Outer Dowsing Offshore Wind

Preliminary Environmental Information Report

Volume 2, Appendix 3.1: Cable Burial Risk Assessment

Date: June 2023

Outer Dowsing Document No: 6.2.3.1
Internal Reference: PP1-ODOW-DEV-CS-REP-0037

Rev: V1.0

OUTER DOWSING
OFFSHORE WIND

The **Offshore Wind** Consultants.

REPORT

Outer Dowsing Offshore WindFarm

Localised CBRA – Export Cable Route Crossing Sandbanks

Document No.: OWC-LO-R10-0133_CTR008

Client: GoBe

Document Notes

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Information

Project Name:	Outer Dowsing Offshore WindFarm
Document Title:	Localised CBRA – Export Cable Route Crossing Sandbanks
Document No.:	OWC-LO-R10-0133_CTR008
Client Doc. No.:	N/A
Document Status:	Approved
Entity:	Offshore Wind Consultants Ltd, No. 07861245 in England, at 1st Floor, The Northern & Shell Building, 10 Lower Thames Street, London, England, EC3R 6EN

Document History

Rev	Date	Authored	Reviewed	Approved	Notes
C	2023-04-17	Various	D. Rushton	D. Caruso	Third Issue
B	2023-03-01	Various	D. Rushton	D. Caruso	Second Issue
A	2023-02-27	Various	D. Rushton	D. Caruso	First Issue

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1 Introduction

1.1 General

OWC has been requested to develop a local CBRA for Outer Dowsing Offshore Wind (ODOW) project (“the Project”). The CBRA relates to a relatively limited section of the cable corridor crossing the Annex I Sandbanks (indicated in yellow) and clustered within the Special Area of Conservation (SAC) shown in green in Figure 1.1 below:

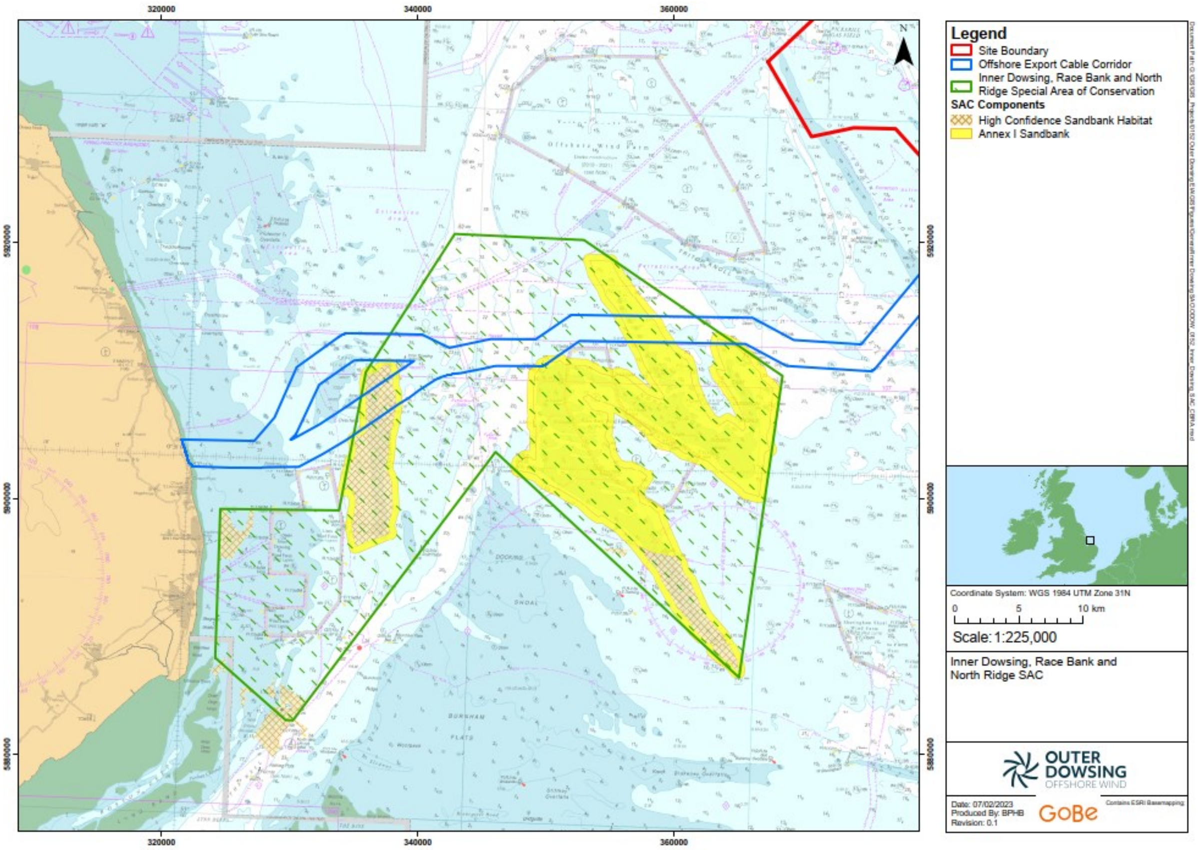


Figure 1.1: ODOW Export Cable Route Crossing the Sandbank

The Project is an Offshore Wind Farm (OWF) development in the North Sea, off the coast of Lincolnshire/Yorkshire, UK, East of the Humber tidal estuary. The proposed offshore site location, illustrated in Figure 1.1, covers an area of 500km^2, and is situated approximately 54km from the coastline at its closest boundary.

The Project is being developed by a JV between TotalEnergies and Corio Generation. The Project is expected to be a 1.5GW bottom-fixed windfarm and it is currently at a Concept stage.

1.2 Report status

This report is the preliminary localised CBRA for the Project export cable route crossing the Annex I sandbanks as shown in Figure 1.1. The scope is to review existing relevant data, including recently acquired geophysical and geotechnical survey data and shipping traffic data along the cable section crossing the sandbank and derive optimised burial strategy and provide recommendation of alternative mitigation measures to be adopted where deemed appropriate.

1.3 Coordinate Reference System

The Project coordinate system is WGS 1984 UTM Zone 31N with parameters as described in Table 1.1and Table 1.2:

Parameter	Value
Geographic coordinate system	WGS 1984
Datum	WGS 1984
Semimajor Axis	6378137.0
Semiminor Axis	6356752.314245179
Inverse Flattening	298.257223563

Table 1.1 Geodetic parameters

Parameter	Value
Projected coordinate system	WGS 1984 UTM Zone 31 N
Projection	Transverse Mercator
False Easting	500000.0
False Northing	0.0
Central Meridian	3.0
Scale Factor	0.9996
Latitude of Origin	0.0
Linear Unit	Metre

Table 1.2 Projection parameters

The offshore vertical datum is lowest astronomical tide (LAT) with parameters as described in Table 1.3:

Parameter	Value
Vertical reference (offshore)	Lowest astronomical tide (LAT)
Height model (offshore)	Vertical offshore reference frame (VORF)

Table 1.3 Vertical reference parameters

The reference depth given for any burial requirement/recommendations will be given from the following reference point:

Parameter	Value
Reference seabed level (RSBL)	Surface level below which sediment is not expected to be mobile during the life of the windfarm. At Sand Bank 1 (western sand bank), RSBL is expected to be 5-6m below current seabed elevation. At Sand Bank 2 (eastern sand bank), RSBL is expected to be 2-3m below current seabed elevation [1].

Table 1.4 Burial reference parameters

1.4 Abbreviations

Table 1.5 presents a list of abbreviations used in this report and their definitions.

Abbreviation	Definition
AIS	Automatic Identification System
bSBL	below Seabed Level
CBRA	Cable Burial Risk Assessment
CPT	Cone Penetration Test
DoC	Depth of Cover
DoL	Depth of Lowering
DoL	Depth of Lowering
DWT	Dead Weight Tonnage
ECC	Export Cable Corridor
GIS	Geographical Information System
ICES	International Council for the Exploration of the Sea
KP	Kilometre Post
MAG	Magnetometer
MBES	Multi-Beam Echo Sounder
MMSI	Maritime Mobile Service Identity
OWF	Offshore Wind Farm
RPL	Route Positioning List
RSBL	Reference Seabed Level (i.e. a surface below which sediment is not expected to be mobile during the life of the windfarm)
SBP	Sub-Bottom Profiler
SSS	Side Scan Sonar
TDoL	Target Depth of Lowering

Abbreviation	Definition
TTD	Target Trench Depth
UTM	Universal Transverse Mercator
UXO	Unexploded Ordnance
WGS	World Geodetic System
WTG	Wind Turbine Generators

Table 1.5 List of abbreviations

2 Method

2.1 Cable Burial Risk Assessment Process

The agreed scope of services comprises the development of Cable Burial Risk Assessments (CBRA) including qualitative and quantitative assessment of the main risks for the Project export cable corridor across the sandbank.

Standard Carbon Trust CBRA definitions [1] describe the depth of lowering as the distance between the undisturbed seabed and the top of cable, as shown in Figure 2.1, denoted as "B":

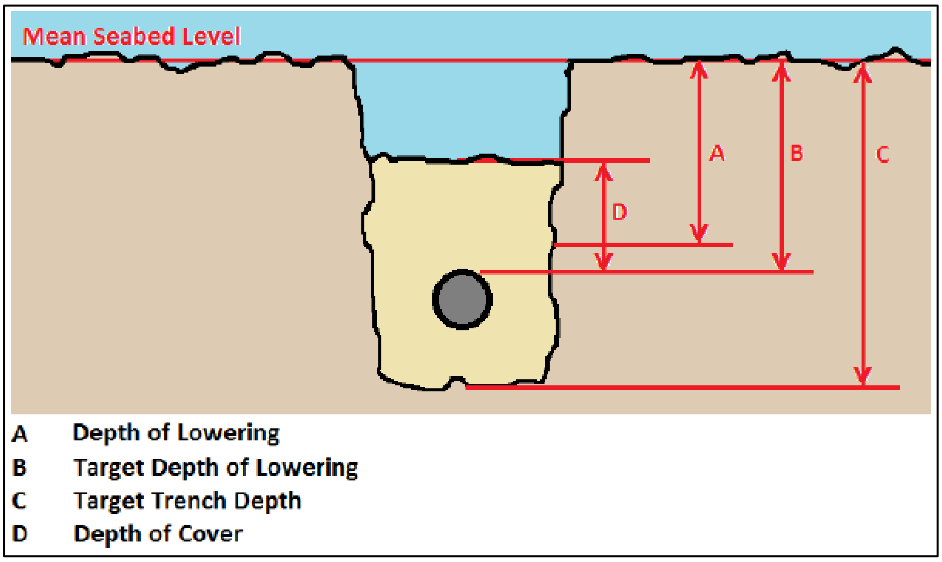


Figure 2.1 Trench Definition taken from Carbon Trust [8]

- A – Depth of Lowering (DoL): This is the minimum depth recommended in order to protect from external risks and should include a safety margin, where applicable.
- B – Target Depth of Lowering (TDoL): This is the minimum that the cable installers should target and should be equal or greater than the recommended DoL (A) to allow for any uncertainty and/or localised depth variations during trenching operations such that the DoL specification is always met. This should be determined by the installation contractor based upon their assessment of seabed conditions and the proposed trenching equipment and is out with the scope of this document.
- C – Target Trench Depth (TTD): The trench depth is determined by the cable installers based on the trenching tool and cable properties (particularly the Overall Diameter and cable stiffness).
- D – Depth of Cover (DoC): The depth of soil to Top of Cable (ToC) to provide protection from risks such as dropped objects and fishing gear.

This CBRA considers DoL as a depth in metres below Reference Seabed Level (RSBL), where RSBL is a surface below which sediment is not expected to be mobile during the life of the wind farm. It is determined by a combination of the geophysical survey data sets and metocean to determine the potential of seabed mobility. This RSBL can be informed based on the results of the Seabed Mobility Assessment [2], which indicates that sand waves are likely to be highly mobile on an annual basis, whereas larger sand banks are less mobile, but may move within the Project design life (25 years).

Further, areas of mobile seabed are observed as discrete zones across the Export Cable Corridor (ECC) and offshore windfarm area and it is considered that these zones represent relatively permanent areas of coarse mobile material, rather than the entire zones of mobility moving laterally.

The CBRA is based on the ‘Carbon Trust Cable Burial Risk Assessment Methodology, Guidance for the preparation of Cable Burial Depth of Lowering Specification CTC835’, February 2015 [1], as well as the corresponding ‘Application Guide for the specification of the Depth of Lowering using the Cable Burial Risk Assessment (CBRA) methodology’, December 2015 [3]. Figure 2.2 below summarises the CBRA process presented by the Carbon Trust [3].

Figure 2.2 CBRA process flow

2.2 Available data

Table 2.1 describes the primary datasets provided to inform this report.

