to inaccurate characterisation of presence of mobile fishing types there is a risk of misunderstanding the risk of mechanical damage to the installed cable.<br><br>Consequence is misspecification of recommended minimum depth of lowering leading to either greater CAPEX or greater risk of damage to the installed cable. Leads to requirement to inspect and potentially to repair. Other consequence is cable outage and increase of monitoring requirements. | 1 | 1 | 1 | No further mitigation expected. Base case assumes sufficient burial to protect from known regional fishing threats applied to the whole cable route. | 1 | 1 | 1 |

| Hazard Log Ref No. | Hazard Class | Hazard Description (Potential) | Risk Description | Initial Risk Rating | | | Mitigation | Residual Risk Rating | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Likelihood | Severity | Risk Rating | | Likelihood | Severity | Risk Rating |
| 14b | | Objects including drums discarded by fishing vessels penetrate the seabed and strike the cable and/or deform the seabed above the cable sufficiently enough to cause damage to the cable. | Discarded objects including drums have been observed on the cable route in the geophysical survey data and are understood to have originated from local fishing vessels.<br><br>Likelihood of a direct strike is considered low but if occurred in area where soil strength is low then a large enough object could penetrate deeper than the 30cm maximum penetration depth assumed for the fishing assessment. | 1 | 3 | 3 | Undertake a specialist study into the risk of dropped objects on route. As part of study engage with the local fishing industry to gain understanding of the types of objects discarded and the circumstances of their disposal. If study concludes penetration >30cm is sufficient risk to the cables in any sections of the route then increase burial depth accordingly (while noting the 2 FOS already applied to the maximum fishing depth). | 1 | 1 | 1 |
| 15.A | Shipping/Anchoring | Snagging of cables during normal or emergency anchoring procedures. | Due to inaccurate characterisation of shipping or soils there is a risk of misunderstanding the risk of mechanical damage to the installed cable.<br><br>Consequence is misspecification of recommended minimum DOL leading to either greater CAPEX or greater risk of damage to the installed cable. Leads to requirement to inspect and potentially to repair. Other consequence is cable outage and increase of monitoring requirements. | 3 | 3 | 9 | Revise the CBRA following receipt of survey data, or significant changes to shipping patterns. (scored on a basis of shipping pattern changes). | 1 | 3 | 3 |

| Hazard Log Ref No. | Hazard Class | Hazard Description (Potential) | Risk Description | Initial Risk Rating | | | Mitigation | Residual Risk Rating | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Likelihood | Severity | Risk Rating | | Likelihood | Severity | Risk Rating |
| 15.B | | | Due to cable design for a return period of 25 years, there is a residual risk of mechanical damage. | 1 | 2 | 2 | No further mitigation required. | 1 | 2 | 2 |
| 16 | Dredging / Aggregate Extraction / Subsea Mining / Dumping | Direct contact to the cable from the dredging equipment or reduction in seabed cover increasing risk to cable. | Damage to cable caused by activities and or increased unplanned for exposure leading to a cable strike by third-party aggressors. | 2 | 3 | 6 | Ensure cable is not installed in areas where dredging / Aggregate Extraction / Subsea Mining / Dumping areas are permitted. Or alternatively ensure risk is identified and designed for. | 1 | 3 | 3 |
| 17 | Renewable Energy Areas | Direct contact to the cable from offshore windfarm construction activities | The cable route avoids offshore windfarm areas **Not scored.** | | | | | | | |
| 18 | Other cables, umbilical, Pipelines | Reduced depth of lowering at crossing and/or proximity of third-party operation. | Cable and pipeline crossings identified along the route. Outside of CBRA scope, thus **not scored.** | | | | | | | |
| 19 | Misc. Activities | Such as construction, rock dumping, marine surveys, leisure activities. Any activity that directly interacts with the seabed and reduces the seabed cover. | Misc., activities are outside of the CBRA scope. **Not scored.** | | | | | | | |
| 20 | Exclusions physical | Defence and acts of aggressions. | Outside CBRA scope, thus **not scored.** | | | | | | | |
| 21 | Exclusions planning | Updated information which significantly changes the recommendations of the CBRA | Potential to require re-routing outside of survey corridor. **Not scored.** | | | | | | | |

# APPENDIX C

## Vessel Density Heat Maps






# CABLE BURIAL RISK ASSESSMENT
# NORTH SEA I - NYMINDEGAB SOUTH

## AUTOMATIC IDENTIFICATION SYSTEM (AIS) Vessel Density (February 2023 - February 2024)

| Drawing No: P2719D-AIS-001 | B |
|---|---|

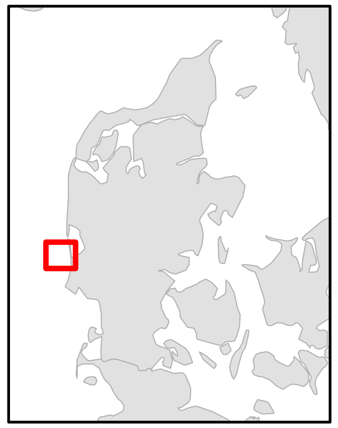
**Legend**

- KP
- Cable Route
- Wind Farm Site

**Vessel Density (Duration per Year)**

- < 15 minutes
- 15 - 30 minutes
- 30 - 45 minutes
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

N W E S



NOTE: Not to be used for Navigation

| | |
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| **Projection** | Transverse Mercator |
| **Datum** | ETRS 1989 |
| **Data Source** | ESRI; NUTS; ENERGINET |
| **File Reference** | J:\P2719\Mxd_QGZ\P2719D\02_AIS\ P2719D-AIS-001.mxd |
| **Created By** | Lewis Castle |
| **Reviewed By** | Emma Langley |
| **Approved By** | Stephane Theurich |

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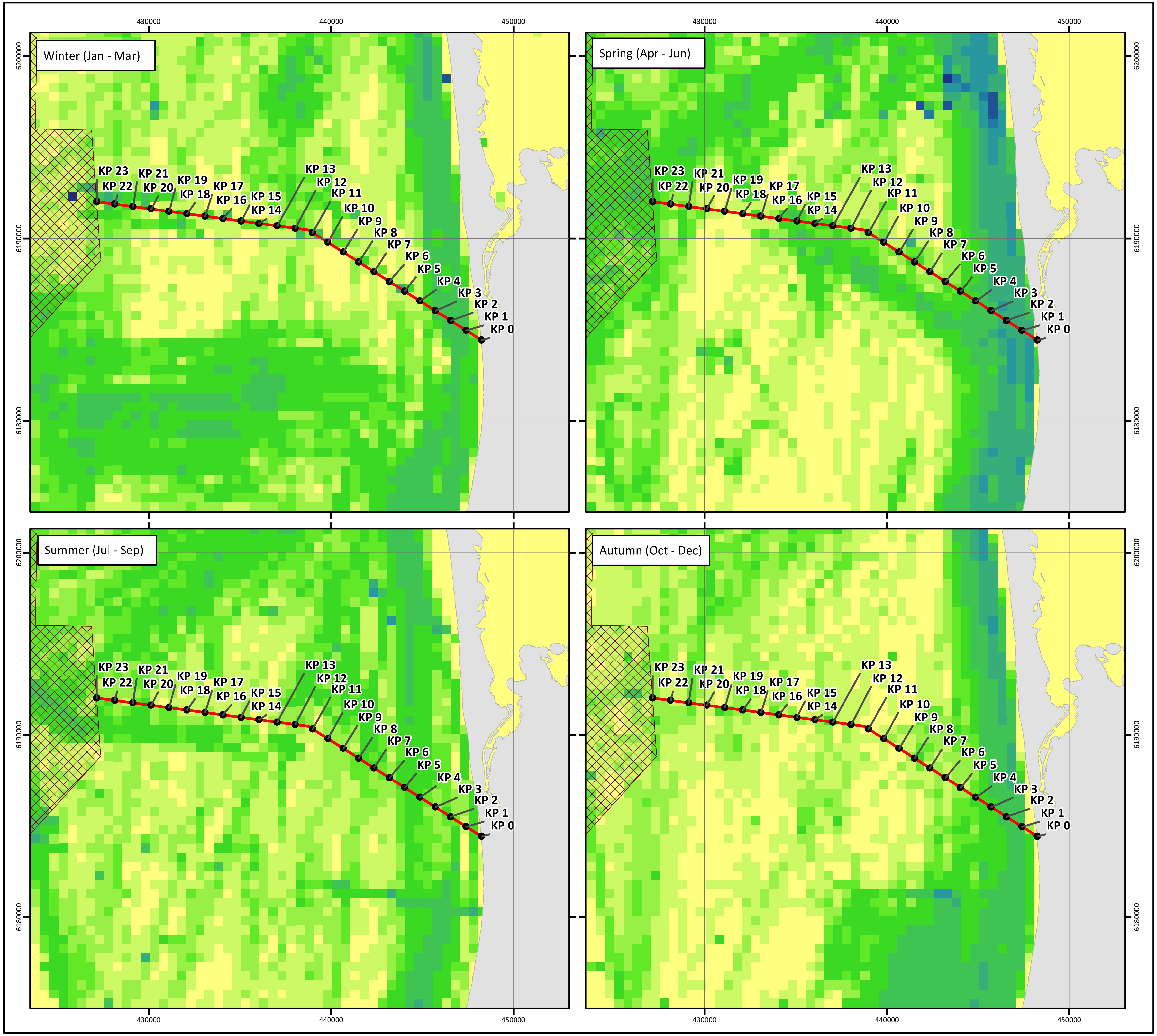
0 1 2 3 4 km

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## CABLE BURIAL RISK ASSESSMENT
## NORTH SEA I - NYMINDEGAB SOUTH

**AUTOMATIC IDENTIFICATION SYSTEM (AIS)**
**Vessel Density by Season**

| Drawing No: P2719D-AIS-002 | B |
|---|---|

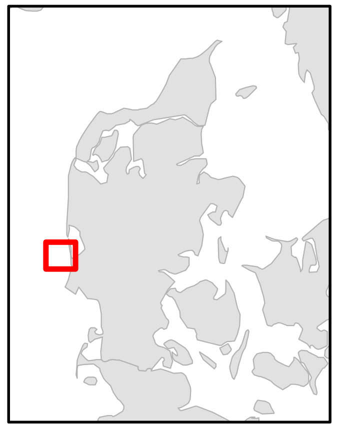
**Legend**

- KP
- Cable Route
- Wind Farm Site

**Vessel Density (Duration per Year)**

- < 15 minutes
- 15 - 30 minutes
- 30 - 45 minutes
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

N
W
E
S



NOTE: Not to be used for Navigation

| | |
|---|---|
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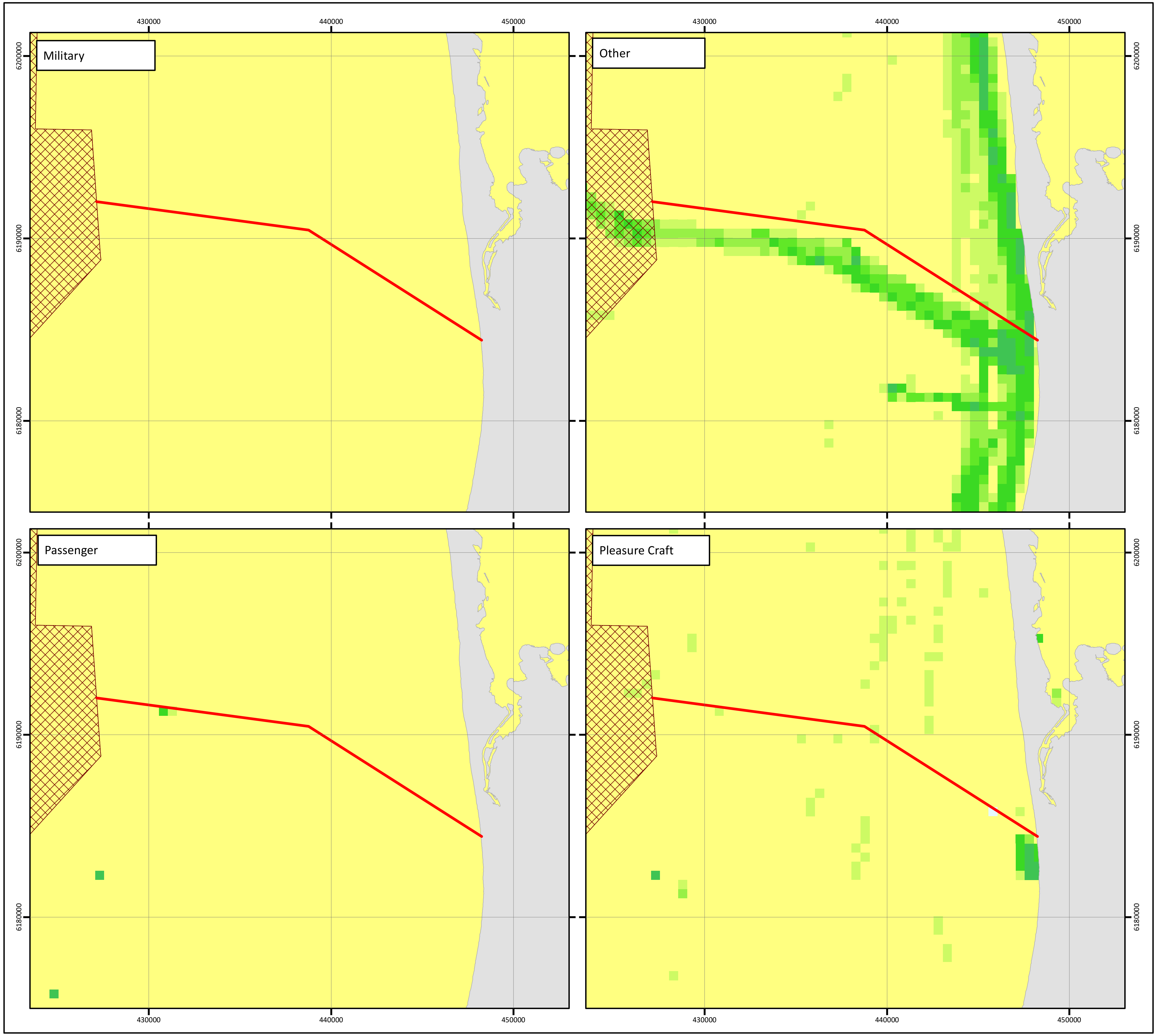
| **Projection** | Transverse Mercator |
| **Datum** | ETRS 1989 |
| **Data Source** | ESRI; NUTS; ENERGINET |
| **File Reference** | J:\P2719\Mxd_QGZ\P2719D\02_AIS\ P2719D-AIS-002.mxd |
| **Created By** | Lewis Castle |
| **Reviewed By** | Emma Langley |
| **Approved By** | Stephane Theurich |

[redacted] [redacted]

0 2 4 6 8 km

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# CABLE BURIAL RISK ASSESSMENT
# NORTH SEA I - NYMINDEGAB SOUTH

## AUTOMATIC IDENTIFICATION SYSTEM (AIS)
## Annual Vessel Density by Type - Sheet 2 of 4

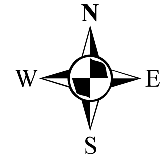
**Drawing No: P2719D-AIS-004** | **A**

### Legend

- Cable Route
- Wind Farm Site

**Vessel Density (Duration per Year)**

- < 15 minutes
- 15 - 30 minutes
- 30 - 45 minutes
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week




NOTE: Not to be used for Navigation

| | |
|---|---|
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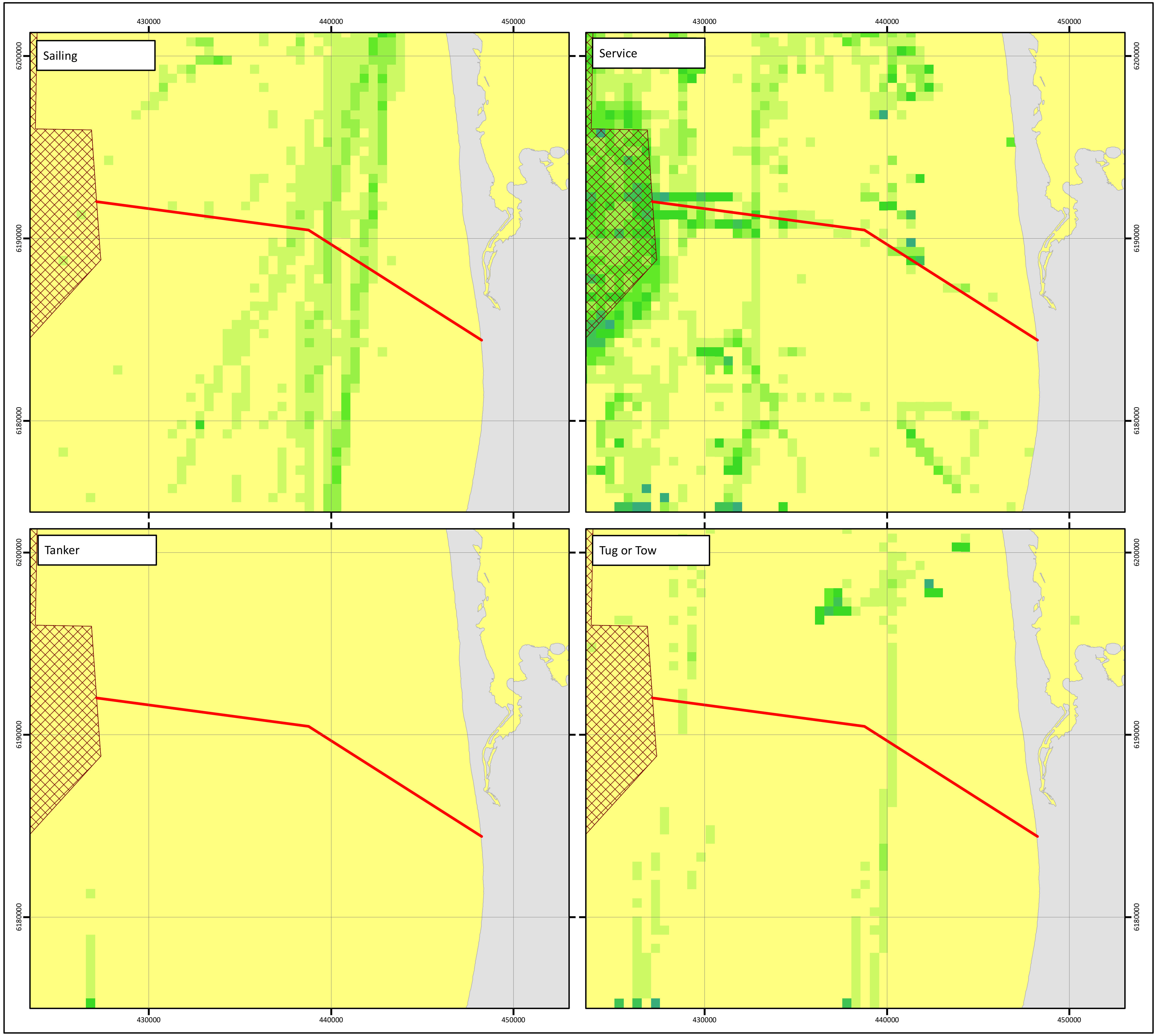
| **Projection** | Transverse Mercator |
| **Datum** | ETRS 1989 |
| **Data Source** | ESRI; NUTS; ENERGINET |
| **File Reference** | J:\P2719\Mxd_QGZ\P2719D\02_AIS\P2719D-AIS-004.mxd |
| **Created By** | Lewis Castle |
| **Reviewed By** | Emma Langley |
| **Approved By** | Stephane Theurich |

[redacted] [redacted]

0 2 4 6 8 km

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# CABLE BURIAL RISK ASSESSMENT
# NORTH SEA I - NYMINDEGAB SOUTH

## AUTOMATIC IDENTIFICATION SYSTEM (AIS)
## Annual Vessel Density by Type - Sheet 3 of 4

| Drawing No: P2719D-AIS-005 | A |
|---|---|

**Legend**

- Cable Route
- Wind Farm Site

**Vessel Density (Duration per Year)**

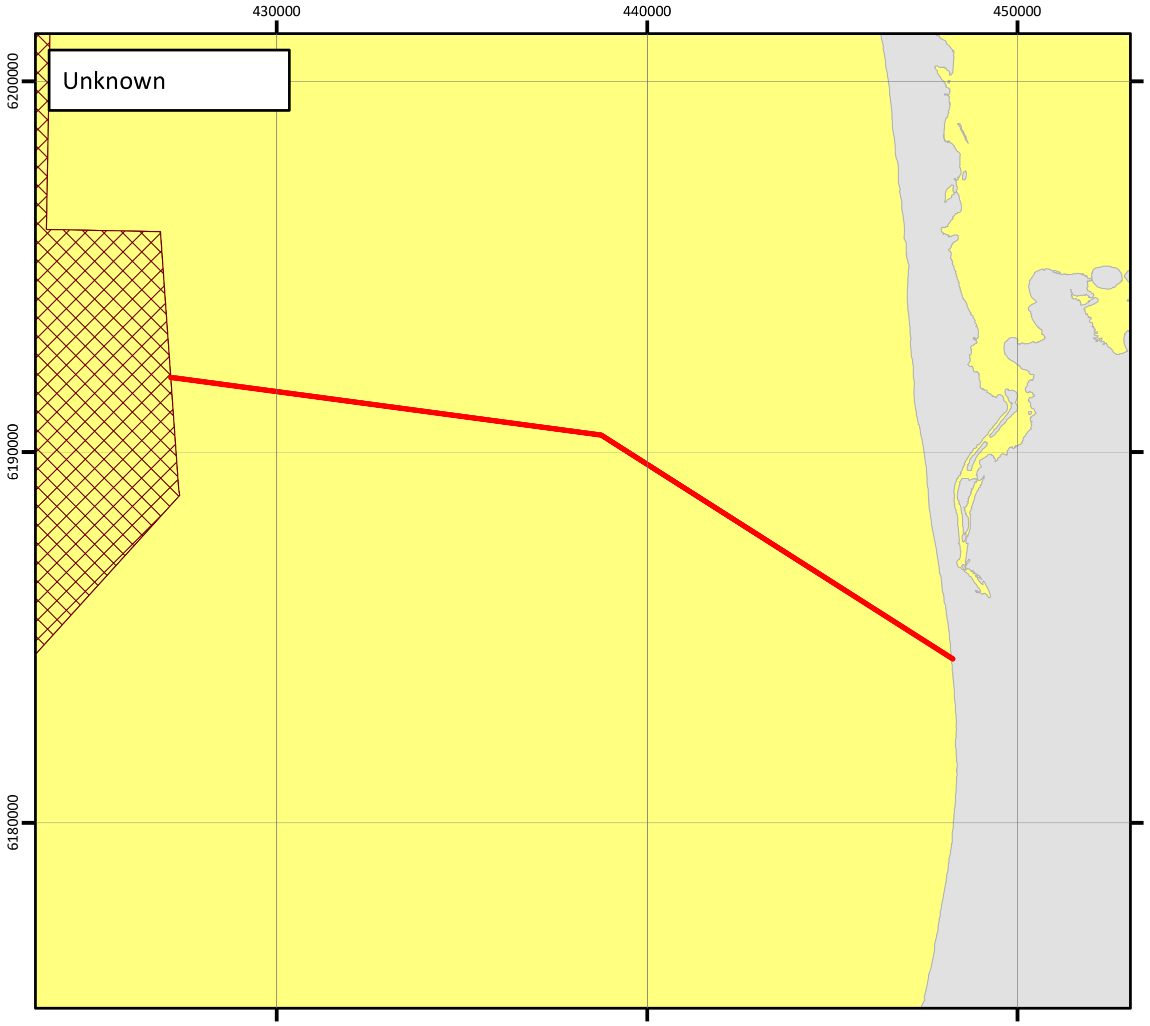
- < 15 minutes
- 15 - 30 minutes
- 30 - 45 minutes
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

NOTE: Not to be used for Navigation

| | |
|---|---|
| **Date** | 04 June 2024 |
| **Coordinate System** | ETRS 1989 UTM Zone 32N |
| **Projection** | Transverse Mercator |
| **Datum** | ETRS 1989 |
| **Data Source** | ESRI; NUTS; ENERGINET |
| **File Reference** | J:\P2719\Mxd_QGZ\P2719D\02_AIS\P2719D-AIS-005.mxd |
| **Created By** | Lewis Castle |
| **Reviewed By** | Emma Langley |
| **Approved By** | Stephane Theurich |

[redacted] [redacted]

0 2 4 6 8 km

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# CABLE BURIAL RISK ASSESSMENT
# NORTH SEA I - NYMINDEGAB SOUTH

## AUTOMATIC IDENTIFICATION SYSTEM (AIS)
## Annual Vessel Density by Type - Sheet 4 of 4

| Drawing No: P2719D-AIS-006 | A |
|---|---|

**Legend**

N
W E
S

Cable Route
Wind Farm Site

**Vessel Density (Duration per Year)**

- < 15 minutes
- 15 - 30 minutes
- 30 - 45 minutes
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

NOTE: Not to be used for Navigation

| | |
|---|---|
| **Date** | 04 June 2024 |
| **Coordinate System** | ETRS 1989 UTM Zone 32N |
| **Projection** | Transverse Mercator |
| **Datum** | ETRS 1989 |
| **Data Source** | ESRI; NUTS; ENERGINET |
| **File Reference** | J:\P2719\Mxd_QGZ\P2719D\02_AIS\ P2719D-AIS-006.mxd |
| **Created By** | Lewis Castle |
| **Reviewed By** | Emma Langley |
| **Approved By** | Stephane Theurich |

[redacted] [redacted]

