K7. Cable Burial Risk Assessment - Export Cable Corridor

Maryland Offshore Wind Project - Design report

Preliminary cable burial risk assessment Export cable corridor

US Wind, Inc.
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A	29 August 2022	Issued for review	JLA / MHA	FAA	AMA
B	4 November 2022	Geophysical data update	JLA	LMC	AMA
C	9 November 2022	Client comments implemented	JLA	PAG	AMA

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ABBREVIATIONS

Abbreviation	Description
AIS	Automatic information system
ALARP	As low as reasonably practicable
ASL	Average seabed level
CBRA	Cable burial risk assessment
CPT	Cone penetration test
DNV	Det Norske Veritas
DoL	Depth of lowering
DWT	Dead weight tonnage
EC	Export cable
ECC	Export cable corridor
ECR	Export cable route
IRB	Indian River Bay
KP	Kilometre point
LAT	Lowest astronomical tide
MDOL	Minimum depth of lowering
MLLW	Mean lower low water
SSB	Stable seabed
SSS	Side scan sonar
TOC	Thickness of cover
TOP	Top of product
t_{soft}	Thickness of soft soil
TSS	Traffic separation scheme
UXO	Unexploded ordnance
VC	Vibracore
WT	Wood Thilsted
WDA	Wind development Area
WEA	Wind Energy Area
WTG	Wind turbine generator

1. Introduction

1.1. Project description

US Wind, Inc. (US Wind) is developing the Maryland Offshore Wind Project (MOWP), an offshore wind energy project of up to approximately 2 gigawatts of nameplate capacity within OCS-A 0490 (the Lease), a Lease area of approximately 80,000 acres located approximately 18.5 km (11.5 miles) off the coast of Maryland on the Outer Continental Shelf. Under a Project Design Envelope (PDE) approach, the MOWP could include as many as 121 wind turbine generators (WTG), up to four offshore substations (OSS), and one meteorological tower (Met Tower) in the Lease area. The MOWP will be interconnected to the onshore electric grid by up to four new 230-275 kV export cables to new US Wind substations, with an anticipated connection to the existing Indian River Substation near Millsboro, Delaware.

Figure 1.1 shows the location of the MOWP area on the Maryland Outer Continental Shelf (OCS) as well as the offshore export cable corridors (ECCs). The trapezoidal-shaped Lease area includes nine full OCS Lease Blocks and portions of 11 other OCS Lease Blocks. Export cables will extend from each OSS to a common offshore ECC that extends along the Lease boundary (or several boundaries) to near the northwest corner of the Lease area. The energy generated from the Project will make landfall through a common offshore ECC from the Lease area to one of two optional landfall locations on the Delaware shoreline. The two offshore ECCs are designated as: a) ECC 1, a southern option that makes landfall at 3R's Beach; and b) ECC 2, a northern option that makes landfall at Tower Road. Both offshore ECCs would require that the Project's onshore ECC crosses the Delaware State Tidelands, inshore of the State/Federal jurisdictional boundary, located 3 statute miles offshore of the coastline. After making landfall, the onshore export cables may be submarine via onshore ECC 1 through Indian River Bay, or land-based if a terrestrial route is pursued to the point of interconnection.

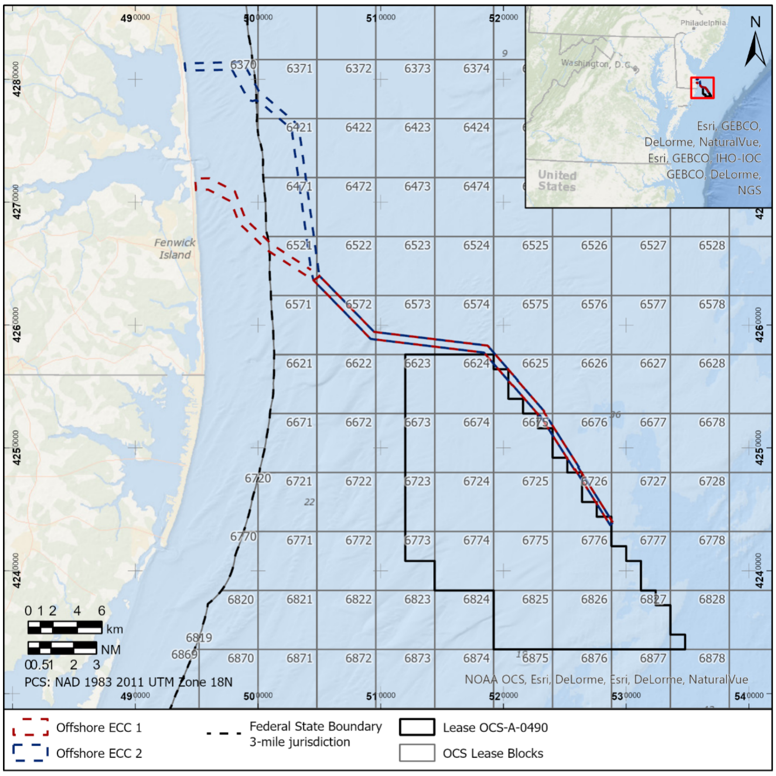


Figure 1.1: US Wind Lease area OCS-A-0490 location with OSS Lease Blocks and Offshore Export Cable Corridors (ECCs).

Wood Thilsted (WT) is commissioned to conduct a preliminary cable burial risk assessment (CBRA) for the two offshore ECCs as well as the onshore ECC1 through IRB.

The CBRA comprises (but is not limited to):

- Qualitative risk assessment considering seabed conditions, bathymetry, shipping and fishing activities.
- Quantitative risk assessment determination of burial depths for a range of risk-return periods.

1.2. Available data

Table 1.1: Available data.

Data	Description	Source
Route Boundary	Cable corridor boundaries for both ECCs and Indian River Bay	Client provided shape files
AIS data	AIS tracking data for a period of two years from 1 January 2018 to 31 December 2019	AccessAIS [1]
Geotechnical and geophysical survey	Boreholes (BH) and cone penetration tests (CPT) at exploratory locations. MBES bathymetry, SSS imagery, medium penetration sub-bottom profiles, shallow penetration sub-bottom profiles and MAG data	Alpine [2], [3] and Gardline [9] [10] [11]
Geotechnical and geophysical survey	BH and CPT at MarWin WTG locations. MBES bathymetry, side scan sonar, sub-bottom profiler, transverse gradiometer-configured magnetometer, single-channel ultra-high-resolution seismic, multi-channel ultra-high-resolution seismic and grab samples	TDI 2021 [21] [20], Fugro 2022 [8]
Fisheries assessment report	-	Sea Risk Solutions LLC [17]
Shallow Geohazards Interpretive Report (Draft)	Details the high-resolution geophysical data and grab sample acquisition (TDI and Fugro), and assesses the seafloor and shallow geologic hazards and constraints that may affect the MOWP	GEMS [12]

1.3. Burial definition

The following definitions relevant for the understanding of the cable burial recommendations provided in this report are illustrated on Figure 1.2 and Figure 1.3. Where a definition is noted as a level this should be understood as being referenced to MLLW (or another agreed reference depth). Definitions given as a depth or distance are referenced between two levels and not to a particular datum.

- Sea level, MLLW; Mean lower low water.
- Stable seabed (SSB); The reference level at which the seabed is considered static i.e. not mobile.
- As-measured seabed; The seabed level to the noted datum at the moment of survey. This is commonly quoted prior to installation.
- As-installed seabed level; The as-measured seabed level at time of installation.
- Engineered seabed level; The seabed level resulting from seabed preparation, e.g. dredging, prior to cable installation
- Top of product (TOP); The shallowest level of the cable within the given measured range i.e. every metre or every 5 metres
- Depth of lowering (DoL); The distance from average seabed to TOP.
- Minimum depth of lowering (MDOL); The minimum DoL calculated by the CBRA to consider the cable safe referenced as depth below SSB.
- Depth of cover (DOC); The distance between the disturbed seabed (directly over the cable) and the TOP.

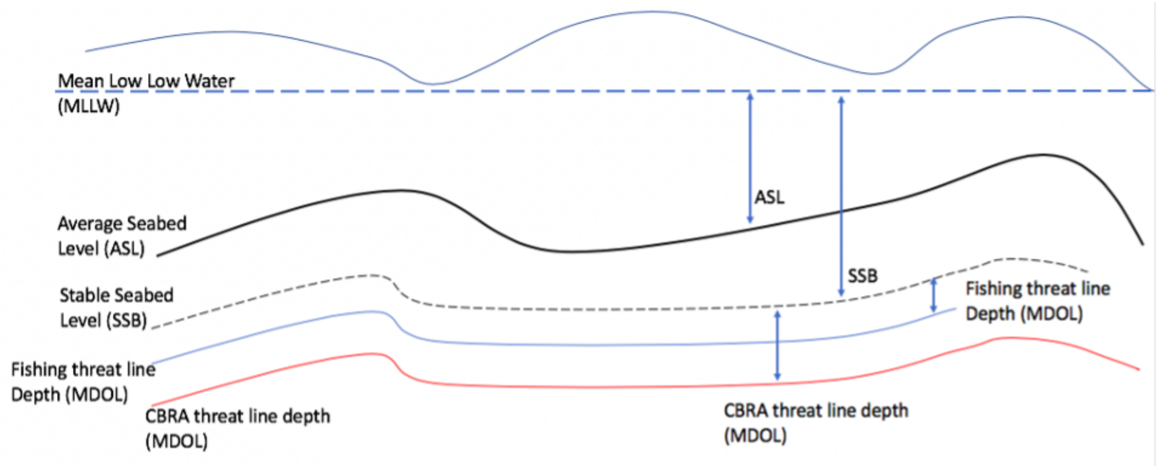


Figure 1.2: Global depth of lowering definitions.

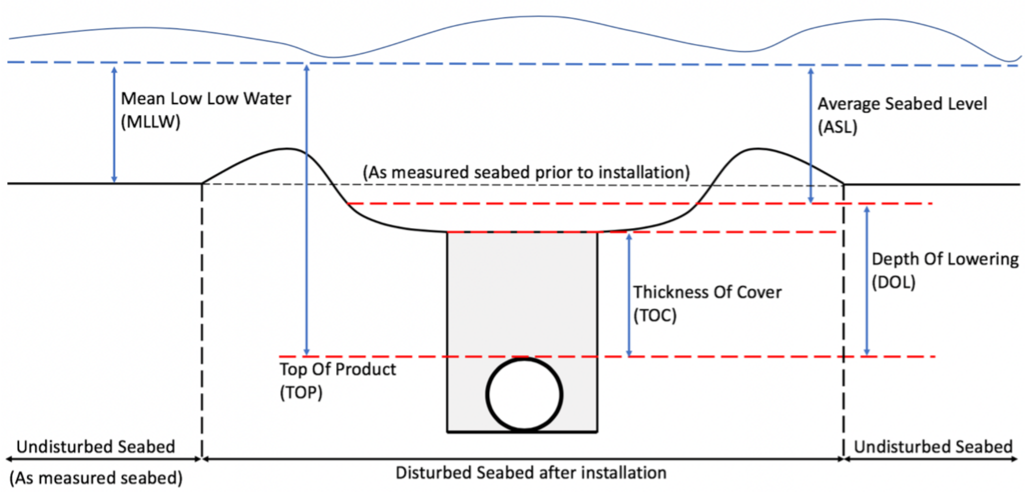


Figure 1.3: Detailed depth of lowering definitions.

1.4. Constraints and limitations

This desk study is prepared considering the particular instruction and requirements of US Wind. It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

The CBRA is based on the data available at the time of writing. The results presented are suitable for planning and are indicative of the depth of lowering (DoL). The currently available data, see Table 1.1, is considered appropriate forcharacterization of the ground conditions and burial constraints for this preliminary analysis.

2. Route segments

The routes analysed in this study are taken as the:

- Centrelines through ECC1 and ECC2 cable corridors
- Onshore ECC1 area in Indian River Bay (IRB) as defined by the zone shown on Figure 1.1

A route position list (RPL) is extracted using a GIS platform. Four segments are adopted for quantitative analysis as shown in Figure 1.1:

- North landfall (ECC2)
- South landfall (ECC1) - from shore to the junction of ECC1 and ECC2
- Common corridor (ECC1 and ECC2) - from the junction of ECC1 and ECC2 to the Lease area
- IRB (onshore ECC1)

Segmentation of the routes is predominantly based on soil conditions. RPL details are presented for each segment in Section 3.3. A graphical representation of the vessel traffic for each segment is presented as part of the probabilistic analysis results in Appendix B and C.

3. Site conditions

The site conditions are assessed along the ECC routes based on geophysical and geotechnical survey data, see Table 1.1.

3.1. Geophysical survey results

Geophysical survey results are used for qualitative risk assessment. Further discussion is presented in Section 4.

3.2. Geotechnical investigations

Geotechnical survey locations along ECC1, ECC2 and onshore ECC1 are shown on Figure 3.1 [2] [19]. Grab samples are not considered due to the limited depth of investigation. There is typically a vibracore (VC) or cone penetration test (CPT) available for each 1 km of cable.

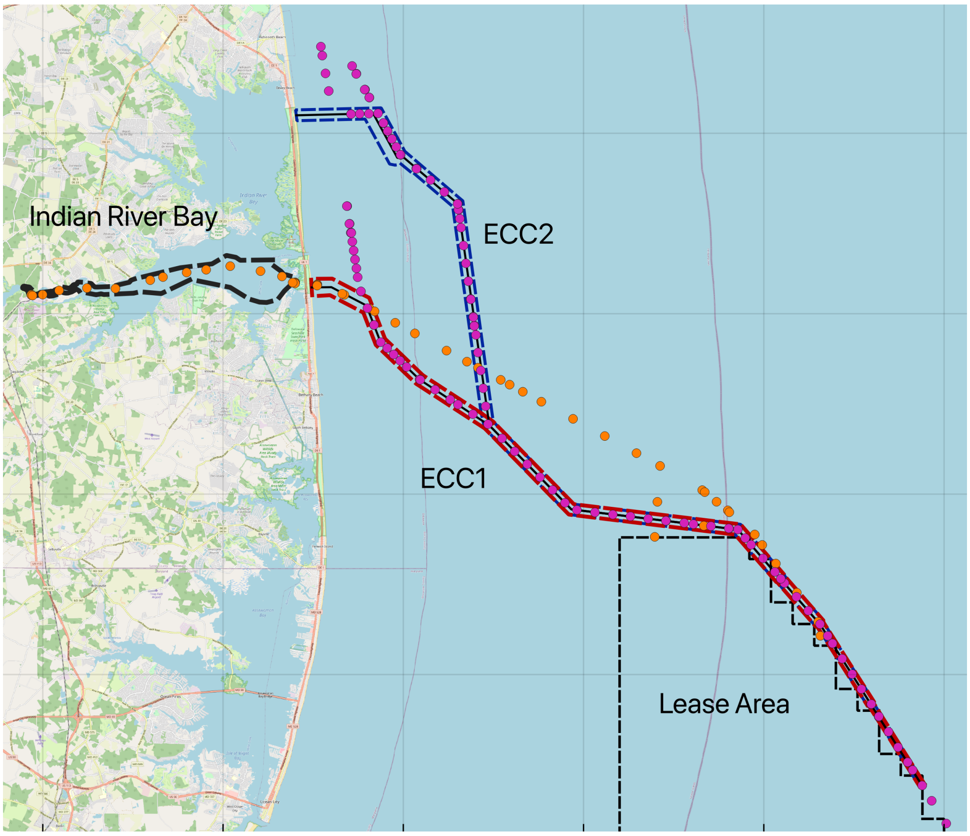


Figure 3.1: Geotechnical survey locations - WEA. Orange (Alpine [2]). Magenta (TDI-Brooks [19]).