Year	Data type	Source
2021	Desktop Study and Preliminary Ground Model	Cathie Associates [4]
2022	Environmental, geophysical and shallow geotechnical survey of ECC	GeoXYZ and Marine Sampling Holland [5]
2022	Shipping data (AIS) for two years covering an area that includes the Offshore windfarm area and ECC	Anatec [6]
2023	Shipping data (AIS) across the two sandbanks area	Marine Traffic [7]
2023	Seabed Mobility Assessment.	East Point Geo [2]

Table 2.1 Available geophysical survey, geological and shipping data, taken from the desktop study and subsequent data acquisition campaigns.

Some additional shipping data (AIS) was procured as part of this study, to ensure the data included vessel size information (“in the format of deadweight tonnage”), which is critical to the analysis of anchor size. Thes additional data was procured from Marine Traffic and include vessel tracks over the area from 01/01/2021 to 31/12/2022.

The methodology followed in this report is adopted in accordance with the following industry standard guidelines:

- Carbon Trust, Cable Burial Risk Assessment Methodology [1]; and
- Carbon Trust, CBRA Application Guide [3].

2.3 Study Area

Figure 2.3 presents a large-scale image of the section of the ECC and the two sand bank zones that are the subject of this CBRA. The background image shows an excerpt from the chart shown in Figure 1.1 and the site-specific bathymetry data are shown overlain, shaded to represent seabed elevation. Inset maps present the morphology and elevation of each of the two sand banks, which are referred to as Sand Bank 1 and Sand Bank 2, as labelled on Figure 2.3.

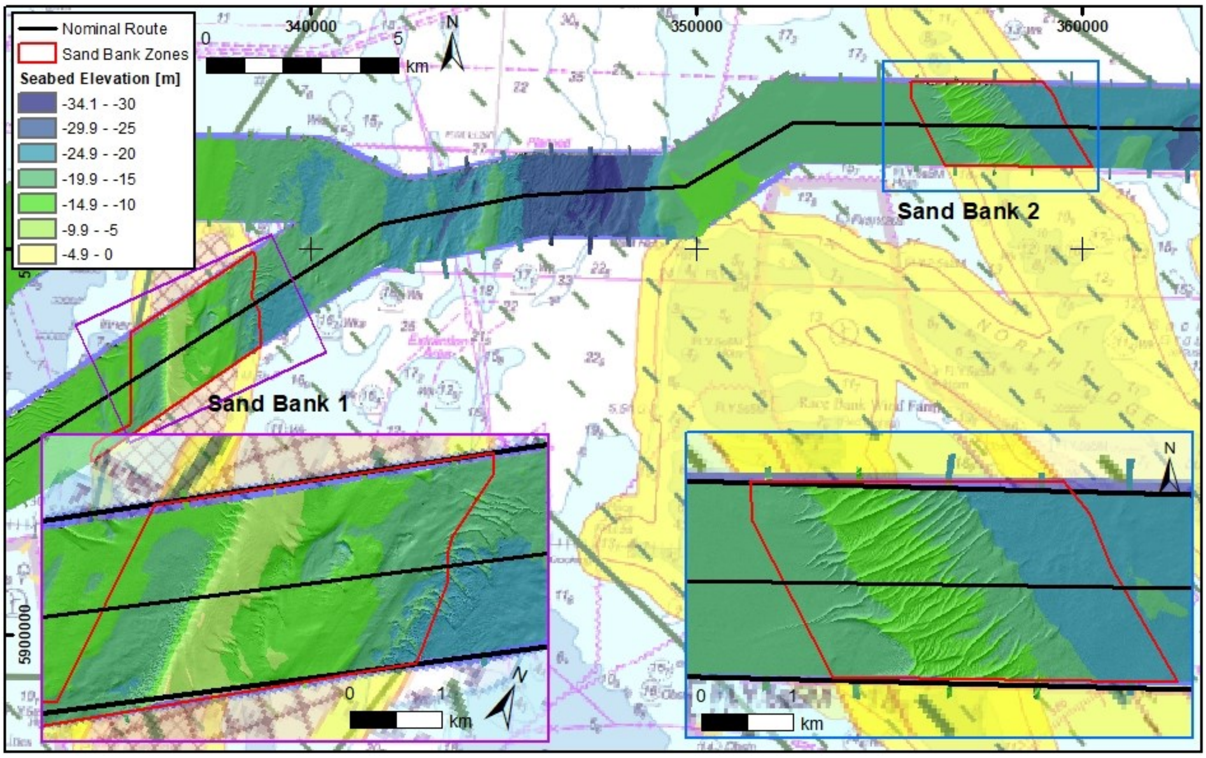


Figure 2.3 Bathymetric overview of the sand bank section of the cable corridor

The migration of the sandbanks has not been considered in this report. Only the search areas outlined in Figure 2.3, based on the present-day location of the sandbanks has been used. However, [1] suggests that migration of the sandbank will occur resulting in a 5-6m seabed elevation change at Sand Bank 1, and a 2-3m seabed elevation change at Sand Bank 2. This reflects the RSBL as described in Table 1.4.

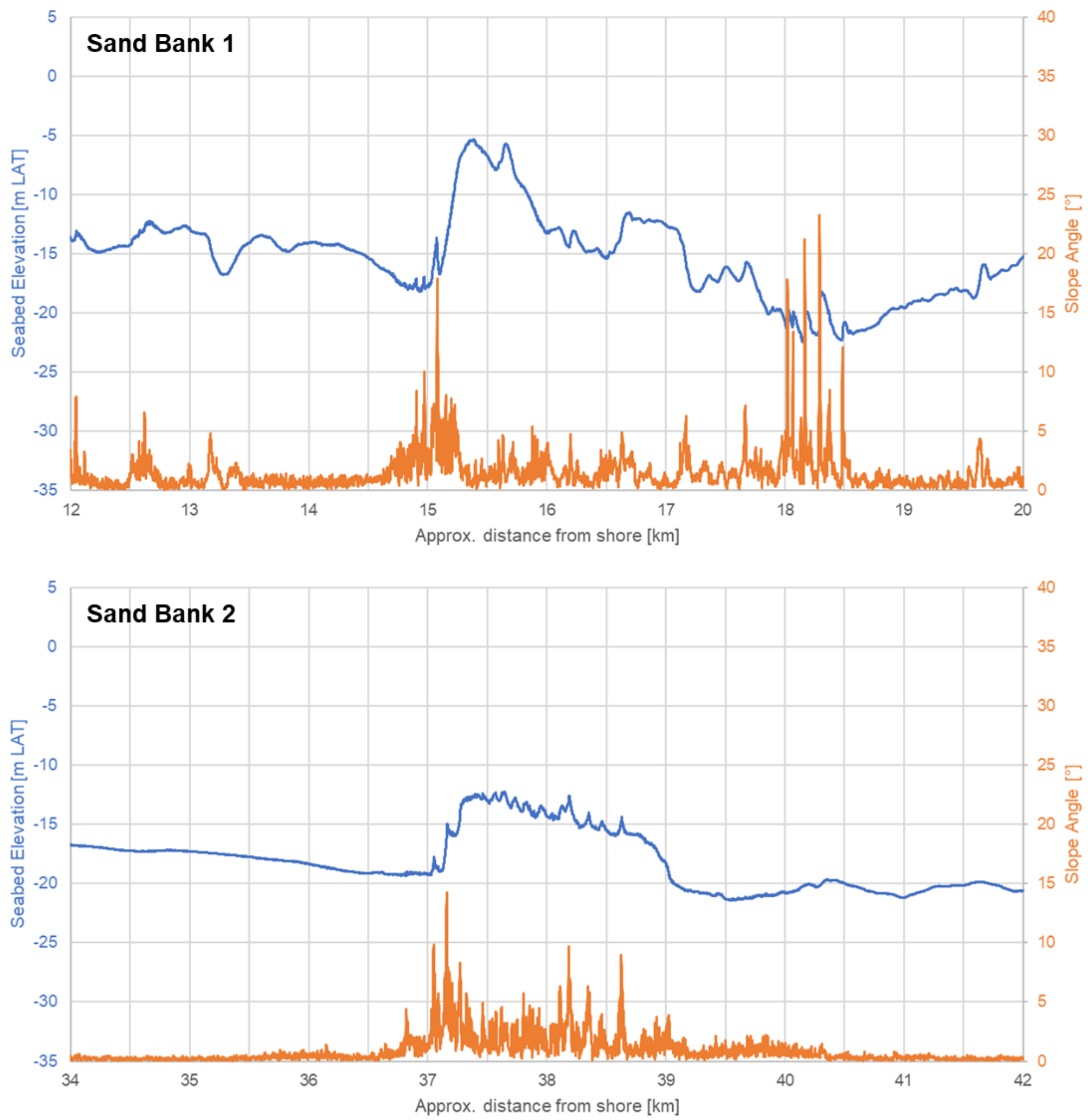


Figure 2.4 Bathymetric and gradient profile along the Sandbank

2.4 AIS dataset

Marine vessel traffic data have been collected in accordance with recommendations made in the Carbon Trust CBRA guidelines [1], amongst other guidance and policy documents. Long-term AIS datasets were used as a record of the recent past shipping activity, which is considered a good proxy for future shipping activity in the same area. AIS data were procured for a 24-month period covering 2021 and 2022. The AIS data were procured with the following details (to cover the sandbank section of the ECC):

- Search areas:
  - Latitude 53.260296 to 53.315501 and Longitude 0.512441 to 0.580764
  - Latitude 53.338440 to 53.359350 and Longitude 0.828343 to 0.901047
- Time range: 2021-01-01 00:00 and 2022-12-31 23:59.

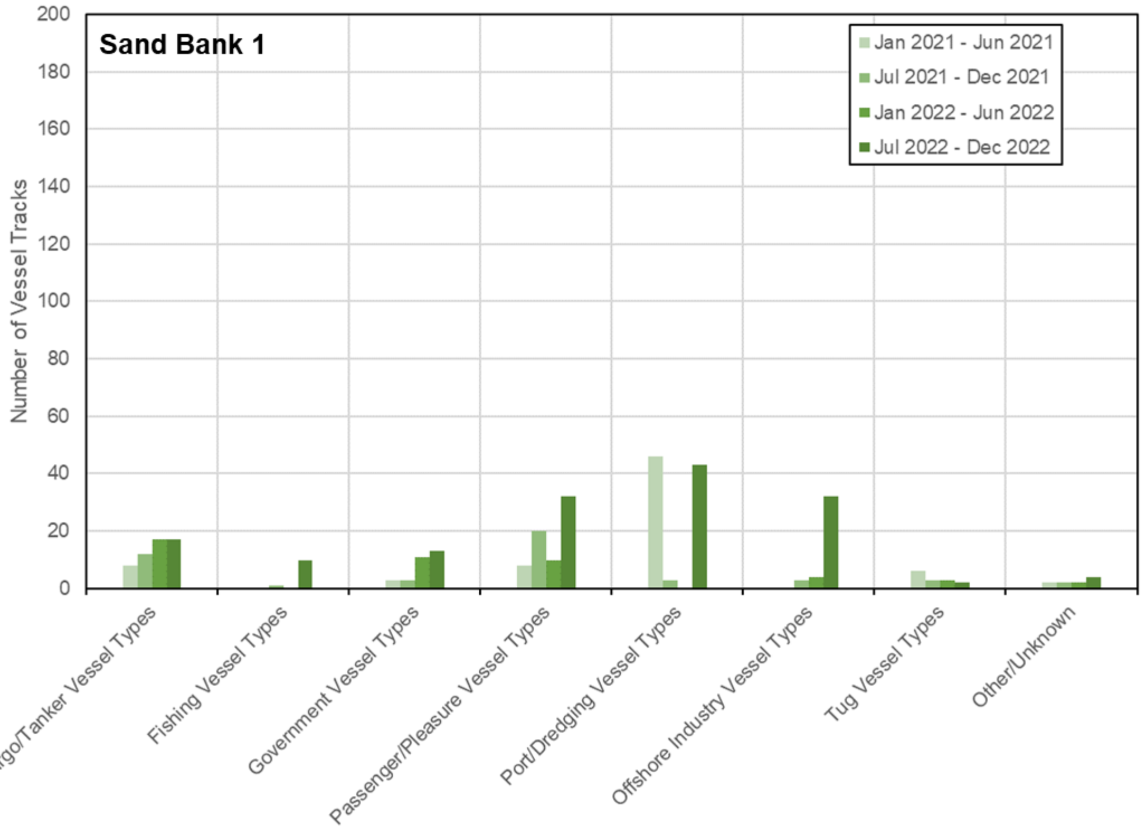
- Vessel attributes:

- Maritime Mobile Service Identity (MMSI)
- Status
- Speed (knots x 10)
- Latitude
- Longitude
- Course
- Heading
- Timestamp (UTC)
- Type
- Dead weight tonnage (DWT)

This search returned 6342 records for Sand Bank 1 and 3935 records for Sand Bank 2 over this time range (where a single record represents a single point on a single vessel's journey, typically transmitted at 2-to-3-minute intervals). When records were converted into vessel tracks (based on a unique combination of vessel MMSI and day of travel), 320 tracks were recorded over Sand Bank 1 and 730 tracks were recorded over Sand Bank 2, over the same two-year period.