0 2 4 6 8 km

# APPENDIX D

## Vessel Density

## Table D-1 Vessel Density

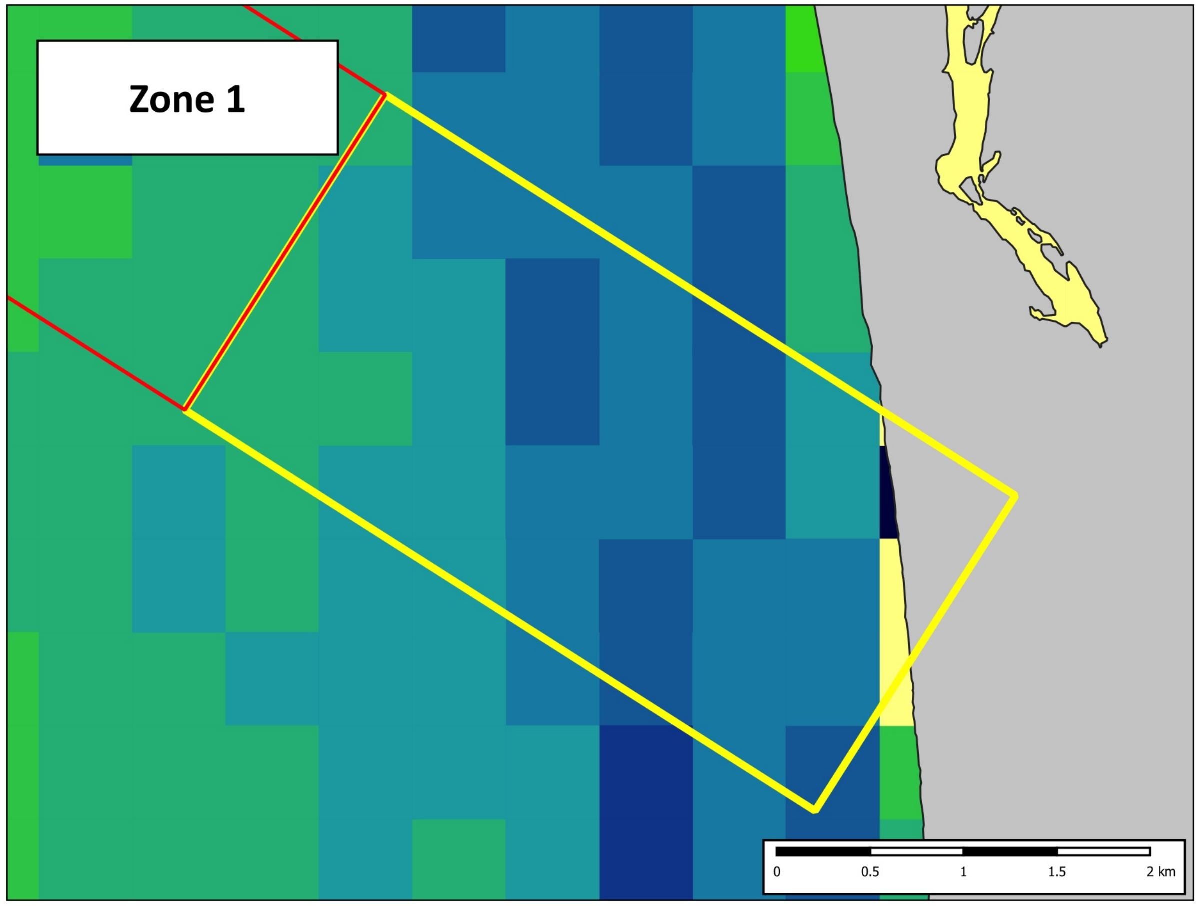
| | | | | | | K - Sample Box Vessel Densities | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | P90 | | | | | | | | |
| Zone Identification | KP Range | | Water Depth Range (m) | | | Band A | Band B | Band C | Band D | Band E | Band F | Band G | Band H | Band I |
| | From | To | Max | Min | Mean | [hr/km2/yr] | [hr/km2/yr] | [hr/km2/yr] | [hr/km2/yr] | [hr/km2/yr] | [hr/km2/yr] | [hr/km2/yr] | [hr/km2/yr] | [hr/km2/yr] |
| 1 | 0.00 | 3.31 | 6.6 | 0.0 | 3.0 | 375.02 | 2.28 | 6.82 | 0.78 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 3.31 | 4.13 | 10.1 | 4.3 | 7.0 | 320.20 | 31.97 | 6.73 | 3.67 | 0.28 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 4.13 | 6.46 | 11.8 | 8.5 | 10.0 | 69.83 | 31.68 | 7.92 | 3.78 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 6.46 | 7.85 | 13.3 | 10.4 | 12.0 | 58.53 | 49.08 | 49.75 | 50.20 | 3.70 | 0.05 | 0.00 | 0.00 | 0.00 |
| 5 | 7.85 | 10.71 | 14.4 | 12.3 | 13.0 | 35.93 | 18.77 | 20.60 | 37.32 | 3.10 | 0.90 | 0.33 | 0.00 | 0.00 |
| 6 | 10.71 | 11.77 | 16.8 | 13.7 | 15.0 | 76.28 | 26.42 | 26.87 | 36.18 | 4.25 | 2.78 | 1.23 | 0.27 | 0.02 |
| 7 | 11.77 | 13.88 | 18.0 | 16.2 | 17.0 | 30.72 | 10.32 | 102.82 | 59.25 | 1.80 | 3.28 | 0.98 | 0.82 | 1.15 |
| 8 | 13.88 | 14.94 | 18.8 | 17.1 | 19.0 | 67.15 | 20.28 | 18.20 | 52.23 | 5.78 | 17.70 | 8.15 | 11.17 | 4.12 |
| 9 | 14.94 | 16.04 | 19.0 | 18.2 | 19.0 | 19.03 | 7.43 | 9.62 | 20.98 | 2.52 | 10.37 | 4.33 | 8.35 | 2.22 |
| 10 | 16.04 | 16.66 | 19.2 | 18.4 | 19.0 | 48.20 | 13.08 | 9.35 | 19.37 | 5.12 | 40.27 | 18.57 | 30.73 | 7.78 |
| 11 | 16.66 | 17.06 | 19.4 | 18.6 | 19.0 | 26.80 | 13.45 | 18.68 | 40.40 | 5.38 | 29.78 | 15.00 | 20.37 | 5.87 |
| 12 | 17.06 | 18.11 | 19.6 | 18.8 | 19.0 | 4.90 | 3.25 | 3.55 | 5.88 | 1.50 | 2.55 | 2.03 | 2.97 | 0.57 |
| 13 | 18.11 | 19.17 | 19.9 | 19.0 | 19.0 | 43.38 | 38.47 | 19.05 | 17.53 | 2.28 | 11.17 | 11.87 | 30.33 | 5.72 |
| 14 | 19.17 | 20.23 | 20.3 | 19.4 | 20.0 | 10.28 | 43.43 | 20.31 | 2.29 | 6.97 | 0.00 | 0.04 | 2.07 | 0.00 |
| 15 | 20.23 | 21.28 | 20.6 | 19.8 | 20.0 | 17.77 | 13.04 | 1.22 | 0.02 | 0.69 | 0.00 | 0.00 | 0.14 | 0.00 |
| 16 | 21.28 | 23.00 | 20.1 | 20.1 | 21.0 | 9.48 | 3.57 | 42.23 | 2.07 | 0.35 | 0.02 | 0.12 | 0.00 | 0.00 |

# CABLE BURIAL RISK ASSESSMENT NORTH SEA I - NYMINDEGAB SOUTH

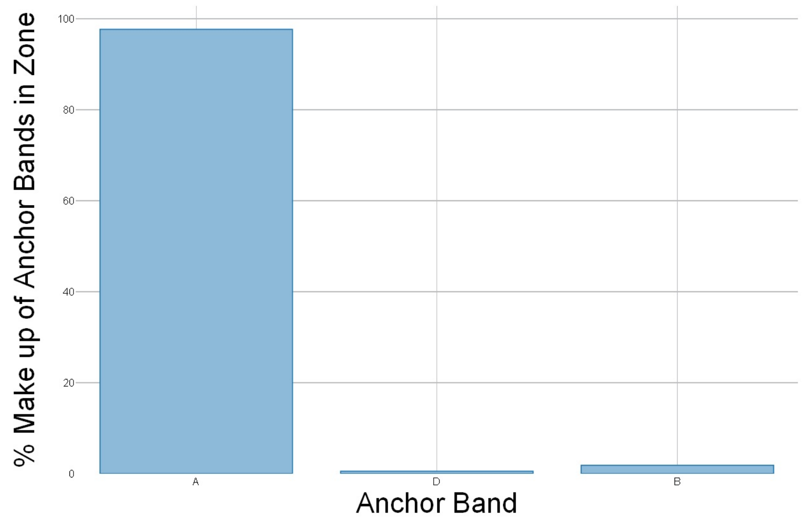
## CABLE BURIAL RISK ASSESSMENT

Anchor Band Statistics - Zone 1

Drawing No: P2719D-CBRA-001_1 | A


## Anchor Band Statistics by Zone - Zone 1




### Legend

N

- Wind Farm Site

**CBRA Zone**

- Zone of Interest
- CBRA Zone

**Vessel Density (Duration per year)**

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

### Legend - Inset

**Vessel Density (Duration per year)**

- < 15 mins
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week

| | |
|---|---|
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| **Scale @A3** | 1:100,000 |
| **Data Sources** | NUTS; ENERGINET |
| **File Reference** | J:\P2719\Mxd_QGZ\P2719D\04_CBRA \P2719D_CBRA.qgz |
| **Created By** | Lewis Castle |
| **Reviewed By** | Emma Langley |
| **Approved By** | Stephane Theurich |

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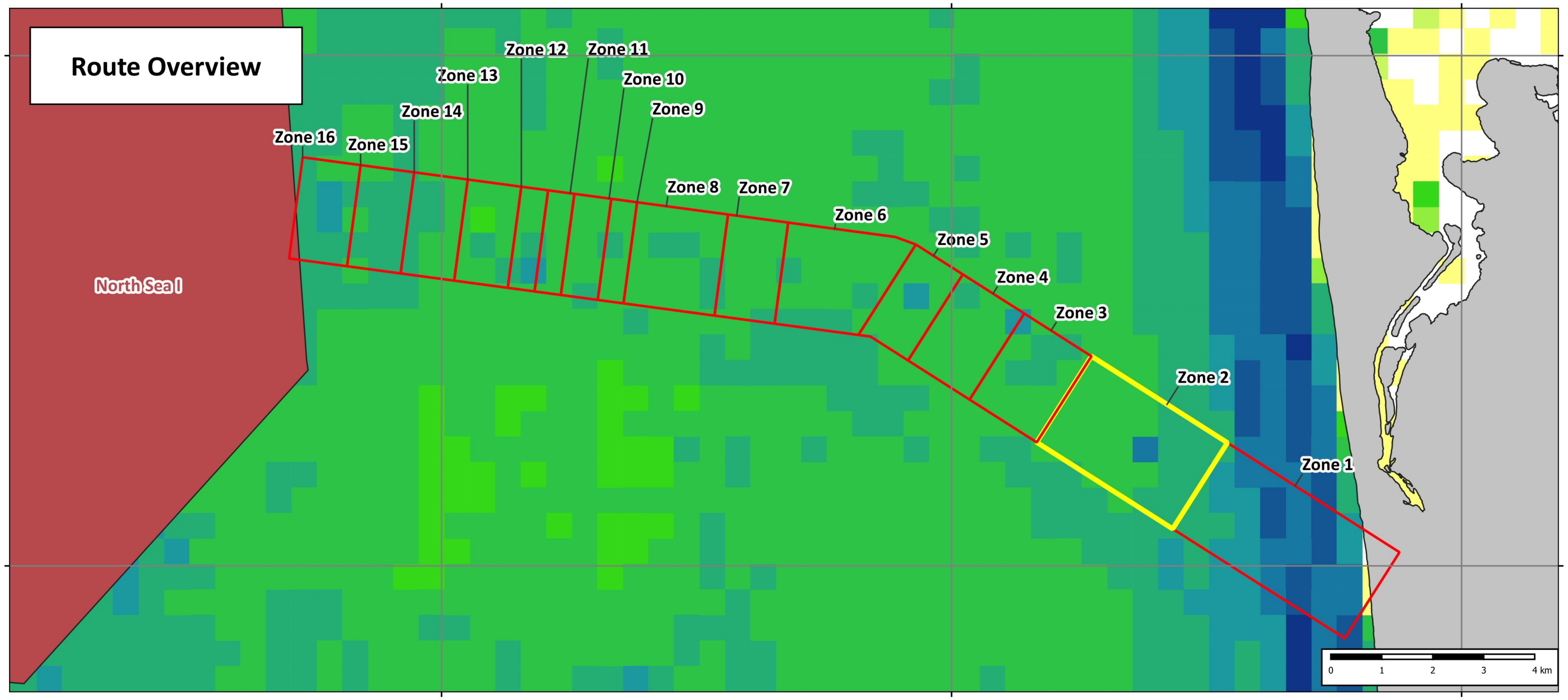
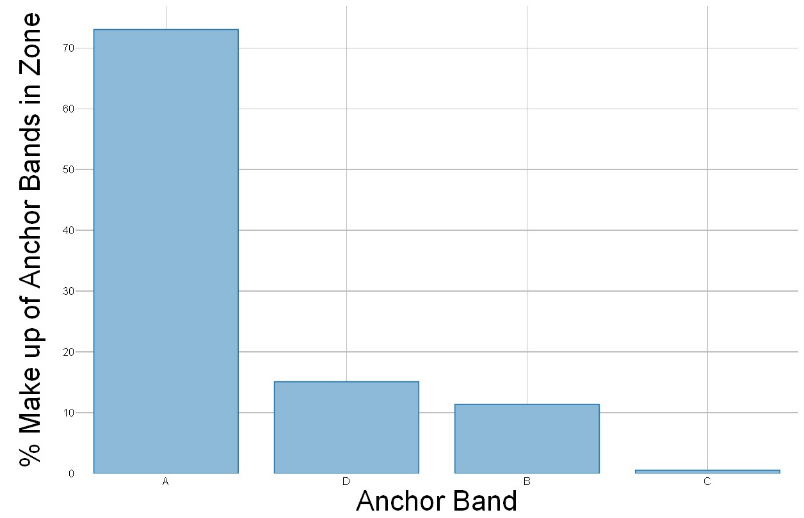




## Anchor Band Statistics by Zone - Zone 2




# CABLE BURIAL RISK ASSESSMENT NORTH SEA I - NYMINDEGAB SOUTH

## CABLE BURIAL RISK ASSESSMENT

Anchor Band Statistics - Zone 2

Drawing No: P2719D-CBRA-001_2 | A

### Legend

N

Wind Farm Site

**CBRA Zone**

- Zone of Interest
- CBRA Zone

**Vessel Density (Duration per year)**

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

### Legend - Inset

**Vessel Density (Duration per year)**

- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours

| | |
|---|---|
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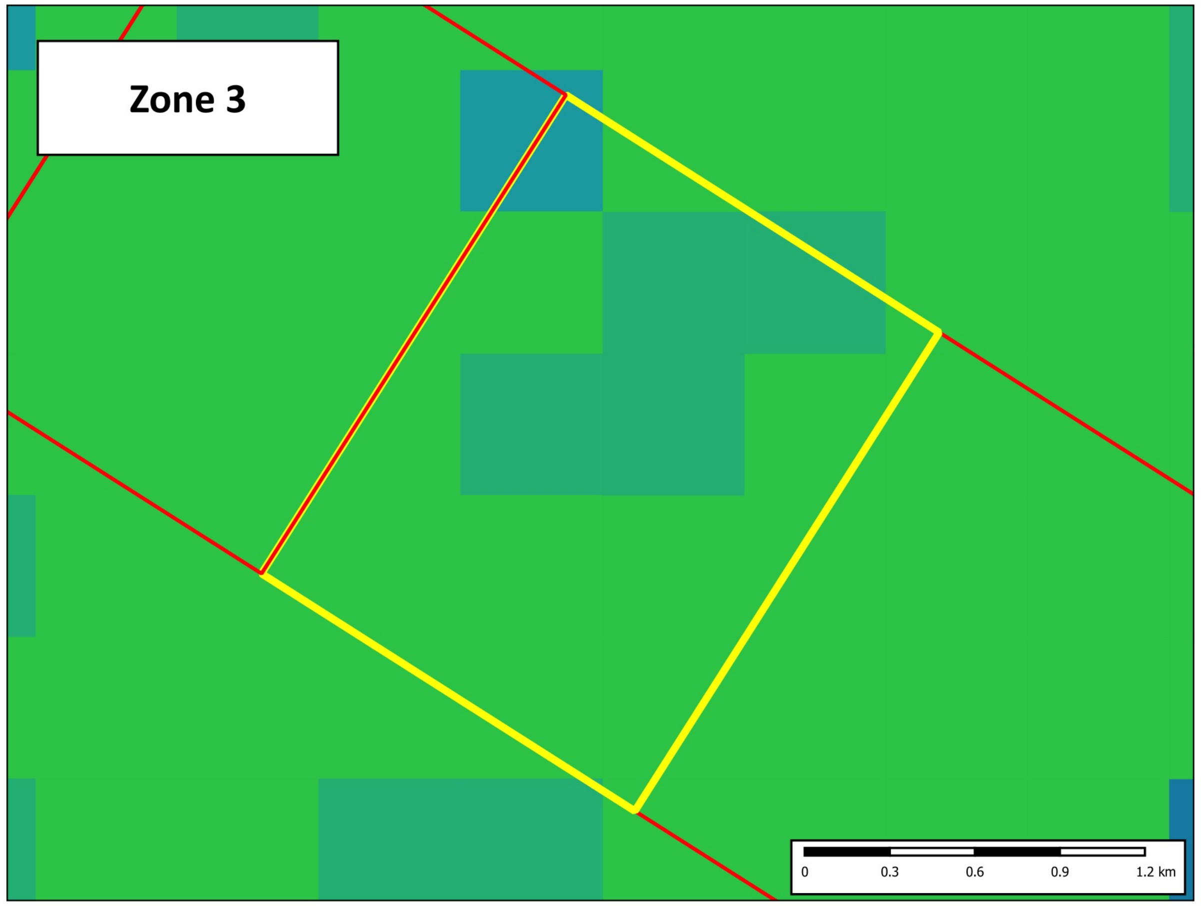
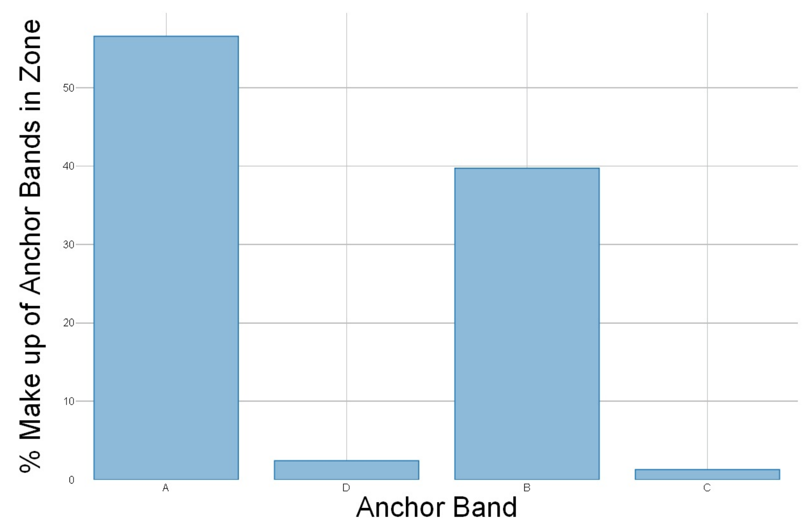
| **Created By** | Lewis Castle |
| **Reviewed By** | Emma Langley |
| **Approved By** | Stephane Theurich |


## Anchor Band Statistics by Zone - Zone 3




# CABLE BURIAL RISK ASSESSMENT NORTH SEA I - NYMINDEGAB SOUTH

## CABLE BURIAL RISK ASSESSMENT

Anchor Band Statistics - Zone 3

Drawing No: P2719D-CBRA-001_3 | A

### Legend

- Wind Farm Site

**CBRA Zone**

- Zone of Interest
- CBRA Zone

**Vessel Density (Duration per year)**

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

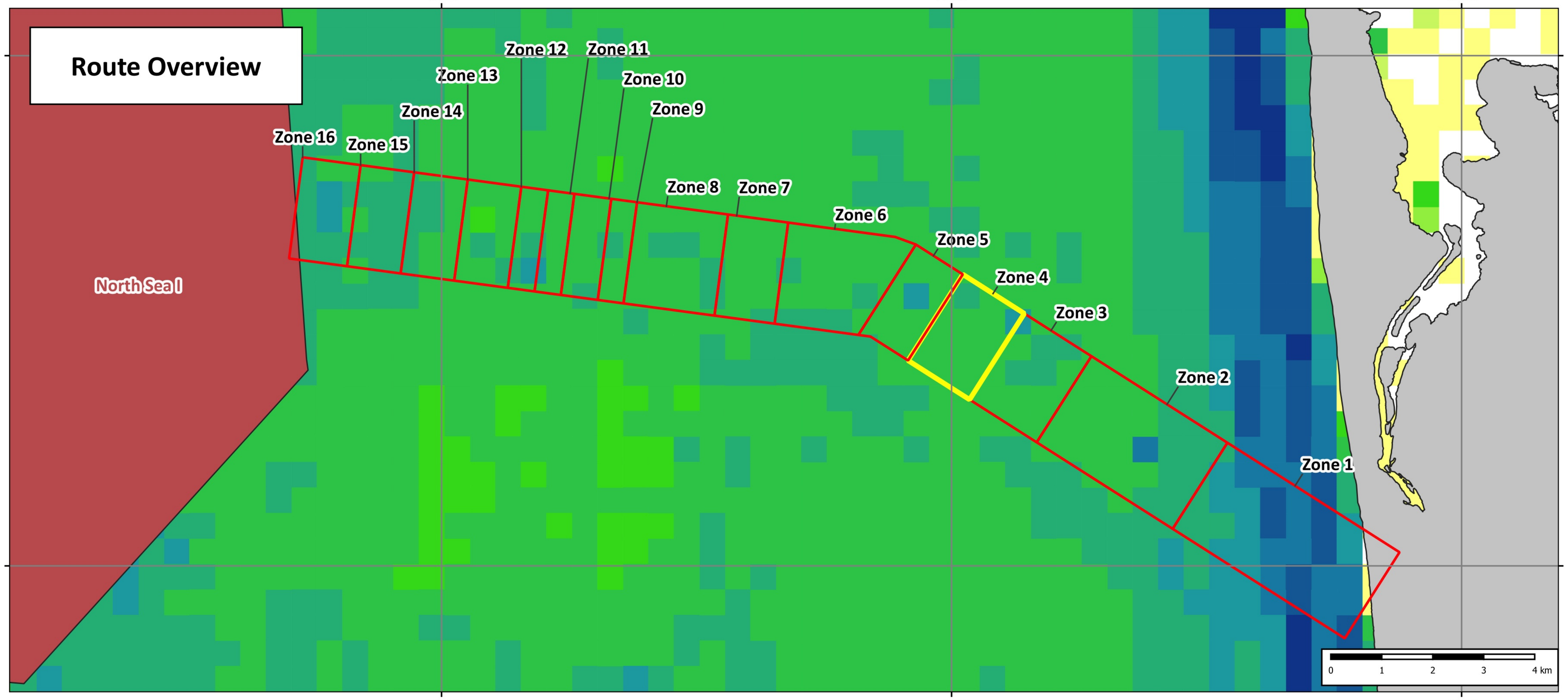
### Legend - Inset

**Vessel Density (Duration per year)**

- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours

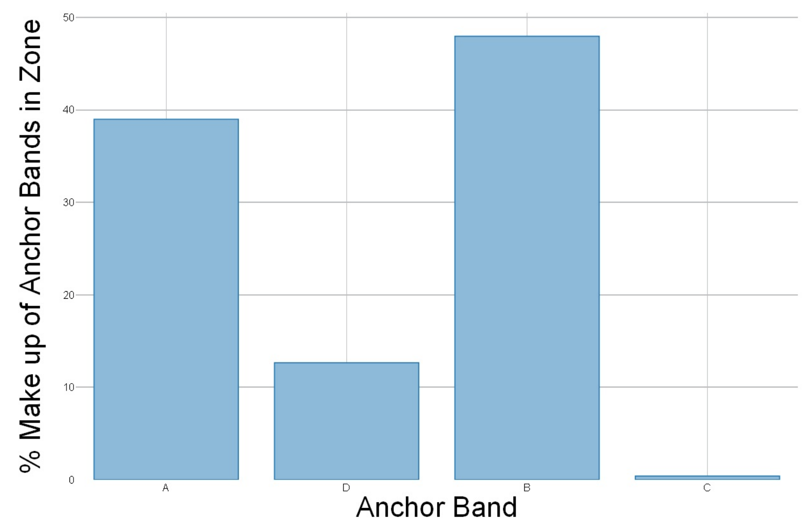
| | |
|---|---|
| **Date** | 2024-06-06 16:51:43 |
| **Coordinate System** | ETRS89 / UTM zone 32N |
| **WKID** | EPSG:25832 |
| **Scale @A3** | 1:100,000 |
| **Data Sources** | NUTS; ENERGINET |
| **File Reference** | J:\P2719\Mxd_QGZ\P2719D\04_CBRA \P2719D_CBRA.qgz |
| **Created By** | Lewis Castle |
| **Reviewed By** | Emma Langley |
| **Approved By** | Stephane Theurich |

ENERGINET intertek





## Anchor Band Statistics by Zone - Zone 4




# CABLE BURIAL RISK ASSESSMENT NORTH SEA I - NYMINDEGAB SOUTH

## CABLE BURIAL RISK ASSESSMENT

Anchor Band Statistics - Zone 4

Drawing No: P2719D-CBRA-001_4 | A

### Legend

Wind Farm Site

**CBRA Zone**

- Zone of Interest
- CBRA Zone

**Vessel Density (Duration per year)**

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

### Legend - Inset

**Vessel Density (Duration per year)**

- 2 - 6 hours
- 12 - 24 hours
- 6 - 12 hours

| | |
|---|---|
| **Date** | 2024-06-06 16:52:08 |
| **Coordinate System** | ETRS89 / UTM zone 32N |
| **WKID** | EPSG:25832 |
| **Scale @A3** | 1:100,000 |
| **Data Sources** | NUTS; ENERGINET |
| **File Reference** | J:\P2719\Mxd_QGZ\P2719D\04_CBRA \P2719D_CBRA.qgz |
| **Created By** | Lewis Castle |
| **Reviewed By** | Emma Langley |
| **Approved By** | Stephane Theurich |