3.3. Classification of soils for quantitative assessment

Understanding the geotechnical conditions is an important factor in determining the required burial depth and to identify any obstacles/challenges to the installation process. The soil stratigraphy along the ECCs are categorised as either; soft soil or hard soil with the thickness of soft soil (t_{soft}) accounted for by applying a two-layer soil model. This classification is undertaken to align with Carbon Trust guidance for cable burial risk assessments. The Carbon Trust guidance [6] classifies soft soil as soft silt or clay (with the non-soft category being sands and firm to stiff clays). WT adopt this guidance as general basis for identification of soft and hard soil for the US Wind ECCs.

t_{soft} is interpreted from VC logs [15] and CPT results [19] and supplemented by engineering judgement. For example, if a clay layer is observed within 1.5 m of the seafloor the profile is considered soft because it is assumed the upper 1.5 m of material will be disturbed during installation exposing the underlying clay material. The largest value of t_{soft} is conservatively adopted for cable sections where multiple observations are available. A value of 10 m is used for t_{soft} to indicate locations where the presence of soft soil extends through the entire depth of the investigation location. A full list of test locations and the interpreted t_{soft} is presented in Appendix A.

3.3.1. South landfall

The south landfall section is part of ECC1. Figure 3.2 presents the south landfall route alignment and t_{soft} from geotechnical interpretation. Table 3.1 presents the RPL and t_{soft} adopted for quantitative CBRA.

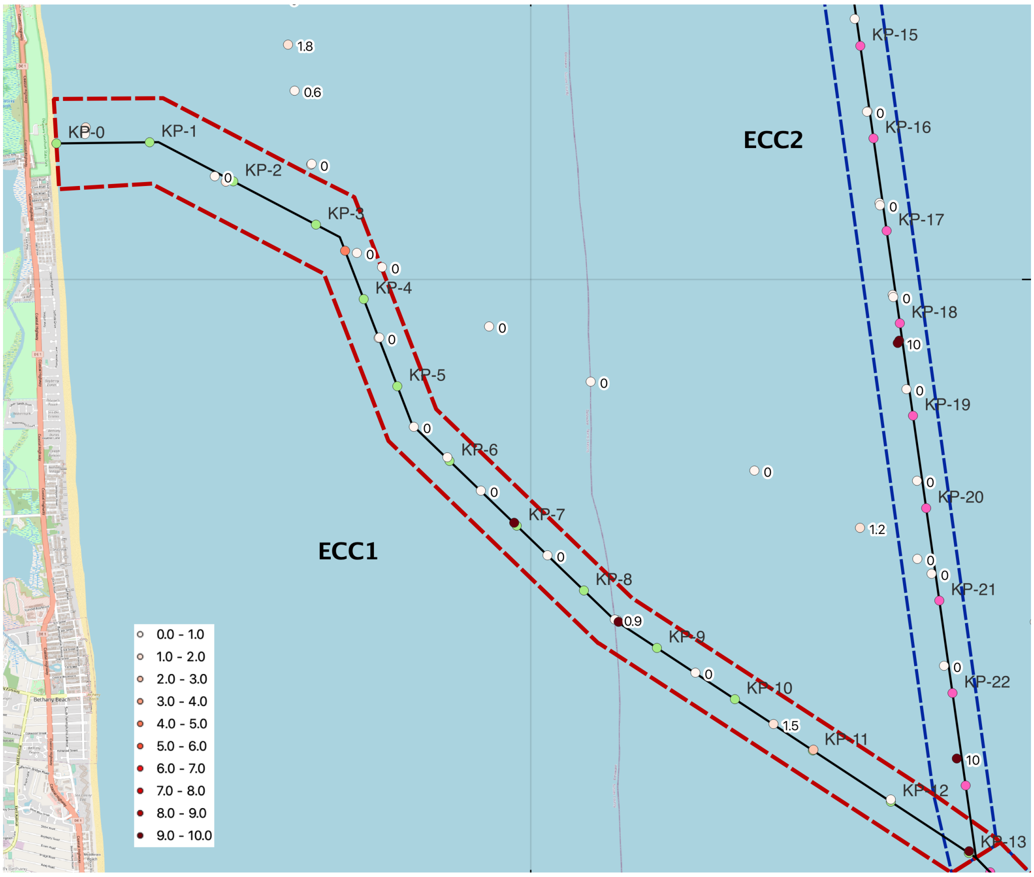


Figure 3.2: Results of soft soil interpretation for south landfall segment. Green dots are KP markers.

Table 3.1: Geotechnical classification of south landfall segment (ECC1).

ID	KP	t_{soft} (m)
1	0 - 3	0
2	3 - 4	4.5
3	4 - 7	0
4	7 - 9	10
5	9 - 10	0
6	10 - 12	2.6
7	12 - end	10

3.3.2. Main corridor

The main corridor section is part of ECC1. It extends from the junction of north and south landfall sections to the Lease area. Figure 3.3 presents the main corridor route alignment and t_{soft} from geotechnical interpretation. Table 3.2 presents the RPL and t_{soft} adopted for quantitative CBRA.

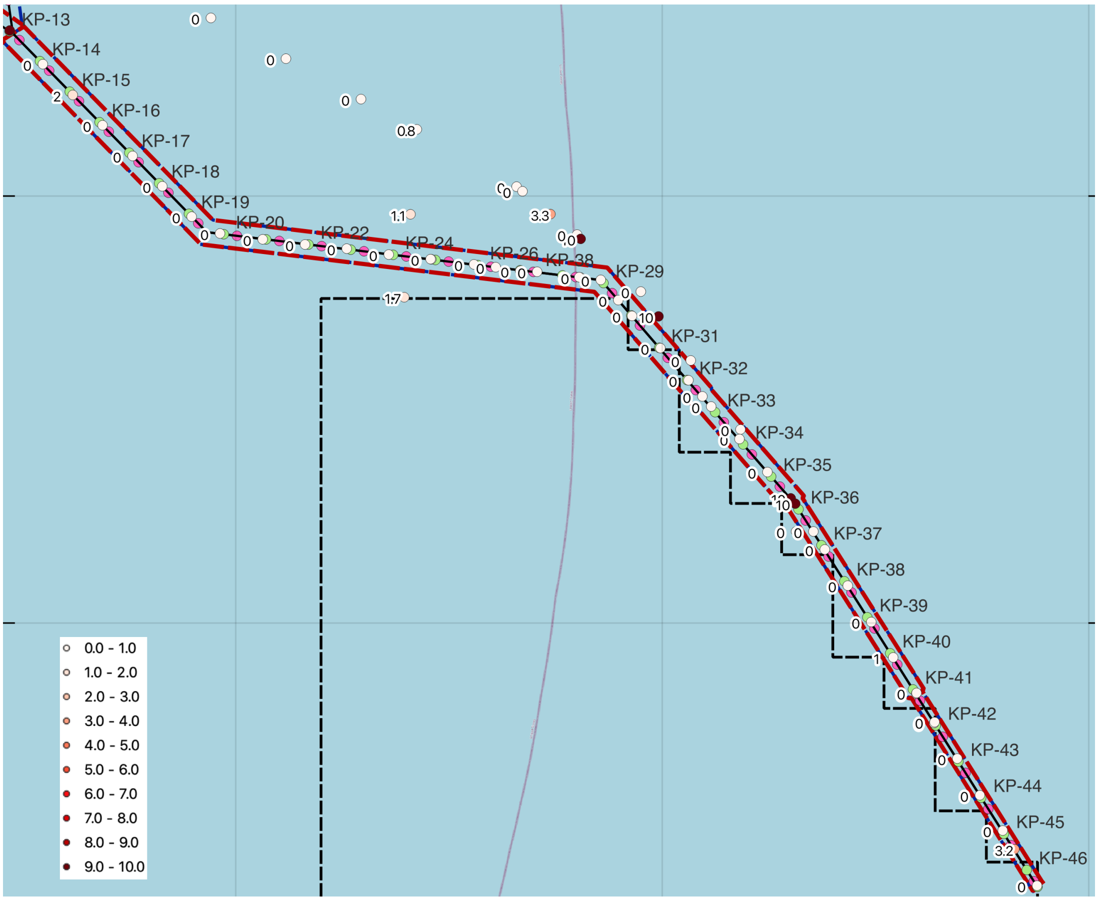


Figure 3.3: Results of soft soil interpretation for main corridor segment. Green dots are KP markers.

Table 3.2: Geotechnical classification of main corridor segment (ECC1).

ID	KP	t_{soft} (m)
1	13 - 14	10
2	14 - 15	0
3	15 - 16	2
4	16 - 35	0
5	35 - 36	10
6	36 - 40	0
7	40 - 41	1
8	41 - 45	0
9	45 - 46	3.2
10	46 - end	0

3.3.3. North landfall

The north landfall section is part of ECC2. Figure 3.4 presents the north landfall route alignment and t_{soft} from geotechnical interpretation. Table 3.3 presents the RPL and t_{soft} adopted for quantitative CBRA.

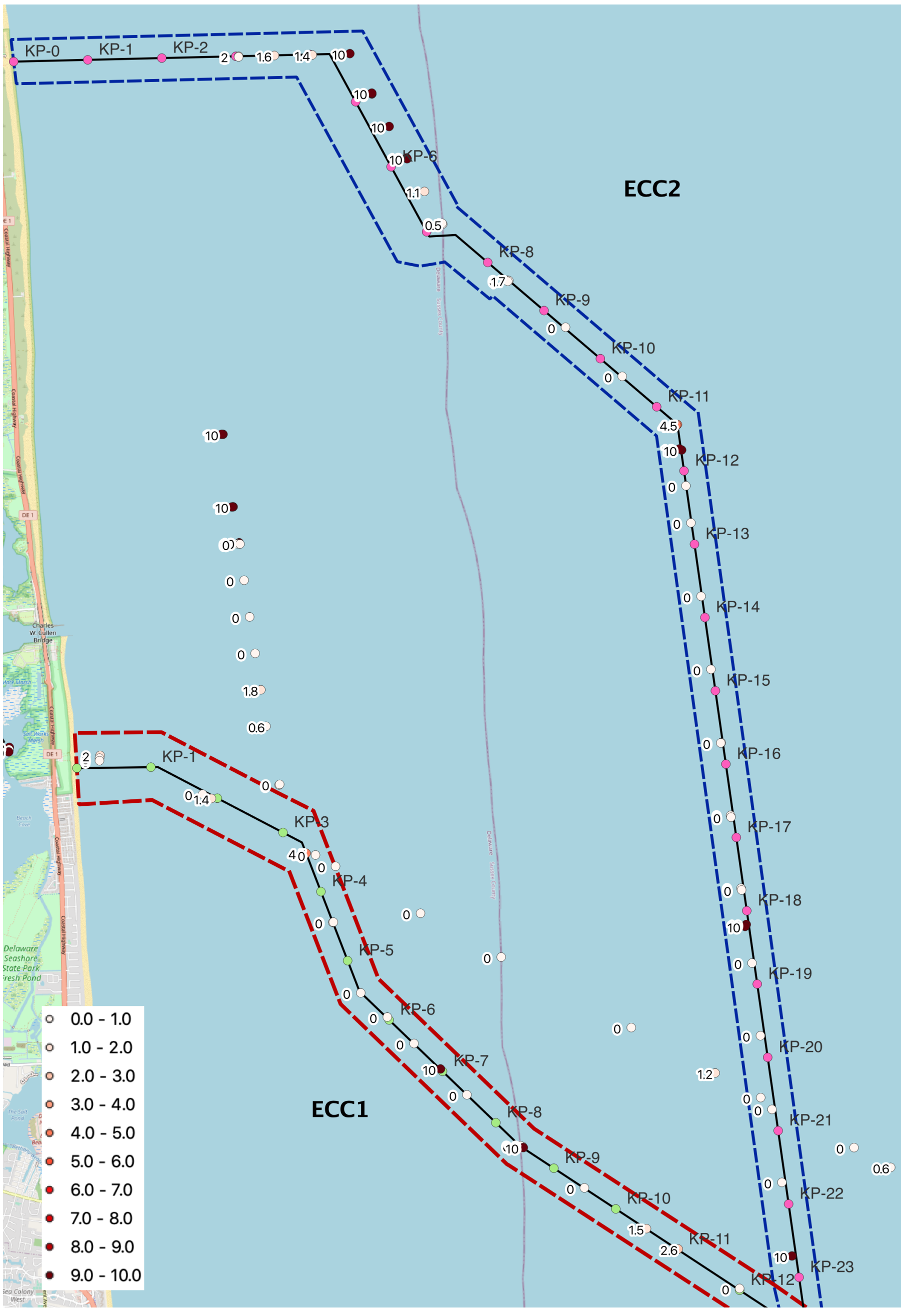


Figure 3.4: Results of soft soil interpretation for north landfall segment. Green dots are KP markers.

Table 3.3: Geotechnical classification of north landfall segment (ECC2).

ID	KP	t_{soft} (m)
1	0 - 4	2
2	4 - 6	10
3	6 - 9	1
4	9 - 11	0
5	11 - 12	10
6	12 - 18	0
7	18 - 19	10
8	19 - 22	0
9	22 - end	10

3.3.4. Indian River Bay

Figure 3.5 presents the Onshore ECC1 and t_{soft} from geotechnical interpretation. The Onshore ECC1 area is analysed as one zone given the relatively limited cable length. Furthermore, analysis of the geotechnical survey results suggest that the majority of the seafloor is expected to comprise soft sediments. Therefore, soft soil is adopted for the entire Onshore ECC1 for quantitative analysis.

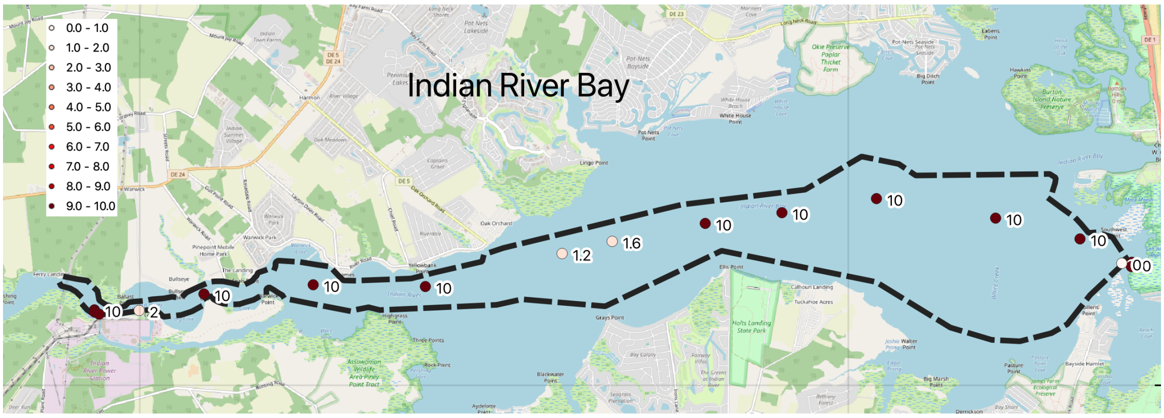


Figure 3.5: Results of soft soil interpretation for the Onshore ECC1.