Figure 2.5 shows a comparison of the number of vessel tracks grouped into 6-month intervals between the beginning and end of the time interval of the AIS data procured for this study. Vessel tracks are classified by type and the number of tracks is shown on common scale between the two sand banks, which highlights the significantly greater number of vessel tracks over Sand Bank 2. Cargo and tanker vessel types dominate the traffic over Sand Bank 2, whereas Passenger / Pleasure vessel types and Port / Dredging vessel types are the most numerous over Sand Bank 1.

Fishing vessel types are relatively few over both sand banks, but it is typical that much of the fishing vessel fleet are smaller than the minimum required size to be obliged to transmit their position and hence this is likely to be an underestimate.



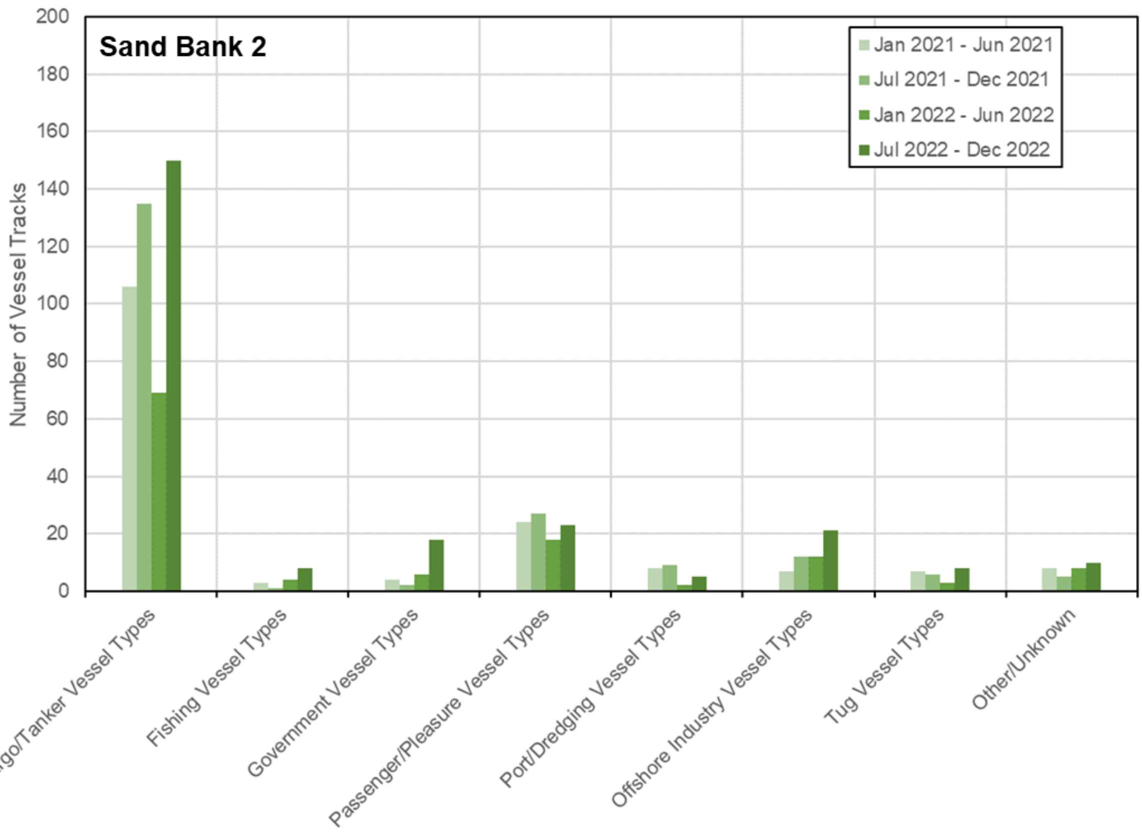


Figure 2.5 Comparison of vessel tracks across the 24-month record interval

2.5 Geotechnical Characterisation

Geotechnical data are available at approximately 500m intervals along the ECC, alternating between vibrocore and shallow CPT [5]. Figure 2.6 shows the positions of the geotechnical locations sited on each of the sand banks and shows coloured columns that summarise the geotechnical findings at each location. From the alignment charts in the GEOxyz Report, the depths of the base of Holocene sediments and the underlying quaternary formations can be determined [2]

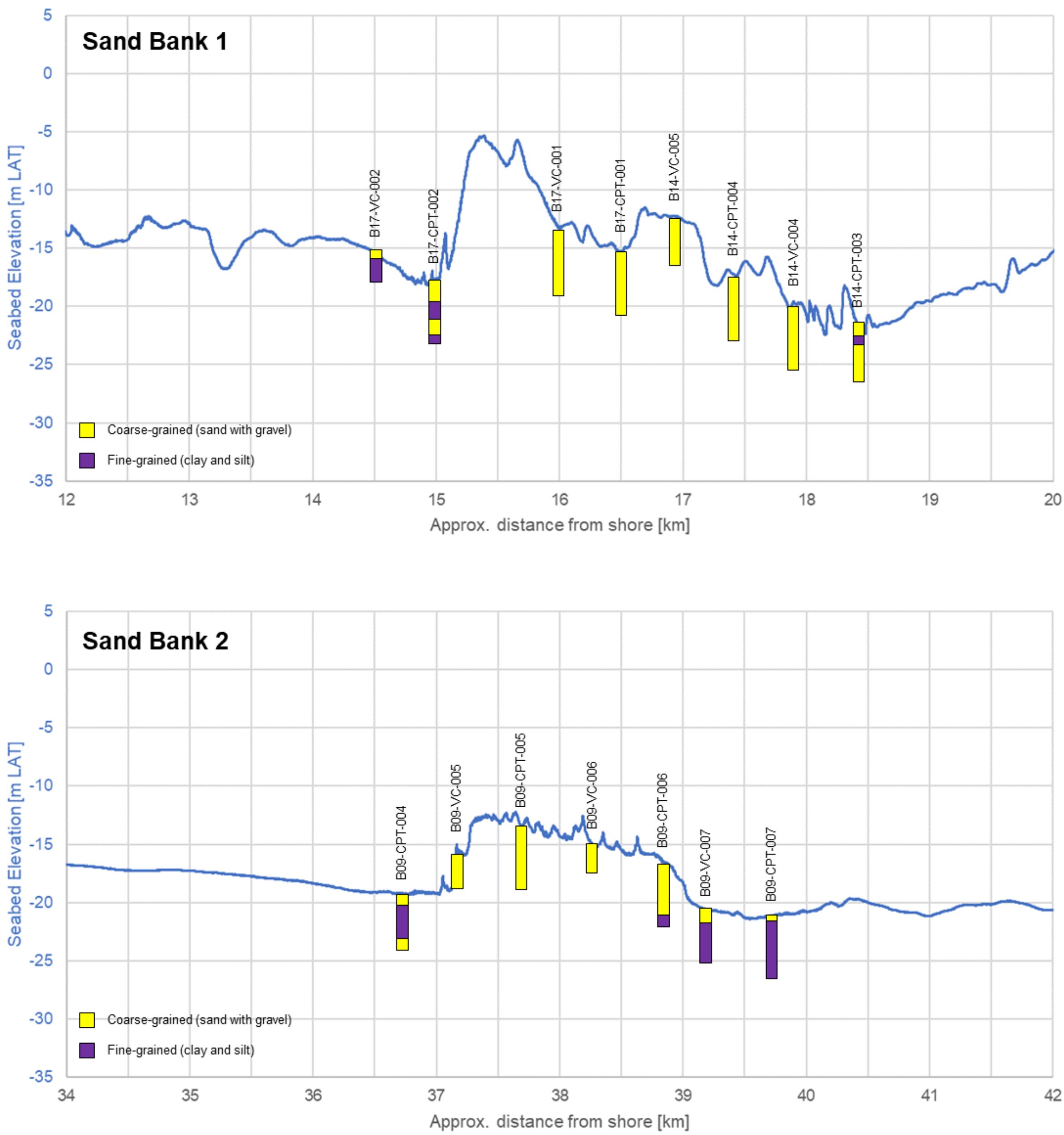


Figure 2.6: Summary of geotechnical conditions within each sand bank

The penetration and data recovery is typically 4m to 5m. The sand banks are confirmed by these geotechnical data as comprising coarse material, predominantly sand with some gravel, typically medium dense to very dense. This is considered to be Holocene sand, based on the British Geological Society regional geological interpretation, as summarised in the desktop study [4] and refined during the geophysical and geotechnical survey [5]. The geotechnical locations acquired at the flanks of the sand banks reveal the underlying seafloor to comprise predominantly fine-grained material, described in the geotechnical logs as high to very high strength clay.

Figure 2.7 presents an excerpt modified from [5], showing a seismic section through Sand Bank 2 (note the orientation shown is reversed relative to Figure 2.6), clearly indicating that the sand bank is situated on a relatively flat underlying seafloor, comprised of Bolders Bank Formation, which is described regionally as a firm to stiff slightly gravelly clay with pockets of sand and gravel [4].

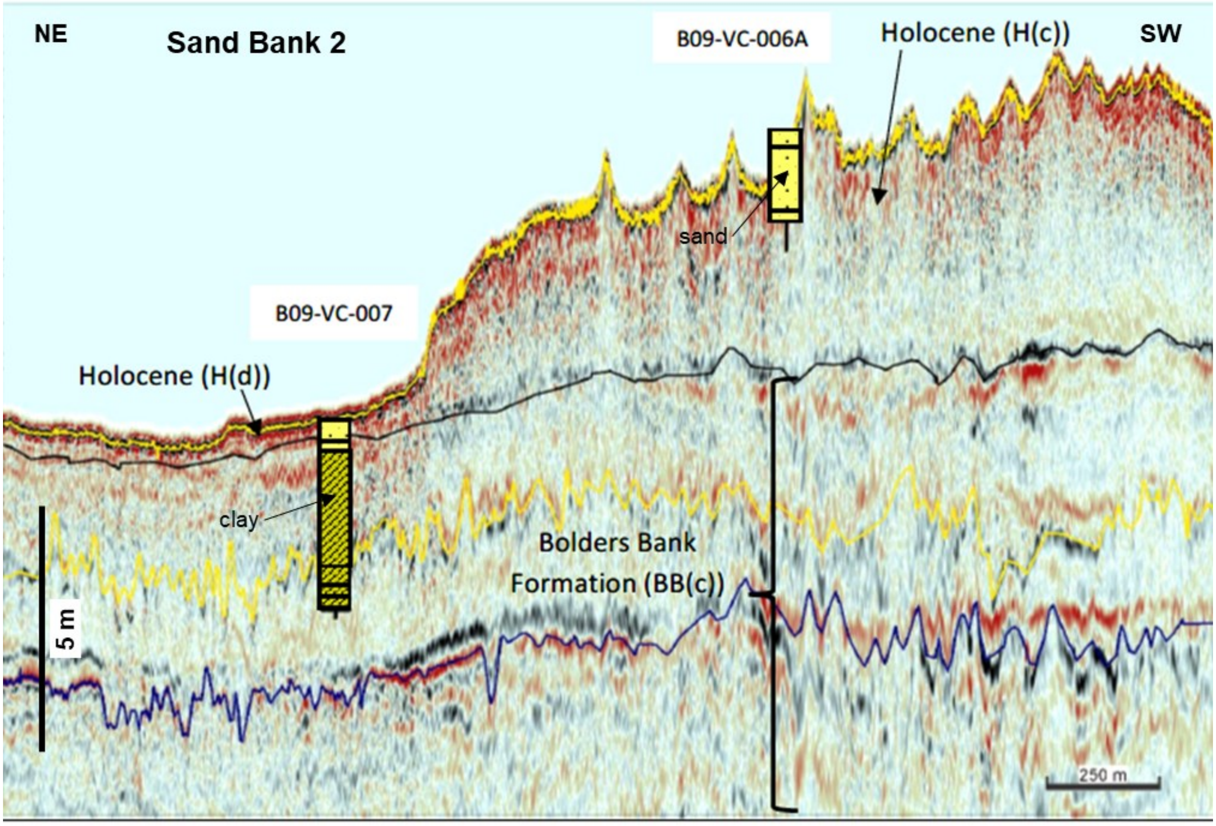


Figure 2.7: Excerpt from [5] showing subsurface geophysical data and interpretation, and overlain with the positions and interpretations of geotechnical data

Therefore, the geotechnical characteristics of the sand bank areas are expected to be medium dense to very dense sand overlying high to very high strength clay.

3 Assessment of threats to Cables

3.1 Risk register

An initial threat assessment was undertaken to qualitatively assess the threats to the integrity of the cable, focusing on hazards that can be mitigated through cable burial, and drawing on the relevant datasets and reports. Likelihood (L) and severity (S) have been qualitatively assessed and assigned a basic ranking from 1 to 9 as shown in Figure 3.1.