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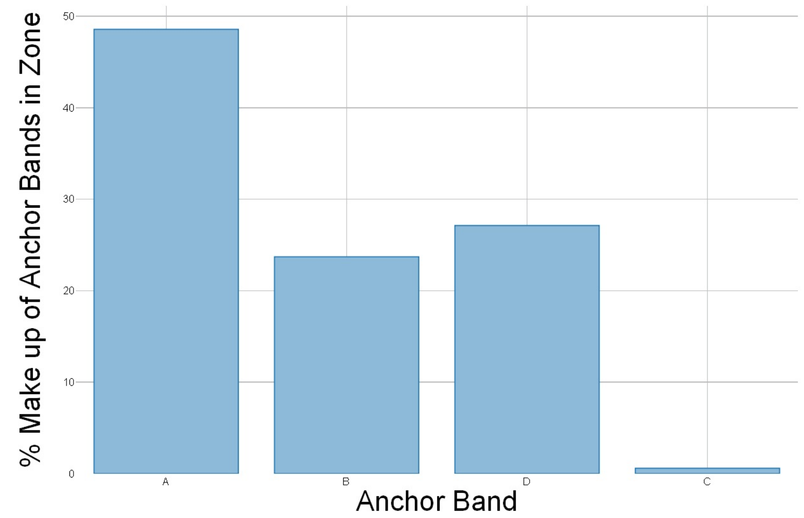
## Anchor Band Statistics by Zone - Zone 5




# CABLE BURIAL RISK ASSESSMENT NORTH SEA I - NYMINDEGAB SOUTH

## CABLE BURIAL RISK ASSESSMENT

Anchor Band Statistics - Zone 5

Drawing No: P2719D-CBRA-001_5 | A

N

### Legend

Wind Farm Site

**CBRA Zone**

- Zone of Interest
- CBRA Zone

**Vessel Density (Duration per year)**

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

### Legend - Inset

**Vessel Density (Duration per year)**

- 2 - 6 hours
- 12 - 24 hours
- 6 - 12 hours

| | |
|---|---|
| **Date** | 2024-06-06 16:52:21 |
| **Coordinate System** | ETRS89 / UTM zone 32N |
| **WKID** | EPSG:25832 |
| **Scale @A3** | 1:100,000 |
| **Data Sources** | NUTS; ENERGINET |
| **File Reference** | J:\P2719\Mxd_QGZ\P2719D\04_CBRA \P2719D_CBRA.qgz |
| **Created By** | Lewis Castle |
| **Reviewed By** | Emma Langley |
| **Approved By** | Stephane Theurich |

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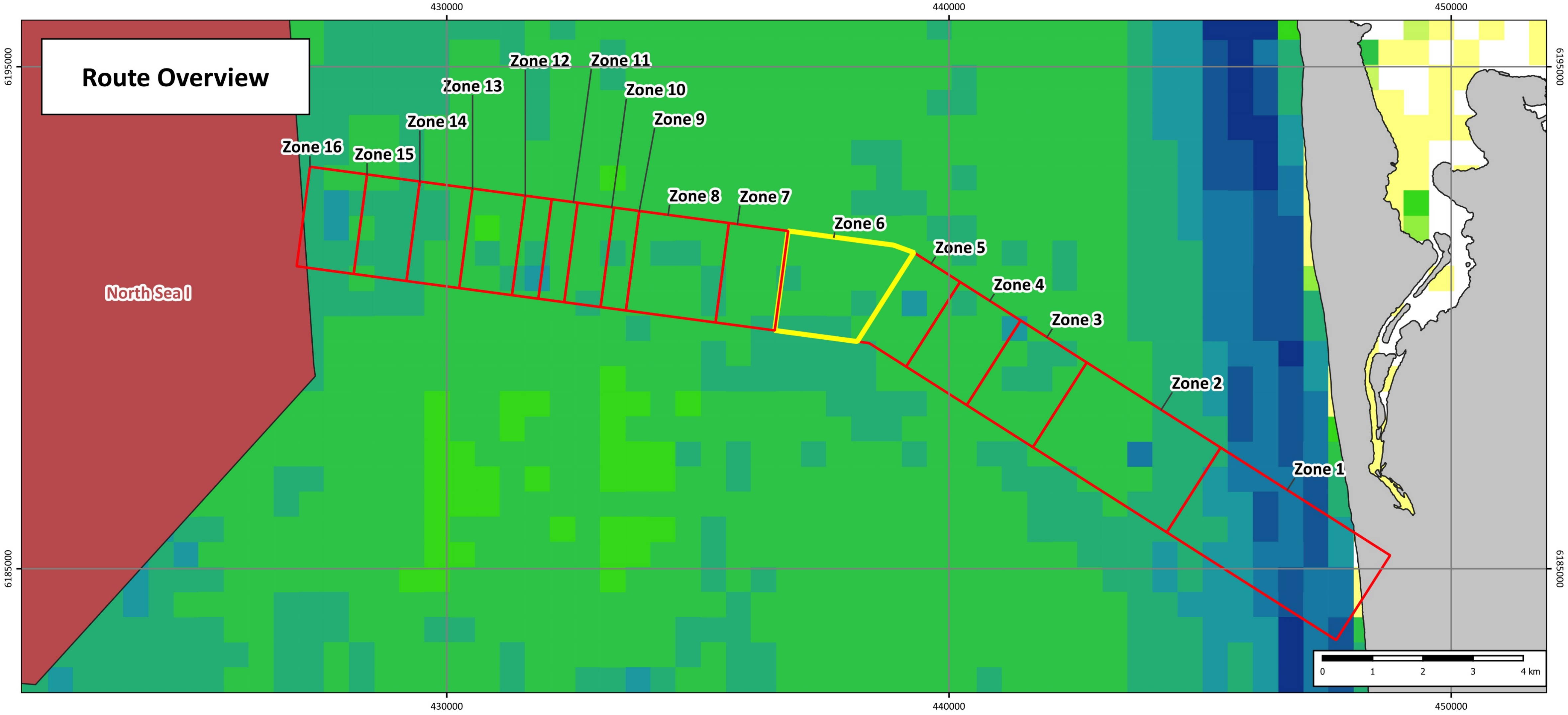
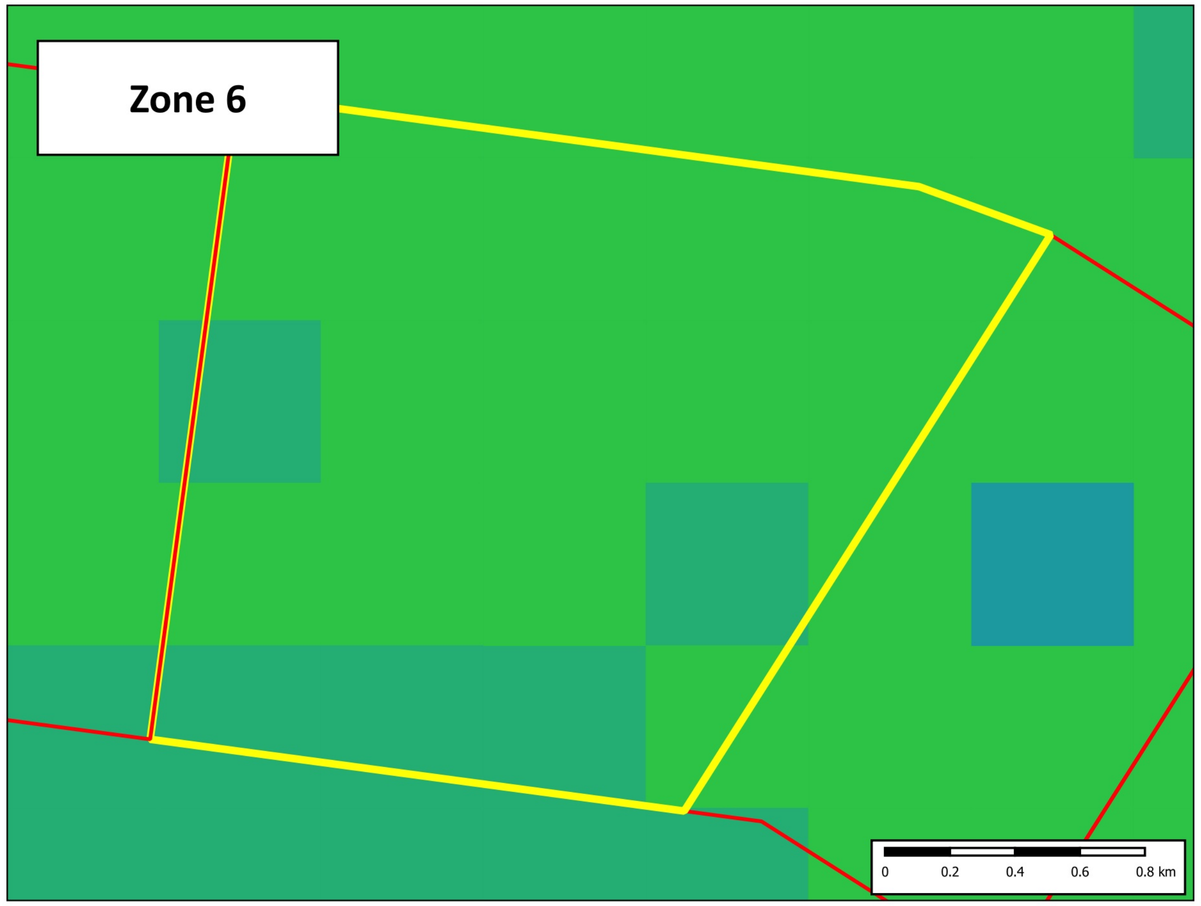
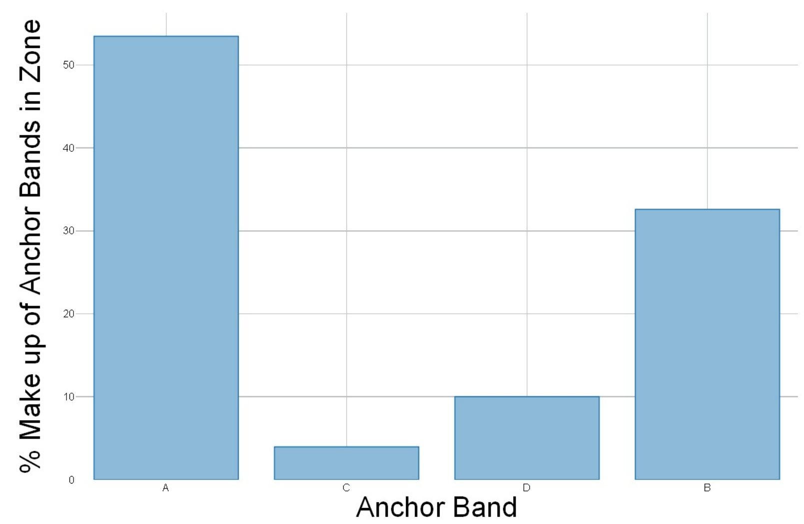



## Anchor Band Statistics by Zone - Zone 6






# CABLE BURIAL RISK ASSESSMENT NORTH SEA I - NYMINDEGAB SOUTH

## CABLE BURIAL RISK ASSESSMENT

Anchor Band Statistics - Zone 6

| Drawing No: P2719D-CBRA-001_6 | A |
|---|---|

### Legend

N

Wind Farm Site

**CBRA Zone**

Zone of Interest

CBRA Zone

**Vessel Density (Duration per year)**

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

### Legend - Inset

**Vessel Density (Duration per year)**

- 2 - 6 hours
- 12 - 24 hours
- 6 - 12 hours

| | |
|---|---|
| **Date** | 2024-06-06 16:52:58 |
| **Coordinate System** | ETRS89 / UTM zone 32N |
| **WKID** | EPSG:25832 |
| **Scale @A3** | 1:100,000 |
| **Data Sources** | NUTS; ENERGINET |
| **File Reference** | J:\P2719\Mxd_QGZ\P2719D\04_CBRA \P2719D_CBRA.qgz |
| **Created By** | Lewis Castle |
| **Reviewed By** | Emma Langley |
| **Approved By** | Stephane Theurich |

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# CABLE BURIAL RISK ASSESSMENT NORTH SEA I - NYMINDEGAB SOUTH

## CABLE BURIAL RISK ASSESSMENT

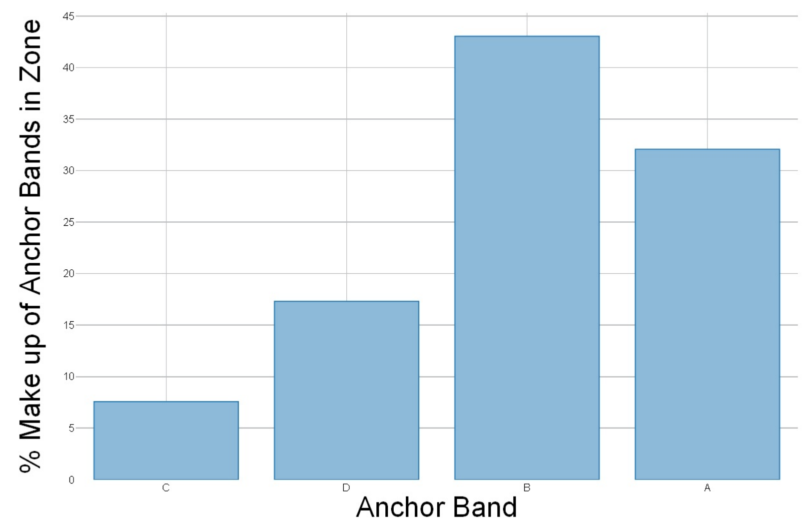
Anchor Band Statistics - Zone 7

Drawing No: P2719D-CBRA-001_7 | A

### Route Overview


### Zone 7


### Anchor Band Statistics by Zone - Zone 7




**Legend**

N

- Wind Farm Site

**CBRA Zone**

- Zone of Interest
- CBRA Zone

**Vessel Density (Duration per year)**

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

**Legend - Inset**

**Vessel Density (Duration per year)**

- 2 - 6 hours
- 6 - 12 hours

| | |
|---|---|
| **Date** | 2024-06-06 16:53:42 |
| **Coordinate System** | ETRS89 / UTM zone 32N |
| **WKID** | EPSG:25832 |
| **Scale @A3** | 1:100,000 |
| **Data Sources** | NUTS; ENERGINET |
| **File Reference** | J:\P2719\Mxd_QGZ\P2719D\04_CBRA \P2719D_CBRA.qgz |
| **Created By** | Lewis Castle |
| **Reviewed By** | Emma Langley |
| **Approved By** | Stephane Theurich |

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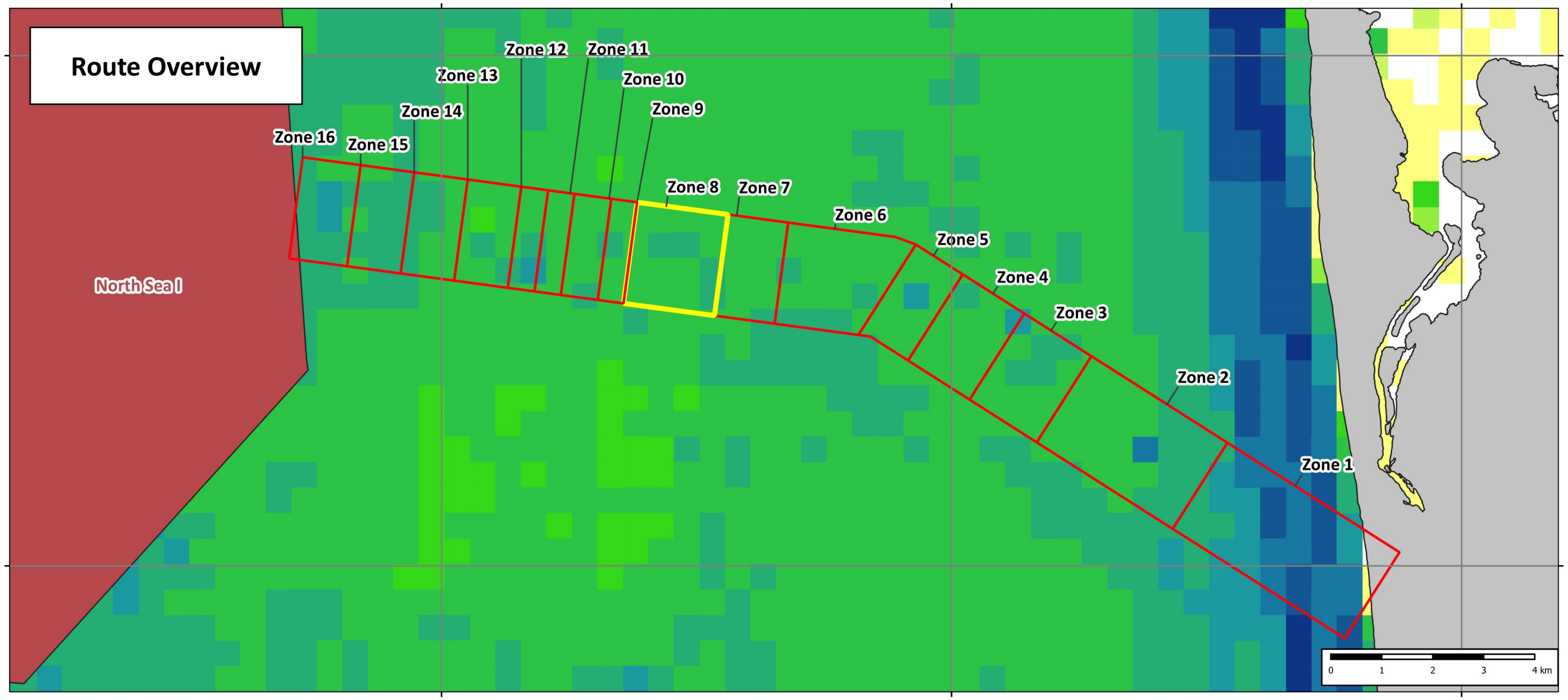
# CABLE BURIAL RISK ASSESSMENT NORTH SEA I - NYMINDEGAB SOUTH

## CABLE BURIAL RISK ASSESSMENT

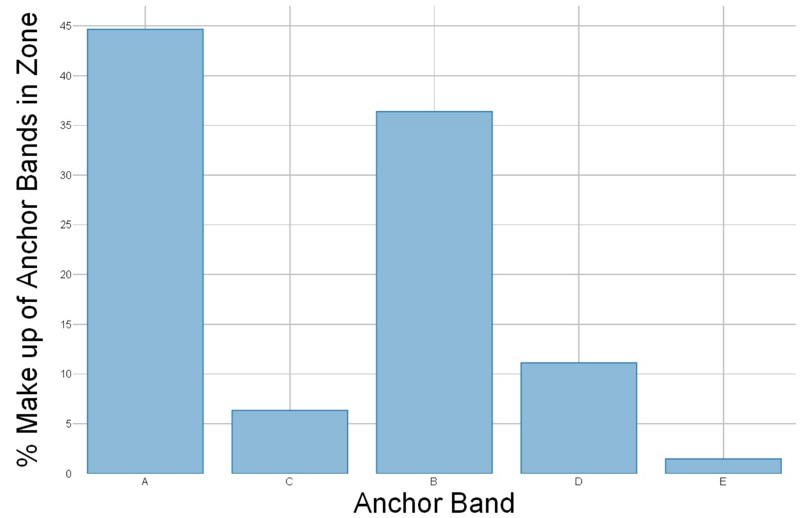
Anchor Band Statistics - Zone 8

Drawing No: P2719D-CBRA-001_8 | A





### Anchor Band Statistics by Zone - Zone 8




**Legend**

N

- Wind Farm Site

**CBRA Zone**

- Zone of Interest
- CBRA Zone

**Vessel Density (Duration per year)**

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

**Legend - Inset**

**Vessel Density (Duration per year)**

- 2 - 6 hours
- 6 - 12 hours

| | |
|---|---|
| **Date** | 2024-06-06 16:54:02 |
| **Coordinate System** | ETRS89 / UTM zone 32N |
| **WKID** | EPSG:25832 |
| **Scale @A3** | 1:100,000 |
| **Data Sources** | NUTS; ENERGINET |
| **File Reference** | J:\P2719\Mxd_QGZ\P2719D\04_CBRA \P2719D_CBRA.qgz |
| **Created By** | Lewis Castle |
| **Reviewed By** | Emma Langley |
| **Approved By** | Stephane Theurich |

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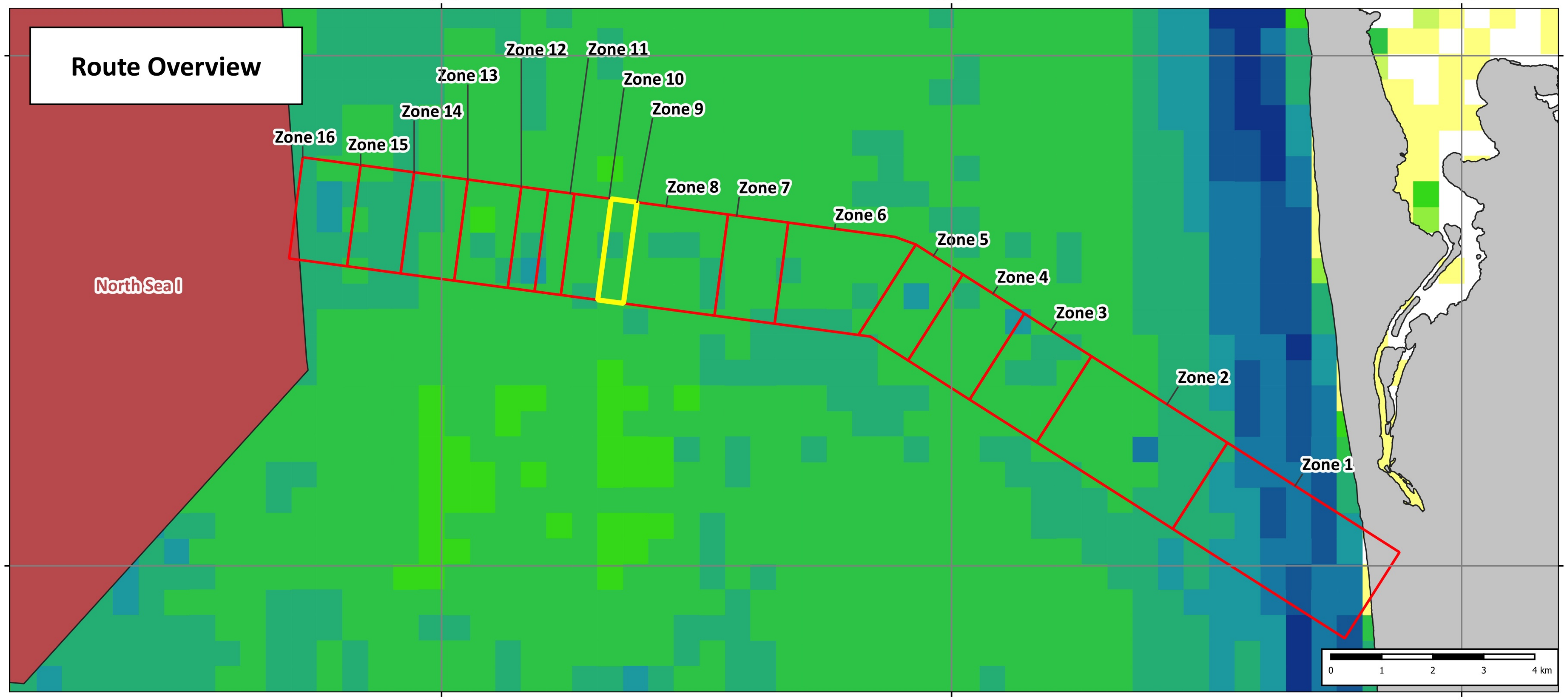
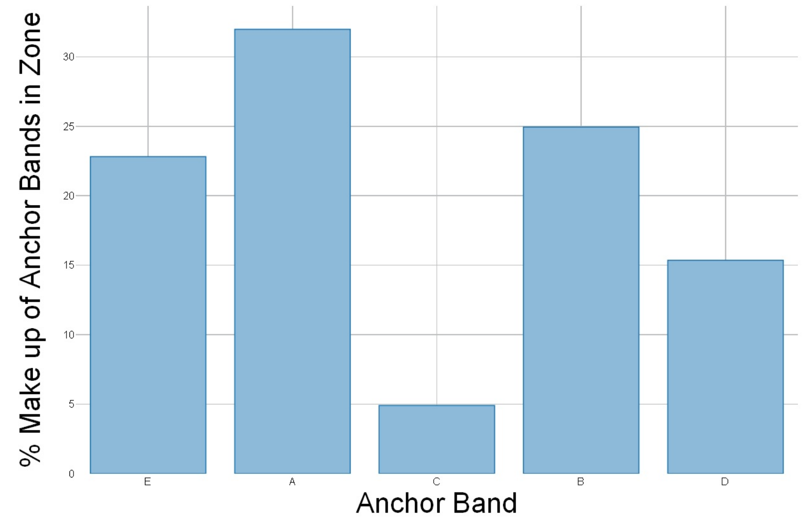