4. Qualitative risk assessment

4.1. Anthropogenic risks

4.1.1. Shipping activity

The Lease area is located just south of the Delaware Bay Southeastern Approach Traffic Separation Scheme (TSS). Traffic separation schemes are usually created in areas with heavy traffic in different directions. It is an area where the navigation of vessels is highly regulated with lanes of vessels travelling the same direction.

The eastern half of the main ECC runs along this TSS. Shipping traffic is identified from AIS data. Figure 4.1 shows the AIS tracks crossing the main ECC. Cargo vessel traffic is shown in blue. It is expected that cargo vessels are less likely to navigate through the Lease area, hence fewer vessels may be expected to cross the export the cable once the windfarm is operational.

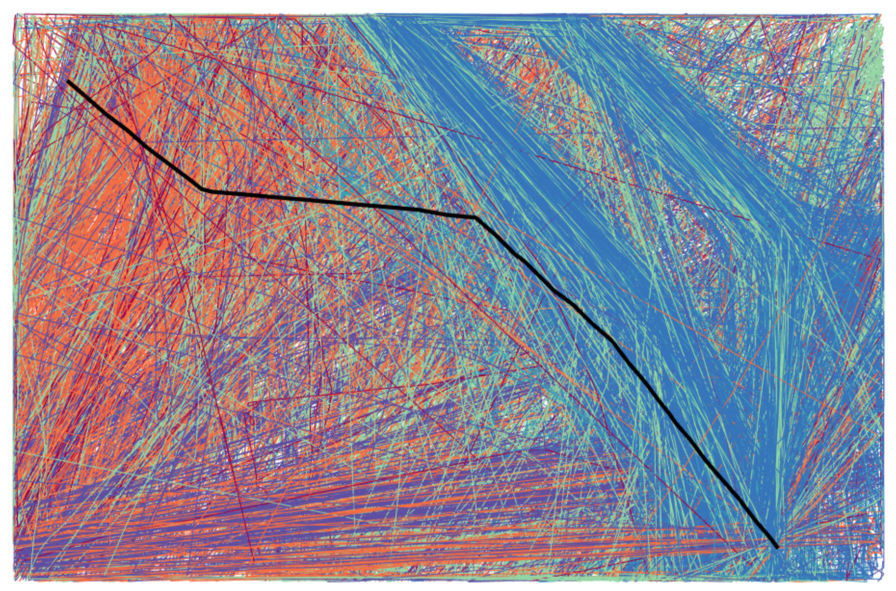
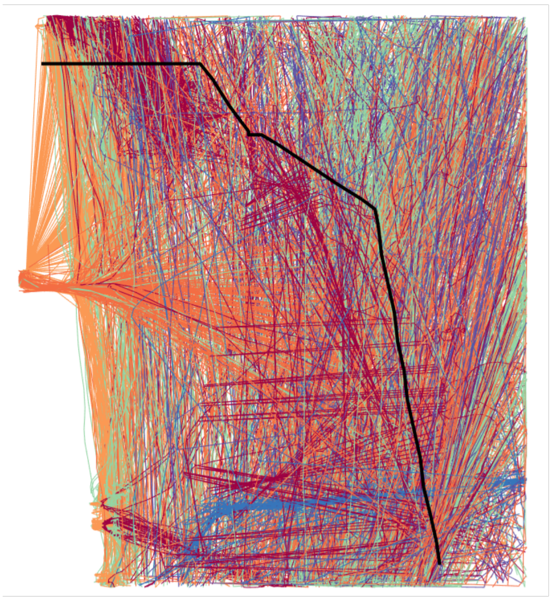
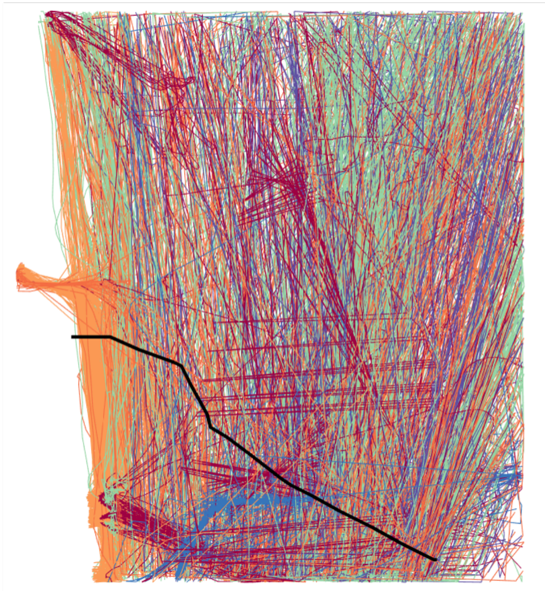


Figure 4.1: AIS Tracks for vessels crossing the main ECC.

Figure 4.2 shows the AIS tracks for vessels crossing the northern and southern ECC landfall sections. Cargo traffic is shown in blue. The data shows very little shipping traffic crossing either of the ECCs in these sections relative to the main corridor section.



(a) ECC Northern landfall



(b) ECC Southern landfall

Figure 4.2: AIS Tracks for vessels crossing the landfall ECC alternatives.

Figure 4.3 shows the AIS tracks for vessels crossing the Onshore ECC1. Cargo traffic is shown in blue. The data shows no shipping traffic in the Onshore ECC1.

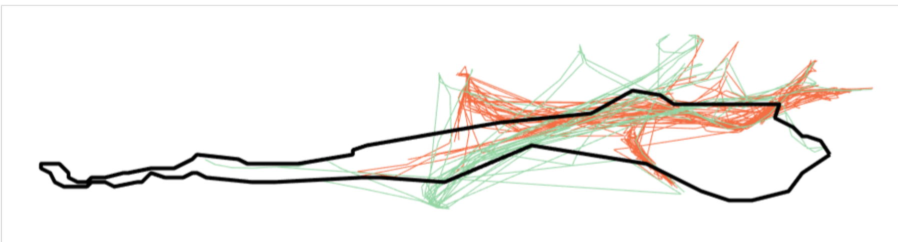


Figure 4.3: AIS Tracks for vessels crossing the Onshore ECC1.

The largest vessels identified crossing the Main ECC has an estimated dead weight tonnage (DWT) of 100,000 tonnes and are identified as cargo vessels. The largest vessel identified for the north and south landfall has an estimated DWT of 40,000 tonnes and only one crossing from this size vessel was identified from AIS data. The second and third largest vessels crossing the north and south landfall have an estimated DWT between 10,000 and 20,000 tonnes. These massive vessels can cause severe damage in case of an anchor strike under accidental/emergency circumstances. The largest vessels identified in the Onshore ECC1 has an estimated DWT of 44 tonnes and are mainly identified as pleasure crafts from AIS data.

4.1.2. Fishing activity

A fisheries assessment report in and around the MOWP area was conducted by Sea Risk Solutions LLC [17]. The findings from this assessment are summarised below.

Bottom otter trawl fishing activity exists to a limited extent between KP-8 and KP13 of ECC2.

Fishing with pots and traps occurs diffusely throughout both ECCs. It is most intensive towards the shoreline from KP-0 to KP-3 of both ECCs and at the end of the main corridor by the Lease area from KP-31 to KP-46. This type of fishing can cause challenges for the survey and installation operations because caution must be taken in order not to snag either the vertical buoy lines or the lines connecting the traps. Black seabass traps are most often set in strings of about 12 to 36 traps connected by a ground line. This gear may need to be removed where cables are planned to cross. This is to install the cable without damaging the gear as well as protect the cable. It is expected that fishing using pots will contribute to the traffic intensity. Additionally pots and traps occurs in the outer part of the Onshore ECC1.

Bottom gillnet fishing occurs to some extent along the main ECC at KP-29 to KP-44, however this type of fishing has low penetration of the seabed (10 cm for anchors) and is not of high concern to the cable. This type of fishing gear should be removed before installation if the cable alignment crosses gillnet locations.

Although very little, if any, commercial clam dredge activity exists along the ECCs nearshore of the Lease area the external aggression risk from this type of fishery should be considered when planning cable burial. According to the North American Submarine Cable Association, NASCA, surf clam dredging operations with hydraulic dredges penetrate the seabed more than other mobile fishing and harvest gear. Historically submarine telecom cables in the Northeast US seaboard have suffered several cases of damage from hydraulic clam dredges and incident of penetration up to 1 m has been reported.

Targeted commercial sea scallop fishery has not been observed within the ECCs and the scallop fishing activity found is most likely to be transit to and from port.

Hiddink et al. [17] conducted a systematic literature review of both North American and European studies that provide measurements of fishing gear penetration depth, including any study for which penetration depth of a fishing gear or a gear component (e.g., doors, sweeps,and bridles of an otter trawl) was measured or inferred. The three primary fishing practices of concern identified were; trawling, towed dredging and hydraulic dredging. These fishing methods are illustrated in Figure 4.4. The penetration depths into the seafloor were modelled by Hiddink et al. [13] and are shown in Table 4.1.

Carbon Trust recommendations [6] states that the maximum penetration depth of towed fishing techniques is 0.3 m. It is, however, common practice to apply a safety factor of 2 to the calculated penetration of fishing gear.

Based on the available data the recommended minimum cable burial depth to protect against fishing is 1 m. This value is the conservative choice for this preliminary analysis to account for the incident reports from hydraulic dredges.

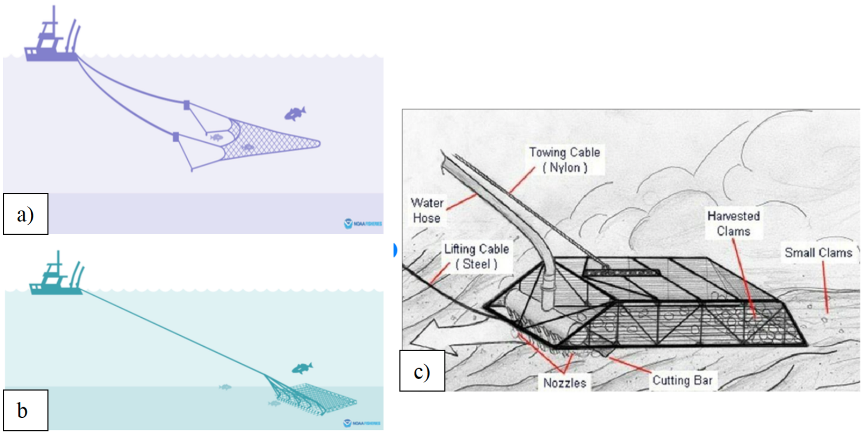


Figure 4.4: Fishing gear: a) Otter trawl. b) Towed dredge. c) Hydraulic dredge.

Table 4.1: Predicted fishing gear penetration [13].

Gear	Penetration Mean $\pm$ standard deviation
Hydraulic Dredge	0.161 $\pm$ 0.058
Towed Dredge	0.055 $\pm$ 0.022
Otter trawl	0.024 $\pm$ 0.011

As has been the case with the Block Island Wind Farm and the Coastal Virginia Offshore Wind Pilot Project, it is likely that the presence of turbines will attract additional recreational activity. It should be expected that recreational fishing activity, and sightseeing, will increase in the offshore area once the wind farm is in operation.

4.1.3. Potential unexploded ordnance

The presence of unexploded ordnances (UXO) is possible due to present and past military use in Warning Area 386 (W-386) [3]. W-386 is special-use airspace over VACAPES OPAREA-Areas 1-12 off the coast of Maryland in which missile, gunnery, and rocket exercises using conventional ordnance are authorized [23]. Many minor magnetic anomalies were identified with potential to be related to shallow buried UXO [3].

4.1.4. Existing infrastructure

Two fish havens or existing recreational fishing hotspots are identified near the northern part of ECC2 according to National Oceanic and Atmospheric Administration (NOAA). The exact coordinates of these areas are not known to WT at this point in time. These areas are usually simulating natural reefs and used for recreational purposes and should be avoided in cable routing.

Pot/trap fishing is known in the ECCs. This method of fishing can complicate installation operations. Therefore, these areas should be avoided if possible.

No wreck contacts were interpreted by TDI or Fugro within the current ECC boundaries, although two possible wreck contacts were interpreted just to the south of the common ECC boundary by Fenwick Shoal and one additional possible wreck contact was interpreted just to the north of the northern most ECC2 boundary. These possible wrecks are marked on Figure 4.5 and 4.6. While no wreck locations have been interpreted by TDI and Fugro within the ECC boundaries, one potential cultural resource has been interpreted within the ECC Preliminary Area of Potential Effect in [16].

No cables or pipelines are identified according to NASCA maps.

4.1.5. Dredging and dumping sites

No dredging or dumping sites are identified from nautical charts for either ECC.

4.1.6. Designated anchorages

No designated anchorages are identified from nautical charts for either ECC.

4.2. Natural risk

As the geophysical survey reports from the inshore and IRB surveys are still pending, the natural risk assessment is considering mainly Federal Waters. For State Waters including IRB the natural risk assessment is inferred based on the Alpine 2017 survey [2]. The natural risk assessment of state waters is to be updated once data becomes available.

4.2.1. Seabed contacts

Seafloor features have been reported by GEMS [12] from MBES, SSS, and MAG based on data acquired by TDI and Fugro in 2021-22. A total of 3,894 sonar point contacts have been identified within the combined ECCs.

The SSS point contacts generally represent modern debris associated with shipping, storms, fishing, or exploration activities, or are geologic in nature [12]. By far most contacts, 2,488, are unspecified debris or unknown items. Debris of anthropogenic or unknown classification is scattered throughout the ECCs.

Contacts interpreted to be anthropogenic or of unknown origin are presented in Figure 4.5 and 4.6 [12] following reclassification by WT to align the combined SSS contact database (using TDI's primary contact classification and Fugro's secondary contact classification) [24]. Interpretation of contacts with regard to cultural resources is provided in [16].