		Severity (S)		
		Low	Moderate	High
Likelihood (L)	Rare	1	2	3
	Likely	2	4	6
	Almost certain	3	6	9

Risk Level		Action
1		Acceptable
2	3 & 4	May be acceptable; subject to implementation of suitable mitigation measures
6	9	Unacceptable, except if specific mitigation measures are designed and implemented

Figure 3.1 Likelihood, severity and qualitative risk ranking matrix

The risk register considers both the likelihood over the Project lifetime and the severity of the identified external threats to the cables. Both natural and anthropogenic threats are assessed.

Each threat is described in terms of potential risk and expected post-mitigation (residual) risk to the proposed cables. The purpose of this exercise is to ensure that all hazards were identified and assessed such that the risk to cables is appropriately understood and mitigated where possible, and to identify risks that require mitigation by burial, since this is the subject of this report.

The risk register for natural threats is presented in is presented in Table 3.1 and the risk register for anthropogenic threats is presented in Table 3.2.

No	Description of potential threat	Potential impact at the site	Initial Risk (prior to mitigation)			Project stage(s) when risk exists	Mitigation, monitoring	Residual Risk (after mitigation)			Does initial risk require mitigating?	If yes, does mitigation involve burial?
			L	S	R			L	S	R		
1	Boulders at or near seafloor	Potential to obstruct cable burial, snag burial tool and/or trap cable between boulder and plough.	3	3	**9**	Installation	Assess boulder distribution based on contractor seabed features interpretation. Micro re-route to avoid major areas of boulders. Undertake pre-lay boulder clearance where appropriate	1	3	**3**	Y	N
2	Earthquake induced liquefaction	Potential to liquefy soil causing reduction of effective stress in cable overburden allowing the cable to rise and hence reduction in burial depth or lead to deeper penetration possibly causing overheating.	1	2	**2**	Operation	Not considered a credible risk on stable UK continental shelf	1	2	**2**	N	n/a
3	Lateral variability of ground conditions due to glaciogenic origin of soils (including infilled palaeo-channels)	Lateral variability, leading to soil variability along cable corridor.	2	2	**4**	Installation	Develop a sufficiently resolute shallow ground model to allow the cable burial plan to be designed to suit the ground conditions	2	1	**2**	Y	N
4	Scour and seabed mobility	Movement of seabed sediment across the site due to the action of currents and waves. Removal of seabed sediment from around cables due to the action of currents and waves. Seabed mobility study identified areas of mobile bedforms (sandwaves, ripples).	2	2	**2**	Operation	Understand the seabed mobility regime and ensure cable burial is below a reference seabed level that is the base of the mobile layer	1	2	**2**	Y	Y

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No	Description of potential threat	Potential impact at the site	Initial Risk (prior to mitigation)			Project stage(s) when risk exists	Mitigation, monitoring	Residual Risk (after mitigation)			Does initial risk require mitigating?	If yes, does mitigation involve burial?
			L	S	R			L	S	R		
6	Shallow gas	Release of potentially noxious and flammable gases into the water column and potentially onto the deck of vessels working at the site	2	3	**6**	Design, Installation	Not anticipated in the vicinity of the two sand banks considered in this report, but two areas of shallow gas were identified along the ECC [5]. Undertake a full shallow gas hazard assessment prior to any seabed intervention works and ensure risk is acceptable prior to proceeding.	2	1	**2**	Y	N
8	Seabed topography	Uneven topography and/or steep gradients, which may lead to variable burial, increased slack requirement, and/or inoperable conditions for cable burial tools.	2	2	**4**	Installation	Micro re-routing to avoid areas of uneven topography Pre-sweeping to prepare the seafloor prior to burial tool use	1	2	**2**	Y	N
9	Density currents / landslides	Potential to impact and brake cables	1	3	**3**	Operation	Not anticipated at the site, but possible in the region subject to the correct geotechnical conditions. If present, assess geotechnical data for presence of any anomalously low strength sediment and corridor cable to avoid (either laterally of vertically)	1	3	**3**	N	n/a

Table 3.1Qualitative risk register: Natural threats

No	Description of potential threat	Potential impact at the site	Initial Risk (prior to mitigation) L	S	R	Project stage(s) when risk exists	Mitigation, monitoring	Residual Risk (after mitigation) L	S	R	Does initial risk require mitigating?	If yes, does mitigation involve burial?
1	Benthic Fishing	Snagging of fishing gear on cables and damage of cables during trawling and gear retrieval. Seabed interacting gear reducing sediment coverage above cable .	2	3	**6**	Operation	Bury cable to sufficient depth below reference seabed level to avoid interaction with benthic fishing	1	3	**3**	Y	Y
2	Shipping (planned anchoring)	Snagging of cables during planned anchoring procedures.	1	3	**3**	Operation	Not expected because area of interest is not in a planned anchorage	1	3	**3**	N	n/a
3	Shipping (emergency anchoring)	Snagging of cables during emergency anchoring procedures.	2	3	**6**	Operation	Bury cable to sufficient depth below reference seabed level to reduce likelihood of strike from emergency anchoring to a tolerably low level	1	3	**3**	Y	Y
4	Dredging, aggregate extraction, subsea mining	Interaction between dredging/mining equipment and cables causing damage or breakage. Reduction in seabed cover increasing risk to cable.	1	3	**3**	Operation	Not expected because area of interest is not in an area of licensed extraction operations. However, a marine extraction area is located nearby and it is essential that the limits of this area are well adhered to by the extraction company. This can be achieved by close stakeholder engagement. In the event that these aggregate areas are expanded and overlap the cable in the future, the L value becomes a 3 and hence R will show an unacceptable risk (9). Hence, careful monitoring of the Tender areas nearby needs to be considered throughout. The only mitigation in this event is to ensure the boundary limits of new zones are outside of the cable corridor through negotiation.	1	3	**3**	N	n/a
5	Spoil dumping	Interaction between dumped material and cables causing damage or breakage.	1	3	**3**	Operation	Not expected because spoil dumping is only permitted in designated areas	1	3	**3**	N	n/a

No	Description of potential threat	Potential impact at the site	Initial Risk (prior to mitigation)			Project stage(s) when risk exists	Mitigation, monitoring	Residual Risk (after mitigation)			Does initial risk require mitigating?	If yes, does mitigation involve burial?
			L	**S**	**R**			**L**	**S**	**R**		
6	Anthropogenic objects, particularly unexploded ordnance (UXO)	Detonation of unexploded device located at or below seabed causing loss of life, damage to vessel, damage to cable, and/or installation tool due to explosion.	1	3	**3**	Installation	Undertake UXO desktop study and subsequent survey for ALARP (As Low As Reasonably Practicable) certification prior to any seabed intervention works	1	3	**3**	Y	N
7	Future linear infrastructure	Third party cable crossing works interacting with cable, e.g., planned future crossings.	2	2	**4**	Operation	Liaise with future third party cable operators and agree crossing approach that is suitable for both cables and that will not damage the Project cable	2	1	**2**	Y	N
8	Restrictions on cable installation in areas of archaeological conservation	Possible requirement to not disturb seafloor (e.g. through cable burial) in areas of archaeological conservation.	1	2	**2**	Installation	Re-route to avoid areas of archaeological conservation (not anticipated along this corridor based on currently available information, although not assessed in detail, it is not confirmed for the moment)	1	1	**1**	Y	N

Table 3.2 Qualitative risk register: Anthropogenic threats

The threats identified by the threat assessment in Table 3.1 and Table 3.2 as requiring mitigation by burial are as follows:

1. Shipping (emergency anchoring): Anchor penetration into the seabed is considered one of the most onerous anthropogenic risks to cables from accidental/emergency deployed anchors penetrating the seabed.
2. Benthic Fishing: Damage to cables by fishing equipment.

The threats from benthic fishing and emergency anchoring by ships are discussed further in the following sections.

3.2 Emergency anchoring by ships

3.2.1 Context

Under normal vessel operations, shipping activities are not expected to interact with seabed cables, since the predominant vessel interaction with the seafloor, anchoring, is only undertaken in designated anchorages, as clearly identified on maritime nautical charts. Other planned vessel interaction with the seafloor, such as dredging, intrusive drilling investigations, etc., are undertaken under strict licensing conditions which include a requirement to avoid charted infrastructure.

However, in emergency situations (e.g., loss of vessel power or control), vessels may deploy anchors without usual consideration of subsea infrastructure. Cable impact or snagging from a ship’s anchor is likely to result in cable damage.

Errant anchoring from shipping is perceived as a significant threat to unburied or shallow buried cables. Shallow cable burial is often considered the most cost-effective mitigation against this external threat.

It is therefore necessary to assess anchor penetration depths as well as the type and intensity of recent shipping activity and expected future shipping activity. Anchor penetration is discussed below, and shipping activity is assessed in Section 4.

The accidental or emergency grounding of ships in shallow water may also present a hazard; however, the likelihood of this happening can be considered small and unpredictable. For this reason, this risk is omitted from this study.

3.2.2 Anchor penetration

When an anchor is deployed and encounters the seabed, the depth of anchor penetration below seabed is a function of the size of the anchor. The expected maximum depth of anchor penetration is therefore a function of the maximum expected size of anchor and the soil conditions at and below the seabed. The appropriate anchor size (typically quantified by weight) for a vessel will vary depending on the type of anchor adopted, but general trends are available, such as those compiled and presented in the Carbon Trust CBRA guidance [1].

Working on the basis that burial is required in order to mitigate against anchor strikes and reduce the likelihood of an anchor impacting the cables, an assessment of expected of anchor penetration depth is required. Anchor penetration is considered further as part of the anchor probabilistic risk assessment in Section 6.

3.3 Benthic fishing

Interaction with fishing gear such as otter boards or beam trawls is assumed to have the potential to cause localised damage for an individual impact and potentially major damage leading to loss of capacity in the event of multiple strikes. In addition to the risk of damage to the cable, cables may pose a risk to the fishing vessels as small vessels might flounder if snagged on a significant obstruction.

AIS data indicates minimal fishing activity over the two sand banks, which may be an under-representation due to fishing vessels falling below the size limit mandating AIS position transmission. The relatively low presence of fishing vessels may also reflect the shallow water represented by these sand banks (5 m LAT for Sand Bank 1 and 10 m LAT for Sand Bank 2), which may be avoided by fishing vessels to avoid grounding (e.g. if the sand banks change in position and size relative to their charted size) and to avoid snagging fishing gear on undulating seafloor.

Intelligence from the Fishing Liaison Officer (FLO) and scout vessels deployed during geophysical survey confirms that local fishing vessels mainly use static gear (i.e. pots). However, even if low in density, of the fishing activities practised in the Southern North Sea, benthic fishing such as trawling is still likely to be present in the area and the cable needs to be protected against potential snagging.

Fishing threat line depths are specified by the Carbon Trust [3] with the maximum penetrations in different soils being as follows:

- 0.2 m in sands and/or stiff clays
- 0.3 m in soft clays

These values are considered appropriate in soils for a single fishing pass, though it should be noted that to account for multiple fishing passes, allowance for seabed mobility or operational reasons, in absence of other risks it is common to allow for a more significant DoL (e.g., 0.5m below reference seabed level).

4 Shipping analysis

4.1 Overview

Under normal vessel operations, shipping activities are not expected to interact with seabed cables, since the predominant vessel interaction with the seafloor, anchoring, is only undertaken in designated anchorages, as clearly identified on maritime nautical charts. Other planned vessel interaction with the seafloor, such as dredging, intrusive drilling investigations, etc., are undertaken under strict licensing conditions which include a requirement to avoid charted infrastructure.

However, in emergency situations (e.g., loss of vessel power or control), vessels may deploy anchors without usual consideration of subsea infrastructure. Cable impact or snagging from a ship's anchor is likely to result in cable damage.

4.2 AIS Data Assessment

4.2.1 Data Processing

The AIS data was received in text format and was loaded into ESRI GIS using the longitude and latitude columns to plot points relating to each AIS record. The points were converted into individual vessel tracks representing single vessel journeys based on a unique combination of vessel MMSI and date of travel. This approach assumes that each journey spans 24 hours from 00:00 to 23:59 and records that fall into the next day are treated as a separate journey.

This is clearly not correct for many vessels which undertake 24-hour operations with journeys which often span several days. However, this approach is a convenient means of converting over ten thousand individual vessel records into a manageable number of vessel tracks, is likely to be representative for the large majority of vessel traffic, and does not affect the assessment of vessel density in the vicinity of the cable corridors.

4.2.2 Vessel Distribution

All observed vessels were classified into a simplified set of vessel type categories that are aligned with vessel type classifications adopted in similar shipping analyses undertaken by OWC at other sites. Table 4.1 presents the as-received vessel type descriptions and the assigned vessel classification.