## Anchor Band Statistics by Zone - Zone 9




# CABLE BURIAL RISK ASSESSMENT NORTH SEA I - NYMINDEGAB SOUTH

## CABLE BURIAL RISK ASSESSMENT

Anchor Band Statistics - Zone 9

Drawing No: P2719D-CBRA-001_9 | A

### Legend

- Wind Farm Site

**CBRA Zone**

- Zone of Interest
- CBRA Zone

**Vessel Density (Duration per year)**

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

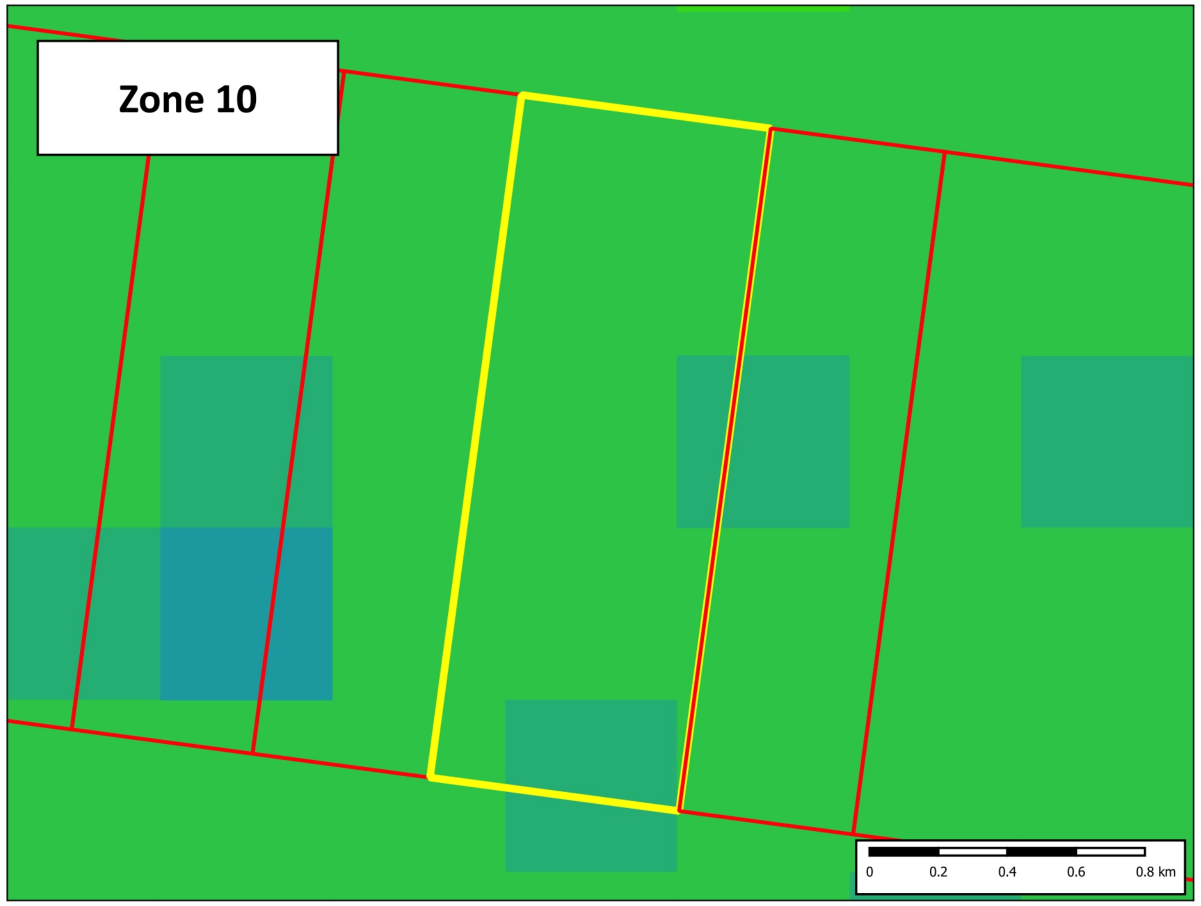
### Legend - Inset

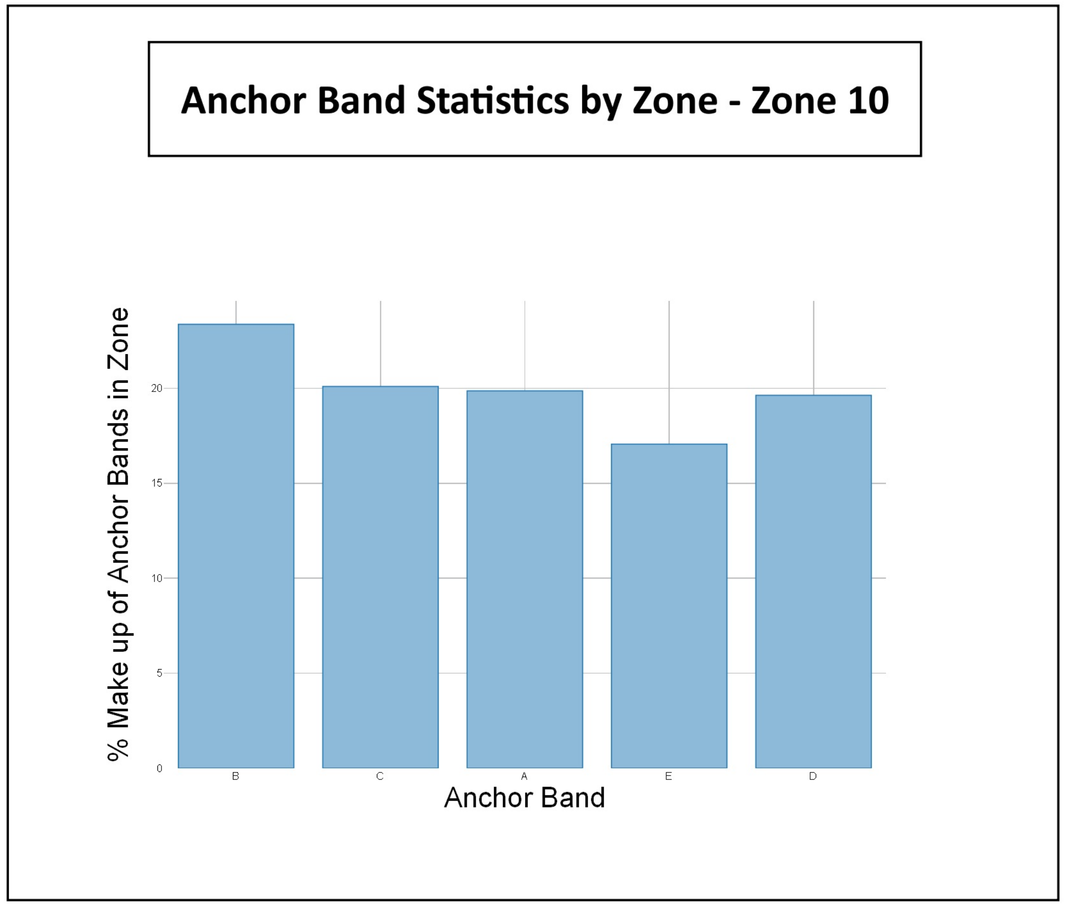
**Vessel Density (Duration per year)**

- 2 - 6 hours
- 12 - 24 hours
- 6 - 12 hours

| | |
|---|---|
| Date | 2024-06-06 16:54:28 |
| Coordinate System | ETRS89 / UTM zone 32N |
| WKID | EPSG:25832 |
| Scale @A3 | 1:100,000 |
| Data Sources | NUTS; ENERGINET |
| File Reference | J:\P2719\Mxd_QGZ\P2719D\04_CBRA \P2719D_CBRA.qgz |
| Created By | Lewis Castle |
| Reviewed By | Emma Langley |
| Approved By | Stephane Theurich |

ENERGINET intertek


# CABLE BURIAL RISK ASSESSMENT NORTH SEA I - NYMINDEGAB SOUTH

## CABLE BURIAL RISK ASSESSMENT

Anchor Band Statistics - Zone 10

Drawing No: P2719D-CBRA-001_10 | A

**Legend**

Wind Farm Site

**CBRA Zone**

Zone of Interest

CBRA Zone

**Vessel Density (Duration per year)**

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

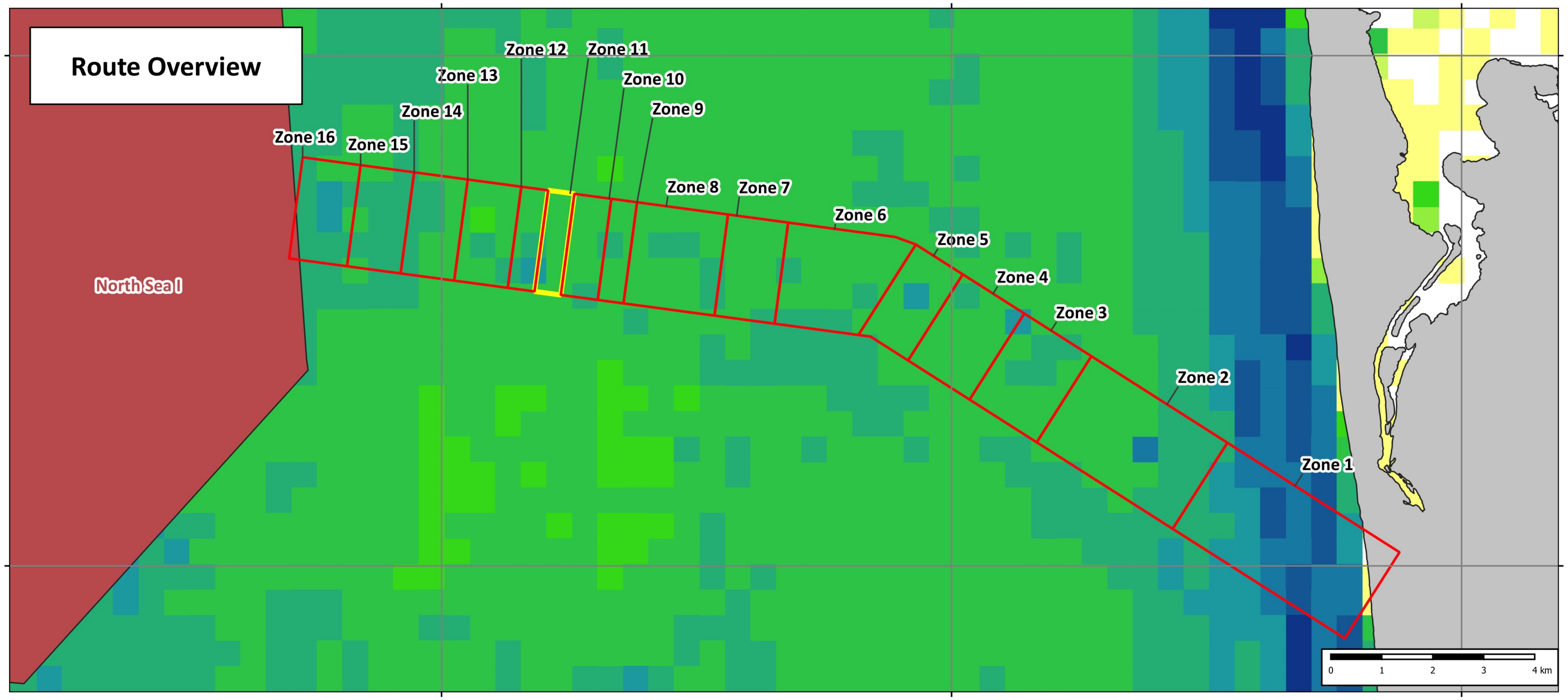
**Legend - Inset**

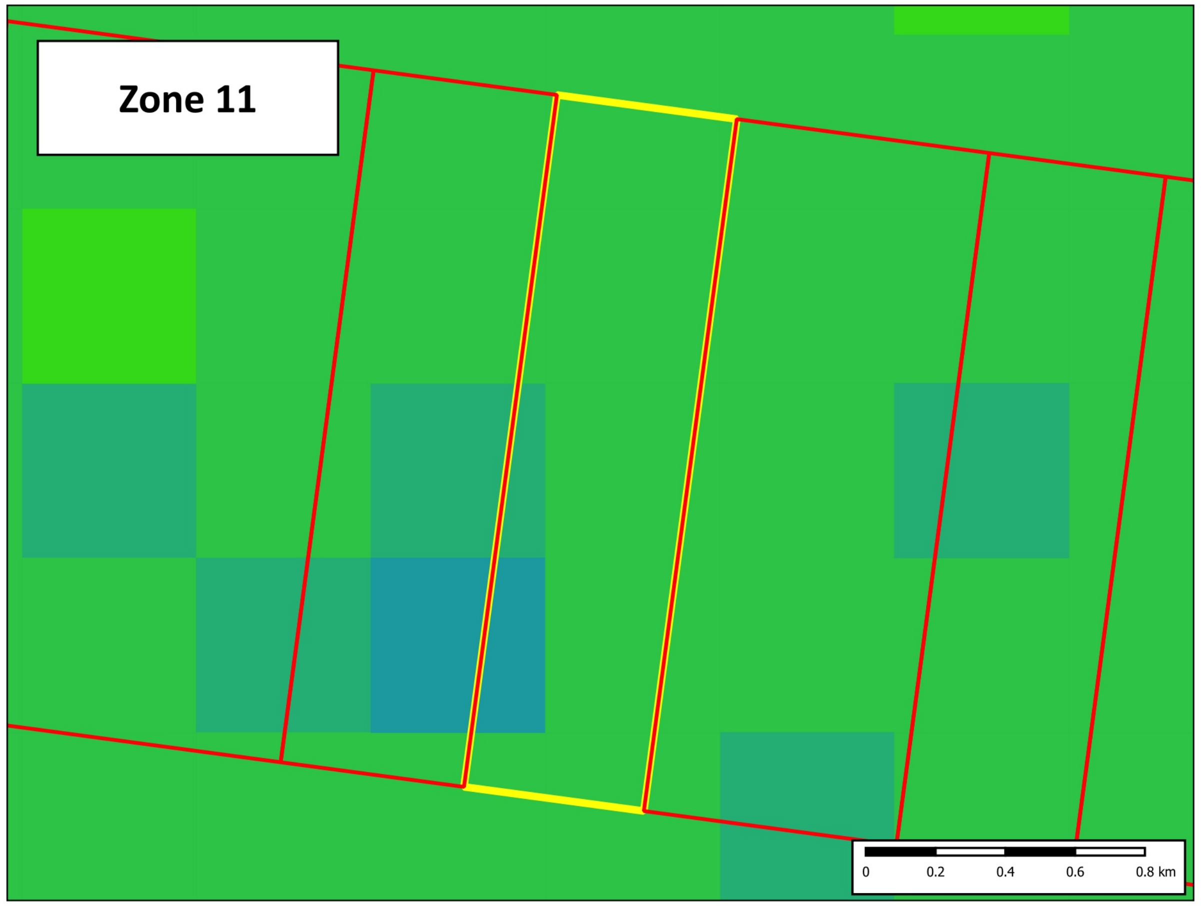
**Vessel Density (Duration per year)**

- 1 - 2 hours
- 6 - 12 hours
- 2 - 6 hours
- 12 - 24 hours

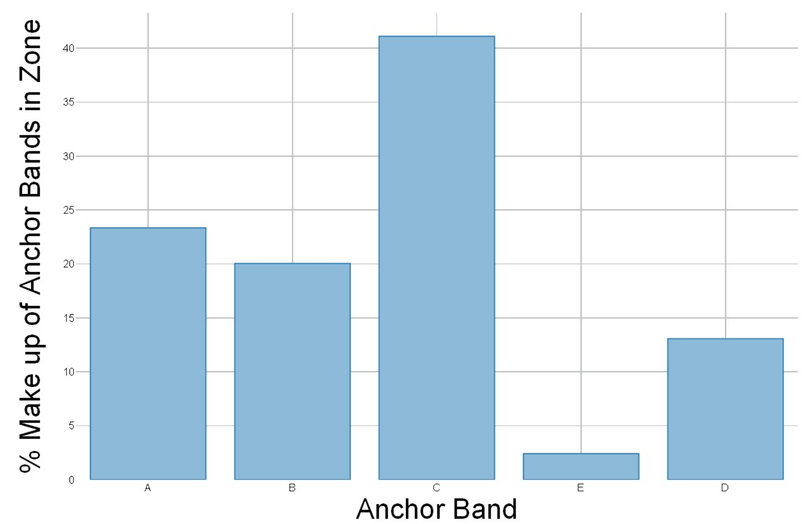
| | |
|---|---|
| Date | 2024-06-06 16:54:47 |
| Coordinate System | ETRS89 / UTM zone 32N |
| WKID | EPSG:25832 |
| Scale @A3 | 1:100,000 |
| Data Sources | NUTS; ENERGINET |
| File Reference | J:\P2719\Mxd_QGZ\P2719D\04_CBRA \P2719D_CBRA.qgz |
| Created By | Lewis Castle |
| Reviewed By | Emma Langley |
| Approved By | Stephane Theurich |

ENERGINET intertek




## Anchor Band Statistics by Zone - Zone 11




# CABLE BURIAL RISK ASSESSMENT NORTH SEA I - NYMINDEGAB SOUTH

## CABLE BURIAL RISK ASSESSMENT

Anchor Band Statistics - Zone 11

Drawing No: P2719D-CBRA-001_11 | A

N

**Legend**

Wind Farm Site

**CBRA Zone**

Zone of Interest

CBRA Zone

**Vessel Density (Duration per year)**

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

**Legend - Inset**

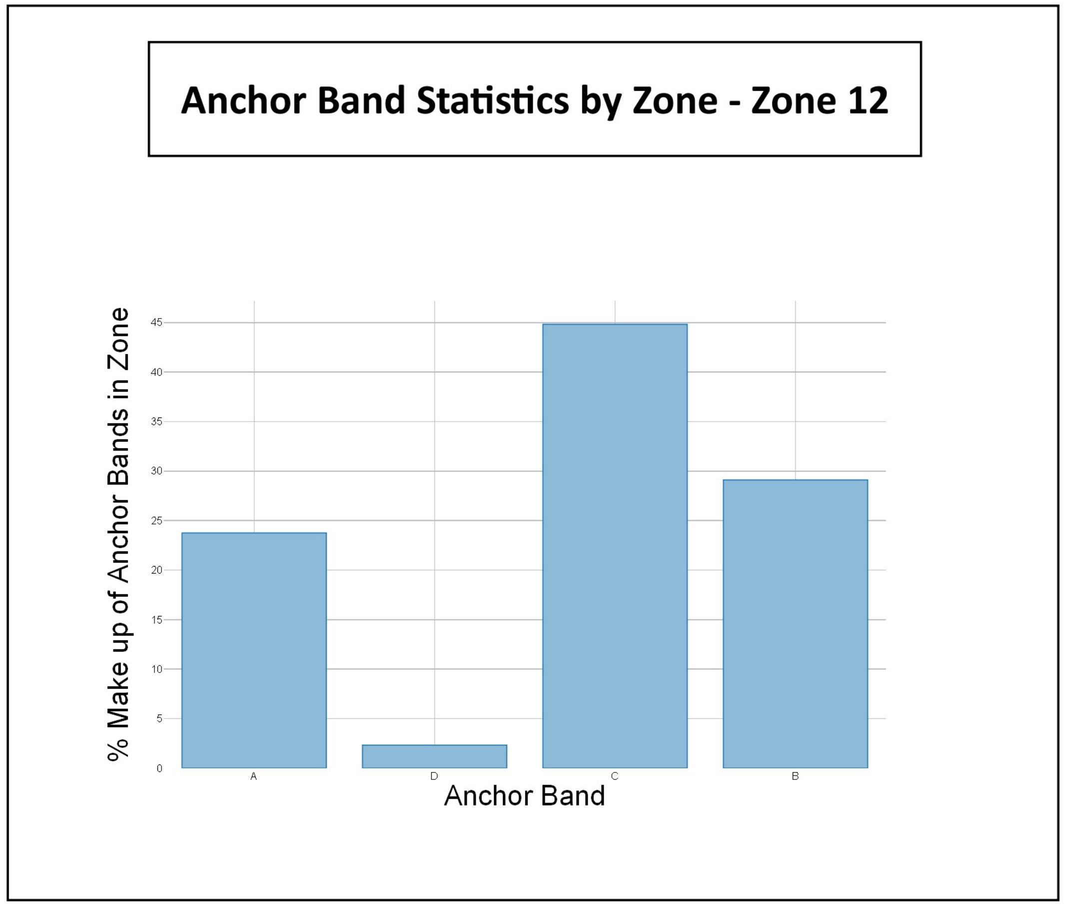
**Vessel Density (Duration per year)**

- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours

| | |
|---|---|
| **Date** | 2024-06-06 16:55:14 |
| **Coordinate System** | ETRS89 / UTM zone 32N |
| **WKID** | EPSG:25832 |
| **Scale @A3** | 1:100,000 |
| **Data Sources** | NUTS; ENERGINET |
| **File Reference** | J:\P2719\Mxd_QGZ\P2719D\04_CBRA \P2719D_CBRA.qgz |
| **Created By** | Lewis Castle |
| **Reviewed By** | Emma Langley |
| **Approved By** | Stephane Theurich |

ENERGINET intertek






# CABLE BURIAL RISK ASSESSMENT NORTH SEA I - NYMINDEGAB SOUTH

## CABLE BURIAL RISK ASSESSMENT

Anchor Band Statistics - Zone 12

| Drawing No: P2719D-CBRA-001_12 | A |
|---|---|

### Legend

- Wind Farm Site

**CBRA Zone**

- Zone of Interest
- CBRA Zone

**Vessel Density (Duration per year)**

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

N

### Legend - Inset

**Vessel Density (Duration per year)**

- 1 - 2 hours
- 6 - 12 hours
- 2 - 6 hours
- 12 - 24 hours

| | |
|---|---|
| Date | 2024-06-06 16:55:46 |
| Coordinate System | ETRS89 / UTM zone 32N |
| WKID | EPSG:25832 |
| Scale @A3 | 1:100,000 |
| Data Sources | NUTS; ENERGINET |
| File Reference | J:\P2719\Mxd_QGZ\P2719D\04_CBRA \P2719D_CBRA.qgz |
| Created By | Lewis Castle |
| Reviewed By | Emma Langley |
| Approved By | Stephane Theurich |