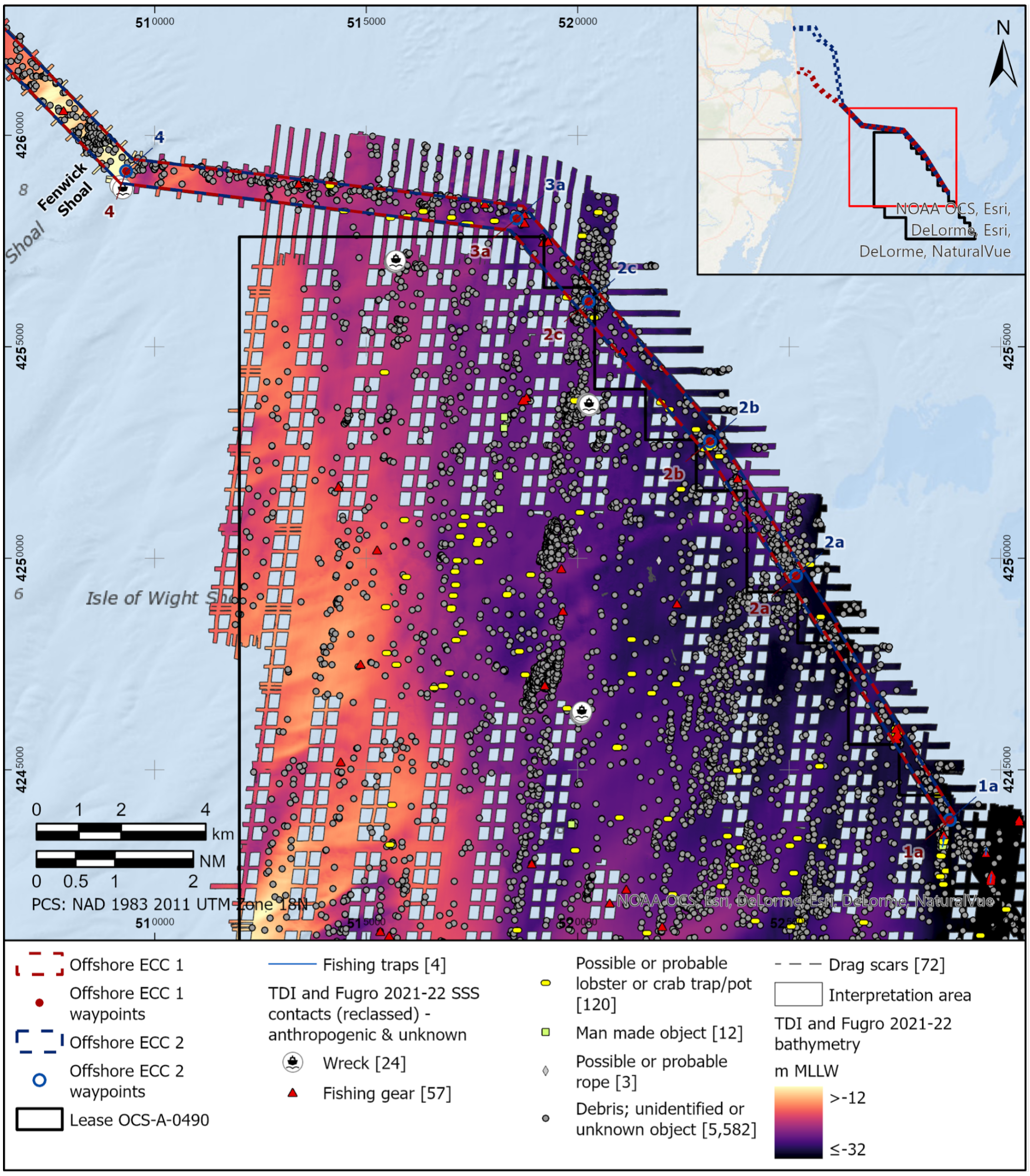


Figure 4.5: Overview map of SSS contacts in the southern ECC from the TDI and Fugro surveys in 2021-22 [24].

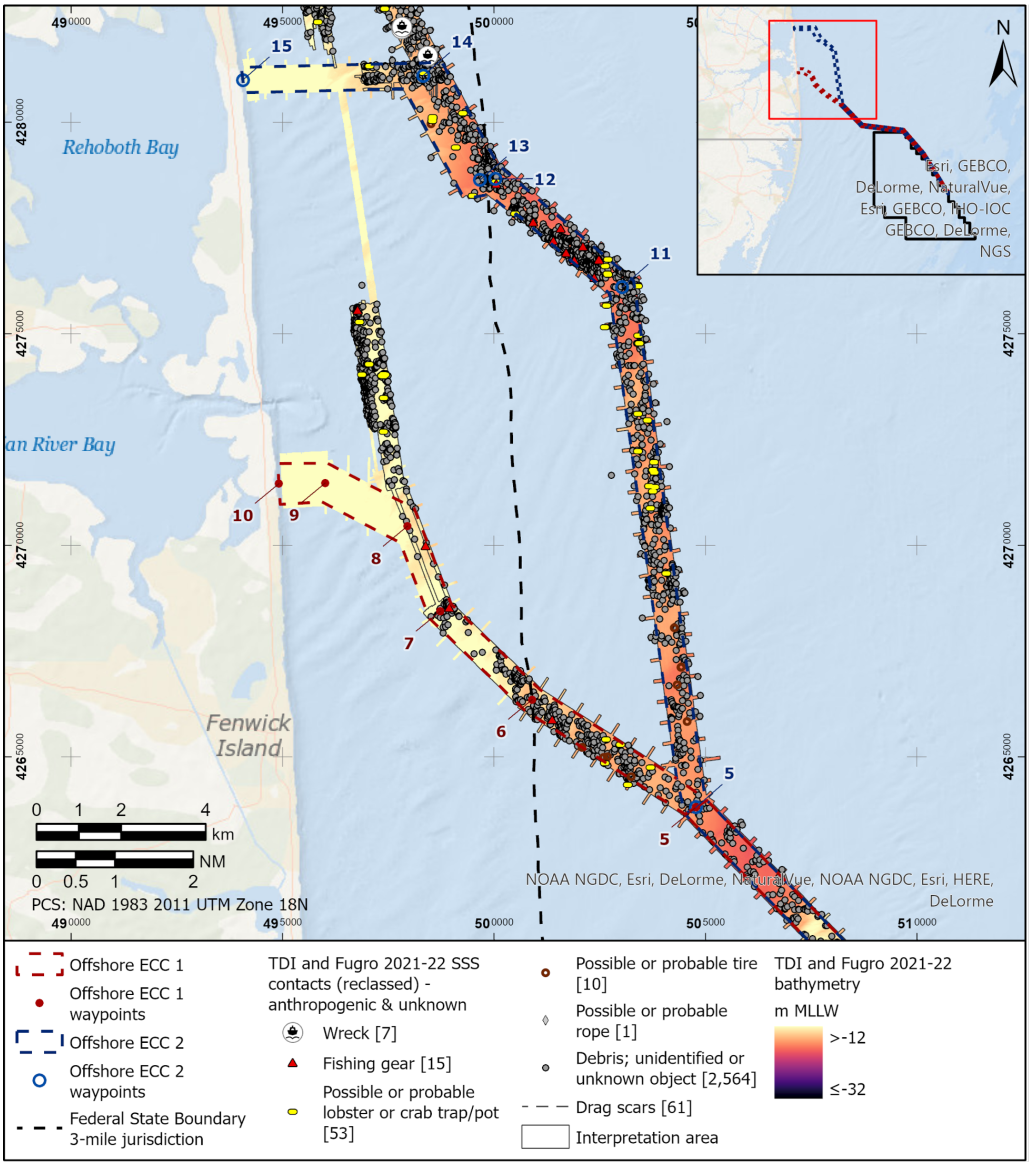


Figure 4.6: Overview map of SSS contacts in the northern ECC sections from the TDI and Fugro surveys in 2021-22 [24].

A total of 356 contacts were identified from the Alpine geophysical survey of IRB. A total of 23 of the observed contacts exhibited relief greater than 0.5 m and 3 were observed with relief greater than 1 m. A large majority of the contacts are interpreted as possible debris or fishing gear with a few contacts classified as possibly geological in origin. Most of the geological contacts are isolated rocks or possible boulders. All identified sonar contacts in the Onshore ECC1 are mapped on Figure 4.7. There is a higher density of contacts in the westernmost part of the Onshore ECC1 coming into the grid connection point. These could pose complications to the cable routing as this is the narrowest part of the corridor. 59 of the contacts in Onshore ECC1 can be associated with magnetic anomalies. Most of the associations are likely to be fishing gear [2].

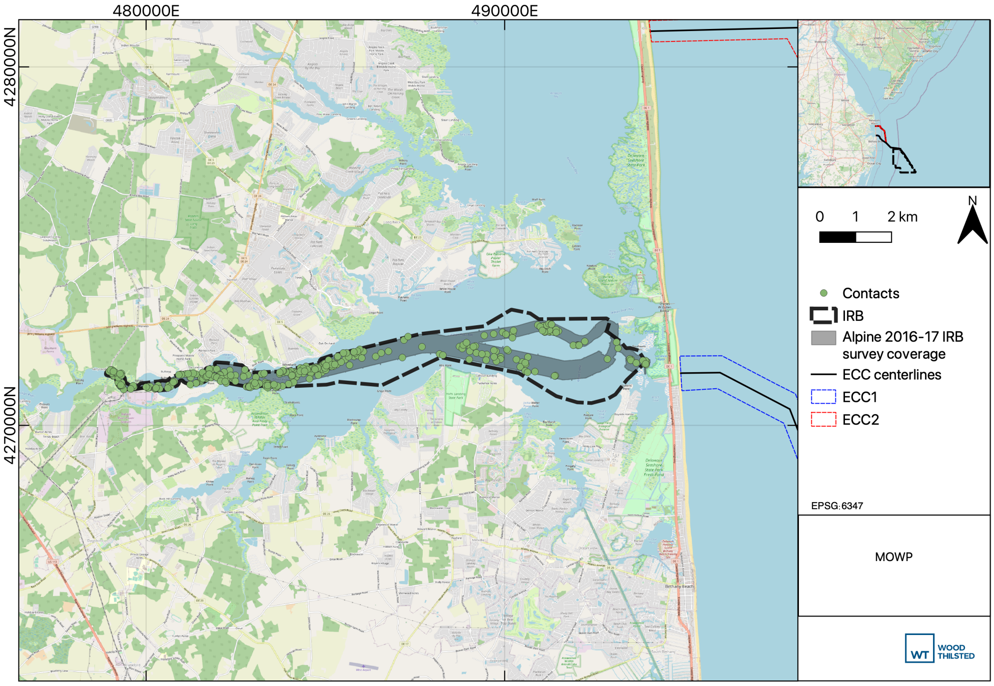


Figure 4.7: Overview map of SSS contacts in the Onshore ECC1 from the Alpine Export Cable Route Survey Results [2].

4.2.2. Magnetic anomalies

A total of 904 magnetic anomalies have been identified within the ECCs. Most of the interpreted targets are of a relatively low amplitude, with a median anomaly amplitude of only 9.6 nT. Only 121 targets (13%) have an amplitude equal to or exceeding 30 nT.

TDI targets are classified as 'Possible geology', 'Possible small object' or 'Possible medium sized object'. Fugro targets are classified as 'Discrete' or 'Non-discrete' [24]. The distribution of interpreted targets is shown in Figure 4.8 and 4.9 and a summary is given in Table 4.2.

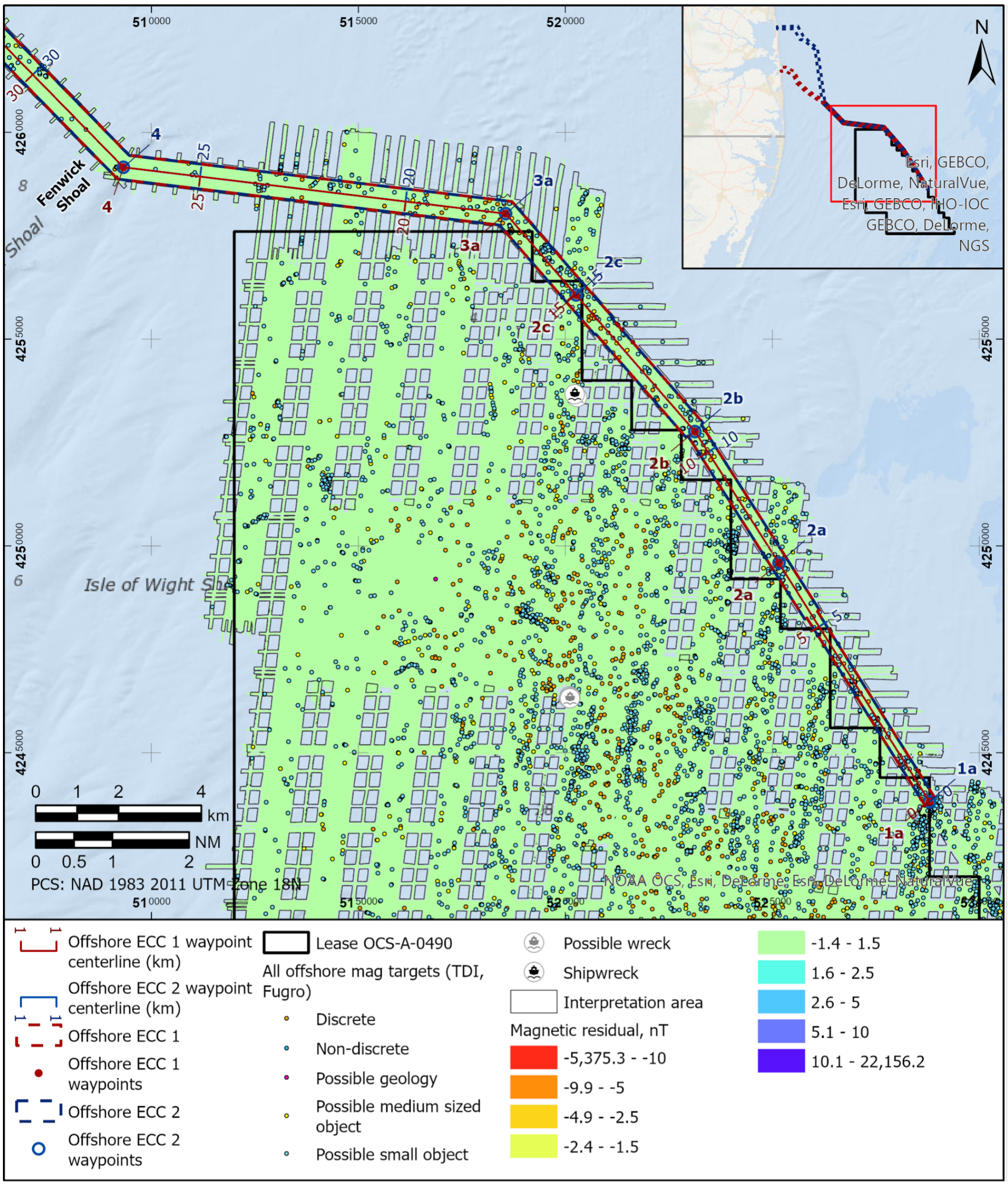


Figure 4.8: Magnetometer anomalies superimposed on magnetic residual grids in the southern ECC section from the TDI and Fugro surveys 2021-22 [24].