	Vessel Type Classification							
	Cargo/Tanker Vessel Types	**Fishing Vessel Types**	**Government Vessel Types**	**Offshore Industry Vessel Types**	**Passenger/Pleasure Vessel Types**	**Port/Dredging Vessel Types**	**Survey Vessel Types**	**Tug Vessel Types**
AIS Vessel Type Description	Cargo	Fishing	Military ops	Diving ops	High speed craft (HSC)	Dredger		Tug
	Tanker, all ships of this type		Reserved	Offshore / Industry	Passenger	Port Tender		
	Cargo, Hazardous category A		Search and Rescue vessel		Sailing	Pilot Vessel		
	Tanker, Hazardous category A				Pleasure Craft			
	Tanker, Hazardous category B				Passenger, Hazardous category A			
	Tanker, Hazardous category C							

Table 4.1: Vessel classification matrix

Table 4.2 presents the number of vessels tracks in each category. In addition to the records presented in Table 4.2, 10 tracks from 3 vessels across Sand Bank 1 and 31 tracks from 4 vessels across Sand Bank 2 are from vessels classed ‘other’, which comprise 2 search and rescue helicopters and two unmanned autonomous small vessels.

Classification	Number of Vessel Tracks (Sand Bank 1)	Number of Vessel Tracks (Sand Bank 2)
Cargo/Tanker Vessel Types	54	461
Fishing Vessel Types	11	16
Government Vessel Types	30	30
Offshore Industry Vessel Types	39	52
Passenger/Pleasure Vessel Types	70	92
Port/Dredging Vessel Types	92	24
Tug Vessel Types	14	24
Other / Unknown	10	31

Table 4.2 Number of vessel tracks classified by vessel type

Figure 4.7 show vessel tracks for each of the vessel type classes described in Table 4.2, overlain on the areas of interest (i.e. the two sandbank crossing locations) The inset graphs show the distribution of vessel size (DWT) for each vessel category (the y-axis scale varies per vessel category). In these graphs, and where references elsewhere in the document, each DWT range includes vessels with a DWT equal to the upper limit of the class. Further, where a single DWT is referenced for simplicity, the referenced DWT is the top of the range, and the lower end of the range is the top of the previous range).

Figure 4.4 shows vessels in the Offshore Industry Vessel type class. Survey vessels are included in this class. Two vessels visible in the dataset over this period are understood to have been used to undertake part of the geophysical survey for the export corridor, since their corridors follow a regular line plan along the export corridor, and this is confirmed in the survey report [5]. These vessels are listed below, and their contribution to the measured vessel density (described further in Section 6) are omitted, since this survey activity, and hence increased vessel density, would not be undertaken post-installation of the cable:

- Geo Ocean III (MMSI 253596000)
- Marshall Art (MMSI 235086495)

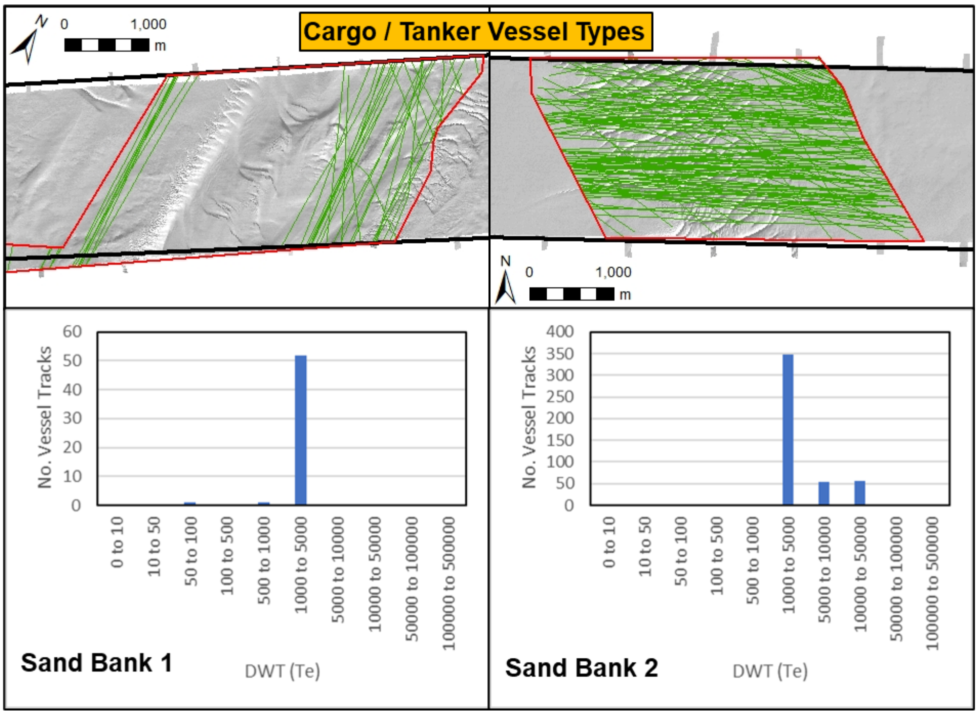

Figure 4.1: Vessel tracks for Cargo / Tanker Vessel Types between January 2021 and December 2022 with a summary of the number of vessels tracks in a range of vessel size (DWT) categories

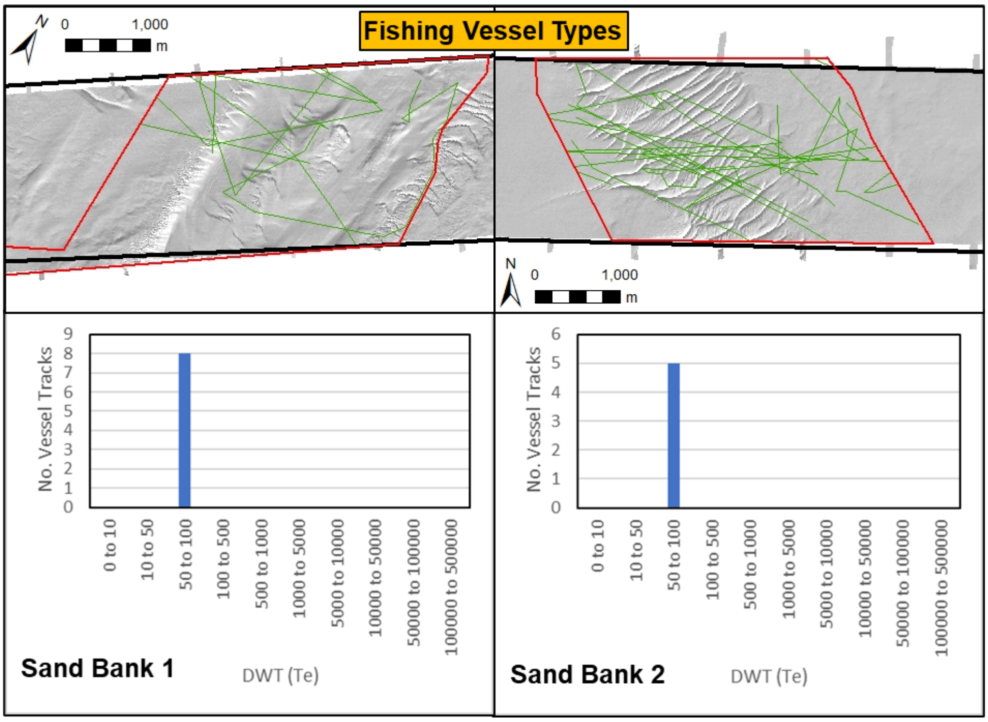

Figure 4.2: Vessel tracks for Fishing Vessel Types between January 2021 and December 2022 with a summary of the number of vessels tracks in a range of vessel size (DWT) categories

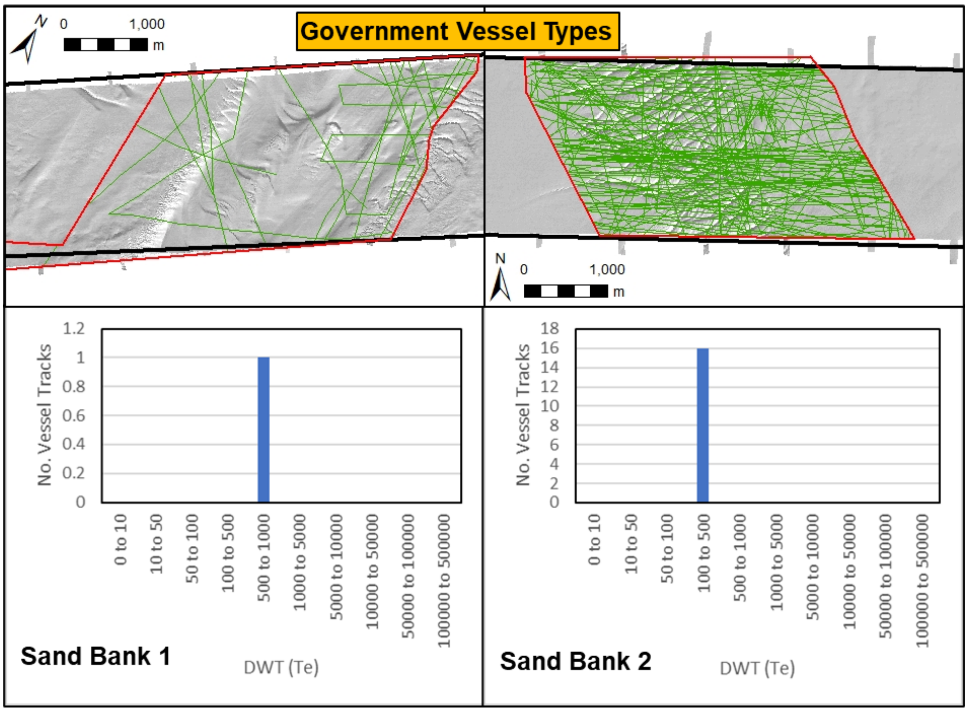

Figure 4.3: Vessel tracks for Government Vessel Types between January 2021 and December 2022 with a summary of the number of vessels tracks in a range of vessel size (DWT) categories

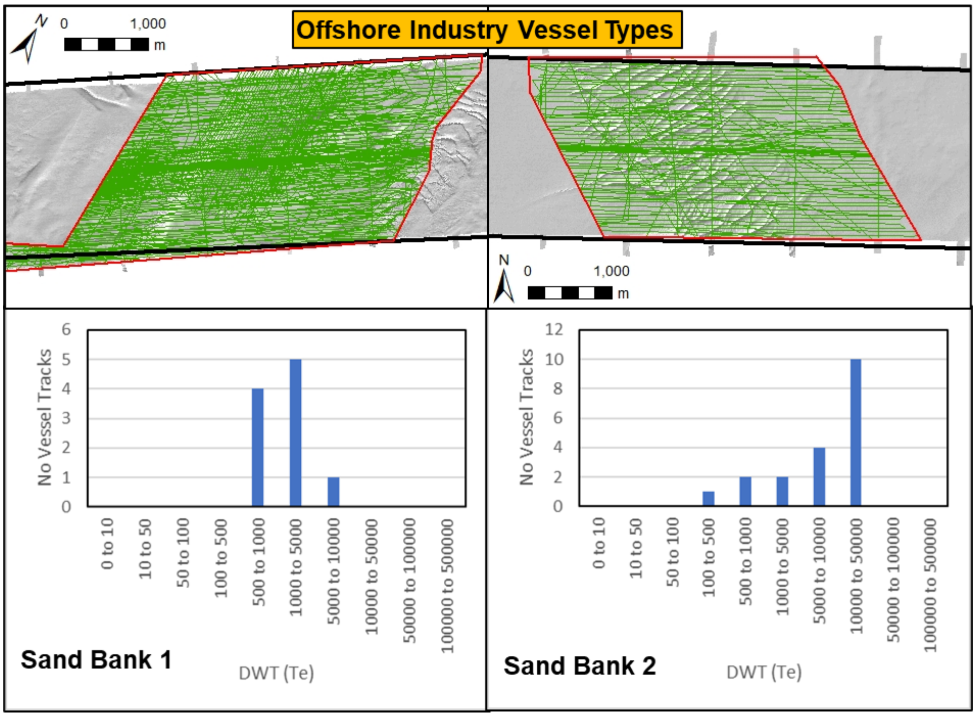

Figure 4.4: Vessel tracks for Offshore Industry Vessel Types between January 2021 and December 2022 with a summary of the number of vessels tracks in a range of vessel size (DWT) categories