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# CABLE BURIAL RISK ASSESSMENT NORTH SEA I - NYMINDEGAB SOUTH

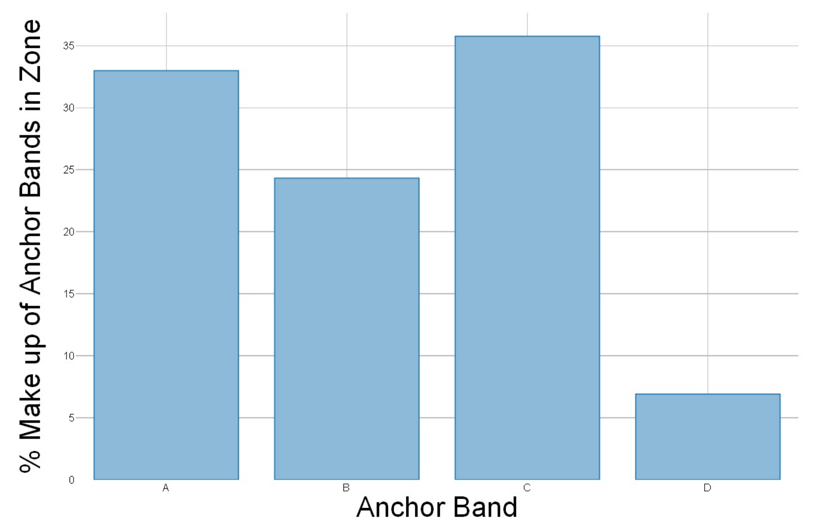
## CABLE BURIAL RISK ASSESSMENT

Anchor Band Statistics - Zone 13

Drawing No: P2719D-CBRA-001_13 | A



## Anchor Band Statistics by Zone - Zone 13




### Legend

Wind Farm Site

**CBRA Zone**

- Zone of Interest
- CBRA Zone

**Vessel Density (Duration per year)**

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

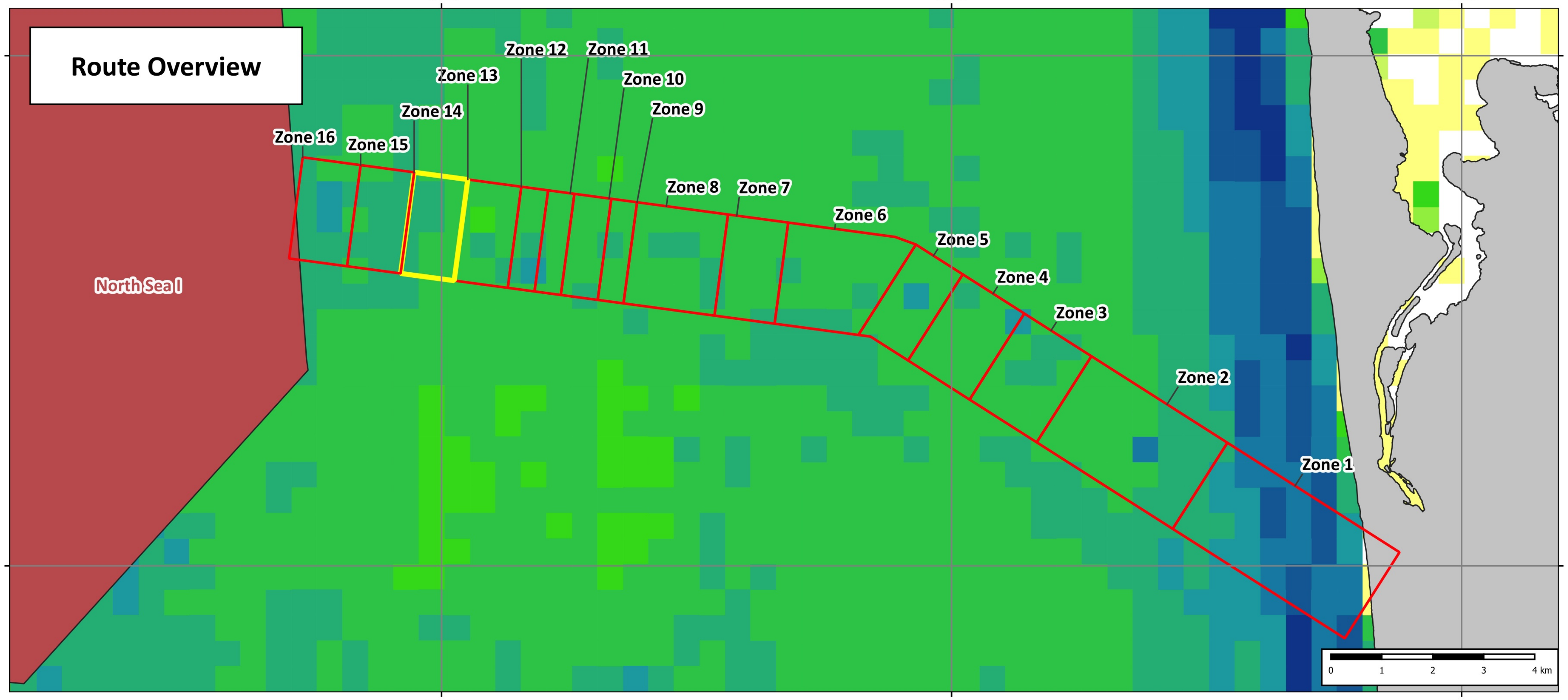
### Legend - Inset

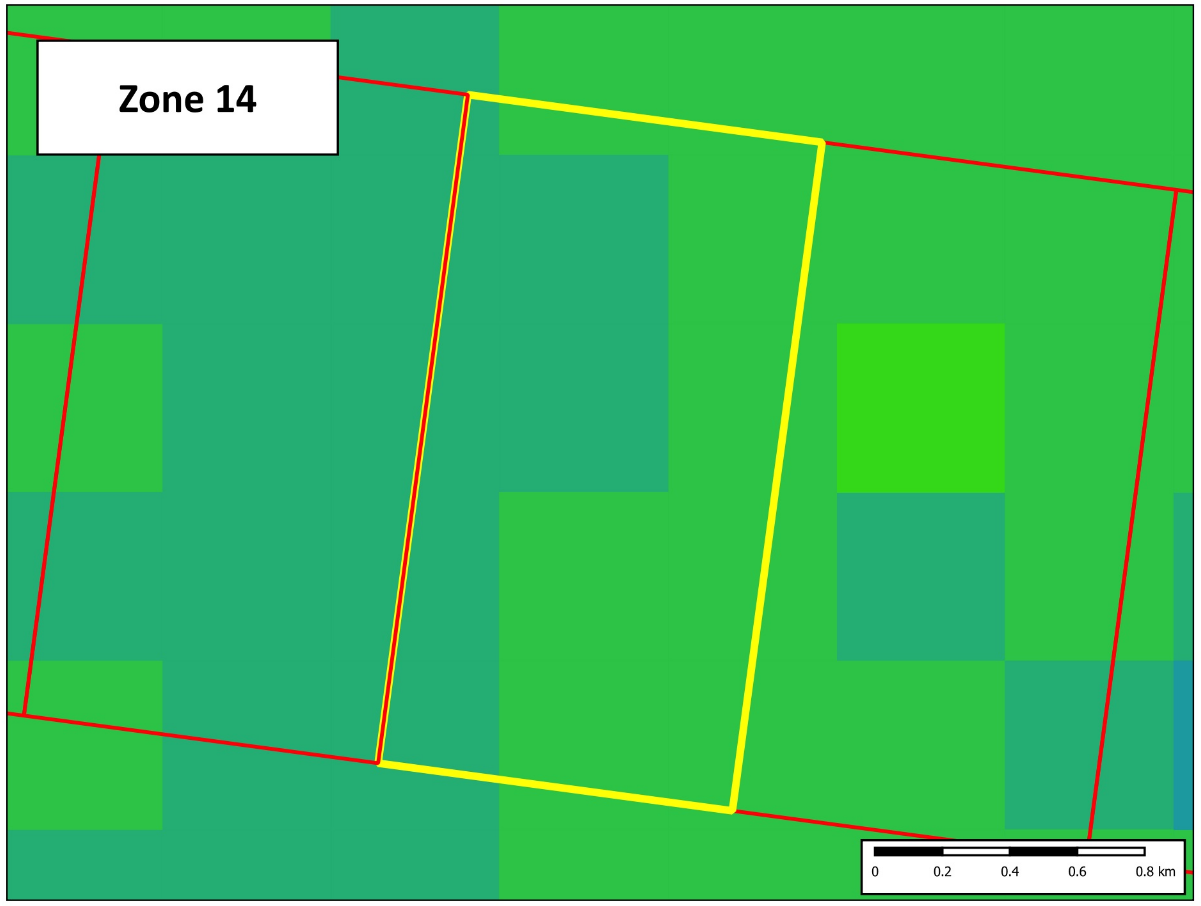
**Vessel Density (Duration per year)**

- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours

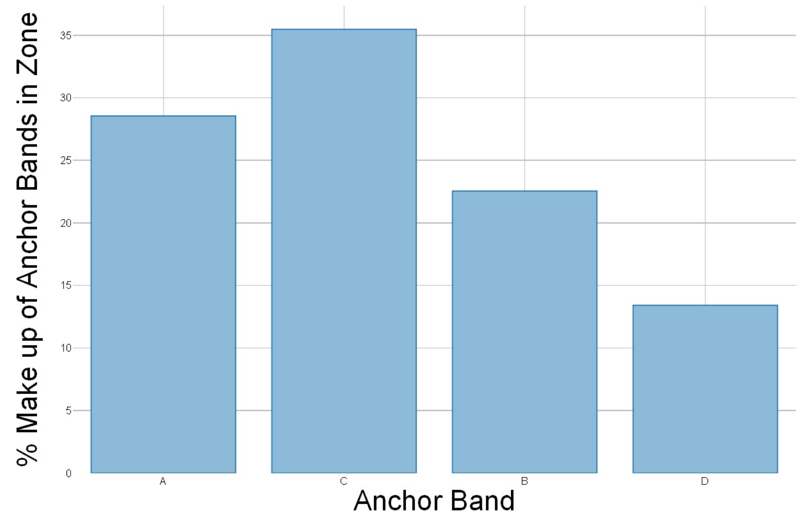
| | |
|---|---|
| **Date** | 2024-06-06 16:56:34 |
| **Coordinate System** | ETRS89 / UTM zone 32N |
| **WKID** | EPSG:25832 |
| **Scale @A3** | 1:100,000 |
| **Data Sources** | NUTS; ENERGINET |
| **File Reference** | J:\P2719\Mxd_QGZ\P2719D\04_CBRA \P2719D_CBRA.qgz |
| **Created By** | Lewis Castle |
| **Reviewed By** | Emma Langley |
| **Approved By** | Stephane Theurich |

ENERGINET intertek




## Anchor Band Statistics by Zone - Zone 14




# CABLE BURIAL RISK ASSESSMENT NORTH SEA I - NYMINDEGAB SOUTH

## CABLE BURIAL RISK ASSESSMENT

Anchor Band Statistics - Zone 14

Drawing No: P2719D-CBRA-001_14 | A

### Legend

- Wind Farm Site

**CBRA Zone**

- Zone of Interest
- CBRA Zone

**Vessel Density (Duration per year)**

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

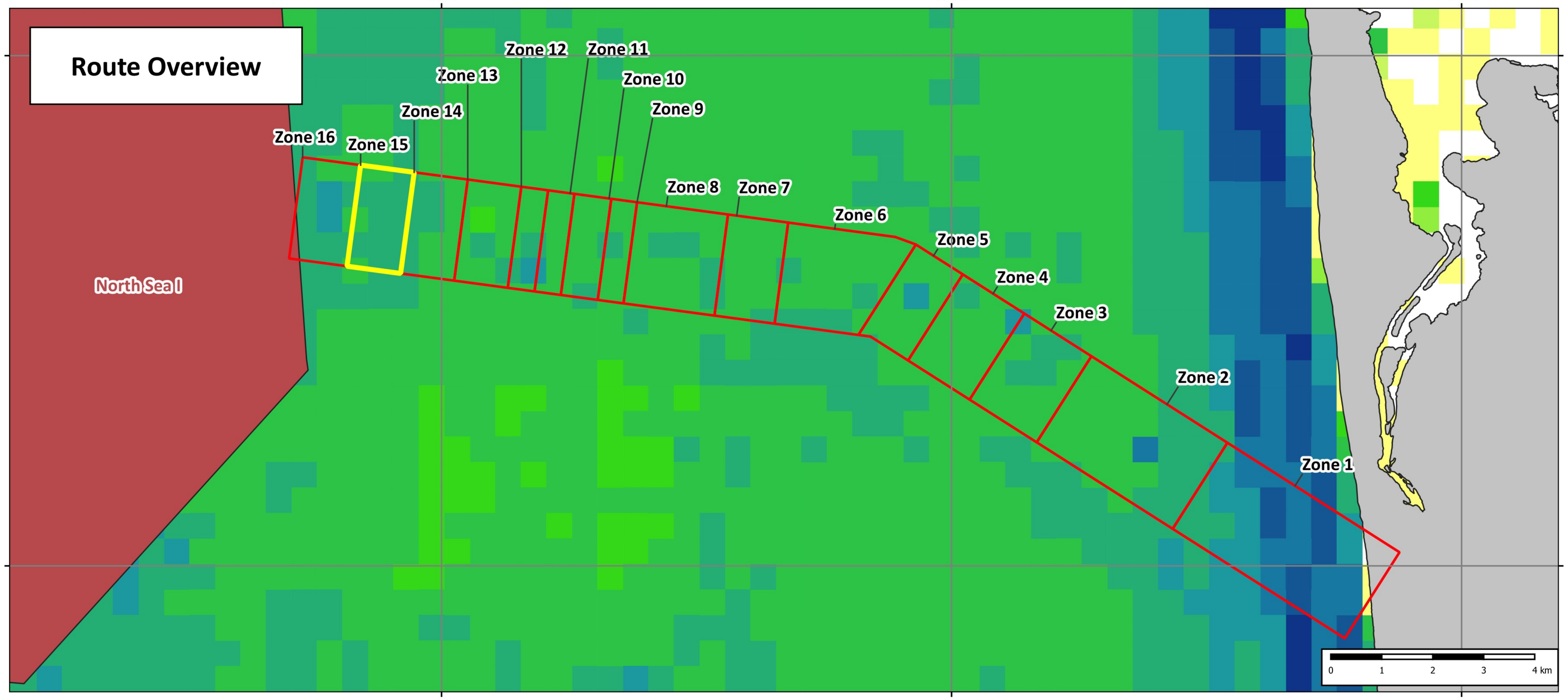
### Legend - Inset

**Vessel Density (Duration per year)**

- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours

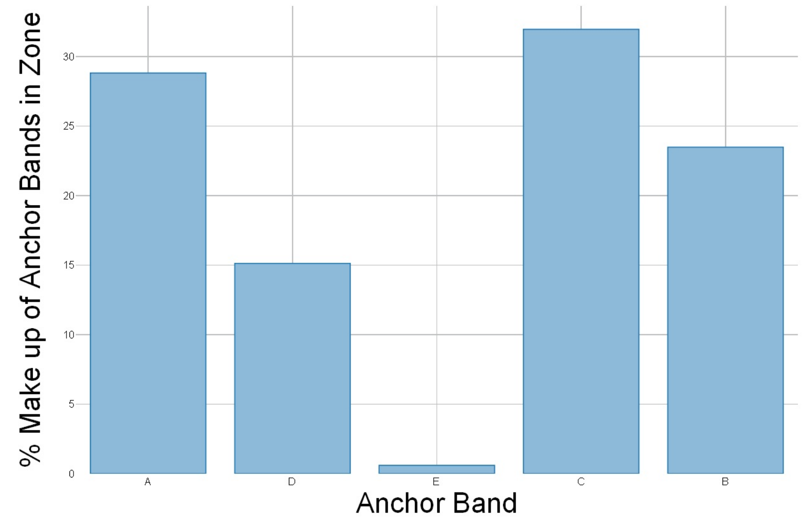
| | |
|---|---|
| **Date** | 2024-06-06 16:56:56 |
| **Coordinate System** | ETRS89 / UTM zone 32N |
| **WKID** | EPSG:25832 |
| **Scale @A3** | 1:100,000 |
| **Data Sources** | NUTS; ENERGINET |
| **File Reference** | J:\P2719\Mxd_QGZ\P2719D\04_CBRA \P2719D_CBRA.qgz |
| **Created By** | Lewis Castle |
| **Reviewed By** | Emma Langley |
| **Approved By** | Stephane Theurich |

ENERGINET intertek





## Anchor Band Statistics by Zone - Zone 15






# CABLE BURIAL RISK ASSESSMENT NORTH SEA I - NYMINDEGAB SOUTH

## CABLE BURIAL RISK ASSESSMENT

Anchor Band Statistics - Zone 15

| Drawing No: P2719D-CBRA-001_15 | A |
|---|---|

N

### Legend

Wind Farm Site

**CBRA Zone**

Zone of Interest

CBRA Zone

**Vessel Density (Duration per year)**

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

### Legend - Inset

**Vessel Density (Duration per year)**

- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours

| | |
|---|---|
| Date | 2024-06-06 16:57:35 |
| Coordinate System | ETRS89 / UTM zone 32N |
| WKID | EPSG:25832 |
| Scale @A3 | 1:100,000 |
| Data Sources | NUTS; ENERGINET |
| File Reference | J:\P2719\Mxd_QGZ\P2719D\04_CBRA \P2719D_CBRA.qgz |
| Created By | Lewis Castle |
| Reviewed By | Emma Langley |
| Approved By | Stephane Theurich |

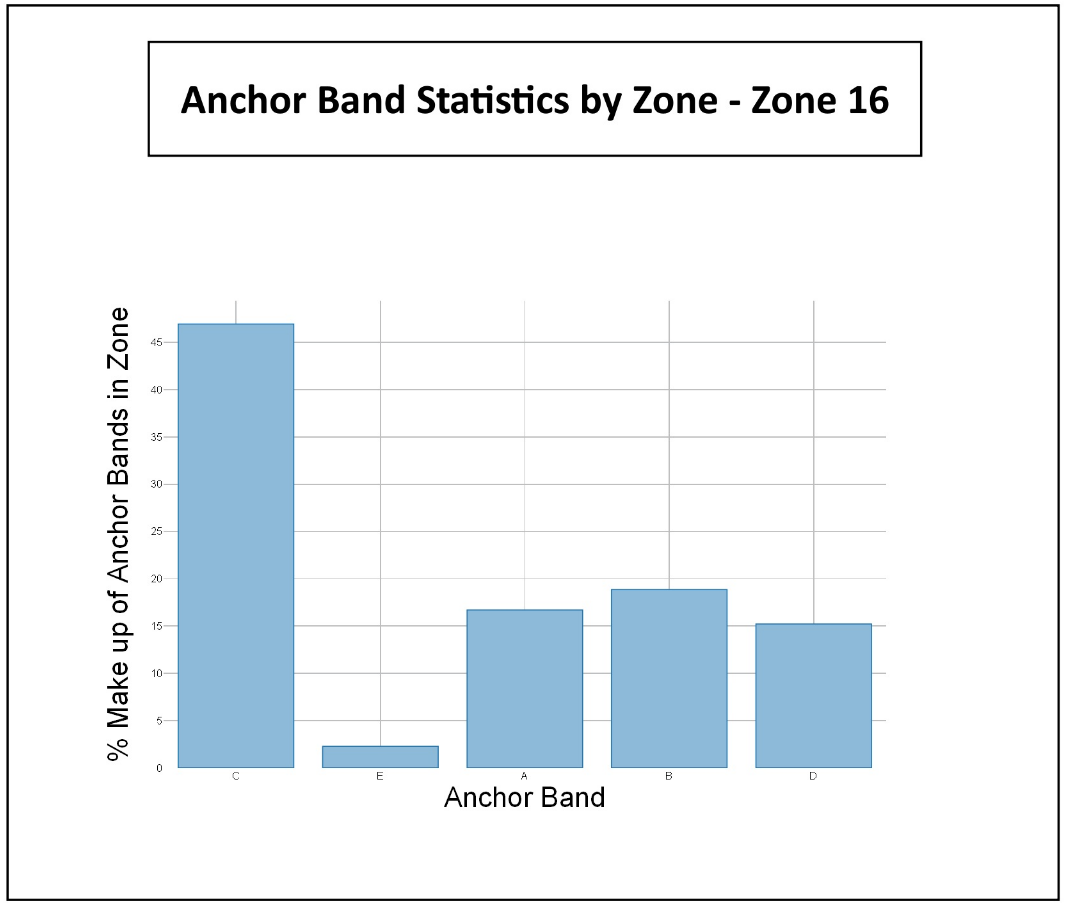
# CABLE BURIAL RISK ASSESSMENT NORTH SEA I - NYMINDEGAB SOUTH

**CABLE BURIAL RISK ASSESSMENT**

Anchor Band Statistics - Zone 16

| Drawing No: P2719D-CBRA-001_16 | A |
| --- | --- |






**Legend**

- Wind Farm Site

**CBRA Zone**

- Zone of Interest
- CBRA Zone

**Vessel Density (Duration per year)**

- < 15 mins
- 15 - 30 mins
- 30 - 45 mins
- 45 mins - 1 hour
- 1 - 2 hours
- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 36 - 48 hours
- 48 hours - 1 week
- > 1 week

**Legend - Inset**

**Vessel Density (Duration per year)**

- 2 - 6 hours
- 6 - 12 hours
- 12 - 24 hours
- 24 - 36 hours
- 48 hours - 1 week

| | |
| --- | --- |
| **Date** | 2024-06-06 16:58:02 |
| **Coordinate System** | ETRS89 / UTM zone 32N |
| **WKID** | EPSG:25832 |
| **Scale @A3** | 1:100,000 |
| **Data Sources** | NUTS; ENERGINET |
| **File Reference** | J:\P2719\Mxd_QGZ\P2719D\04_CBRA \P2719D_CBRA.qgz |
| **Created By** | Lewis Castle |
| **Reviewed By** | Emma Langley |
| **Approved By** | Stephane Theurich |

ENERGINET intertek

# APPENDIX E

## Probabilistic Risk Assessment

## Table E-1 Probabilistic Results for Each Scenario

| Zone | Scenario 1 - Protection against Band A: Recommended Minimum DoL (m) | Scenario 1: Segment annual failure probability $P_{anchor\ damage}$ | Scenario 2 - Protection against Bands A to B: Recommended Minimum DoL (m) | Scenario 2: Segment annual failure probability $P_{anchor\ damage}$ | Scenario 3 - Protection against Bands A to C: Recommended Minimum DoL (m) | Scenario 3: Segment annual failure probability $P_{anchor\ damage}$ | Scenario 4 - Protection against Bands A to D: Recommended Minimum DoL (m) | Scenario 4: Segment annual failure probability $P_{anchor\ damage}$ | Scenario 5 - Protection against Bands A to E: Recommended Minimum DoL (m) | Scenario 5: Segment annual failure probability $P_{anchor\ damage}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.30 | 5.34E-04 | 0.35 | 4.11E-04 | 0.40 | 4.64E-05 | 0.50 | 4.46E-06 | 0.65 | 0.00E+00 |
| 2 | 0.65 | 5.66E-04 | 0.80 | 1.42E-04 | 1.00 | 5.24E-05 | 1.10 | 3.76E-06 | 1.25 | 0.00E+00 |
| 3 | 0.65 | 1.64E-03 | 0.80 | 4.45E-04 | 1.00 | 1.46E-04 | 1.10 | 3.77E-06 | 1.25 | 0.00E+00 |
| 4 | 0.65 | 4.93E-03 | 0.80 | 3.35E-03 | 1.00 | 1.74E-03 | 1.20 | 1.21E-04 | 1.55 | 1.61E-06 |
| 5 | 0.65 | 6.74E-03 | 0.80 | 5.18E-03 | 1.00 | 3.46E-03 | 1.20 | 3.60E-04 | 1.55 | 1.03E-04 |
| 6 | 0.65 | 4.21E-03 | 0.80 | 3.07E-03 | 1.00 | 1.92E-03 | 1.20 | 3.67E-04 | 1.65 | 1.85E-04 |
| 7 | 0.30 | 1.54E-02 | 0.35 | 1.45E-02 | 0.40 | 5.75E-03 | 0.50 | 6.87E-04 | 0.65 | 5.33E-04 |
| 8 | 0.50 | 9.60E-03 | 0.55 | 8.19E-03 | 0.70 | 6.92E-03 | 0.85 | 3.27E-03 | 1.15 | 2.87E-03 |
| 9 | 0.80 | 7.16E-03 | 0.85 | 6.35E-03 | 1.00 | 5.31E-03 | 1.15 | 3.03E-03 | 1.35 | 2.75E-03 |
| 10 | 0.60 | 8.84E-03 | 0.70 | 8.04E-03 | 0.85 | 7.47E-03 | 1.00 | 6.28E-03 | 1.30 | 5.97E-03 |
| 11 | 0.30 | 2.80E-03 | 0.35 | 2.54E-03 | 0.40 | 2.19E-03 | 0.50 | 1.44E-03 | 0.65 | 1.33E-03 |
| 12 | 0.65 | 9.48E-04 | 0.70 | 8.10E-04 | 0.75 | 6.59E-04 | 0.85 | 4.09E-04 | 1.00 | 3.45E-04 |
| 13 | 0.30 | 6.79E-03 | 0.35 | 4.88E-03 | 0.40 | 3.93E-03 | 0.50 | 3.06E-03 | 0.65 | 2.95E-03 |
| 14 | 0.30 | 1.29E-03 | 0.35 | 5.45E-04 | 0.40 | 1.95E-04 | 0.50 | 1.56E-04 | 0.65 | 3.62E-05 |
| 15 | 0.35 | 5.36E-04 | 0.40 | 7.34E-05 | 0.45 | 3.02E-05 | 0.55 | 2.96E-05 | 0.70 | 5.03E-06 |
| 16 | 0.55 | 1.73E-03 | 0.70 | 1.60E-03 | 0.85 | 9.11E-05 | 0.95 | 1.73E-05 | 1.10 | 4.76E-06 |
| Annual Failure Probability for Entire route | 7.37% | | 6.02% | | 3.99% | | 1.92% | | 1.71% | |
| Return Period (years) | 13.56 | | 16.62 | | 25.05 | | 51.98 | | 58.52 | |
| Failure Probability in the lifetime (40 years) | 95.33% | | 91.64% | | 80.40% | | 54.03% | | 49.82% | |

| Zone | Scenario 6 - Protection against Bands A to F: Recommended Minimum DoL (m) | Scenario 6: Segment annual failure probability $P_{anchor\ damage}$ | Scenario 7 - Protection against Bands A to G: Recommended Minimum DoL (m) | Scenario 7: Segment annual failure probability $P_{anchor\ damage}$ | Scenario 8 - Protection against Bands A to H: Recommended Minimum DoL (m) | Scenario 8: Segment annual failure probability $P_{anchor\ damage}$ | Scenario 9 - Protection against Bands A to I: Recommended Minimum DoL (m) | Scenario 9: Segment annual failure probability $P_{anchor\ damage}$ | Scenario 10 - Selected Protection Section by Section: Recommended Minimum DoL (m) | Scenario 10: Segment annual failure probability $P_{anchor\ damage}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00E+00 | 0.70 | 0.00E+00 | 0.75 | 0.00E+00 | 0.80 | 0.00E+00 | 0.50 | **4.46E-06** |
| 2 | 1.30 | 0.00E+00 | 1.30 | 0.00E+00 | 1.35 | 0.00E+00 | 1.40 | 0.00E+00 | 1.10 | **3.76E-06** |
| 3 | 1.30 | 0.00E+00 | 1.30 | 0.00E+00 | 1.35 | 0.00E+00 | 1.40 | 0.00E+00 | 1.10 | **3.77E-06** |
| 4 | 1.70 | 0.00E+00 | 1.70 | 0.00E+00 | 1.85 | 0.00E+00 | 1.90 | 0.00E+00 | 1.55 | **1.61E-06** |
| 5 | 1.65 | 0.00E+00 | 1.65 | 0.00E+00 | 1.80 | 0.00E+00 | 1.85 | 0.00E+00 | 1.65 | **0.00E+00** |
| 6 | 1.70 | 1.22E-05 | 1.70 | 1.22E-05 | 1.75 | 0.00E+00 | 1.75 | 0.00E+00 | 1.70 | **1.22E-05** |
| 7 | 0.70 | 1.68E-04 | 0.70 | 1.68E-04 | 0.75 | 9.83E-05 | 0.80 | 0.00E+00 | 0.80 | **0.00E+00** |
| 8 | 1.30 | 1.07E-03 | 1.30 | 1.07E-03 | 1.55 | 0.00E+00 | 1.55 | 0.00E+00 | 1.55 | **0.00E+00** |
| 9 | 1.40 | 1.16E-03 | 1.40 | 1.16E-03 | 1.45 | 2.50E-04 | 1.50 | 0.00E+00 | 1.50 | **0.00E+00** |
| 10 | 1.40 | 2.37E-03 | 1.40 | 2.37E-03 | 1.55 | 0.00E+00 | 1.55 | 0.00E+00 | 1.55 | **0.00E+00** |
| 11 | 0.70 | 4.95E-04 | 0.70 | 4.95E-04 | 0.75 | 1.12E-04 | 0.80 | 0.00E+00 | 0.80 | **0.00E+00** |
| 12 | 1.05 | 1.50E-04 | 1.05 | 1.50E-04 | 1.10 | 2.41E-05 | 1.15 | 0.00E+00 | 1.15 | **0.00E+00** |
| 13 | 0.70 | 1.80E-03 | 0.70 | 1.80E-03 | 0.75 | 2.93E-04 | 0.90 | 0.00E+00 | 0.90 | **0.00E+00** |
| 14 | 0.70 | 3.55E-05 | 0.70 | 3.55E-05 | 0.75 | 0.00E+00 | 0.80 | 0.00E+00 | 0.70 | **3.55E-05** |
| 15 | 0.75 | 5.03E-06 | 0.75 | 5.03E-06 | 0.80 | 0.00E+00 | 0.85 | 0.00E+00 | 0.70 | **5.03E-06** |
| 16 | 1.15 | 0.00E+00 | 1.15 | 0.00E+00 | 1.20 | 0.00E+00 | 1.25 | 0.00E+00 | 0.95 | **1.73E-05** |
| Annual Failure Probability for Entire route | 0.73% | | 0.73% | | 0.08% | | 0.00% | | 0.00836% | |
| Return Period (years) | 137.75 | | 137.75 | | 1286.87 | | ∞ | | 11957.95 | |
| Failure Probability in the lifetime (40 years) | 25.28% | | 25.28% | | 3.06% | | 0.00% | | 0.33% | |