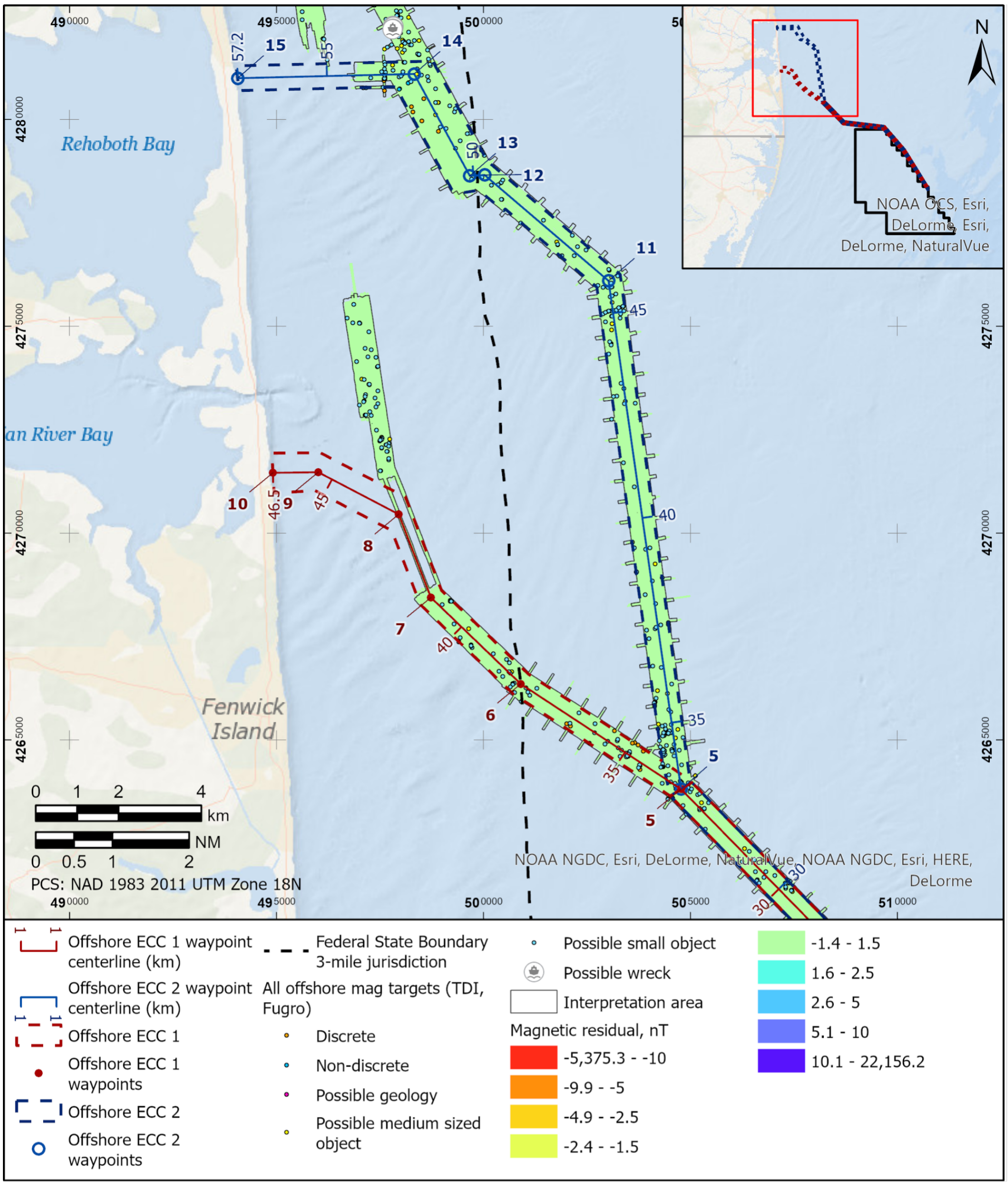


Figure 4.9: Magnetometer anomalies superimposed on magnetic residual grids in the northern ECC sections from the TDI and Fugro surveys 2021-22 [24].

Table 4.2: Summary of magnetometer contacts within the Lease area boundary [24].

Target class	$< 30\,\text{nT}$	$\geq 30\,\text{nT}$	Total
Discrete	74	12	86
Non-discrete	11	2	13
Possible geology	0	2	2
Possible medium sized object	0	105	105
Possible small object	698	0	698
Total	783	121	904

Given the dynamic seabed and conditions within the ECCs there is the potential for objects to become covered and uncovered due to bedform and sediment migration and due to self-burial, and potentially also for objects to move over time. It should also be noted that the coastal and OCS regional magnetic environment offshore Maryland is characterized by a strong geologic influence [3].

The Alpine geophysical survey identified a total of 1756 magnetic anomalies in the IRB. Of all the targets, a total 384 magnetic anomalies exhibited amplitude values above 100 nT and 256 anomalies exhibited amplitude values between 50 nT and 100 nT. All the magnetic anomalies identified within the Onshore ECC1 are mapped in Figure 4.10.

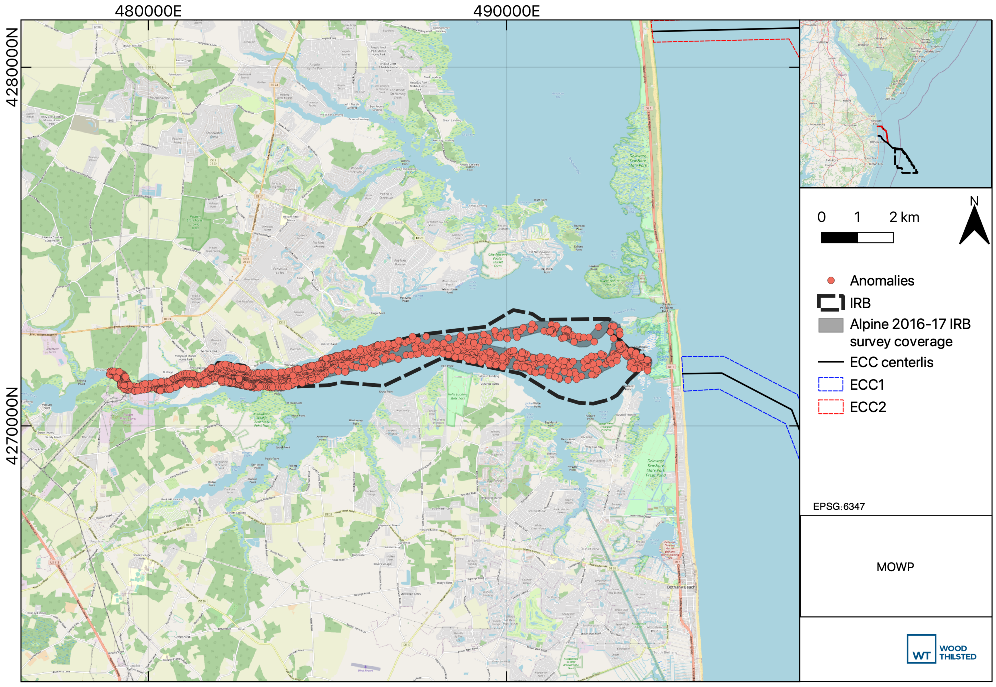


Figure 4.10: Overview map of magnetic geological anomaly polygons in the Onshore ECC1 from the Alpine Export Cable Route Survey Results [2].

There is a large amount of magnetic anomalies in the Onshore ECC1 as shown on Figure 4.10. The large quantity of magnetic anomalies makes it difficult to distinguish any linear patterns from possible cables or pipelines. One probable reason for the high number of magnetic anomalies in the area is high fishing activities [2].

4.2.3. Water depth

The water depth in the ECCs in federal waters ranges from -11.1 to -31.8 m MLLW. The water depth typically increases from northwest to southeast, with variations due to bedforms superimposed on this trend. The bathymetric data is acquired by TDI in 2021 [21] and Fugro in 2022 [8] and merged by WT [24]. Shallower water depths are generally limited to the locations of the taller sand ridges. An overview is shown in Figure 4.11 and 4.12.

The nearshore part of the ECCs has a relatively shallow water with depths of less than 15 m. Shallow water access and navigational risk must be considered as part of the cable installation strategy for the nearshore area. It is expected that most installation vessels should be able to operate for the part of the ECC with water depths deeper than 15 m.

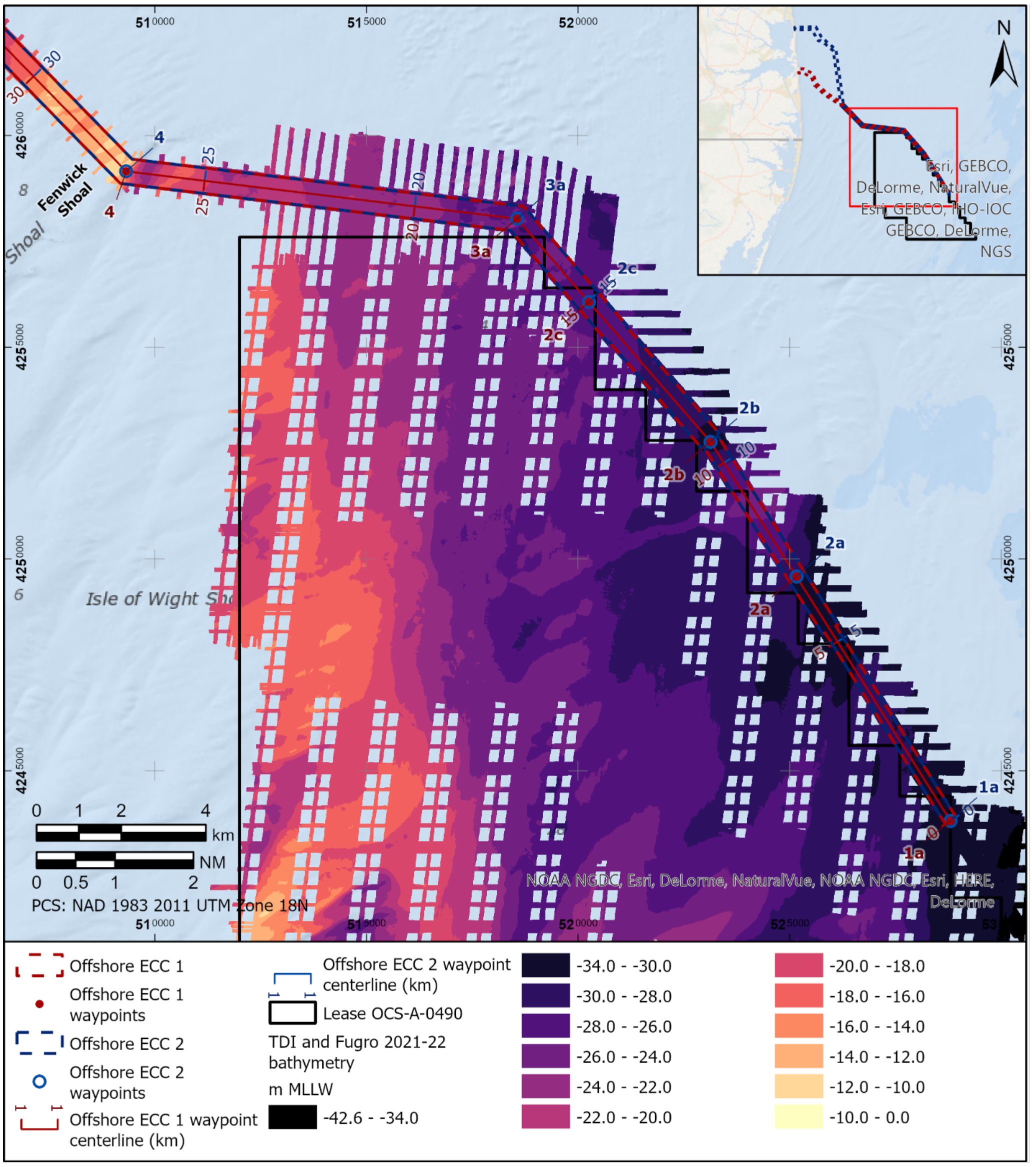


Figure 4.11: Merged TDI and Fugro 2021-2022 bathymetry, Lease area, 0.5x0.5 m resolution [24].

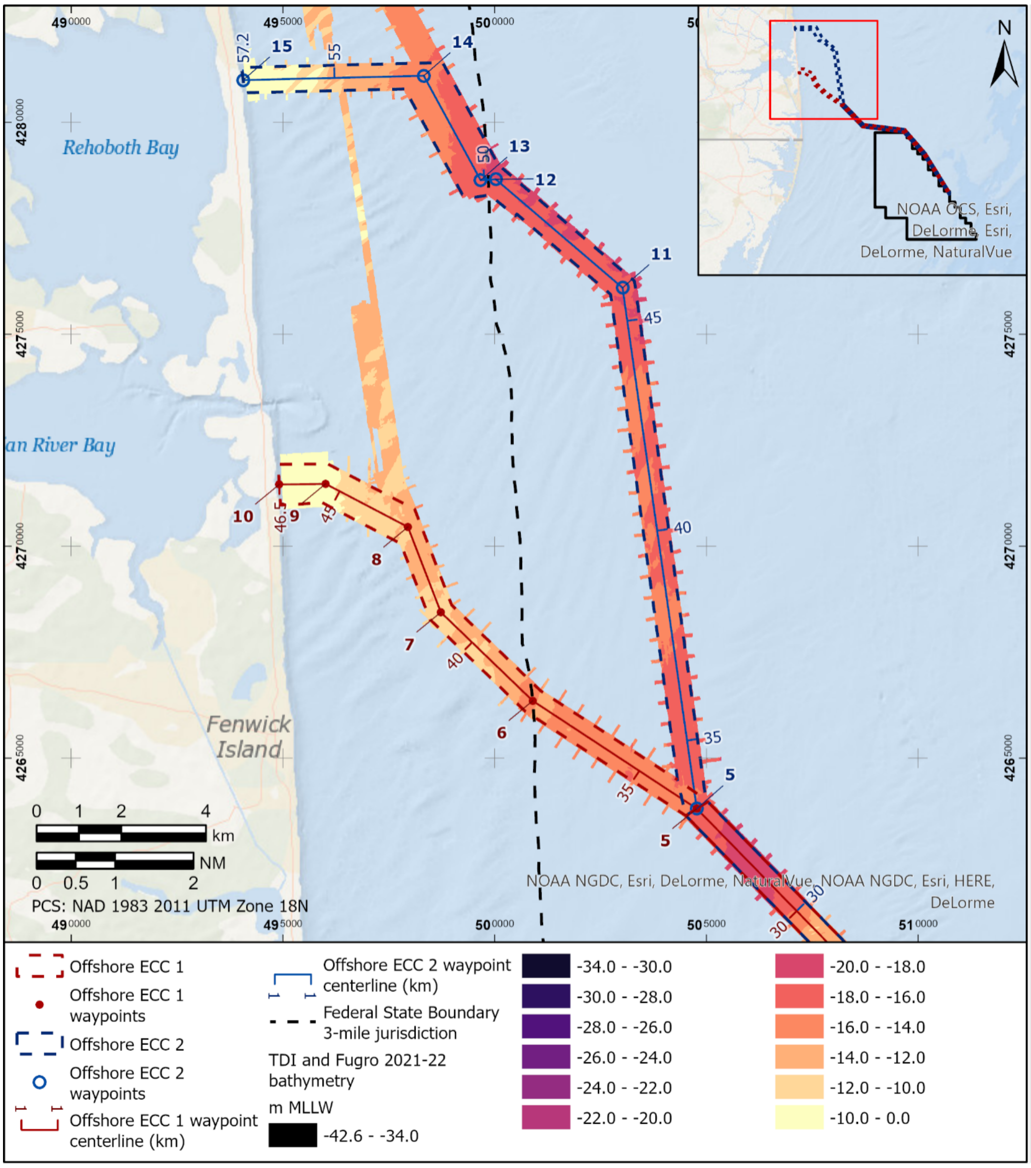


Figure 4.12: Merged TDI and Fugro 2021-2022 bathymetry, Lease area, 0.5x0.5 m resolution [24].

The Onshore ECC1 has water depths shallower than 10 m according to the geophysical survey by Alpine [2]. Special considerations for cable installation may apply in the Onshore ECC1 due to the shallow waters.

4.2.4. Slopes

Within Federal waters the seafloor across both ECCs slopes regionally from west to east at a gentle gradient of less than 1 percent. However, topographic variations are encountered along the common portions of both ECCs [24].

The average slope in the ECCs is 0.5°. In general, slopes do not exceed 1° over 92% of the ECCs: in addition, slopes exceed 2° for only 1% of the ECCs. The distribution of slopes within the Lease area is shown in Table 4.3.

Table 4.3: Seafloor slopes within the interpretation area coverage of the ECCs [24].

Classification	Gradient	ECCs interpretation area coverage
(-)	(°)	(%)
Very gentle	< 1	92.9%
Gentle	1-4.9	7.1%
Moderate	5-9.9	0.0%
Steep	10-14.9	0.0%
Very steep	> 15	0.0%

The maximum sampled slope of both ECCs is 5.0° hence slopes within the interpretation area coverage of the ECCs are not likely to cause cable installation complications as they are less than 10°. The variations in slope along both ECCs are illustrated in Figure 4.13 and 4.14.