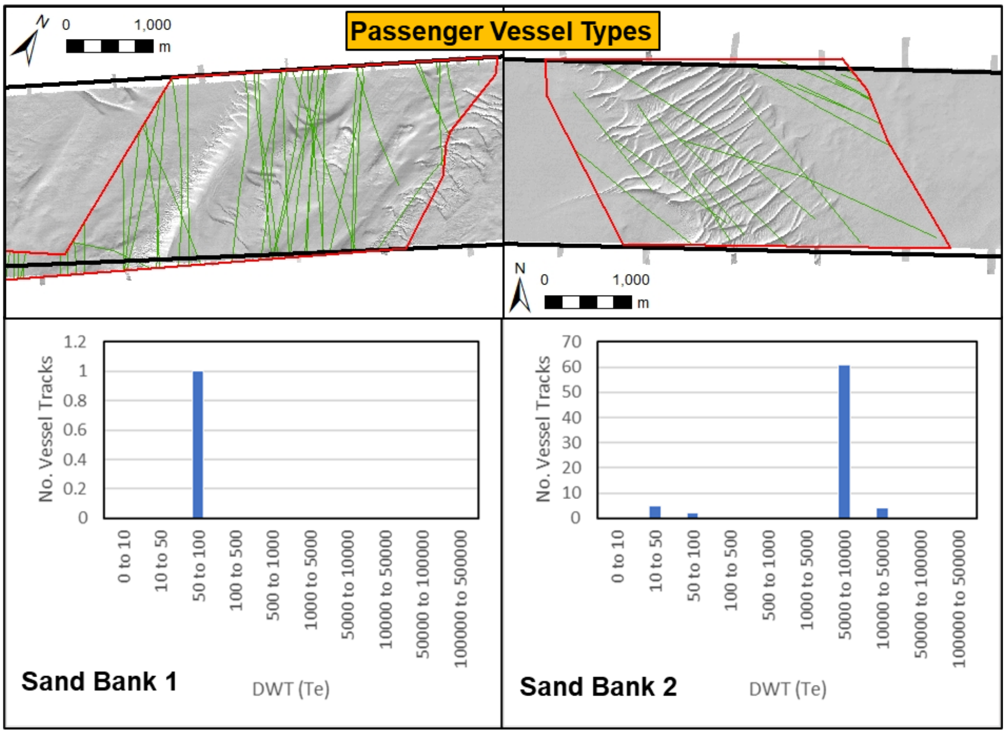

Figure 4.5: Vessel tracks for Passenger Vessel Types between January 2021 and December 2022 with a summary of the number of vessels tracks in a range of vessel size (DWT) categories

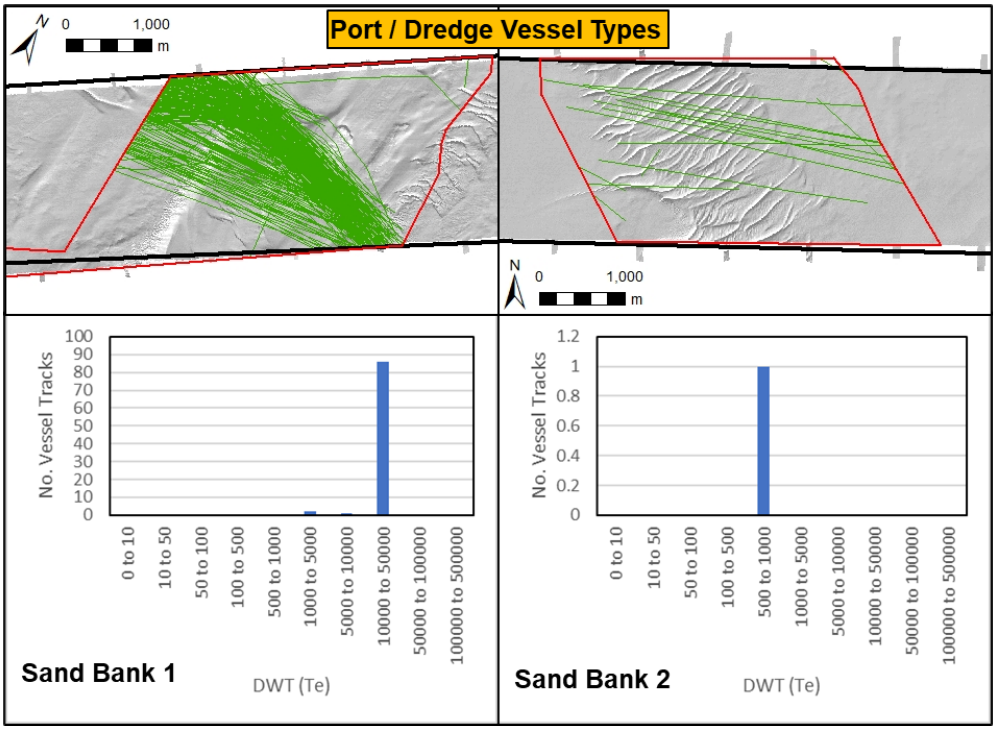

Figure 4.6: Vessel tracks for Port / Dredge Vessel Types between January 2021 and December 2022 with a summary of the number of vessels tracks in a range of vessel size (DWT) categories

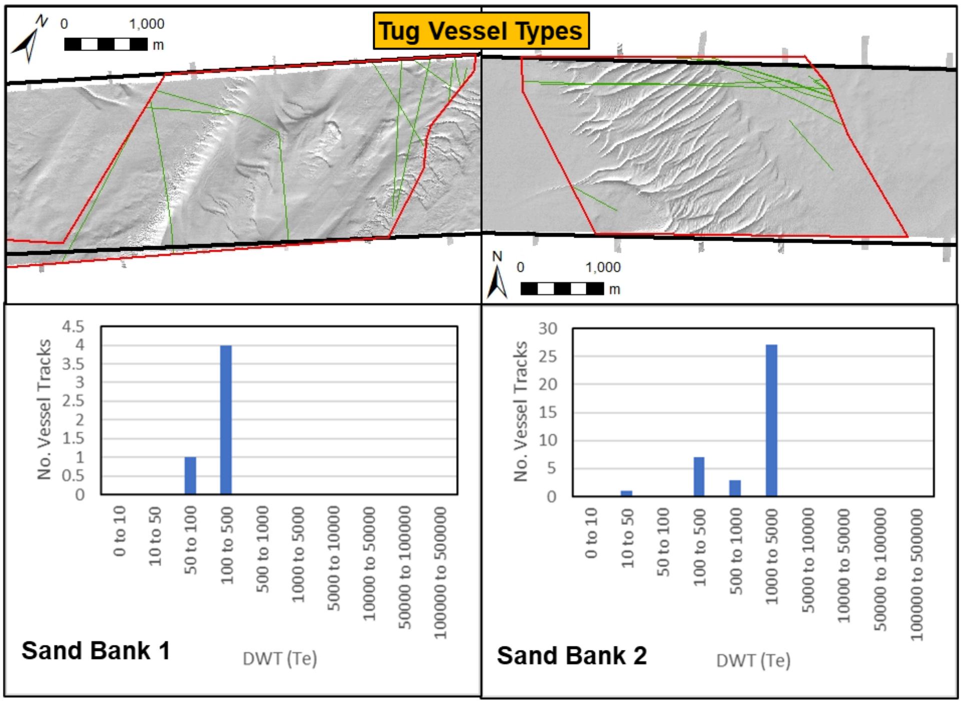

Figure 4.7: Vessel tracks for Tug Vessel Types between January 2021 and December 2022 with a summary of the number of vessels tracks in a range of vessel size (DWT) categories

4.2.3 AIS Data Gaps

DWT was not recorded in the AIS dataset for some vessels. An average DWT was calculated for each vessel class, from records where DWT was recorded. For the purpose of the probabilistic assessment (Section 6) the appropriate vessel class average was assigned to each vessel where no DWT was recorded. Table 4.3 and Table 4.4 present the average DWT and other statistics for each vessel class, based on all vessel records from the recent AIS dataset (for Sand Bank 1 and 2 respectively).

As demonstrated by Table 4.3 and Table 4.4, the vessel classes where DWT reporting is poorest coincides with the lightest vessel classes (Passenger/Pleasure Vessel Types, Fishing Vessels and Government Vessels). This is because DWT is a measure of how much weight a vessel can carry, which is not an appropriate measure for vessels that are not designed purely for load carrying purposes (whereas Cargo/Tanker Vessel Types have an almost complete DWT record). These light vessels are expected to carry small anchors and therefore present a lower hazard to seabed cables than larger vessels.

The Passenger/Pleasure Vessel Types class, and potentially the Fishing Vessel Types class, are likely to be underrepresented by the AIS dataset since many of these vessel types will be small enough to not be required to carry AIS transmitting equipment. However, as described above, these vessels are expected to carry small anchors which present a low hazard to the cable.

Classification	No. Vessels	No. Vessels with DWT recorded		DWT Statistics [Te]		
		Number	Percent	Minimum	Maximum	Average
Cargo/Tanker Vessel Types	33	33	100	50	4210	2815
Fishing Vessel Types	4	1	25	76	76	76
Government Vessel Types	7	1	14	957	957	957
Offshore Industry Vessel Types	8	4	50	650	8887	8605
Passenger/Pleasure Vessel Types	56	1	2	60	60	60
Port/Dredging Vessel Types	5	4	80	2305	13700	6418
Tug Vessel Types	7	2	29	97	254	176
Other / Unknown	3	0	0	n/a	n/a	n/a

Table 4.3 Number of vessels and DWT statistics for each vessel class (Sand Bank 1)

Classification	No. Vessels	No. Vessels with DWT recorded		DWT Statistics [Te]		
		Number	Percent	Minimum	Maximum	Average
Cargo/Tanker Vessel Types	265	265	100	1275	62594	5445
Fishing Vessel Types	9	1	11	76	76	76
Government Vessel Types	6	1	17	957	957	957
Offshore Industry Vessel Types	17	12	71	25	4229	1858
Passenger/Pleasure Vessel Types	27	11	41	30	10100	4626
Port/Dredging Vessel Types	14	10	71	183	27162	8605
Tug Vessel Types	18	10	56	107	285	194
Other / Unknown	4	0	0	n/a	n/a	n/a

Table 4.4 Number of vessels and DWT statistics for each vessel class (Sand Bank 2)

4.2.4 AIS Data Summary

The vessel traffic from the latest AIS dataset is considered to be a reasonable representation of future vessel activity. The areas of interest are sufficiently far from the planned offshore Project that the diverted vessels post-construction are not expected to impact the vessel density across these areas of interest. However, future development of other parts of this region may impact the vessel density (although the shallow nature of these sand banks may preclude vessels diverting in this direction).

5 Fishing Assessment

5.1 Fishing Activity with Seabed Interaction

As described in Section 3.3, interaction with fishing gear such as otter boards or beam trawls is assumed to have the potential to cause significant damage to the cable.

5.2 Bottom-contacting Trawling Gear

Bottom trawling fishing gear is relatively simple and comprises a shaped net to guide fish in and collect the fish, and a mechanism to keep the mouth of the net open when it is being towed. The net opening mechanism typically falls into two categories:

- Beam trawling – a solid beam maintains the width of the net opening and metal end plates maintain the height of the net opening. The metal end plates slide along the seabed.

- Otter trawling – no fixed beam is used to maintain the width. Instead, the plates, or 'doors' that slide along the seabed and maintain the net height are designed so that the hydrodynamic forces created when pulled through the water push the plates outward, thus maintaining the net width.

Seabed penetration of bottom trawling gear is kept to a minimum to maximise the efficiency of the trawling operations. Towing a net, trawl boards and beam, and towing chain, through water requires significant towing force. Additional drag from interaction with the seabed requires more fuel and hence reduces the profitability of the operation.

However, a small amount of seabed interaction is considered desirable because the minor seabed disturbance causes surficial sediment to go into suspension, hiding the net from the fish. Further, the noise of the trawl board is thought to attract the fish to the source of the noise and into the mouth of the net.

Estimates of the range of trawler gear seabed penetration vary, but otter and beam trawl techniques are expected to be limited to a small number of centimeters, and less than 10 cm (Figure 5.1). Dredging techniques (not identified in the Project area) may exceed 10 cm seabed penetration, especially hydraulic dredging, but not typically greater than 30 cm.