## Table E-2 Probabilistic Results for Each Zone in 0.25m Increments

| Zone | Selected Protection Section by Section at 0.25m: DoL (m) | Segment annual failure probability $P_{anchor\ damage}$ | Selected Protection Section by Section at 0.50m: DoL (m) | Segment annual failure probability $P_{anchor\ damage}$ | Selected Protection Section by Section at 0.75m: DoL (m) | Segment annual failure probability $P_{anchor\ damage}$ | Selected Protection Section by Section at 1.00m: DoL (m) | Segment annual failure probability $P_{anchor\ damage}$ | Selected Protection Section by Section at 1.25m: DoL (m) | Segment annual failure probability $P_{anchor\ damage}$ | Selected Protection Section by Section at 1.50m: DoL (m) | Segment annual failure probability $P_{anchor\ damage}$ | Selected Protection Section by Section at 1.75m: DoL (m) | Segment annual failure probability $P_{anchor\ damage}$ | Selected Protection Section by Section at 2.00m: DoL (m) | Segment annual failure probability $P_{anchor\ damage}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.25 | 2.06E-02 | 0.50 | 4.46E-06 | 0.75 | 0.00E+00 | 1.00 | 0.00E+00 | 1.25 | 0.00E+00 | 1.50 | 0.00E+00 | 1.75 | 0.00E+00 | 2.00 | 0.00E+00 |
| 2 | 0.25 | 4.81E-03 | 0.50 | 4.81E-03 | 0.75 | 5.66E-04 | 1.00 | 5.24E-05 | 1.25 | 0.00E+00 | 1.50 | 0.00E+00 | 1.75 | 0.00E+00 | 2.00 | 0.00E+00 |
| 3 | 0.25 | 4.27E-03 | 0.50 | 4.27E-03 | 0.75 | 1.64E-03 | 1.00 | 1.46E-04 | 1.25 | 0.00E+00 | 1.50 | 0.00E+00 | 1.75 | 0.00E+00 | 2.00 | 0.00E+00 |
| 4 | 0.25 | 6.82E-03 | 0.50 | 6.82E-03 | 0.75 | 4.93E-03 | 1.00 | 1.74E-03 | 1.25 | 1.21E-04 | 1.50 | 1.21E-04 | 1.75 | 0.00E+00 | 2.00 | 0.00E+00 |
| 5 | 0.25 | 9.73E-03 | 0.50 | 9.73E-03 | 0.75 | 6.74E-03 | 1.00 | 3.46E-03 | 1.25 | 3.60E-04 | 1.50 | 3.60E-04 | 1.75 | 0.00E+00 | 2.00 | 0.00E+00 |
| 6 | 0.25 | 7.48E-03 | 0.50 | 7.48E-03 | 0.75 | 4.21E-03 | 1.00 | 1.92E-03 | 1.25 | 3.67E-04 | 1.50 | 3.67E-04 | 1.75 | 0.00E+00 | 2.00 | 0.00E+00 |
| 7 | 0.25 | 1.80E-02 | 0.50 | 6.87E-04 | 0.75 | 9.83E-05 | 1.00 | 0.00E+00 | 1.25 | 0.00E+00 | 1.50 | 0.00E+00 | 1.75 | 0.00E+00 | 2.00 | 0.00E+00 |
| 8 | 0.25 | 1.43E-02 | 0.50 | 9.60E-03 | 0.75 | 6.92E-03 | 1.00 | 3.27E-03 | 1.25 | 2.87E-03 | 1.50 | 1.07E-03 | 1.75 | 0.00E+00 | 2.00 | 0.00E+00 |
| 9 | 0.25 | 9.22E-03 | 0.50 | 9.22E-03 | 0.75 | 9.22E-03 | 1.00 | 5.31E-03 | 1.25 | 3.03E-03 | 1.50 | 0.00E+00 | 1.75 | 0.00E+00 | 2.00 | 0.00E+00 |
| 10 | 0.25 | 1.18E-02 | 0.50 | 1.18E-02 | 0.75 | 8.04E-03 | 1.00 | 6.28E-03 | 1.25 | 6.28E-03 | 1.50 | 2.37E-03 | 1.75 | 0.00E+00 | 2.00 | 0.00E+00 |
| 11 | 0.25 | 3.30E-03 | 0.50 | 1.44E-03 | 0.75 | 1.12E-04 | 1.00 | 0.00E+00 | 1.25 | 0.00E+00 | 1.50 | 0.00E+00 | 1.75 | 0.00E+00 | 2.00 | 0.00E+00 |
| 12 | 0.25 | 1.16E-03 | 0.50 | 1.16E-03 | 0.75 | 6.59E-04 | 1.00 | 3.45E-04 | 1.25 | 0.00E+00 | 1.50 | 0.00E+00 | 1.75 | 0.00E+00 | 2.00 | 0.00E+00 |
| 13 | 0.25 | 8.95E-03 | 0.50 | 3.06E-03 | 0.75 | 2.93E-04 | 1.00 | 0.00E+00 | 1.25 | 0.00E+00 | 1.50 | 0.00E+00 | 1.75 | 0.00E+00 | 2.00 | 0.00E+00 |
| 14 | 0.25 | 1.47E-03 | 0.50 | 1.56E-04 | 0.75 | 0.00E+00 | 1.00 | 0.00E+00 | 1.25 | 0.00E+00 | 1.50 | 0.00E+00 | 1.75 | 0.00E+00 | 2.00 | 0.00E+00 |
| 15 | 0.25 | 1.17E-03 | 0.50 | 3.02E-05 | 0.75 | 5.03E-06 | 1.00 | 0.00E+00 | 1.25 | 0.00E+00 | 1.50 | 0.00E+00 | 1.75 | 0.00E+00 | 2.00 | 0.00E+00 |
| 16 | 0.25 | 2.07E-03 | 0.50 | 2.07E-03 | 0.75 | 1.60E-03 | 1.00 | 1.73E-05 | 1.25 | 0.00E+00 | 1.50 | 0.00E+00 | 1.75 | 0.00E+00 | 2.00 | 0.00E+00 |
| Annual Failure Probability for Entire route | 12.5181% | | 7.2327% | | 4.5031% | | 2.2549% | | 1.3030% | | 0.4284% | | 0.0000% | | 0.0000% | |
| Return Period (years) | 7.99 | | 13.83 | | 22.21 | | 44.35 | | 76.75 | | 233.40 | | ∞ | | ∞ | |
| Failure Probability in the lifetime (40 years) | 99.52% | | 95.04% | | 84.17% | | 59.84% | | 40.82% | | 15.78% | | 0.00% | | 0.00% | |

# APPENDIX F

## Navigation and Shipping

# F.1 AIS INFORMATION

## F.1.1 EMODnet Human Activities Classes Translations

### Table F-1 EMODnet Human Activities Classes Translations

| Original Vessel Type | Aggregated Category Consistent with EMODnet Human Activities |
|---|---|
| Asphalt/Bitumen Tanker | Tanker |
| Bulk Carrier | Cargo |
| Cargo | Cargo |
| Cargo/Containership | Cargo |
| Cement Carrier | Cargo |
| Chemical Tanker | Tanker |
| Container Ship | Cargo |
| Crude Oil Tanker | Tanker |
| Dive Vessel | Dredging or underwater operations |
| Dredger | Dredging or underwater operations |
| Exhibition Ship | Other |
| Fish Carrier | Cargo |
| Fishery Research Vessel | Service |
| Fishing | Fishing |
| Fishing Vessel | Fishing |
| General Cargo | Cargo |
| High Speed Craft | High-speed craft |
| Houseboat | Pleasure craft |
| Inland; Motor Freighter | Cargo |
| Inland; Passenger Ship; Ferry; Cruise ship | Passenger |
| Inland; Pleasure Craft; >20 metres | Pleasure craft |
| Inland; Unknown | Unknown |
| Light; without Sectors | Other |
| Livestock Carrier | Cargo |
| LNG Tanker | Tanker |
| Local Vessel | Other |
| LPG Tanker | Tanker |
| Military Ops | Military |
| Naval/Naval Auxiliary Vessel | Military |
| NULL | Unknown |
| Offshore Supply Ship | Service |
| Oil Products Tanker | Tanker |
| Oil/Chemical Tanker | Tanker |
| Other | Other |

| Original Vessel Type | Aggregated Category Consistent with EMODnet Human Activities |
|---|---|
| Passenger | Passenger |
| Passenger Ship | Passenger |
| Passenger/Cargo Ship | Passenger |
| Pilot Vessel | Service |
| Pleasure Craft | Pleasure craft |
| Port Tender | Service |
| Research/Survey Vessel | Service |
| Reserved | Other |
| Ro-Ro Cargo | Cargo |
| Ro-Ro/Container Carrier | Cargo |
| Ro-Ro/Passenger Ship | Passenger |
| Safe Water | Other |
| Sailing Vessel | Sailing |
| Salvage/Rescue Vessel | Service |
| SAR | Service |
| SAR Aircraft | REMOVE |
| Special Vessel | Other |
| Supply Vessel | Service |
| Tanker | Tanker |
| Trawler | Fishing |
| Tug | Tug or Towing |
| Unspecified | Unknown |
| Unspecified | Sailing |
| Vehicles Carrier | Cargo |
| Work Vessel | Service |
| Yacht | Sailing |

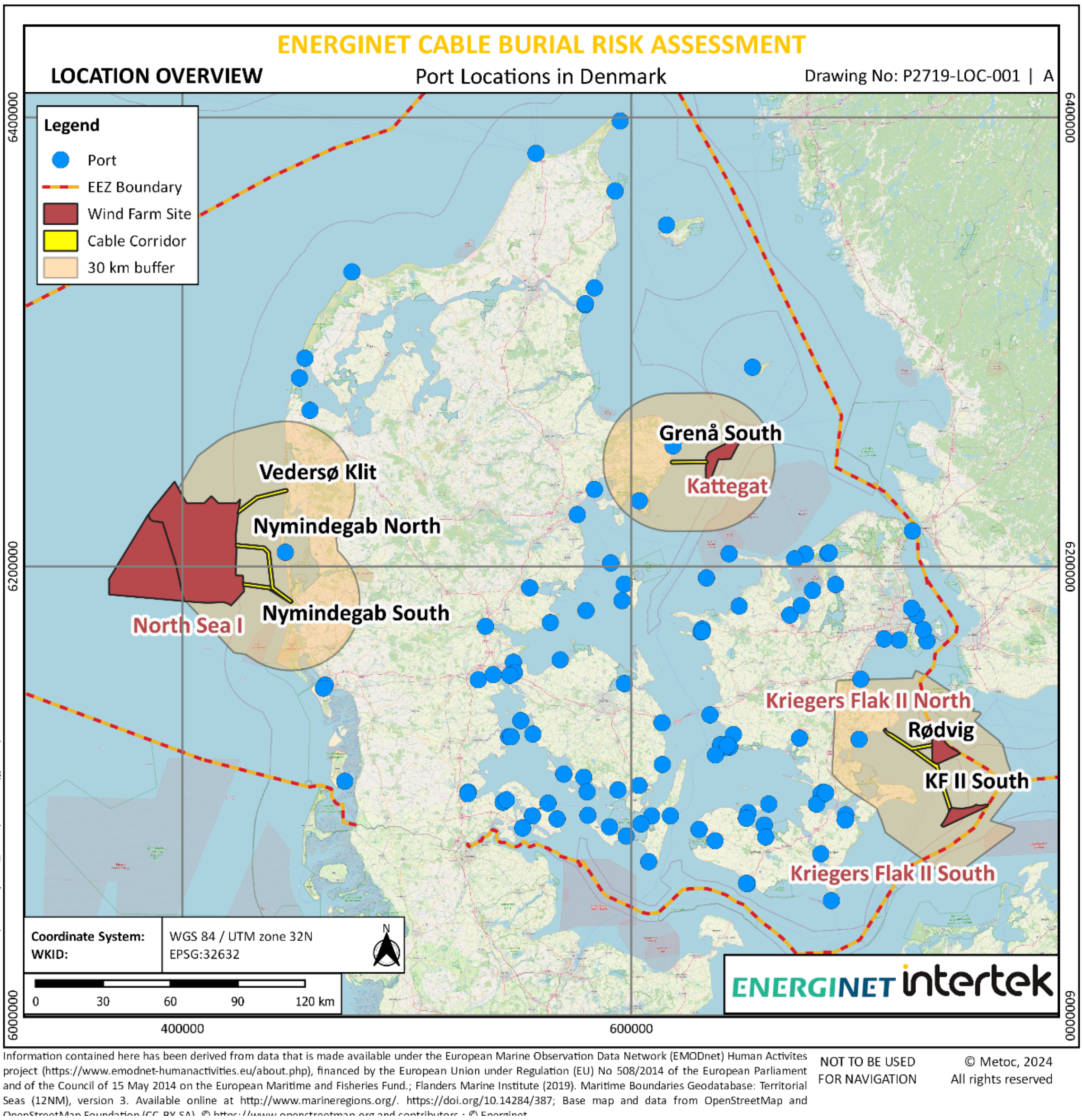
# F.2 PORTS

There is one port within 30km of the study area this is Hivde Sande, however there are numerous ports and harbours north and south  of the study area , ranging from large ferry and goods ports to small fishing and recreational harbours.  There are two major ports which have more of an influence on the Project area these are located both north east and south east of the North Sea 1 study area, there are also various small harbours and marinas located further south of the study area;

- Port of Esbjerg
- Port of Thyboron
- Port of  Romo
- Nordby Havn, Fanø
- Hvide Sande

- Ringkobing
- Sylt Marina

## Figure F-1 Port and Harbour Locations



## F.2.2 Port of Esbjerg

The Port of Esbjerg is located on the southwest coast of Jutland, Denmark and is the world's largest base port for offshore wind activities , it is home to more than 200 companies and supports 10'000 people who work there. The port is managed and owned by the Municipality of Esbjerg and operates in accordance with the Danish Port Act. The port is a hub for cargo transport in northern Europe and one of the world's largest originating ports for wind power. As much as 1,500 MW offshore wind is shipped out of the Port of Esbjerg every year. The annual cargo turnover is 4.3 million tonnes, and port have some 6,000 vessels transiting entering and exiting the port in 2022 (Port Esbjerg, 2022). Sustainability is a key focus area at Port Esbjerg. The Port works consistently to lower their carbon footprint with the aim of becoming a climate-neutral port, in 2022 it was announced that a land power plant is being built which will use excess energy from wind turbines, which will be converted into hydrogen energy which the ships in the port can use (Energy Cluster Denmark, 2022) . The Port works extensively on several green initiatives and partners with national and international sustainability projects, with the focus on waste recycling and on increasing the use of onshore power.

## F.2.3 Port of Thyboron

The Port of Thyboron is a dynamic commercial port going back over 100 years, with a strategic location on the Danish North Sea coast and safe navigation in any weather conditions. The Port underwent a full renovation in 2020, this renovation included New quayside unloading facilities had been built for industrial fishing, with high capacity and easy access to services and supplies. The renovation also included the deepen of the entrance to the port to 10m which will accommodate the growing size of vessels for industrial fishing, the cargo sector and the offshore wind energy industry, and the port had been working hard for more than 10 years to achieve this goal (Port of Thyboron, 2024).

## F.2.4 Port of Romo

The Port of Romo is one of Denmark's medium sized ports and a port that is under development. For many years, the main activities have been shrimp fishing and ferry services between Sylt and Rømø. Major investments have been made in new facilities, which makes the Port of Romo an attractive partner for offshore activities in the North Sea and for freight transport. The port's geographical position makes it an ideal choice for wind farms in the North Sea.

## F.2.5 Nordby Havn, Fano

Nordby harbour at Fanø, the island in the Wadden Se at Esbjerg, Denmark. This harbour has 70 moorings for vessels, vessels of a maximum length of 10m can enter this harbour.

## F.2.6 Hvide Sande

The port of Hvide Sande is the only port within the Project's study area, this is the fifth largest fishing port in Denmark, the port has recently evolved into a commercial port that serves the entire mid-Jutland and west-Jutland area (4C Offshore, 2024). The port has a resident fishing fleet, which consists of 60 vessels with a total gross tonnage of approx. 4,000 BT

## F.2.7 Sylt Marina

Yacht Club of Sylt is a marina in Hornum municipality on the southern shore of the island of Sylt, close to the Danish border. Vessels of 60m length and 5m draught can enter this marina.

# F.3 PORT ACTIVITIES AND GROWTH PLANS

## F.3.1 Port of Esbjerg

Port Esbjerg has been the primary base port for all oil and gas activities in the Danish part of the North Sea. Port Esbjerg is the leading port for wind power in Europe From 2021 to 2022 the port of Esbjerg experienced limited growth across the entirety of the port. The amount of passengers stayed the same as 2021 levels at 1.923 million persons, ship calls slightly decreased from 5,342 to 5,376. Table 2-1 to table 2-3 presents an overview of ship calls, cargo volume and offshore wind shipped since 2017.

### Table F-2 Ship Calls from 2017 - 2022

| Year | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|
| Ship calls | 5,867 | 5,974 | 5,696 | 5,379 | 5,342 | 5,376 |

Source: Port of Esbjerg 2022

### Table F-3 Cargo Volume from 2017 - 2022

| Year | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|
| Cargo Volume (Million tonnes) | 4.5 | 4.4 | 4.3 | 4.3 | 4.1 | 4.3 |

Source: Port of Esbjerg 2022

### Table F-4 Offshore Wind Shipped from 2017 – 2022

| Year | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|
| Offshore Wind Shipped (MW) | 1,300 | 1,210 | 1,500 | 1,100 | 557 | 1,100 |

Source: Port of Esbjerg 2022

## F.3.2 Port of Thyboron Overview

The Port of Thyboron is a unique port which is located on the West coast of Denmark, this port is undergoing huge development Each year there is over 5000 vessels call at the Port of Thyboron each year with rising cargo transportation, lucrative maritime and fishery sidelines and has the potential to increase together with the rise in the offshore wind farm activity in the North Sea (Corporate focus, 2019) . Thyboron port is an independent port was originally a fishing port in 1914 and is now one of the three largest fishing ports in Denmark, 100 fishing vessels are registered at the Port of Thyboron Table 2-4 and Table 2-5 present an overview of ship calls and throughput of goods in the Port of Thyboron.

### Table F-5 Ship Calls from 2017 - 2022

| Year | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|
| Ship calls | 6,801 | 6,650 | 5,461 | 5,519 | 5,954 | 5,274 |

**Table F-6 Call of Cargo Ships and Cruiser Ships on the Port of Thyboron**

| Year | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|
| Container ships | 0 | 0 | 0 | 0 | 0 | 0 |
| Bulk carriers | 99 | 94 | 36 | 70 | 41 | 40 |
| Reefer ships | 4 | 2 | 3 | 18 | 34 | 29 |
| Tankers | 77 | 68 | 74 | 44 | 67 | 52 |
| Special ships | 328 | 393 | 411 | 488 | 426 | 402 |
| Other general cargo ships | 137 | 124 | 113 | 124 | 123 | 131 |
| Barges | 4 | 0 | 0 | 0 | 1 | 0 |
| Cruiser ships | 0 | 0 | 0 | 0 | 0 | 0 |
| Cargo Ships and Cruise Ships Total | 649 | 681 | 637 | 744 | 692 | 654 |

Source: (Statistics Denmark, 2024)

**Table F-7 Call of Vessels, Passengers and Throughput of Goods in the Port of Thyboron**

| Year | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|
| Ships calling at port | | | | | | |
| Passengers, domestic traffic | 132 | 127 | 117 | 129 | 139 | 115 |
| Passengers, international traffic | 0 | 0 | 0 | 0 | 0 | 0 |
| Throughput of goods, domestic traffic | 1,117 | 1,115 | 1,123 | 1,082 | 1,194 | 1,059 |
| Throughput of goods, international traffic | 751 | 491 | 408 | 753 | 611 | 771 |

## F.3.3 Port of Romo

The Port of Rømø is one of Denmark's medium-sized ports and a developing port. Shrimp fishing and ferry service between Herring and Rømø have been the primary activities for many years. Large investments have been made in new facilities, which make the Port of Rømø an attractive business partner for offshore activities in the North Sea and for freight transport.

The Port of Romo operates a ferry service between Romo and Slyt. The Syltferries operate all-season between the Danish island Rømø, which is easily accessible via a free causeway from the Danish mainland, and the island Sylt. The modern double ended ferries "SyltExpress" and "RömöExpress" take all cars, motorcycles, pedestrians and cyclists, as well as horse and boat trailers, caravans, motor homes, busses, trucks and even heavy cargo to and from the Island Sylt in a very comfortable way.

**Table F-8 Call of Vessels by Type of Vessel**

| Year | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|
| Cargo vessels | 1 | 0 | 14 | 0 | 0 | 0 |
| Passenger ships and ferries | 0 | 0 | 0 | 0 | 0 | 0 |

### F.3.4 Hvide Sande

Port of Hvide Sande's development in recent years has provided significant advantages for local companies and means they are able to offer greatly enhanced service to their clients across all sectors – bulk, general cargo, special transport, offshore, offshore wind, renewables, and fishing industry.

**Table F-9 Call of Vessels by Type of Vessel**

| Year | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|
| Cargo vessels | 63 | 63 | 69 | 72 | 70 | 73 |
| Passenger ships and ferries | 0 | 0 | 0 | 0 | 0 | 0 |

# F.4 NAVIGATIONAL ACTIVITY

The eastern North Sea off the coast of Denmark is highly significant due to the region's strategic importance to maritime trade, fishing offshore oil and gas operations, and wind energy production. The eastern North Sea serves major shipping routes in northern Europe, such as Denmark, Germany, the Netherlands, and the United Kingdom. Vessels of various types, including container ships, tankers, bulk carriers, and ferries, traverse these routes, carrying goods and passengers.

The Eastern North Sea is also known for its significant offshore wind energy developments. Denmark, along with neighbouring countries, has invested heavily in offshore wind farms to harness renewable energy. These wind farms require ongoing maintenance and occasional vessel traffic for installation or repair work.

Given the high volume of maritime traffic and the presence of offshore installations, navigational safety is paramount in the Eastern North Sea. This includes the implementation of navigational aids such as buoys, lighthouses, and radar systems, as well as the enforcement of maritime regulations to prevent collisions and protect the marine environment.

Overall, the navigational activity in the Eastern North Sea off the coast of Denmark is diverse and dynamic, driven by various economic, environmental, and regulatory factors. Effective navigation and maritime management are essential to ensure the safety and sustainability of this vital maritime region.

## F.4.1 Marine Traffic Trends

### F.4.1.1 Global

An estimated 80% of international trade is carried by sea, with higher rates seen in developing countries (UNCTAD, 2023). In 2022, sea transport accounted for 46% of goods traded between the EU and the rest of the world (Eurostat, 2023), showing how important marine traffic routes are globally.

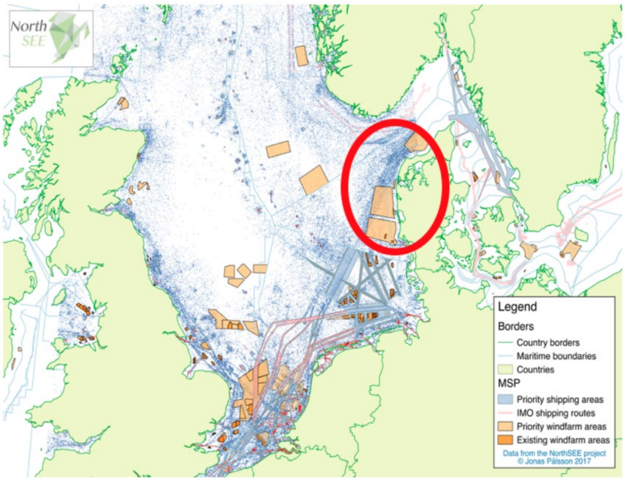
Overall, Seaborne trade and traffic declined by 0.4% in 2022 however, so far in 2023 predictions show growth of 2.4% that is set to increase by 2.1% over the coming years (UNCTAD, 2023). Whilst this growth is down compared to previous 3% over the last 4 decades, its bounce back from the COVID Pandemic has increased (UNCTAD, 2023). Finally, global shipping and trading routes are changing – the average distance travelled is increasing; oil and grain cargo travelled further in 2023 then every year recorded by the UN derived from the current war in Ukraine (UNCTAD, 2023).

Traffic changes can also be initiated the digitization of the industry. The COVID pandemic caused a shift in digital innovation, for example, paperless solutions regarding electronic traffic scheduling (UNCTAD, 2023). In 2020 1 in 20 ports worldwide increased investment into digital technology accounting for increase efficiency in trade facilitation, scheduling, training, and planning (Nic, et al., 2021) (UNCTAD, 2023).