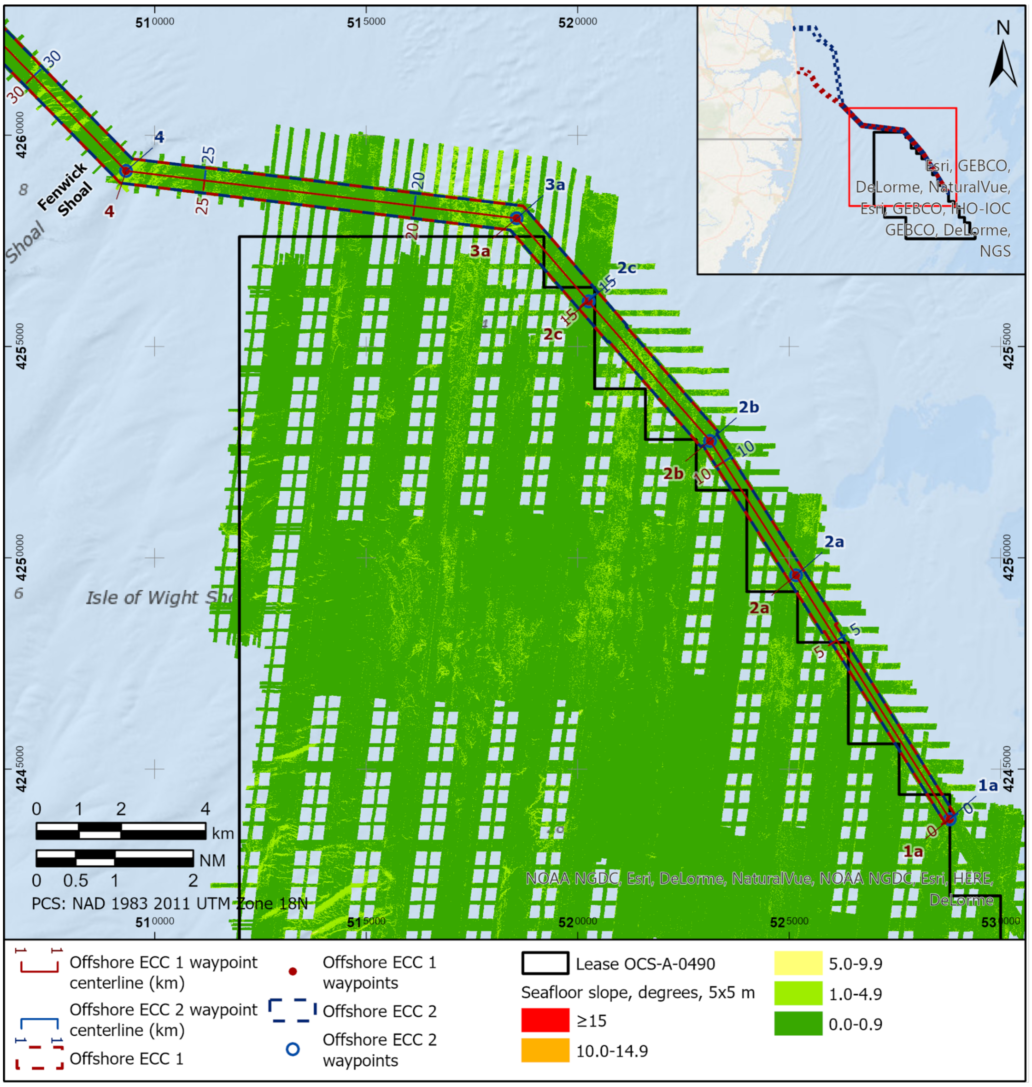


Figure 4.13: Seafloor slope in the southern ECC section [24].

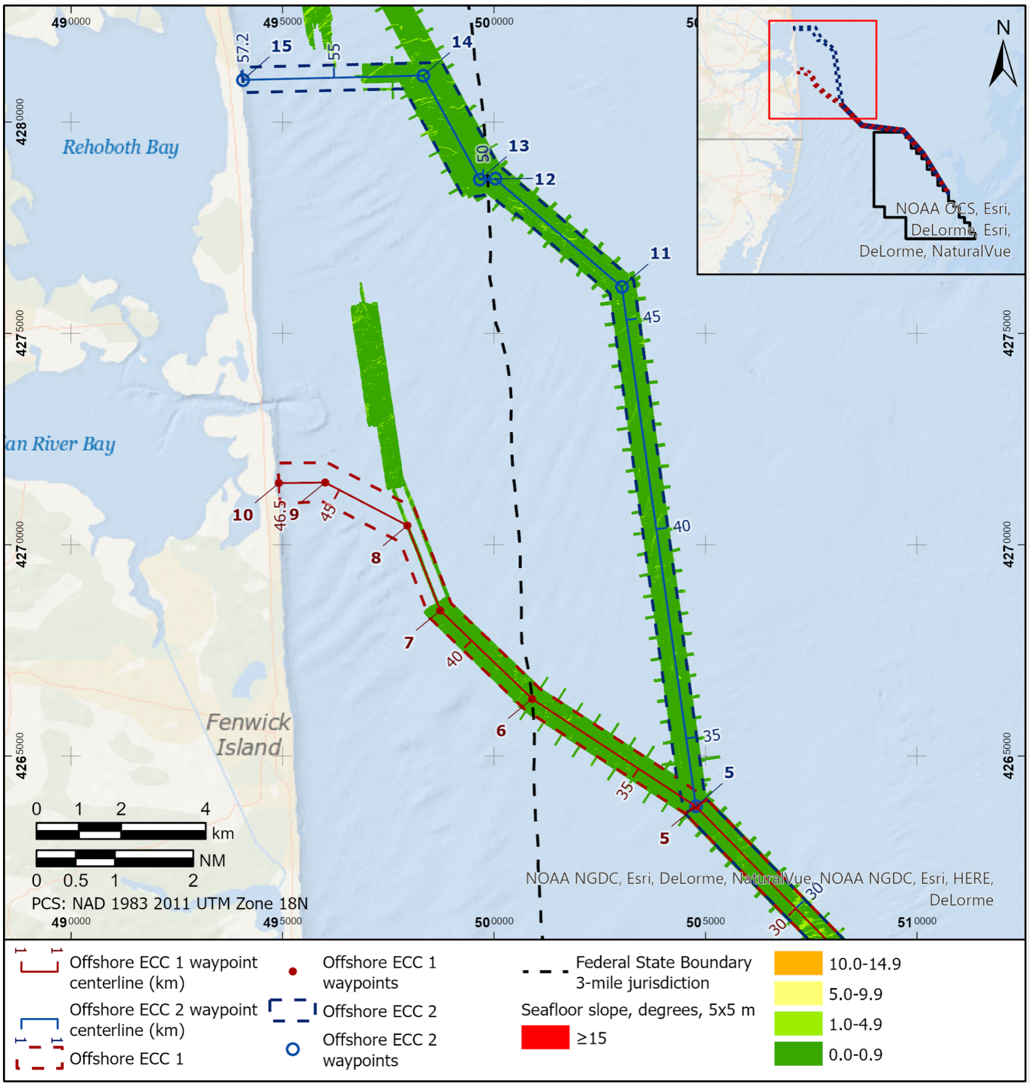


Figure 4.14: Seafloor slope in the northern ECC sections [24].

For the Onshore ECC1 the seafloor is relatively flat and no significant slopes are identified.

4.2.5. Seabed mobility

Evidence of seabed mobility is demonstrated throughout the ECCs [24]. Minor bedforms (minor sand ridges, sand waves/dunes, bedforms in irregular seafloor areas) are migrating at a significant rate relative to the project lifetime. A high-level classification of different seabed mobility zones based on vertical differences between successive bathymetric surveys within the ECCs is shown in Figure 4.15 and 4.16 [24].

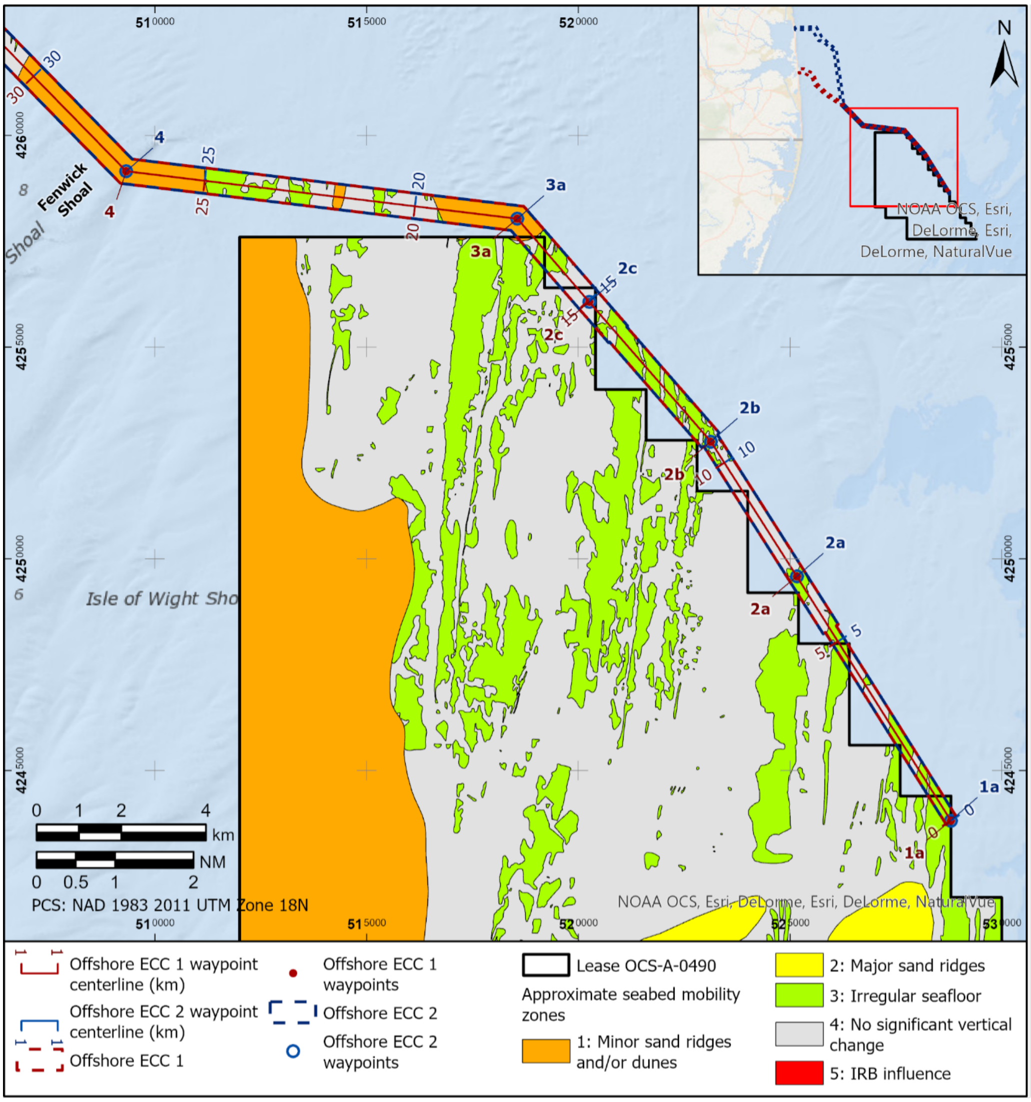


Figure 4.15: Seabed mobility zones [24].

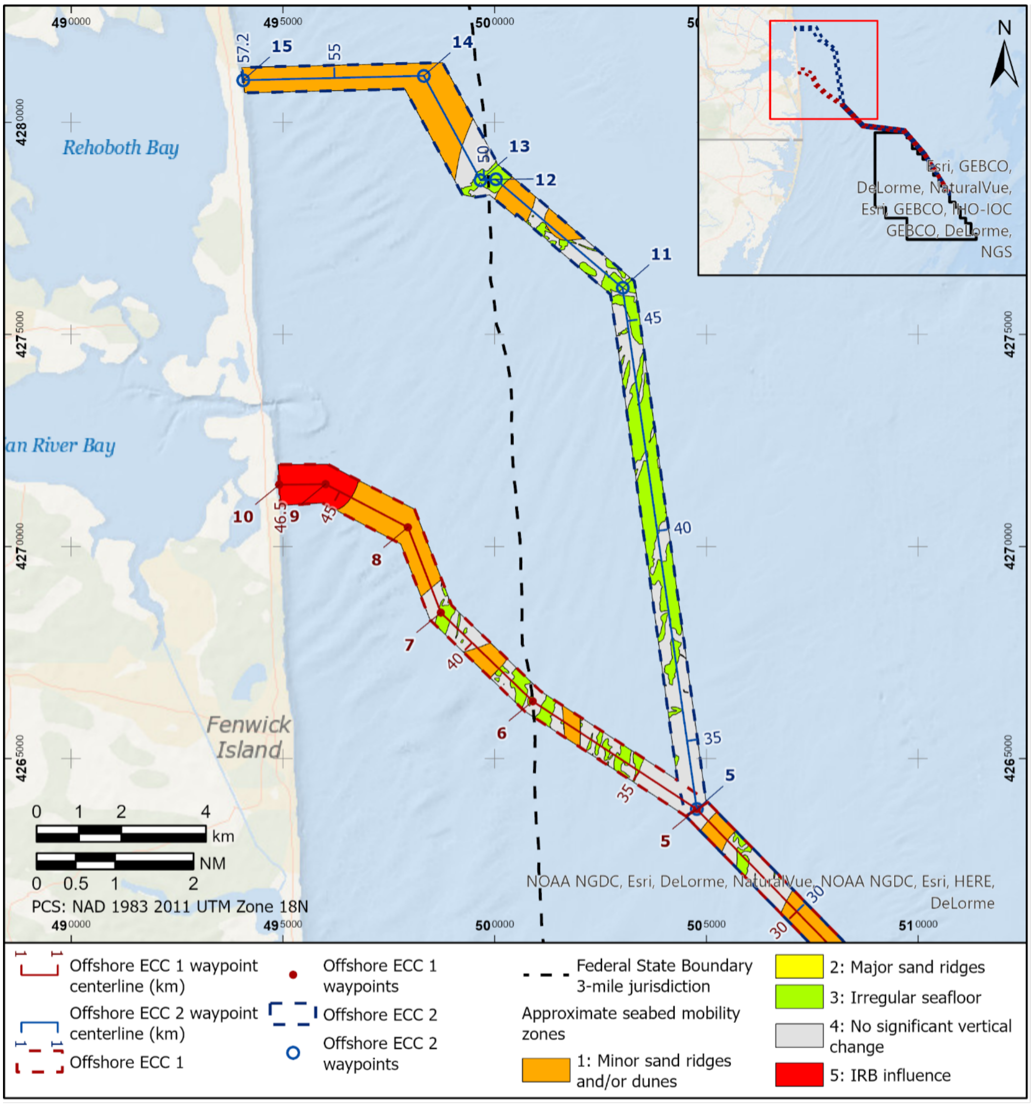


Figure 4.16: Seabed mobility zones [24].

The ECC within State Waters is an area prone to bottom currents that are capable of transporting sediments and causing scour around future export cables. The presence of mobile bedforms supports that inference. Based on the project location, a relatively high potential for sediment transport and scour is anticipated. Within Federal Waters, areas of potential hazard include on mobile bedforms in shallower water depths and around Fenwick Shoal where the largest bedforms identified in the ECCs are mobile [24].