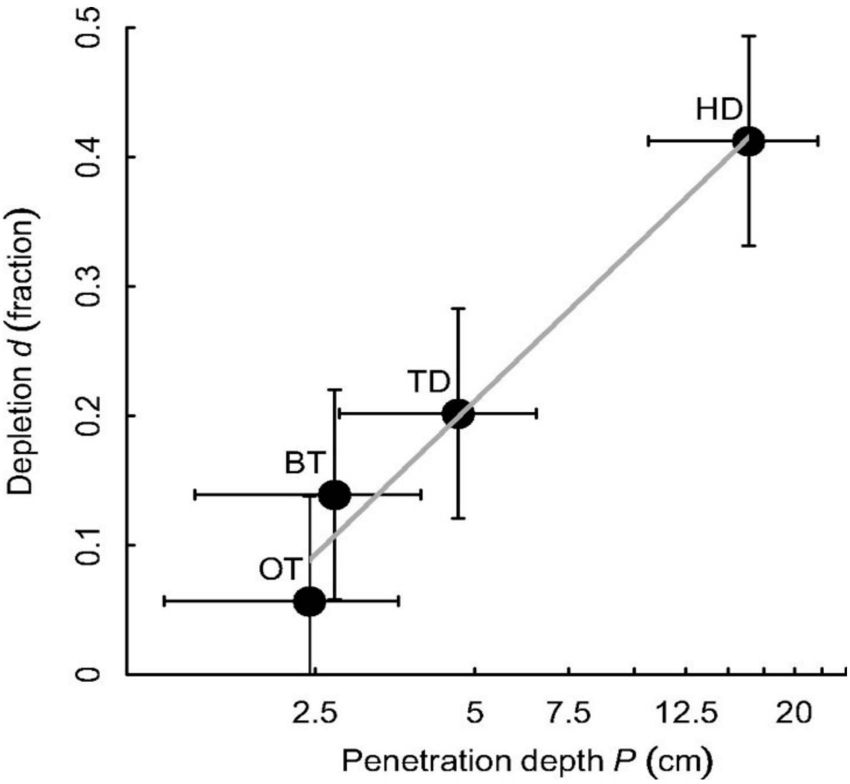

Figure 5.1 Correlation of typical fishing gear penetration depth against biota depletion (OT: Otter Trawl, BT – Beam Trawl, TD, Towed Dredger, HD, Hydraulic Dredger) [6]

5.3 Implications for Cable Burial

Seabed penetration from trawling is expected to be limited, and AIS data indicate that fishing activity across the sand banks is relatively low (although this may be an under-representation).

Therefore, burial requirements to mitigate against fishing are typically not significant.

It is recommended that a minimum burial of 0.5 m is achieved to mitigate against benthic fishing, which includes allowance for trawling gear digging into the seabed in rugged areas (e.g. the flanks of sand banks), which may increase the penetration more than during standard operations.

6 Anchor Probabilistic Risk Assessment

6.1 Anchor Threat line Assessment

The anchor threat line is the maximum depth of anchor penetration expected within each zone of the cable corridors, which is a function of the maximum size of anchor expected, and the soil conditions within the cable zone/ECC.

The appropriate anchor size (typically quantified by weight) for a vessel will vary depending on the type of anchor adopted, but general trends are available, such as those compiled and presented in the Carbon Trust CBRA guidance [1]. Anchor penetration varies depending on soil type, anchor size, configuration and type, loading direction, etc. However, basic relationships between the anchor fluke (i.e. the anchor appendage that digs into the seabed) and the seabed penetration are generally adopted. This is the approach recommended in the Carbon Trust CBRA guidance [1]. Based on a modern stockless anchor design, the following has been considered:

- Sand and stiff clay: penetration = 1 × fluke length
- Soft clay: penetration = 3 × fluke length

Vessel size is provided by the AIS dataset in the form of DWT, which can be related to fluke length. Well established relationships exist between vessel size and anchor size (kg), as shown in [1], based on publications by the IACS (2007) [7] and Luger (2006) [8], although in these correlations vessel size is typically quoted in terms of the Equipment Number (EN), rather than DWT, since the size of anchor required by law on a vessel is determined by the Equipment Number (EN). The Carbon Trust guidance indicates that some assumptions are required in order to establish a link between EN and DWT [1]. Investigation of the relationship between EN and DWT has allowed the same assumptions to be made as part of this assessment, thus enabling the use of anchor weight data published by IACS [9] and DNV-GL [10] for all the DWT ranges requiring consideration. For the purposes of this study EN is approximated as $EN = 2DWT^{2/3}$. The calculated EN was then used to lookup the appropriate anchor mass for a stockless bower anchor in the IACS [9] and DNV-GL [10] catalogues.

With the relationship between DWT and anchor weight established, the next step is to relate anchor weight to fluke length. Standard commercial shipping anchor catalogues (e.g. [11]) can be used to derive a relationship between anchor weight and fluke length. Figure 6.1 shows this relationship for a range of anchor types and for the Stockless Bower anchor a simple curve fit relationship was determined:

$$Fluke\ Length\ [m] = 0.0387\ x\ Anchor\ Weight\ [kg]^{0.3271}.$$

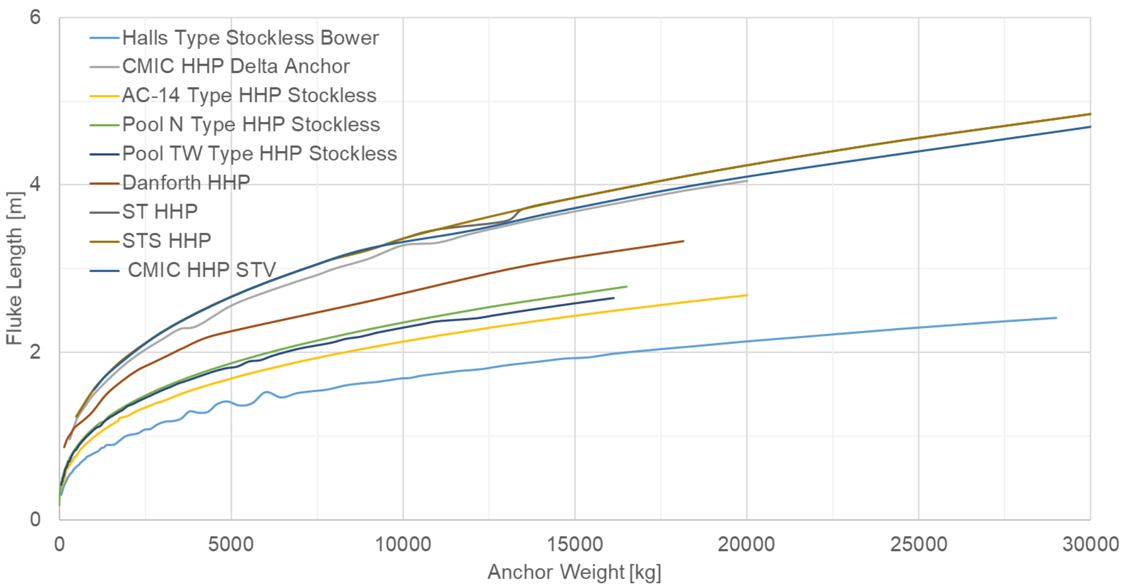

Figure 6.1 Fluke Length as a function of anchor weight (compiled from [11])

Table 6.1 presents the estimated anchor penetration depth for a range of vessel sizes in DWT. These DWT categories were adopted for use in the anchor probabilistic assessment.

DWT [Tons]	Estimated Displacement [Tons]	Calculated EN	Equivalent Anchor Mass [kg] (Stockless Bower)	Fluke Length [m]	Anchor Penetration Depth [m]	
					Sand and Stiff Clay	Soft Clay
10	17	9	75*	0.34	0.34	1.03
50	85	27	120	0.40	0.40	1.20
100	170	43	180	0.46	0.46	1.37
500	850	126	360	0.57	0.57	1.72
1000	1700	200	570	0.67	0.67	2.00
5000	8500	585	1740	0.96	0.96	2.88
10000	17000	928	2850	1.13	1.13	3.39
50000	85000	2714	8300	1.60	1.60	4.81
100000	170000	4309	12900	1.85	1.85	5.55
500000	850000	12599	38500	2.65	2.65	7.94
*inferred since this size is below the range of published values						

Table 6.1 Estimated Anchor Penetration Depth

The deepest anchor threat is provided per cable zone in the CBRA table (Appendix A) on the largest vessel class identified in each zone from the latest AIS dataset and based on the dominant interpreted soil conditions in that zone.

In all cases, depths below seafloor are in metres below reference seabed level (RSBL), which is the base of the mobile seabed layer.

6.2 Anchor Probabilistic Assessment

6.2.1 Overview

The basis of a probabilistic anchor assessment is that, even though the burial depth to mitigate against the deepest anchor threat may be several metres, for much of the corridor the probability of a vessel anchor strike from the largest vessel types is so low that the risk may be considered acceptable. The approach considers the annual exposure time for each section of cable to each class of vessel.

Equation 6-1 describes the calculation for the probability of an anchor strike P_{strike}.

$$P_{strike} = P_{traffic} \times P_{wd} \times \sum_{1}^{No.ships\ in\ section} t \times P_{incident}$$

Equation 6-1 Probability of anchor strike (P_{strike})

Where:

- $P_{traffic}$ is a probability modifier based on the tolerable level of risk.
- P_{wd} is a probability modifier for the nature and depth of the seabed.
- t is vessel time in 'critical zone', $t = \frac{D_{ship}}{V_{ship} \times 8760}$
- V_{ship} is ship speed (metres per hour).
- D_{ship} is the distance travelled by a ship (metres) during which it could pose a threat to the cable.
- $P_{incident}$ is the probability of an incident occurring which would cause it to deploy an anchor.

It is assumed that the cable resilience to an anchor strike is low and therefore the consequence of an anchor strike will be cable failure. Therefore, the risk associated with emergency anchoring is directly equal to the probability of an anchor strike.

6.2.2 Inputs

6.2.2.1 $P_{traffic}$

All vessels are considered and therefore $P_{traffic} = 1$. The variation in exposure is calculated as a result of parametrically varied burial depth, which provides a clearer expression of the relationship between P_{strike} and burial depth than is achieved using the $P_{traffic}$ parameter.

6.2.2.2 P_{wd}

Table 6.2 presents the value of P_{wd} used in different water depths, which is informed by the recommendations in the Carbon Trust methodology [1].

Water Depth (m)	P_{wd} (Recommended in [[3]])
<20	0.5 (not stated at <10)
20 – 30	0.5
30 – 50	0.1
>50	0.0

Table 6.2 P_{wd} for Water Depth Ranges

6.2.2.3 V_{ship}

Guidance and discussion presented in the Carbon Trust CBRA documents ([1], [3]) indicates that vessels are only likely to deploy anchors at very slow speeds to prevent damage to the anchor system, and further that only vessels that are drifting are likely to require emergency anchoring. Therefore, a value of 2 knots was assumed and so $V_{ship} \approx 1\ m/s$.

6.2.2.4 D_{ship}

D_{ship} is calculated as the distance travelled by all vessels within each cable section, as estimated through spatial analysis of the AIS vessel track data.

For this assessment, the full width of the cable corridor and some additional conservatism (1km either side of the cable) was considered as the distance from which the cable may be vulnerable to anchor drag and strike of the cable. This is conservative, since typical anchor drag distances are on the order of 10s of metres to low 100s of metres for large vessels. However, it is assumed that the anchor deployment may not be optimal and immediate and hence vessels operating within the full 2 km wide corridor may feasibly be a threat.

6.2.2.5 $P_{incident}$

The probability of an incident that will lead to the emergency deployment of an anchor has a significant influence over the anchor probabilistic risk assessment. Published values of $P_{incident}$ range from 1.5 x 10^{-4} incidents per year to a very conservative value of 1.4×10^{-5} incidents per hour [1]. The value 1.4×10^{-5} incidents per hour is considered to be a very conservative estimate of $P_{incident}$, since it is based on a published frequency of machinery breakdown and makes the assumption that every instance of machinery breakdown will lead to an emergency anchoring situation. However, in order to maintain a conservative approach, this conservative value of $P_{incident}$ equal to 1.4×10^{-5} incidents per hour has been maintained for this CBRA.

6.2.3 Application

The following steps were undertaken to apply the probabilistic assessment method using the inputs described in Section 6.2.2:

- GIS spatial analysis was used to interrogate the latest AIS dataset of vessel tracks and determine the distance of all vessel track crossings of each DWT class within each zone.
- The vessel track distance for each cable zone (see Appendix A) and DWT class was multiplied by 12/24 to represent the distance travelled in a single year period (since the latest AIS data spans a 24-month period), which makes the reasonable assumption that there is no significant change in vessel traffic over the overall period.

- Time in the critical zone t was calculated by assuming the appropriate D_{ship} value for the vessel DWT class and dominant soil type, with a V_{ship} value of 2 knots, this time converted into metres per hour and annualised by the multiple 8760. This gives a total exposure time per cable section per vessel DWT class (see Appendix A).
- The total exposure time in the critical zone was summed across all vessel DWT classes for each cable section, to give an all-vessel total exposure time for each cable section (see Appendix A).
- The all-vessel total exposure time is converted into P_{strike} for a seabed-laid cable through multiplication with $P_{traffic}$ and P_{wd}.

6.2.4 Results

Results are presented in Appendix A as P_{strike} for a range of burial depths.

However, it is also convenient to quote the required burial to achieve a certain P_{strike} threshold. In the absence of any specification of tolerable risk from the Project, the burial required to achieve DNV Risk Categories 1 and 2 [12] have been specified, where DNV Risk Category 1 equates to $P_{strike} < 10^{-5}$ and the slightly less onerous DNV Risk Category 2 equates to $P_{strike} < 10^{-4}$.