#### F.4.1.2 Eastern North Sea

The Danish waters of the North Sea, encompass a wide variety of water depths, with the deepest depth of over 480m recorded in the region of Skagerrak. This region is home to a wide range of seabed habitats and flora and fauna species, including species that are priorities for marine conservation at European Union (EU) and international levels (Oceana, 2019). The Eastern North Sea is one of the busiest seas in the world, due to its significant socio- economic value, as a result of its fisheries, oil and gas extraction, ports and harbours and offshore renewable industry (Oceana, 2019). The eastern North Sea is home to several important shipping routes, these include routes connecting the Baltic Sea to the Atlantic Ocean and routes leading to the English Channel and beyond. These lanes are vital for the transportation of goods, energy resources, and passengers. The study area is an area that is a designated area for OWF development, however it is an area that is intensely shipped by all types of vessels, including cargo, fishing and passenger vessels indicated by the red circle in figure 2-2 below (Nilsson et al, 2018).

**Figure F-2 AIS Data and Areas Prioritised for Offshore Wind Development (Nilsson et al 2018)**




# F.5 MARITIME REGULATIONS AND NAVIGATIONAL RULES

Numerous regulations and rules are present within the study area and across the Kattegat Sea.

## F.5.1 Global and EU Regulations

Danish waters are influenced by global and EU regulations.

International regulations are governed by the International Maritime Organisation (IMO). Key conventions include; SOLAS - International Convention for the Safety of Life at Sea, MARPOL - International Convention for the Prevention of Pollution from Ships, ISPS - the International Ship and

Port Facility Security Code and STCW - International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (IMO, 2023). Other laws relating to maritime safety Further information can be found on the International Maritime Organization website: https://www.imo.org/en/about/Conventions/Pages/ListOfConventions.aspx.

EU regulations cover numerous topics including training and qualifications, Marine equipment, Security on ships, Passenger ship safety and digital maritime systems (European Parliment, 2023). Further information on EU laws and regulations can be found on the EU website: https://www.europarl.europa.eu/factsheets/en/sheet/125/maritime-transport-traffic-and-safety-rules.

Summary of relevant law is presented in **Table F-9**.

## Table F-10 Summary of Relevant Global and EU Regulations

| Governing Body | Convention Topic | Regulation |
|---|---|---|
| IMO | Maritime safety and security and ship/port interface | Convention on the International Regulations for Preventing Collisions at Sea (COLREG), 1972<br>Convention on Facilitation of International Maritime Traffic (FAL), 1965<br>International Convention on Load Lines(LL), 1966<br>International Convention on Maritime Search and Rescue(SAR), 1979<br>Convention for the Suppression of Unlawful Acts Against the Safety of Maritime Navigation(SUA), 1988, and Protocol for the Suppression of Unlawful Acts Against the Safety of Fixed Platforms located on the Continental Shelf (and the 2005 Protocols)<br>International Convention for Safe Containers (CSC), 1972<br>Convention on the International Maritime Satellite Organization (IMSO C), 1976<br>The Torremolinos International Convention for the Safety of Fishing Vessels (SFV), 1977, superseded by the 1993 Torremolinos Protocol; Cape Town Agreement of 2012 on the Implementation of the Provisions of the 1993 Protocol relating to the Torremolinos International Convention for the Safety of Fishing Vessels<br>International Convention on Standards of Training, Certification and Watchkeeping for Fishing Vessel Personnel (STCW-F), 1995<br>Special Trade Passenger Ships Agreement (STP), 1971 and Protocol on Space Requirements for Special Trade Passenger Ships, 1973 |
| IMO | Marine pollution | International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties (INTERVENTION), 1969<br>Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter(LC), 1972 (and the 1996 London Protocol)<br>International Convention on Oil Pollution Preparedness, Response and Co-operation(OPRC), 1990<br>Protocol on Preparedness, Response and Co-operation to pollution Incidents by Hazardous and Noxious Substances, 2000 (OPRC-HNS Protocol)<br>International Convention on the Control of Harmful Anti-fouling Systems on Ships (AFS), 2001<br>International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004<br>The Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships, 2009 |
| IMO | Liability and compensation | International Convention on Civil Liability for Oil Pollution Damage (CLC), 1969 |

| Governing Body | Convention Topic | Regulation |
|---|---|---|
| | | 1992 Protocol to the International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (FUND 1992)<br>Convention relating to Civil Liability in the Field of Maritime Carriage of Nuclear Material (NUCLEAR), 1971<br>Athens Convention relating to the Carriage of Passengers and their Luggage by Sea (PAL), 1974<br>Convention on Limitation of Liability for Maritime Claims(LLMC), 1976<br>International Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances by Sea (HNS), 1996 (and its 2010 Protocol)<br>International Convention on Civil Liability for Bunker Oil Pollution Damage, 2001<br>Nairobi International Convention on the Removal of Wrecks, 2007 |
| EU | Training and qualifications | Directive 94/58/EC of 22 November 1994<br>Directive (EU) 2017/2397 of 12 December 2017 |
| EU | Marine equipment | Directive 96/98/EC of 20 December 1996 |
| EU | Security on Ships and Port facility standards | The ISPS (International Ship and Port Facility Security) |
| EU | Passenger ship safety | Directive 94/57/EC of 22 November 1994.<br>Directive 2009/45/EC of 6 May 2009,<br>Directive 98/18/EC. Directive 98/41/EC of 18 June 1998<br>Directive (EU) 2019/1159 was published in the Official Journal on 12 July 2019.<br>Directive (EU) 2017/2108 of 15 November 2017<br>Directive (EU) 2016/1629 of 14 September 2016 |
| EU | Digital Maritime systems and services | Directive (EU) 2005/44/EC<br>Directive 2010/65/EU of October 2010<br>Commission Delegated Regulation (EU) 2023/205 of November 2022 |

## F.5.2 Danish Regulations

Denmark's has a comprehensive framework of maritime legislation to govern various aspects of maritime activities. Some of the main maritime legislation in Denmark includes:

1. **Merchant Shipping Act (Søloven)**: The Merchant Shipping Act regulates various aspects of Danish merchant shipping, including the registration of vessels, safety standards, crewing requirements, navigation, pollution prevention, and liability issues.

2. **Danish Maritime Authority (DMA) Regulations**: The Danish Maritime Authority issues regulations and guidelines covering a wide range of maritime matters, including ship safety, navigation, environmental protection, crewing standards, and port operations. These regulations are often aligned with international conventions and standards.

3. **Maritime Labor Law**: Denmark has legislation governing maritime labor matters, including seafarers' rights, employment conditions, wages, working hours, and health and safety standards onboard Danish-flagged vessels. These regulations typically comply with international labor conventions such as those established by the International Labour Organization (ILO).

4. **Environmental Regulations**: Denmark has stringent environmental regulations aimed at preventing pollution from ships and offshore installations. These regulations cover issues such as ballast water management, waste disposal, emissions control, and environmental impact assessments for maritime projects.
5. **Port Regulations**: Danish ports are governed by regulations covering port operations, infrastructure development, safety standards, port dues, and environmental management. These regulations ensure the efficient and safe operation of Danish ports while promoting trade and commerce.
6. **Offshore Energy Legislation**: Denmark has specific legislation governing offshore energy activities, including oil and gas exploration and production, offshore wind energy projects, and marine renewable energy developments. These regulations address licensing, safety standards, environmental impact assessments, and decommissioning requirements for offshore installations.
7. **Maritime Security Laws**: Denmark implements maritime security measures in accordance with international conventions and guidelines to enhance the security of ships, ports, and offshore installations against security threats such as piracy, terrorism, and smuggling.
8. **International Conventions and Treaties**: Denmark is a party to numerous international maritime conventions and treaties, including those established by the International Maritime Organization (IMO), International Labour Organization (ILO), International Convention for the Prevention of Pollution from Ships (MARPOL), and International Convention for the Safety of Life at Sea (SOLAS), among others. These conventions influence Danish maritime legislation and ensure alignment with international maritime standards and best practices.

# APPENDIX G

## Fishing Information

# G.1 MAIN FISHING METHODS

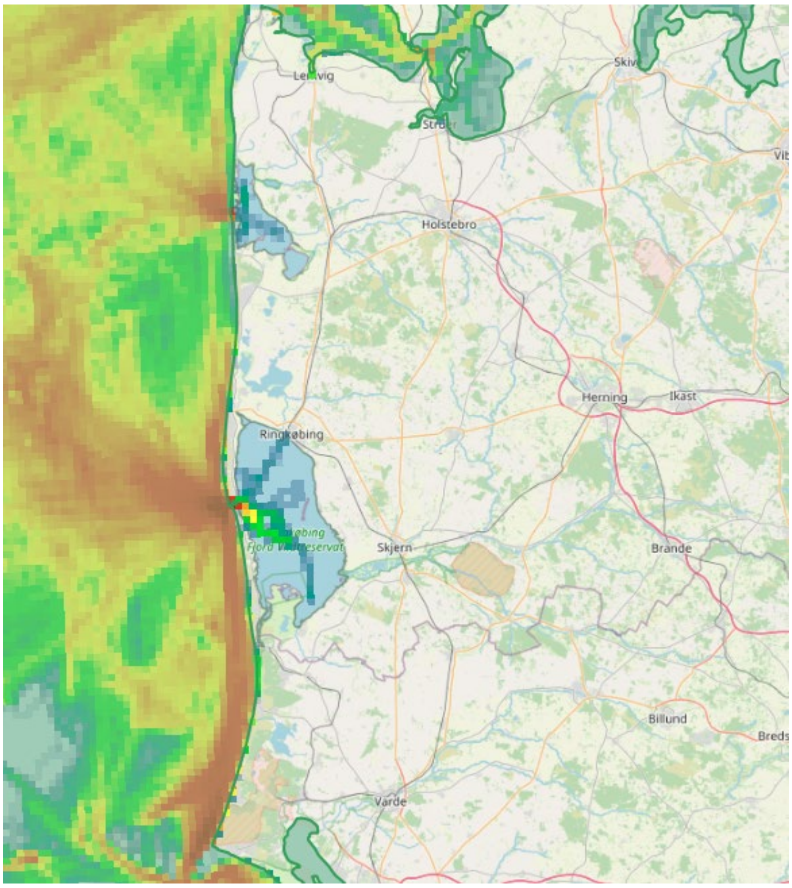
The following provides information on the main types of fishing methods, operating patterns and vessels registered at ports in the proximity of the Project. It should be noted that no direct consultation with the fishing industry in respect of the cable route has been undertaken to collect data on fishing practices to inform this report. As such, the descriptions provided in the following sections are based on publicly available information and do not take account of feedback from the fishing industry on local practices.

Fishing is a significant industry to the Danish economy, there are over 2,700 fishing vessels which contain 1,900 crew ad support around 8,000 jobs in Denmark (DFA, 2024). This section compromises of the fishing study for North Sea 1 export routes. It should be noted that the fishing study has been carried out without consultation. However, the following key European and Danish Sea fishing organisations were identified as being relevant to the area:

- Baltic Fishermen's Association (BFA)
- European Association of Fish Producers Organisations (EAPO)
- Nordsø AC
- Pelagic AC
- Østersø AC
- European Bottom Fisheries Alliance (EBFA)
- Association of Sustainable Fisheries (ASF)
- International Coalitio of Fisheries Asscoiation (ICFA)
- European Fisheries Alliance (EUFA)
- Ministry of Environment and Food
- Ministry for Business
- Daniah Fisheries Association (DFA)

Within the 30km study area there are various forms of fishing that takes places, these include beam trawls, bottom otter trawls, bottom seines, pelagic trawls, and seines, along with static gear fishing. Figure G-1 below is taking from the EMODnet fishing vessel annual totals 2019-2023 data set, heavy traffic can be seen transiting from the port of Hvide Sande, throughout the study area, towards the port of Thyboron in the north and to the port of Esbjerg in the south.

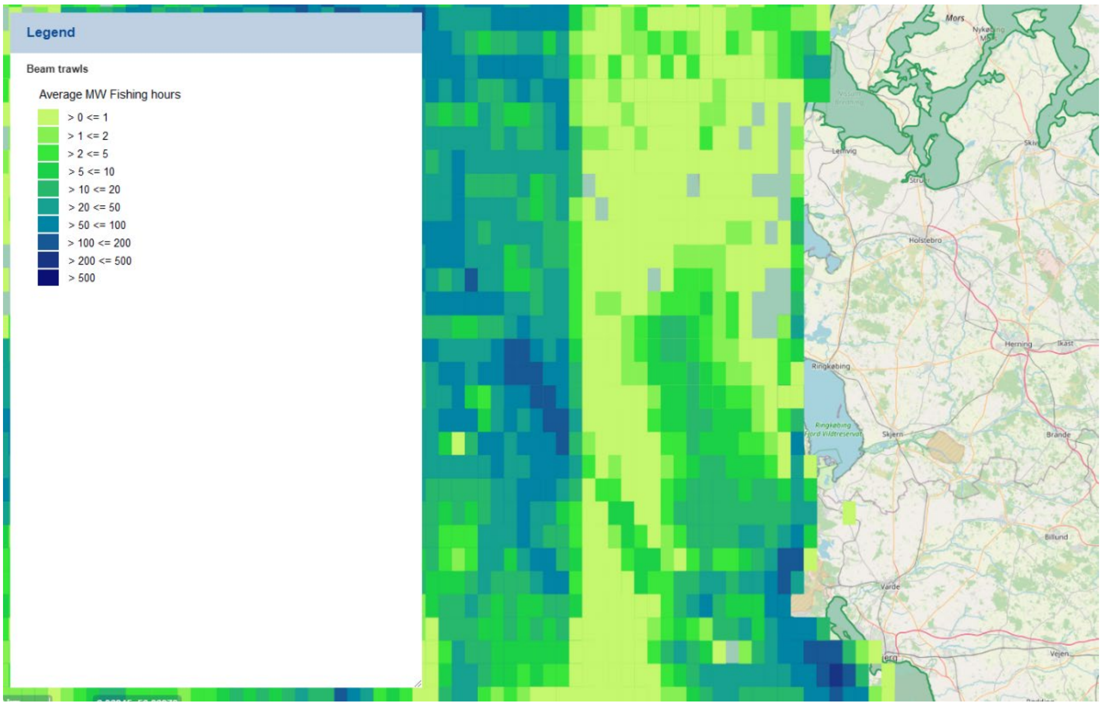
**Figure G-1 Fishing Vessel AIS Data, EMODnet Annual Totals 2019-2023**




## G.1.2 Beam Trawls

According to EMODnet data, beam trawl fishing levels in the study area are notably low. Figure G-2, depicted below, illustrates that beam trawl activity is concentrated primarily in the southern section of the near-shore area. In 2022, over 113 MW fishing hours were recorded in these specific zones. However, the majority of the study area exhibits less than 10 MW fishing hours, indicating that beam trawling is not a predominant fishing method in this region.

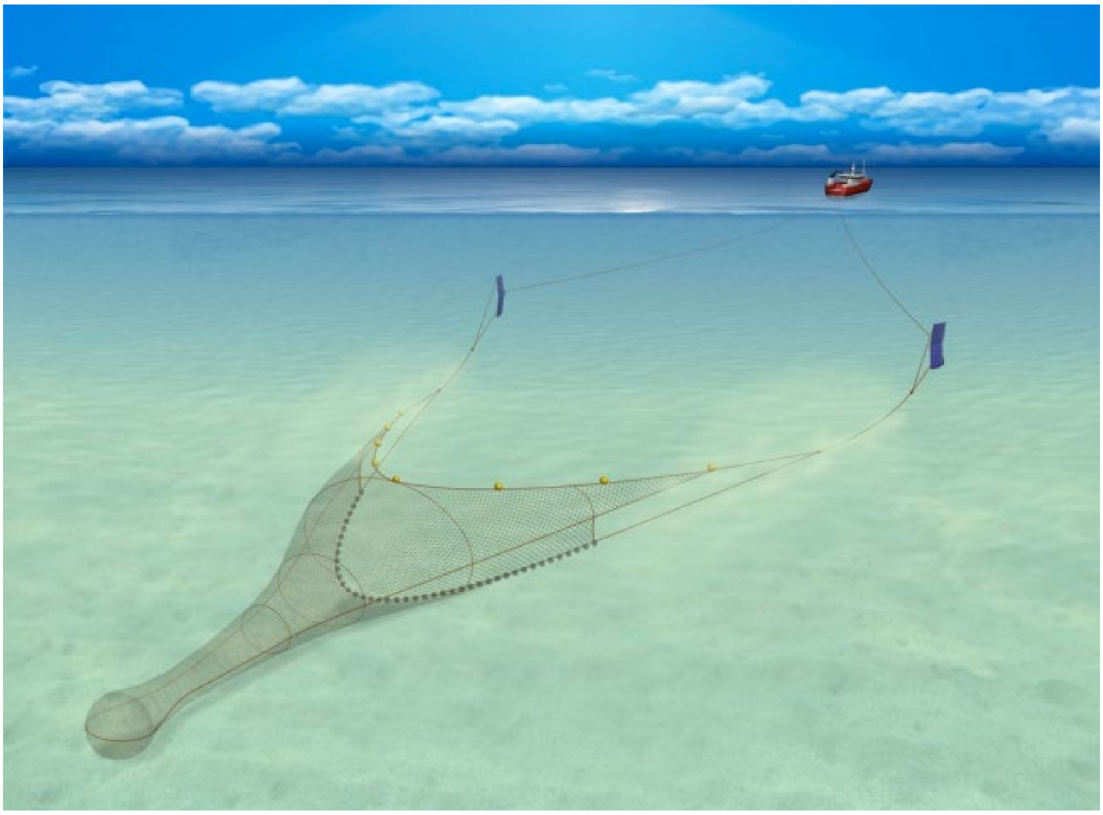
**Figure G-2 Fishing Vessel Density**



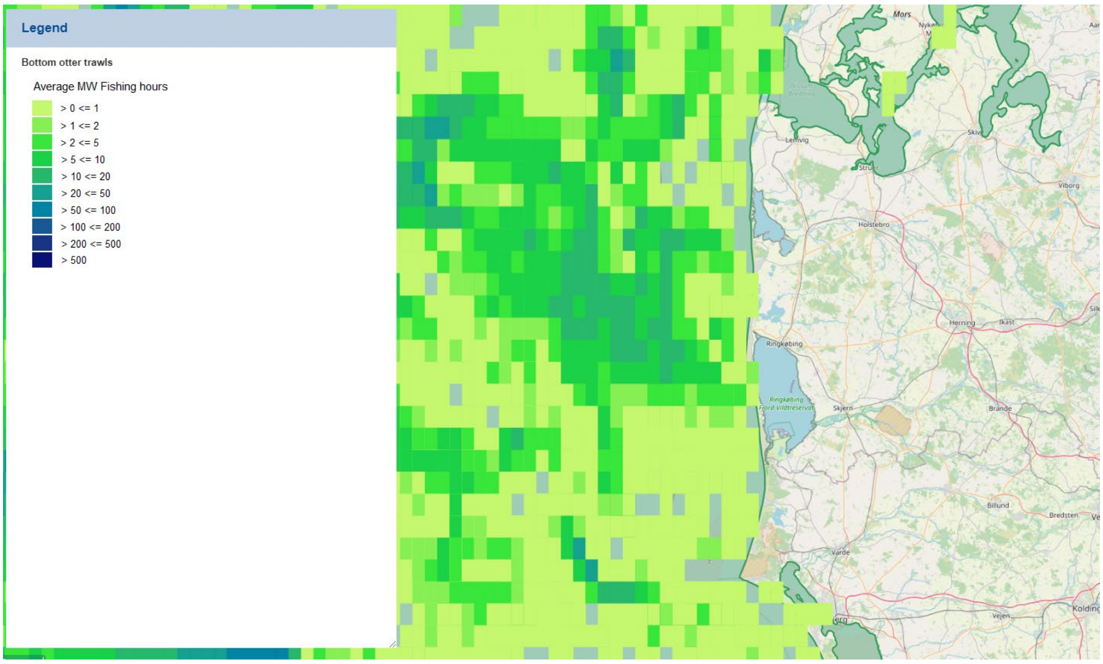

## G.1.3 Bottom-Otter Trawling

Bottom-otter trawling, Figure G-3, is the principal fishing gear used in the area, with Otter trawling consists of demersal trawling and the use of otter boards to maintain the opening of the net mouth (Seafish, 2022). Ropes, wires, bridles or sweeps are used to herd fish into the path of the net and allow a large area of seabed to be swept by the gear. Vessel speeds for active bottom trawling are roughly between 1 and 5 knots (NIRAS, 2022).

## Figure G-3 Demersal Trawl Net on the Seabed (Seafish, 2022)



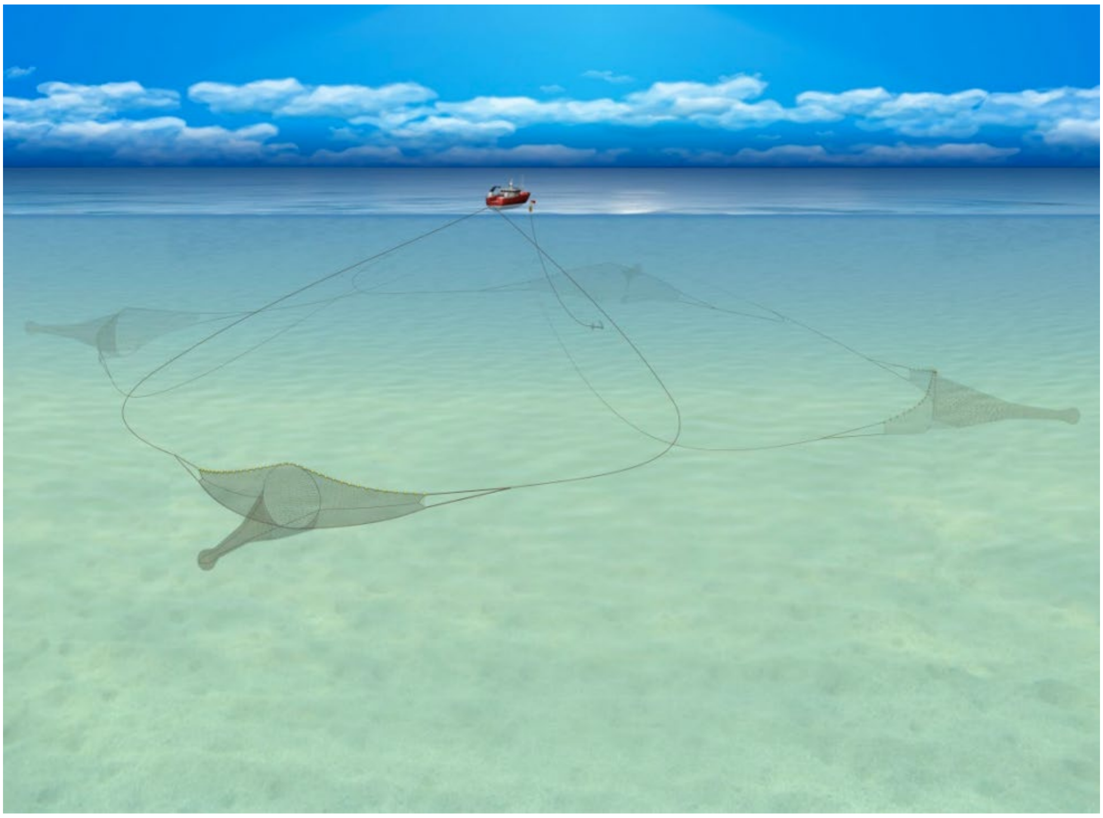
## Figure G-4 Density Map of Bottom Otter Trawls



## G.1.4 Bottom Seines

Anchor seine, also known as Danish seine, fishing involves the use of long ropes on the seabed along with a circular net. When the ropes up, the movement herds demersal fish into the net (Seafish, 2022). Anchor seines vary to other seine gears due to the use of an anchor to moor the boat and the use of opposite end, to that of Scottish seines, of the seine net ropes upon collection. Anchor seine, shown in Figure G-5, originates in Denmark and mainly targets cod and plaice (DTU, 2024). Vessel speeds for active seine gears are roughly between 0.2 and 3 knots (NIRAS, 2022). Anchored seine net fishing is less prominent in the Kattegat than other gears, such as trawlers and gillnets and primarily targets cod and flatfish (NIRAS, 2022).