Tidal scour is identified in IRB near the cut banks along the Indian River as well as in areas west of Indian River Inlet [2]. Sand ripples were also identified in areas of tidal scour.

Large seabed mobility activity, whether it is sand waves or scour, should be considered due to the risk of exposing or over-heating the cable where there are high volumes of sediment transport.

5. Quantitative risk assessment

Quantitative assessment of the cable burial risk is performed according to the methodology by Carbon Trust [5] and [6]. The thickness of soft soil is accounted for by adopting a two-layer anchor penetration model. Calculation methodology and results are presented in Appendix B and C.

5.1. AIS data

Vessel traffic is assessed from available automatic identification system (AIS) tracking in the area. The AIS data for this assessment is obtained from [1] for a period of 2 years. The AIS data set is processed to establish unique vessel timestamps and AIS type codes. Approximately 16% of the total data set for the offshore ECCs and 30% for the Onshore ECC1 are ignored because of missing vessel length information that is used to estimate vessel dead weight tonnage (DWT). Changes to the vessel traffic pattern due to construction of the wind farm is not considered in this preliminary assessment. Further refinement of the AIS data and anticipated vessel traffic patterns following construction can be completed in subsequent design stages.

5.2. Input parameters

The burial depths are defined based on the fluke penetration of standard anchors and the type of sediment encountered. The route is divided into segments of varying lengths representing sections of similar ground conditions in order to perform the evaluation (c.f. Section 3.3). The cable burial risk assessment (CBRA) method only considers anchorages in emergency cases (e.g. due to a mechanical failure or to prevent a collision). The probability of strike (p_{strike}) is based on vessel size, vessel speed when emergency anchoring, probability of emergency anchoring and ground conditions/cable burial depth. Details on anchor models and calculation of p_{strike} and depth of lowering (DoL) are provided in Appendix B and C. Table 5.1 summarises the main inputs adopted for the quantitative CBRA for the ECCs.

Table 5.1: Main input parameters for the quantitative CBRA for the cable corridors.

Parameter	Value	Description
$P_{traffic}$	1	Modifier for traffic within each route section
P_{wd}	0.9	Modifier for water depth
V_{ship}	4 kts	Based on assumption of peak tidal current speed
$P_{incident}$	0.01	Conservative value from findings by SAFECO [14]

5.2.1. Water depth modifier

The water depth profile and adjacent obstacles govern a vessel's need for performing emergency anchorage if it loses control (e.g. due to engine failure). The value for P_{wd} should represent the degree of constraints that the vessel master faces in assuring the safety of vessel and crew in case of an incident. A P_{wd} value of 0.9 is conservatively adopted for this preliminary analysis. Further optimisation may be possible in subsequent design stages to adopt lower values in areas characterised by deeper water and fewer restrictions/obstacles that would reduce the likelihood of needing to deploy an anchor.

5.2.2. Vessel speed when anchoring

The vessel speed at which a safe emergency anchorage would normally occur is 1-2 knots dependent on vessel size [6]. The larger the vessel the lower the acceptable speed for anchorage. The speed of vessel drift is assumed to be governed by local current speeds, particularly tidal currents. A value of 4 kts is conservatively adopted for V_{ship}. The value may be refined for final design based on analysis of the maximum tidal current speeds for the US Wind ECC.

5.2.3. Incident rate

Literature provides a large range for the incident rate ($P_{incident}$). DNV [7] reports incident rates as low as 0.0002 for loss of control when on collision course and up to 0.1752 based on engine failure of single-engined tankers in the North Sea. A $P_{incident}$ value of 0.01 is adopted for preliminary analysis based on WT experience and engineering judgement. Sensitivity is assessed by performing analyses considering the upper and lower bound $P_{incident}$ values indicated by DNV [7]. Results of the sensitivity study are presented in Section 6.3.

5.3. Results of quantitative analysis

DoL is derived for a range of return periods, presented in Appendix B and C. Results for DoL are reported for risk level 1 in 100,00 yrs in Section 6, which is considered neglible risk [22]. Results are summarised in terms of burial depth for defined risk levels and vice versa in Section 6. The detailed results of the CBRA are included in Appendix B and C.

6. Depth of lowering

The DoL is considered from the stable seabed level. The DoL is selected to reflect the acceptable risk level to the project and considers:

- Results of the qualitative risk assessment (i.e. threat of damage from anthropogenic and natural risks)
- Results of the quantitative CBRA (i.e. the risk of anchor strike to the cable)

Fishing activity is seen to be the main qualitative risk directly affecting the depth of lowering. Vessel traffic intensity and vessel size coupled with geotechnical conditions govern the quantitative risk level.

6.1. DoL by acceptable risk level

Table 6.1 present the minimum depth of lowering (MDOL) for protection against:

- Snagging and/or impact of fishing gear
- Best estimate of an anchor strike occurrence of 1 in 100,000 years (10^{-5}yrs) based on t_{soft} for ECC1 and ECC2 and considering soft soils only for the Onshore ECC1

The recommended DoL is the deeper of the two burial depths. Quantitative assessment of vessel traffic indicates that burial is not required and a cable laid at the stable seabed elevation will satisfy the frequency of anchor strike being less than 1 in 100,000 years. Therefore, a minimum DoL of $1.0\,\mathrm{m}$ is specified based on mitigation of threat of damage from fishing activity. The recommended DoL reported below constitutes the target TOP level from an engineering perspective for a 1 in 100,000 year return period of anchor strike. The target DoL for installation must be decided based on the project acceptable risk level and account for local permitting requirements for minimum burial depth.

Table 6.1: Recommended DoL below stable seabed for the ECCs.

Segment	Section	t_{soft}* (m)	Fishing DoL	Vessel interaction DoL	Recommended DoL
South landfall	KP00 to KP03	0	1.0	0.0	1.0
South landfall	KP03 to KP04	4.5	1.0	0.0	1.0
South landfall	KP04 to KP07	0	1.0	0.0	1.0
South landfall	KP07 to KP09	10	1.0	0.0	1.0
South landfall	KP09 to KP10	0	1.0	0.0	1.0
South landfall	KP10 to KP12	2.6	1.0	0.0	1.0
South landfall	KP12 to End	10	1.0	0.0	1.0
Main corridor	KP13 to KP14	10	1.0	0.0	1.0
Main corridor	KP14 to KP15	0	1.0	0.0	1.0
Main corridor	KP15 to KP16	2	1.0	0.0	1.0
Main corridor	KP16to KP35	0	1.0	0.0	1.0
Main corridor	KP35 to KP36	10	1.0	0.0	1.0
Main corridor	KP36 to KP40	0	1.0	0.0	1.0
Main corridor	KP40 to KP41	1	1.0	0.0	1.0
Main corridor	KP41 to KP45	0	1.0	0.0	1.0
Main corridor	KP45 to KP46	3.2	1.0	0.0	1.0
Main corridor	KP46 to End	0	1.0	0.0	1.0
North landfall	KP00 to KP04	2	1.0	0.0	1.0
North landfall	KP04 to KP06	10	1.0	0.0	1.0
North landfall	KP06 to KP09	1	1.0	0.0	1.0
North landfall	KP09 to KP11	0	1.0	0.0	1.0
North landfall	KP11 to KP12	10	1.0	0.0	1.0
North landfall	KP12 to KP18	0	1.0	0.0	1.0
North landfall	KP18 to KP19	10	1.0	0.0	1.0
North landfall	KP19 to KP22	0	1.0	0.0	1.0
North landfall	KP22 to End	10	1.0	0.0	1.0
Onshore ECC1	IRB	10	1.0	0.0	1.0

* : A value of 10 m is used for soft soil thickness (t_{soft}) to indicate locations where the presence of soft soil extends through the entire depth of the investigation location.

6.2. Risk level by depth

The risk of anchor strike for a specific DoL is derived for all cable sections. Results are provided as figures and tables in Appendix B and C. These charts may be helpful in assessing the balance between burial depth, risk appetite and cable installation tool constraints. Figure 6.1 presents an example diagram for the cable section KP40 to KP41 of the main corridor segment. A specific risk level (horizontal axis) can be read for a given burial depth (vertical axis).

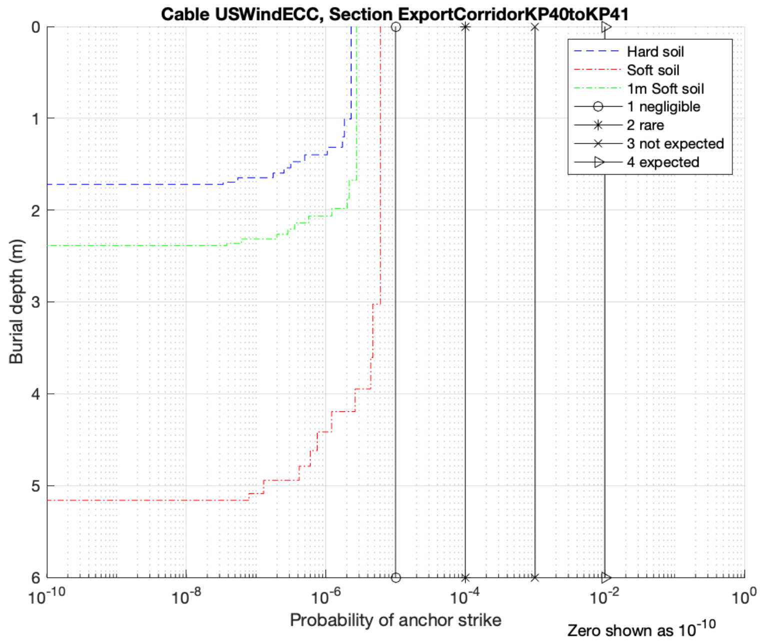


Figure 6.1: Example of risk level by DoL (KP40 to KP41 - Main corridor segment).

6.3. Sensitivity analysis - $P_{incident}$

Results of sensitivity analyses are presented in Table 6.2. The analyses show that results are sensitive to the value of $P_{incident}$. However, preliminary assumptions adopting $P_{incident}$ of 0.01 are deemed acceptable based on the findings presented in [14] and that an upper bound value of 0.1752 would lead to overly conservative burial depths. In any case, further assessment is recommended for subsequent design stages to confirm preliminary assumptions are valid.

Table 6.2: DoL below stable seabed for the ECCs for different values of $P_{incident}$.

Segment	Section	t_{soft}* (m)	$P_{incident,LB}$	$P_{incident,BE}$	$P_{incident,UB}$
South landfall	KP00 to KP03	0	0.0	0.0	0.8
South landfall	KP03 to KP04	4.5	0.0	0.0	0.0
South landfall	KP04 to KP07	0	0.0	0.0	0.0
South landfall	KP07 to KP09	10	0.0	0.0	2.5
South landfall	KP09 to KP10	0	0.0	0.0	0.8
South landfall	KP10 to KP12	2.6	0.0	0.0	2.5
South landfall	KP12 to End	10	0.0	0.0	2.5
Main corridor	KP13 to KP14	10	0.0	0.0	3.0
Main corridor	KP14 to KP15	0	0.0	0.0	1.0
Main corridor	KP15 to KP16	2	0.0	0.0	2.3
Main corridor	KP16to KP35	0	0.0	0.0	1.5
Main corridor	KP35 to KP36	10	0.0	0.0	4.2
Main corridor	KP36 to KP40	0	0.0	0.0	1.6
Main corridor	KP40 to KP41	1	0.0	0.0	2.1
Main corridor	KP41 to KP45	0	0.0	0.0	1.6
Main corridor	KP45 to KP46	3.2	0.0	0.0	3.5
Main corridor	KP46 to End	0	0.0	0.0	1.0
North landfall	KP00 to KP04	2	0.0	0.0	2.2
North landfall	KP04 to KP06	10	0.0	0.0	2.5
North landfall	KP06 to KP09	1	0.0	0.0	1.5
North landfall	KP09 to KP11	0	0.0	0.0	0.8
North landfall	KP11 to KP12	10	0.0	0.0	2.5
North landfall	KP12 to KP18	0	0.0	0.0	0.8
North landfall	KP18 to KP19	10	0.0	0.0	2.5
North landfall	KP19 to KP22	0	0.0	0.0	0.8
North landfall	KP22 to End	10	0.0	0.0	2.5
Onshore ECC1	IRB	10	0.0	0.0	1.2

* : A value of 10 m is used for soft soil thickness (t_{soft}) to indicate locations where the presence of soft soil extends through the entire depth of the investigation location.

7. Recommendations for future assessment

7.1. AIS data quality

AIS data quality is identified as a key issue given that over 15% of data points from the original data set for the ECC and 30% from the Onshore ECC1 were ignored due to lack of vessel lengths in the available data set. There is a risk that a statistically significant amount or size of vessels are not included in this preliminary assessment and that the overall risk is underestimated and recommended burial depths are too shallow. Figures 7.1, 7.2 and 7.3 show the distribution of vessel types for ignored data points for each area. Figure 7.4 presents the distribution of available vessel length for pleasure craft in each area as well as tankers for the main corridor as these vessel types form the majority of ignored data. From these figures WT has conservatively assumed a vessel length of 25 m for pleasure craft and 250 m for tankers to calculate DWT and include the majority of missing data in sensitivity analysis to assess the potential impact of baseline assumptions. WT confirm there is no change to the recommended DoL when including these additional vessels in the analysis.

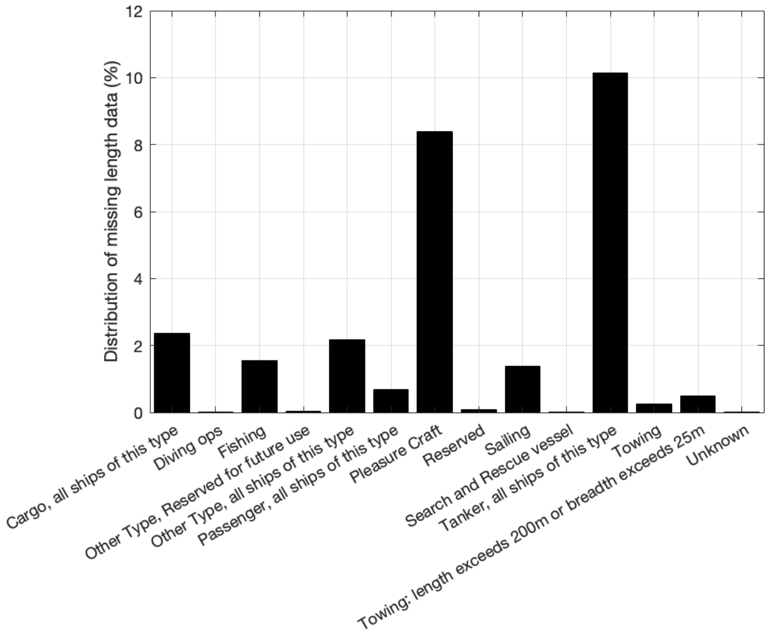


Figure 7.1: Distribution of vessel type for AIS data points missing length information.