Table 6.3 presents the resulting burial recommendations, rounded to the nearest 0.25 m. These results assume burial into a sand or stiff clay seafloor, which is consistent with the geotechnical characterisation presented in Section 2.5

Section ID	Burial Recommendation (Depth of Cover) [m RSBL]	
	DNV Category 2	DNV Category 1
Sand Bank 1	1.75	1.75
Sand Bank 2	1.00	1.75

Table 6.3 Burial Recommendations along the Sandbank

The results are different to the initial expectation, since Sand Bank 2, which is in deeper water, further from shore and hence expected to be exposed to a larger volume of larger vessels, actually requires less burial to achieve DNV Category 2, although both sand banks require the same burial amount to achieve DNV Category 1.

Upon further investigation, the elevated hazard and hence maintained burial depth of 1.75 m, even for DNV Category 2 at Sand Bank 1, is caused by a single large vessel that has made a large number of journeys across Sand Bank 1 in the past 2 years. This vessel is the HAM 316 (MMSI 244521000), a suction dredger operated by Van Oord, with a DWT of 13,700 and it is undertaking repeated journeys to the marine aggregate area near to the ECC.

It is understood that the Project is already in discussions with Van Oord regarding the marine extraction area. It is suggested that the exposure to this specific vessel threat may be achieved through stakeholder liaison rather than burial alone. For example, it is possible to make all Van Oord HAM 316 crew explicitly aware of the location of the buried cable (which is not possible for the other more random selection of vessels that might cross the cable), to the extent that vessel position relative to the cable shall be checked in the event of an emergency anchoring situation. In this case, if exposure to the HAM 316 were removed from the threat assessment, the burial recommendations reduce as shown in Table 6.4.

Section ID	Burial Recommendation (Depth of Cover) [m RSBL]	
	DNV Category 2	DNV Category 1
Sand Bank 1	1.25	1.75
Sand Bank 2	1.00	1.75

Table 6.4 Burial Recommendations along the Sandbank (assuming HAM 316 Suction Dredger threat is mitigated through stakeholder engagement with Van Oord)

Such stakeholder engagement is advised outside of the purposes of this CBRA, since suction dredging has a significant seafloor interaction and hence it is essential that the limits of the marine extraction area are adhered to by the dredging team.

6.3 Uncertainties

Some uncertainties exist in the cable burial risk assessment approach due to the requirement to make assumptions as part of the analysis. Where possible, conservative assumptions have been made, but the main uncertainties are documented here for clarity:

- **Vessel traffic intensity:** historical vessel activity is used to inform the likely density of future vessel activity and the range of vessel sizes operating in the area and this approach is considered to provide a reasonable estimate of the vessel intensity. However, the presence of an array of wind turbine generators is likely to cause most of the vessel traffic to divert from the existing unobstructed shipping routes and hence may increase the vessel exposure in the immediate vicinity of the array area. This increase is not considered to significantly change the results of the analysis.
- **Anchor penetration:** vessel anchors range in type, number and efficiency and behave differently depending on the ground conditions and loading direction. Therefore, it is difficult to accurately predict the penetration depth associated with an anchor for a given vessel size. The estimates used in this assessment take a coarse approach, premised on best practice guidance for similar applications, and therefore are considered appropriate and relatively conservative. However, the uncertainty associated with this aspect of the analysis is high and the sensitivity of the results to variations in this parameter is also high.
- **Exposure time:** the cumulative time that a cable is exposed to vessels is a function of the zone around the cable that is considered the critical zone in which an anchor deployment could result in a cable strike. This critical zone (D_{ship}) is estimated based on anchor drag distances using conservative estimates of anchor efficiencies in a simple kinetic energy calculation. The calculation of drag distance itself is relatively crude but is considered appropriate for this study. The use of this to define D_{ship} and hence exposure time t is relatively conservative because no consideration is given to the direction of vessel drift in the event of an emergency anchoring situation (i.e. the vessel may drift parallel to or away from the cable).
- **Probability of an incident ($P_{incident}$):** This is another difficult element of the anchor strike equation to estimate to an appropriate level of detail for CBRA. A range of published values are available and a the most conservative estimate of $P_{incident}$ has been adopted from this range, which is based on a published frequency of machinery breakdown and hence assumes that every instance of machinery breakdown will lead to an emergency anchoring situation. Reduction in conservatism of this element would have a significant impact on the results.

7 Conclusions and Recommendations

7.1 Background

OWC has developed a local CBRA for a relatively limited section of the export cable from the Project crossing the Annex I Sandbanks.

The scope was to review existing relevant data, including recently acquired geophysical and geotechnical survey data and shipping traffic data along the cable section crossing the sandbank and derive optimised burial strategy and provide recommendation of alternative mitigation measures to be adopted where deemed appropriate.

7.2 Approach

The CBRA is based on the 'Carbon Trust Cable Burial Risk Assessment Methodology, Guidance for the preparation of Cable Burial Depth of Lowering Specification CTC835', February 2015 [1], as well as the corresponding 'Application Guide for the specification of the Depth of Lowering using the Cable Burial Risk Assessment (CBRA) methodology', December 2015 [3].

An initial threat assessment was undertaken to qualitatively assess the threats to the integrity of the cable, focusing on hazards that can be mitigated through cable burial, and drawing on the relevant datasets and reports.

The threats identified by the threat assessment as requiring mitigation by burial are as follows:

1. Shipping (emergency anchoring): Anchor penetration into the seabed is considered one of the most onerous anthropogenic risks to cables from accidental/emergency deployed anchors penetrating into the seabed.
2. Benthic Fishing: Damage to cables by fishing equipment.

7.3 Emergency Anchoring from Shipping

An anchor probabilistic risk assessment was undertaken to determine the burial depth required to achieve DNV Risk Categories 1 and 2 where DNV Risk Category 1 equates to $P_{strike} < 10^{-5}$ and the slightly less onerous DNV Risk Category 2 equates to $P_{strike} < 10^{-4}$ (P_{strike} is the probability of an anchor strike in the event of an emergency on the vessel).

This study was informed by a 24-month record of vessel activity (AIS data) over the two sand banks in the area of interest, procured specifically for this study. The AIS data comprised 6342 records for Sand Bank 1 and 3935 records for Sand Bank 2 between January 2021 and December 2022 (where a single record represents a single point on a single vessel's journey, typically transmitted at 2-to-3-minute intervals). When records were converted into vessel tracks (based on a unique combination of vessel MMSI and day of travel), 320 tracks were recorded over Sand Bank 1 and 730 tracks were recorded over Sand Bank 2, over the same two-year period.

Table 7.1 presents the resulting burial depth recommendations (DoC), rounded to the nearest 0.25 m. DoL should be at least as much as DoC.

Section ID	Burial Recommendation (Depth of Cover) [m RSBL]	
	DNV Category 2	DNV Category 1
Sand Bank 1	1.75	1.75
Sand Bank 2	1.00	1.75

Table 7.1 Burial Recommendations along the Sandbank

The elevated hazard and hence maintained burial depth of 1.75 m, even for DNV Category 2 at Sand Bank 1, is caused by a single large vessel that has made a large number of journeys across Sand Bank 1 in the past 2 years: the HAM 316, a suction dredger that is undertaking repeated journeys to the marine aggregate area near to the ECC.

It is suggested that the exposure to this specific vessel threat may be achieved through stakeholder liaison rather than burial alone, by making all HAM 316 crew explicitly aware of the location of the buried cable to the extent that vessel position relative to the cable shall be checked in the event of an emergency anchoring situation. In this case, if exposure to the HAM 316 were removed from the threat assessment, the burial recommendations reduce as shown in Table 7.2.

Section ID	Burial Recommendation (Depth of Cover) [m RSBL]	
	DNV Category 2	DNV Category 1
Sand Bank 1	1.25	1.75
Sand Bank 2	1.00	1.75

Table 7.2 Burial Recommendations along the Sandbank (assuming HAM 316 Suction Dredger threat is mitigated through stakeholder engagement with operator)

7.4 Benthic Fishing

Interaction with fishing gear such as otter boards or beam trawls is assumed to have the potential to cause significant damage to the cable. Seabed penetration from trawling is expected to be limited, and shipping traffic data indicate that fishing activity across the sand banks is relatively low (although this may be an under-representation). Therefore, burial requirements to mitigate against fishing are typically not significant.

It is recommended that a minimum burial of 0.5 m is achieved to mitigate against benthic fishing, which includes allowance for trawling gear digging into the seabed in rugged areas (e.g., the flanks of sand banks), which may increase the penetration more than during standard operations.

7.5 Recommendations

Burial recommendations to mitigate against benthic fishing and emergency anchoring are summarised in Section 7.4 and 7.3 respectively.

The decision of what level of risk, and hence what magnitude of P_{strike} that should be tolerated, is generally borne by the development Project team, since this decision must be evaluated as a cost-benefit scenario, along with all other Project risks. OWC experience shows that developers typically evaluate the required depth of lowering to achieve both DNV Risk Category 1 ($P_{strike} < 10^{-5}$) and DNV Risk Category 2 ($P_{strike} < 10^{-4}$) and use these results to evaluate, alongside the cost differential for the different amounts of cable burial. This only occurs once EPCI contractors have been engaged. In cases where only a single tolerable level of risk is required to be assessed, it is typical for developers to require the burial depth to achieve $P_{strike} < 10^{-5}$ in our experience.

Stakeholder engagement with the operator of the HAM 316 suction dredger, as described in Section 7.3, is advised, to reduce the requirement to bury the cable excessively to protect against the exposure from a single known vessel. However, beyond the purposes of this CBRA, communication with the dredging company is advised since suction dredging has a significant seafloor interaction and hence it is essential that the limits of the marine extraction area are adhered to by the dredging team.

It is typical for a Factor of Safety to be applied to each of the cable threats. It is also important to note that as part of the CBRA methodology, sufficient conservatism is considered to exist in the inputs to the anchor probabilistic risk assessment that an additional Factor of Safety is unlikely to be warranted.

In conclusion, when defining an acceptable burial class, it is important to consider any future commercial risk implication resulting from a deeper burial option with respect to EPCI procurement cost. This will also have an impact on the cost of cable de-burial in case of cable repair operations. The balance between a deeper and shallower burial option, goes beyond the purpose of a CBRA and should fall within the developer's definition of degree of tolerable risk considering a variety of factors involving commercial risk and bankability requirements with particular emphasis to Offshore Transmission Owner's Projects carrying the associated financial constraints.

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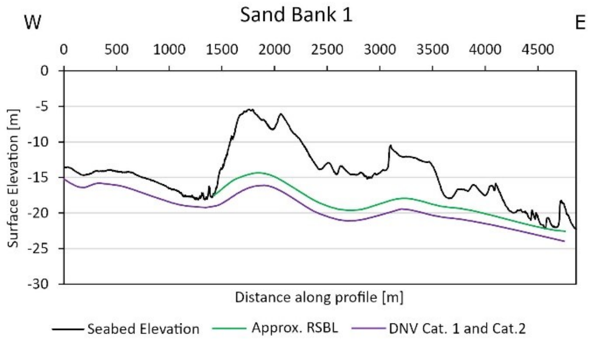
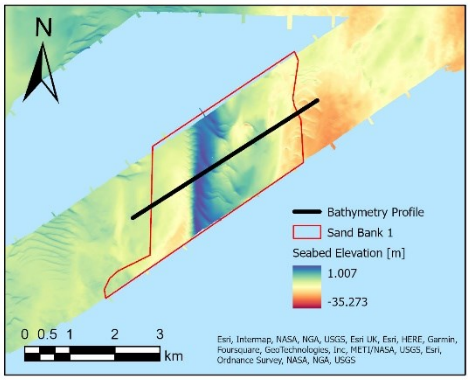
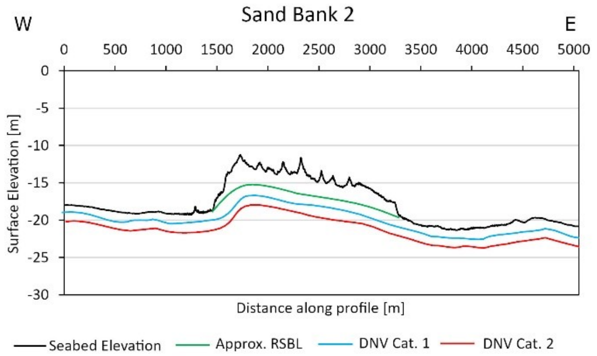
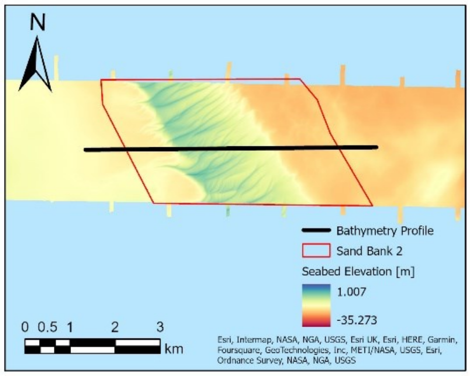
9 Appendix A – Shipping Analysis and Anchor Penetration Assessment









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