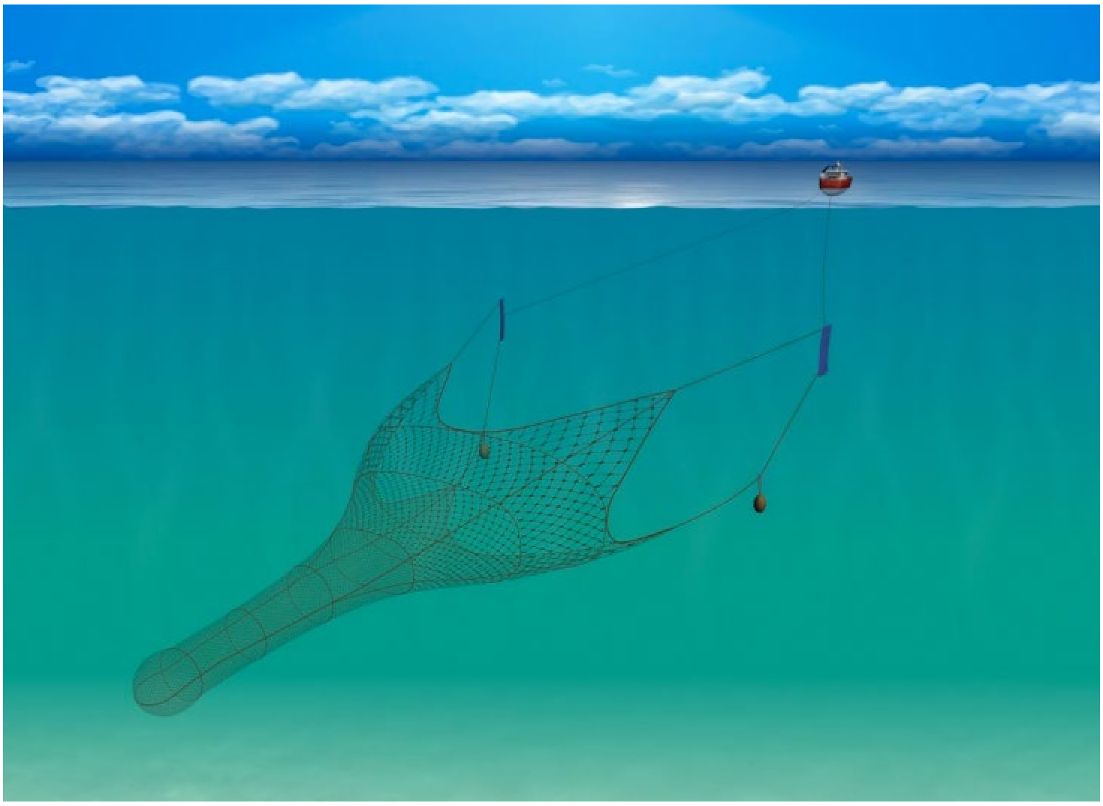
**Figure G-5 Anchor Seining (Seafish, 2022)**



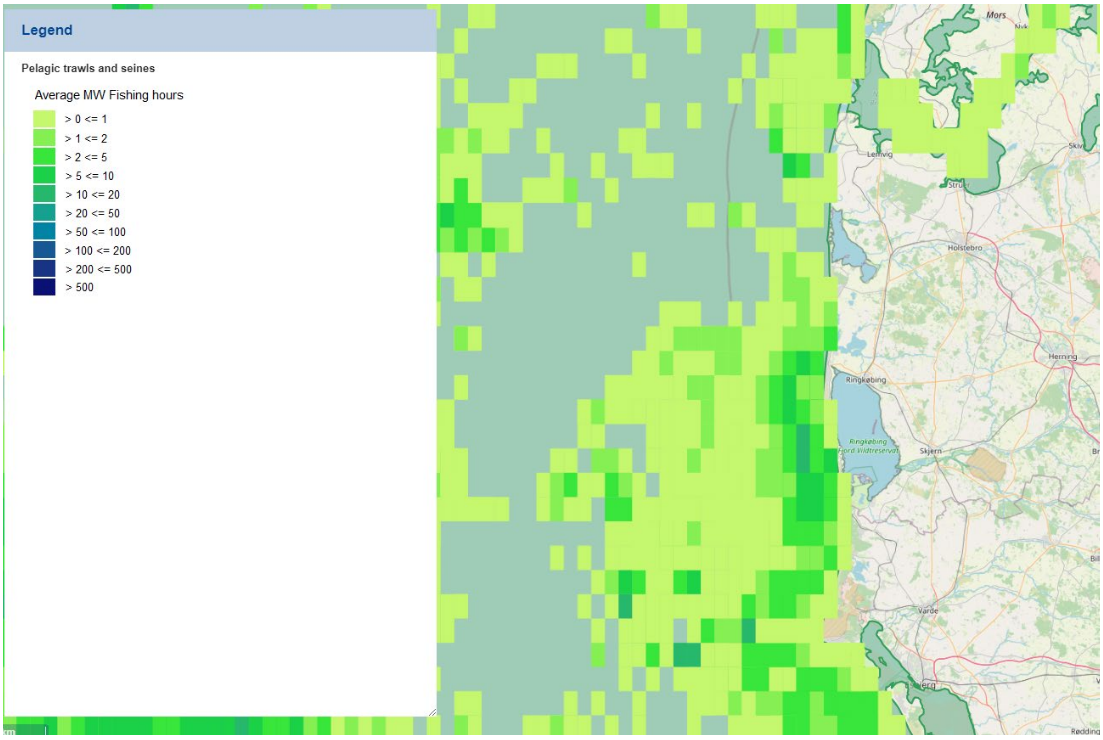
## G.1.5 Pelagic Trawls

Pelagic trawling, Figure G-6, involves trawling in mid-water in order to target shoaling fish species. Modern pelagic trawls consist of large meshes in the mouth and forward sections of the trawl, with four panels to enable a greater height than demersal trawling (Seafish, 2022). The mesh size of the net decreases as it gets closer to the cod-end of the trawl. Pelagic nets can be towed by two vessels, known as pair trawling, or by one vessel, known as single trawling. Vessel speeds for active pelagic trawling are roughly between 1 and 5 knots (NIRAS, 2022).

## Figure G-6 Pelagic Single Trawling (Seafish, 2022)



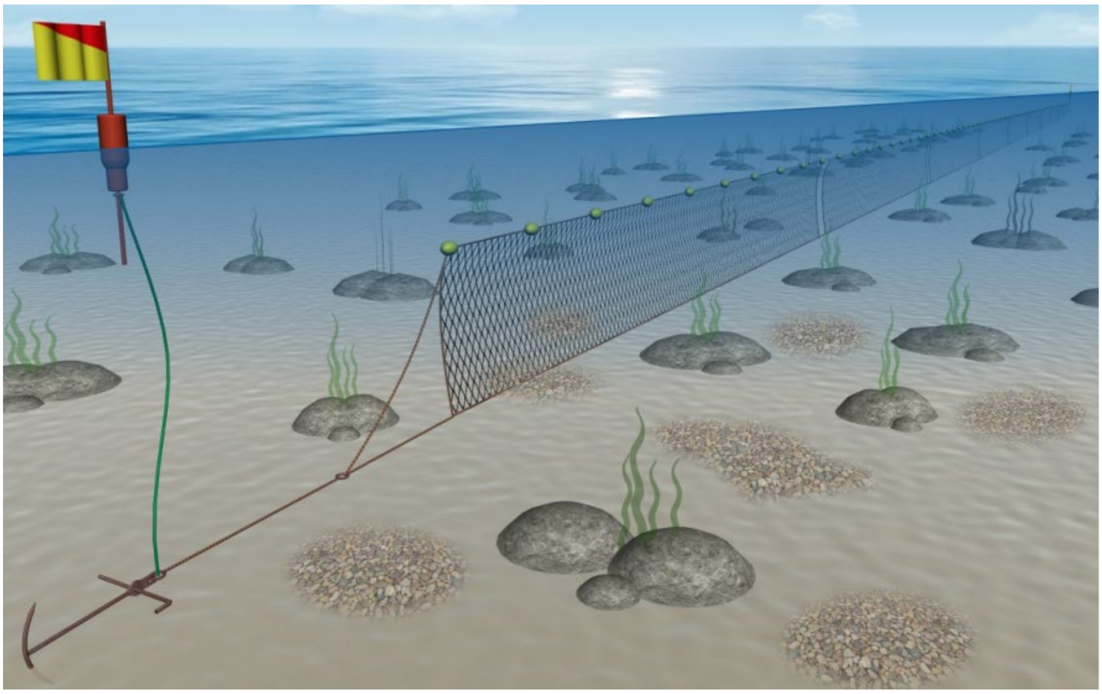
## Figure G-7 Density Map of Pelagic Trawls and Seines



### G.1.6 Gill Nets

Gill net fisheries involve the use of passive gear consisting of panels of nets. Typically, gill nets are used along the bottom of the seafloor, as seen in Figure G-8, however can also be used in midwater. In the Kattegat, gill nets target flatfish, cod and lumpsuckers (NIRAS, 2022). Vessel speeds for gill net fishing are roughly between 0.4 and 5 knots (NIRAS, 2022).

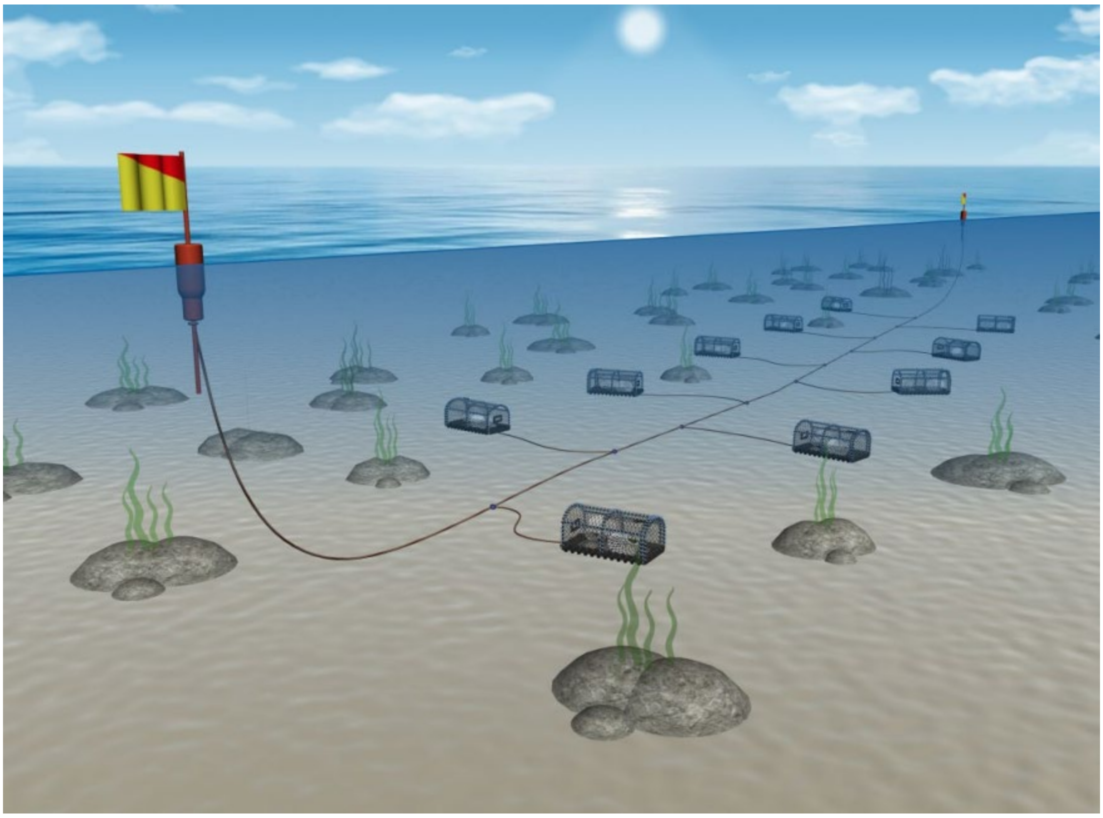
**Figure G-8 Fleet of Gill Nets (Seafish, 2022)**



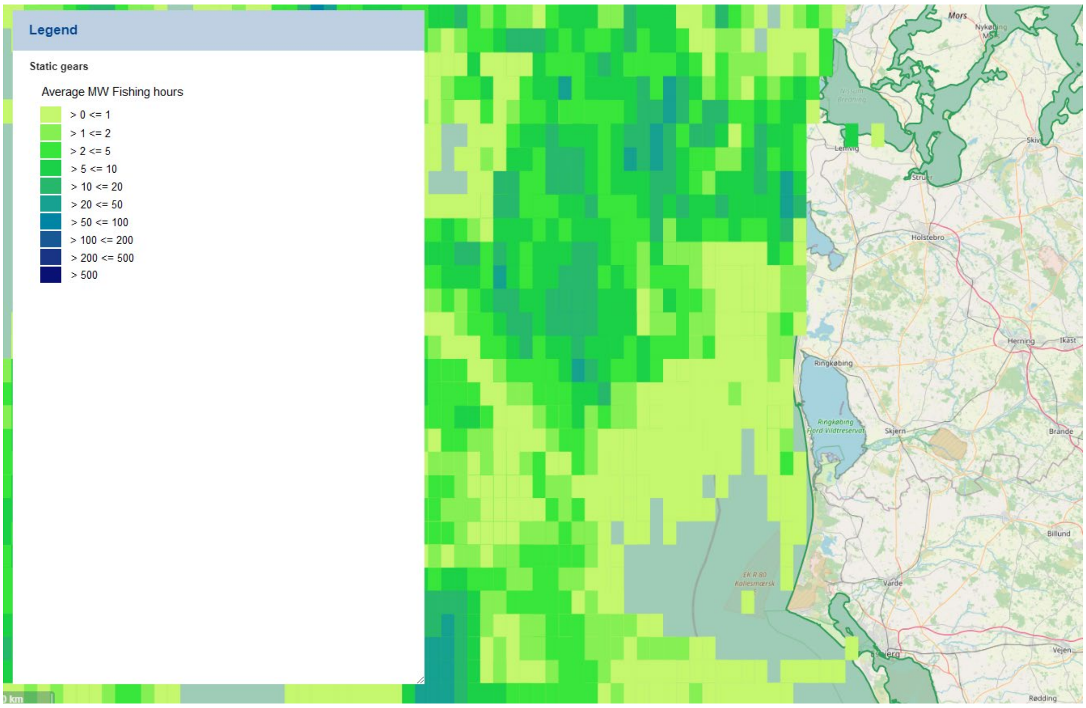
### G.1.7 Static Gear

Static gears such as pots, traps, hooks and line and fkye nets are also used in the Kattegat. In recent years the use of static gear has increased in Kattegat, mainly for shellfish and whelk fisheries (NIRAS, 2022). Whelk pots consist of plastic containers with a main entrance of which is near impossible to exit. Pots, as seen in Figure G-9, are mainly used to trap crabs and lobsters, including Nephrops. These static gears are often baited and left overnight (NIRAS, 2022; Seafish, 2022).

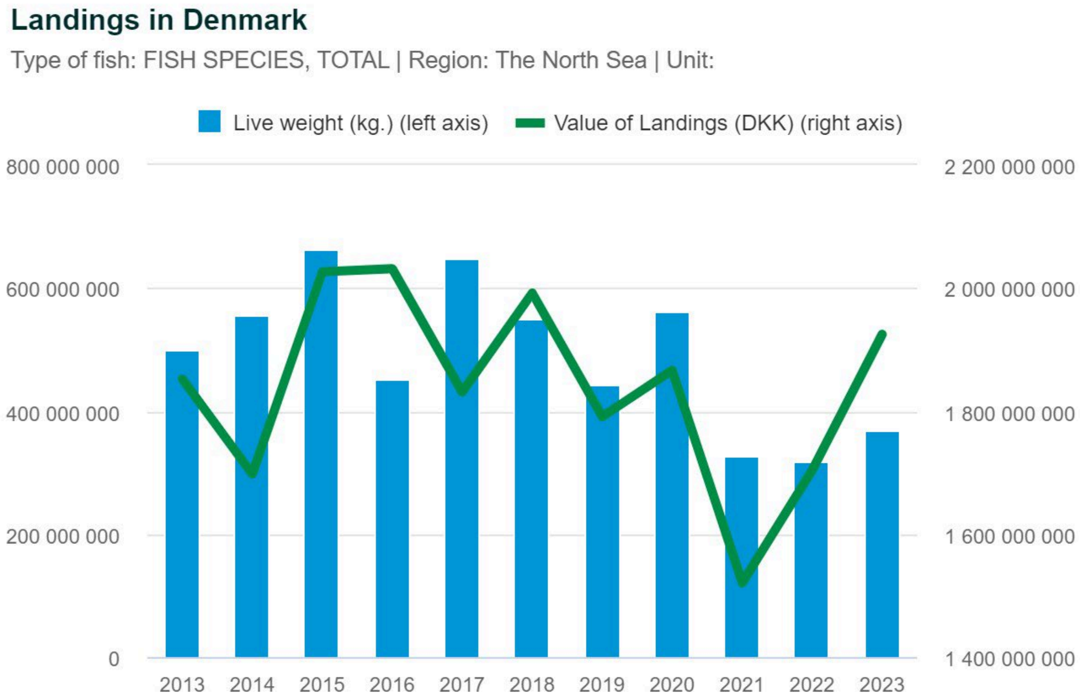
## Figure G-9 Fleet of Pots (Seafish, 2022)



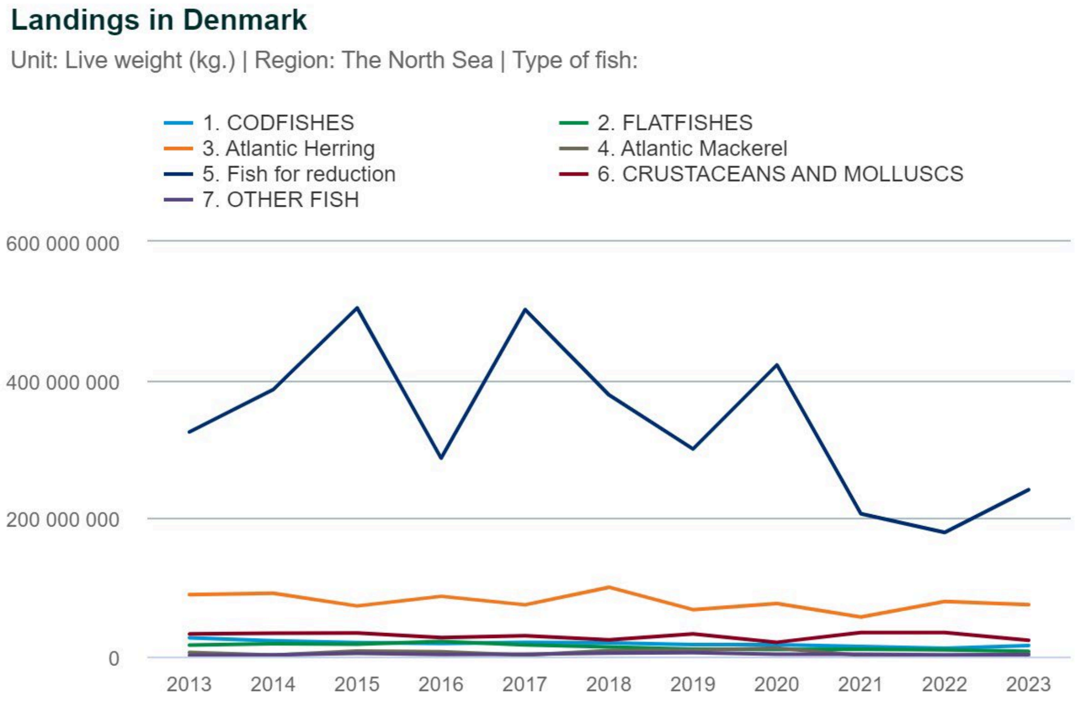
## Figure G-10 Density Map of Static Gear



### Figure G-11 Total Fish Landings by Danish Vessels (Norwegian Fisheries Agency, 2024)




### Figure G-12 Landings in Denmark for Various Fish (Norwegian Fisheries Agency, 2024)



## G.1.8 All Vessels

Catch data for Danish, German and Dutch vessels in the Central North Sea ICES area 27.4.b is provided in Table G-1 as annual Tonnes Live Weight (TLW) from 2017 to 2021 (ICES, 2023). As shown, pelagic fish such as Atlantic herring, Blue Herring, Atlantic mackerel, Atlantic cod and European Sprat account for a large proportion of the catch by weight. Demersal fish species, such as European plaice and common sole, as well as shellfish, such as Norway lobster, edible crab, blue mussels and whelk are also amongst the main target biota.

It should be noted that the catch data included in Table G-1 is for the top 48 species by TLW and being for the whole Central North Sea (ICES Are 27.4.b), may not be necessarily representative of the main species targeted in the exact area where the Project is located.

### Table G-1 IUCN Catch Data 2017 – 2021, Top 50 Species by TLW (ICES,2023)

| Common Name | Latin Name | Tonnes Live Weight (TLW) | | | | |
|---|---|---|---|---|---|---|
| | | 2021 | 2020 | 2019 | 2018 | 2017 |
| Atlantic herring | Clupea harengus | 5144539.86 | 5721310.81 | 6141065.16 | 6174619.87 | 6255156.88 |
| Blue whiting(=Poutassou) | Micromesistius poutassou | 3463012.34 | 5810485.91 | 5802754.04 | 6715426.36 | 6315413.92 |
| Atlantic mackerel | Scomber scombrus | 3260200.95 | 3314814.17 | 2796648.35 | 3320207.29 | 4141433.71 |
| Atlantic cod | Gadus morhua | 3063907.2 | 3906684.86 | 4067294 | 4364348.43 | 4651989.73 |
| European sprat | Sprattus sprattus | 1404586.15 | 1709895.03 | 1792001.28 | 1872006.1 | 1595849.05 |
| Saithe(=Pollock) | Pollachius virens | 946231.419 | 1194975.82 | 1278813.54 | 1355657.93 | 1204322.9 |
| Haddock | Melanogrammus aeglefinus | 856372.886 | 1003311.93 | 1032540.44 | 1050234.81 | 1132094.69 |
| Sandeels(=Sandlances) nei | Ammodytes spp | 701245.126 | 1353626.81 | 707311.473 | 820829.058 | 1619490.08 |
| Beaked redfish | Sebastes mentella | 340122.613 | 301451.338 | 311313.693 | 294473.535 | 243386.29 |
| European hake | Merluccius merluccius | 255346.362 | 278299.311 | 297039.683 | 315853.645 | 376352.827 |
| Atlantic horse mackerel | Trachurus trachurus | 250921.658 | 252792.629 | 342091.992 | 293638.412 | 250467.064 |
| Capelin | Mallotus villosus | 232765.164 | 99.613 | 136.787 | 1888841.57 | 1239656.97 |
| European pilchard(=Sardine) | Sardina pilchardus | 231260.086 | 213551.005 | 148466.557 | 176568.574 | 199526.27 |
| Norway pout | Trisopterus esmarkii | 219435.099 | 403562.449 | 306074.351 | 109071.599 | 102128.61 |
| Northern prawn | Pandalus borealis | 209119.403 | 233890.096 | 267055.244 | 223007.092 | 153504.69 |
| European plaice | Pleuronectes platessa | 166296.372 | 224629.103 | 257238.253 | 285491.045 | 329654.195 |
| Greenland halibut | Reinhardtius hippoglossoides | 149185.753 | 202517.031 | 205361.437 | 223869.742 | 198231.605 |
| Norway lobster | Nephrops norvegicus | 148917.789 | 117648.334 | 156799.222 | 130936.652 | 170430.475 |
| Anglerfishes nei | Lophiidae | 146853.991 | 140071.119 | 152798.046 | 159817.63 | 184202.81 |
| European anchovy | Engraulis encrasicolus | 141069.94 | 124327.039 | 126333.858 | 134911.524 | 153109.66 |
| Great Atlantic scallop | Pecten maximus | 120493.177 | 166576.626 | 177779.972 | 267383.399 | 180668.69 |

| Common Name | Latin Name | Tonnes Live Weight (TLW) | | | | |
|---|---|---|---|---|---|---|
| | | 2021 | 2020 | 2019 | 2018 | 2017 |
| Tangle | Laminaria digitata | 116808.001 | 107058.213 | 114622.143 | 95304.516 | 91188.88 |
| Ling | Molva molva | 116789.361 | 158117.712 | 176966.966 | 165683.719 | 129015.094 |
| Jack and horse mackerels nei | Trachurus spp | 98778.4716 | 97537.9512 | 94943.523 | 125187.911 | 164928.01 |
| Whiting | Merlangius merlangus | 89369.4981 | 100306.504 | 101184.552 | 99930.265 | 108216.55 |
| Atlantic chub mackerel | Scomber colias | 83163.312 | 104222.657 | 138654.592 | 113882.98 | 244948.09 |
| Blue mussel | Mytilus edulis | 78293.115 | 70559.849 | 115527.093 | 124920.279 | 130937.87 |
| Albacore | Thunnus alalunga | 77561.866 | 81214.5155 | 90973.9394 | 85364.137 | 62002.3 |
| European flounder | Platichthys flesus | 74533.5438 | 83010.1265 | 92244.2547 | 90855.208 | 71416.17 |
| Common shrimp | Crangon crangon | 73123.0202 | 90819.23 | 83493.6158 | 153414.93 | 77642.08 |
| Queen crab | Chionoecetes opilio | 64680.08 | 53102.9 | 41641.782 | 37245.85 | 32679.03 |
| Northern wolffish | Anarhichas denticulatus | 63779.3955 | 54907.8379 | 46209.2299 | 52480.9 | 43845.033 |
| Tusk(=Cusk) | Brosme brosme | 55629.2007 | 66732.4753 | 82529.0235 | 70600.202 | 60596.116 |
| North European kelp | Laminaria hyperborea | 54023.862 | 52304.709 | 40122.143 | 30058.221 | 29718.36 |
| Whelk | Buccinum undatum | 53174.0265 | 108330.174 | 110819.58 | 107425.493 | 115315.114 |
| Megrims nei | Lepidorhombus spp | 53092.8896 | 55135.1543 | 52173.8422 | 53540.431 | 61818.84 |
| Common sole | Solea solea | 52032.9817 | 54010.9845 | 52537.5646 | 60409.992 | 63353.334 |
| Golden redfish | Sebastes marinus | 51737.3776 | 210455.347 | 228438.969 | 228953.306 | 34089.39 |
| Solid surf clam | Spisula solida | 45977.174 | 31340.34 | 23801.97 | 12715.77 | 7707.36 |
| Queen scallop | Aequipecten opercularis | 45783.8937 | 49207.6288 | 46722.3702 | 45289.031 | 46145.515 |
| Greater argentine | Argentina silus | 44016.8835 | 28513.168 | 29089.4641 | 28434.194 | 30918.87 |
| Common edible cockle | Cerastoderma edule | 43713.917 | 48355.5736 | 72712.5183 | 52537.754 | 66155.48 |
| Red king crab | Paralithodes camtschaticus | 41791.3 | 39257.29 | 35158.77 | 34758.01 | 33886.56 |
| Edible crab | Cancer pagurus | 41476.7934 | 126856.925 | 141168.557 | 151161.438 | 161950.836 |
| Argentines | Argentina spp | 39826.7404 | 84386.2802 | 102550.607 | 118085.37 | 100909.452 |
| Boarfishes nei | Caproidae | 35816.5574 | 30799.2894 | 3813.973 | 3320.138 | 49051.64 |
| Angler(=Monk) | Lophius piscatorius | 32738.9678 | 33708.7622 | 43124.4407 | 33344.063 | 28367.405 |
| Common cuttlefish | Sepia officinalis | 31849.0126 | 33385.234 | 35098.447 | 29164.683 | 34971.995 |