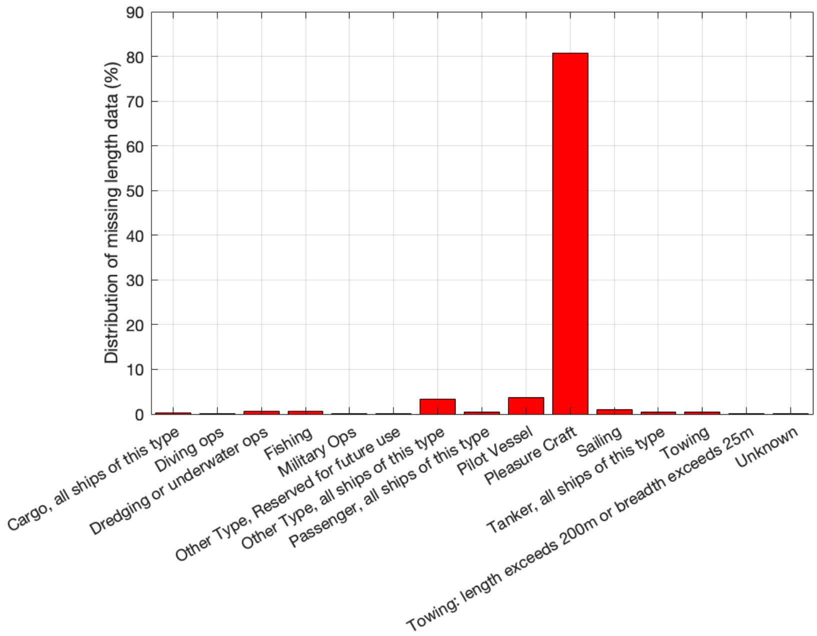


Figure 7.2: Northern and southern landfall

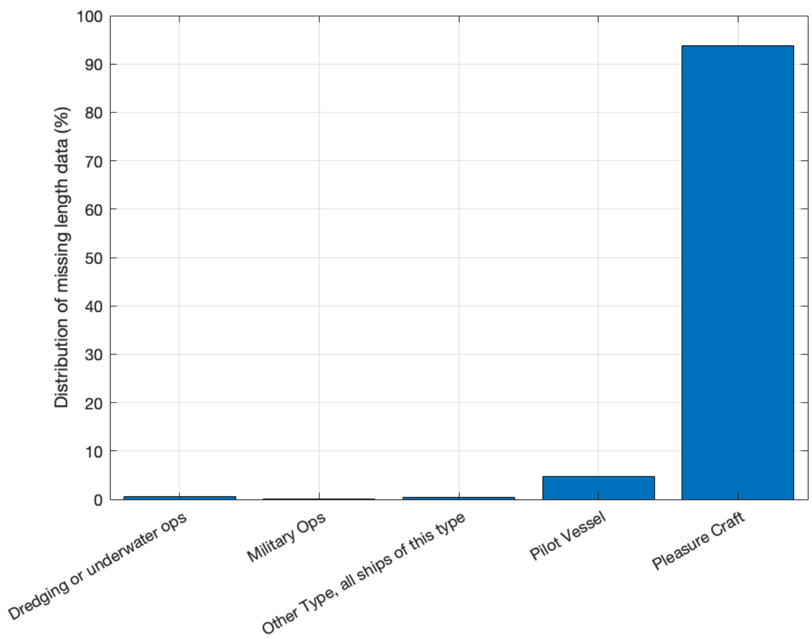
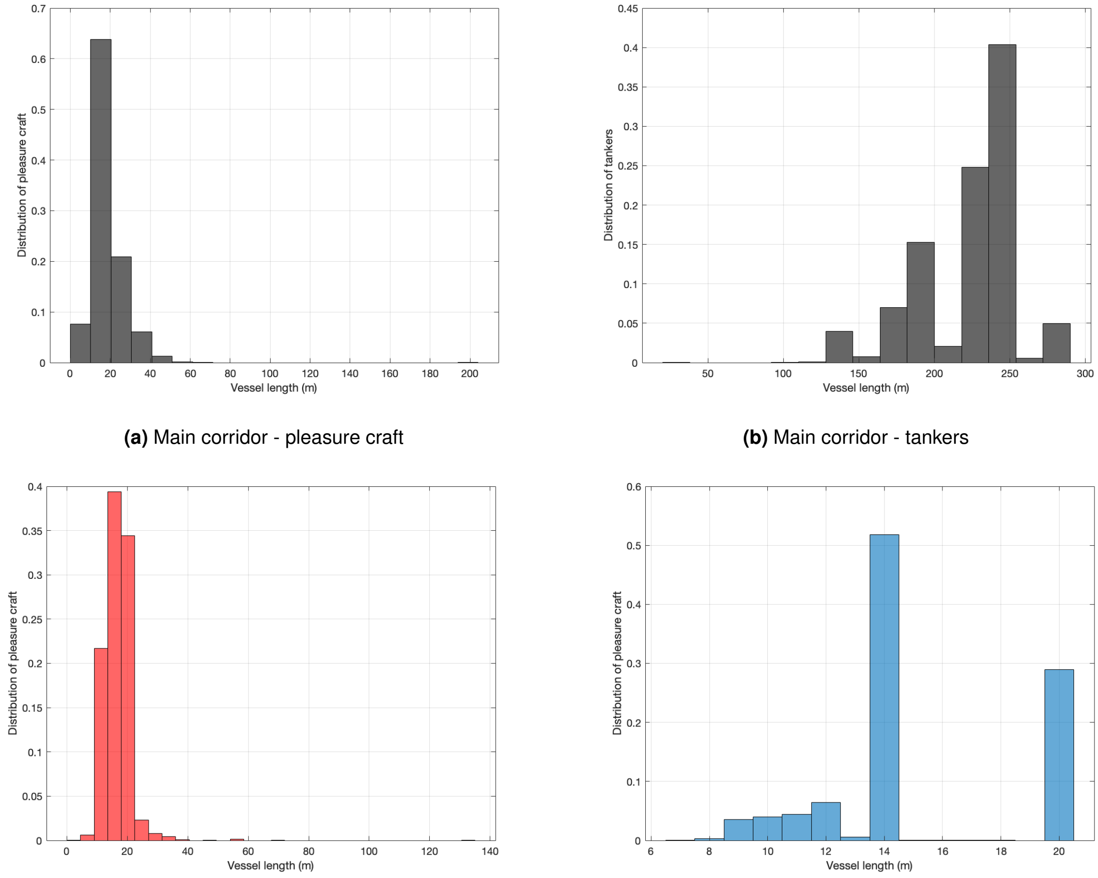


Figure 7.3: Onshore ECC1



(a) Main corridor - pleasure craft

(b) Main corridor - tankers

(c) Northern and southern landfall - pleasure craft

(d) Onshore ECC1 - pleasure craft

Figure 7.4: Distribution of vessel length information from available AIS data within corresponding area.

Notwithstanding the results of sensitivity analysis, WT recommends that the AIS data is refined or appropriate assumptions made to provide better quality estimates of vessel type, traffic patterns, dimensions and DWT. A data set for for a limited area may be procured from a commercial vendor for comparison of data quality.

7.2. Geotechnical interpretation

Interpretation of geophysical surveys within the nearshore area (State Waters) and Indian River Bay is ongoing at the time of writing and geotechnical survey operations in IRB have not yet concluded. It is recommended that classification of geotechnical conditions for CBRA is confirmed during detailed assessment. An upper bound of burial depth is provided in Appendix B and C for consideration where soft soils may be present at the seafloor.

7.3. Opportunities for optimisation

WT identify the following opportunities for optimisation:

- Consideration of future vessel traffic patterns to potentially remove shipping vessels that may divert around the ECC following construction. This would reduce the risk of incident and likelihood of deeper anchor penetrations resulting in a more favourable target burial depth.
- Further subdivision of the ECC based on qualitative risks identified in Section 4
- Optimisation of input parameters (P_{wd}, V_{ship}, $P_{incident}$)

8. Conclusion

A preliminary cable burial risk assessment is undertaken for the US Wind ECCs. A qualitative risk assessment is completed to identify anthropogenic and natural threats to the cables along the planned cable route. A quantitative risk assessment is evaluated to determine the required burial depth for a range of risk return-periods.

Quantitative assessment is completed following the methodology outlined in the Carbon Trust guidelines. Several cable segments are considered based on interpretation of geotechnical conditions. The thickness of soft soil is accounted for by adopting a two-layer anchor penetration model.

Potential hydraulic dredging operations within the ECC poses risk to the cable once installed. Previous incidents of penetrations up to 1 m have been reported in the area. Consequently, the DoL is set to a minimum of 1 m with regards to fishing activity. Shipping activity may continue along the Main ECC. A depth of lowering of 1.0 m from the stable seabed elevation is recommended for all ECC sections to account for fishing activity and risk of anchor strike.

WT has identified issues with the quality of AIS data used for the quantitative assessment. It is recommend the AIS data is refined or appropriate assumptions made in subsequent design stages to better capture the vessel details and traffic patterns.

A number of magnetic anomalies are identified in the ECCs with data and known military activity in the area indicating risk of potential UXO's (pUXO). At the time of writing US Wind is conducting a review of the survey data to identify any pUXO to be avoided or removed for cable installation operations. Large numbers of magnetic anomalies in the Onshore ECC1 are expected to be due to fishing gear.

Avoidance of shipwrecks and potential cultural resources will be required and therefore are not expected to pose additional risk.

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A. Geotechnical interpretation of vibracores and cone penetration tests

A value of 10 m is used for soft soil thickness (t_{soft}) to indicate locations where the presence of soft soil extends through the entire depth of the investigation location.

Table A.1: Geotechnical interpretation summary.

ID	Easting	Northing	Type	t_{soft} (m)	Source
A01	495228	4271628	VC	2	Alpine
A02	495220	4271591	VC	0	Alpine
A03	495219	4271557	VC	0	Alpine
A04	496731	4271047	VC	1.4	Alpine
A05	498136	4270284	VC	0	Alpine
A06	499553	4269497	VC	0	Alpine
A07	500643	4268906	VC	0	Alpine
A08	502398	4267953	VC	0	Alpine
A09	504145	4267008	VC	0	Alpine
A10	505900	4266066	VC	0.6	Alpine
A11	507659	4265121	VC	0	Alpine
A12	509418	4264171	VC	0	Alpine
A13	511177	4263217	VC	0	Alpine
A14	512937	4262270	VC	0	Alpine
A15	514245	4261561	VC	0.8	Alpine
A16	514097	4259571	VC	1.1	Alpine
A17	513950	4257629	VC	1.7	Alpine
A18	516585	4260219	VC	0	Alpine
A19	516671	4258246	VC	0	Alpine
A20	518004	4259098	VC	0	Alpine
A21	519497	4257762	VC	0	Alpine
A22	520668	4256149	VC	0	Alpine
A23	521835	4254533	VC	0	Alpine
A24	523014	4252920	VC	10	Alpine
A25	523139	4252143	VC	0	Alpine
A26	503530	4267340	VC	1.2	Alpine
A27	519913	4257181	VC	10	Alpine
A28	518087	4258996	VC	10	Alpine
A29	517379	4259576	VC	3.3	Alpine
A30	516723	4260110	VC	0	Alpine
A31	506630	4265673	VC	0	Alpine
A32	505405	4266333	VC	0	Alpine
A33	498406	4270131	VC	0	Alpine
A34	496612	4271105	VC	0	Alpine
VC-IRB-01	479360	4271065	VC	10	Alpine
VC-IRB-02	479364	4271033	VC	10	Alpine
VC-IRB-03	479427	4271004	VC	10	Alpine
VC-IRB-04	480906	4271289	VC	10	Alpine

Table A.2: Geotechnical interpretation summary (cont.).

ID	Easting	Northing	Type	t_{soft} (m)	Source
VC-IRB-05	482447	4271419	VC	10	Alpine
VC-IRB-06	484031	4271394	VC	10	Alpine
VC-IRB-07-ALT	485960	4271859	VC	1.2	Alpine
VC-IRB-08-ALT	486667	4272032	VC	1.6	Alpine
VC-IRB-09-ALT	489063	4272437	VC	10	Alpine
VC-IRB-10-ALT	490397	4272635	VC	10	Alpine
VC-IRB-11-ALT	492079	4272360	VC	10	Alpine
VC-IRB-12	493270	4272066	VC	10	Alpine
VC-IRB-13-ALT	494002	4271737	VC	10	Alpine
VC-IRB-14-ALT	493998	4271708	VC	0	Alpine
VC-IRB-15-ALT	493995	4271676	VC	10	Alpine
VC-IRB-16	493860	4271723	VC	0	Alpine
VC-IRB-17	479991	4271057	VC	2	Alpine
VC-IRB-24	487981	4272285	VC	10	Alpine
21VC_003	498368	4269374	VC	0	TDI Brooks
21VC_007	497645	4271230	VC	0	TDI Brooks
21VC_028_R	498091	4281087	VC	1.4	TDI Brooks
21VC_030	497098	4281069	VC	2	TDI Brooks
21VC_062_R	497398	4272515	VC	1.8	TDI Brooks
21VC_064_R	497246	4273499	VC	0	TDI Brooks
21VC_066_R	497105	4274499	VC	10	TDI Brooks
21VC_069	496887	4275964	VC	10	TDI Brooks
21VC_167_R	500930	4266349	VC	1.6	TDI Brooks
21VC_168	500901	4266359	VC	0.9	TDI Brooks
21VC_171	499822	4267395	VC	10	TDI Brooks
21VC_173	499106	4268096	VC	0	TDI Brooks
21VC_209_R	499852	4278802	VC	0.5	TDI Brooks
21VC_210_R	499606	4279244	VC	1.1	TDI Brooks
21VC_212	499130	4280120	VC	10	TDI Brooks
21VC_213_R	498897	4280560	VC	10	TDI Brooks
21cs_003	498377	4269377	CPT	0	TDI Brooks
21cs_005	498009	4270308	CPT	4.5	TDI Brooks
21cs_007	497651	4271237	CPT	0	TDI Brooks
21cs_029	497581	4281079	CPT	1.6	TDI Brooks
21cs_030	497097	4281060	CPT	0	TDI Brooks
21cs_042	495862	4282343	CPT	10	TDI Brooks
21cs_044	495684	4283319	CPT	0	TDI Brooks
21cs_046	495505	4284306	CPT	2.3	TDI Brooks
21cs_047	495428	4284803	CPT	2.4	TDI Brooks
21cs_061	497468	4272021	CPT	0.6	TDI Brooks
21cs_063	497321	4273006	CPT	0	TDI Brooks
21cs_065	497172	4273993	CPT	0	TDI Brooks
21cs_066	497087	4274485	CPT	0	TDI Brooks
21cs_066_R	497115	4274482	CPT	0	TDI Brooks
21cs_067	497023	4274985	CPT	10	TDI Brooks

Table A.3: Geotechnical interpretation summary (cont.).

ID	Easting	Northing	Type	t_{soft} (m)	Source
21cs_067_R	497008	4274983	CPT	10	TDI Brooks
21cs_069	496869	4275964	CPT	10	TDI Brooks
21cs_084	530122	4241741	CPT	0	TDI Brooks
21cs_087	529314	4243001	CPT	0	TDI Brooks
21cs_089	528789	4243849	CPT	0	TDI Brooks
21cs_091	528257	4244702	CPT	3.2	TDI Brooks
21cs_092_R	527984	4245140	CPT	0	TDI Brooks
21cs_094	527447	4245966	CPT	0	TDI Brooks
21cs_096	526919	4246825	CPT	0	TDI Brooks
21cs_098	526375	4247656	CPT	0	TDI Brooks
21cs_098_R	526387	4247679	CPT	0	TDI Brooks
21cs_100	523119	4252795	CPT	10	TDI Brooks
21cs_102_R	522467	4253536	CPT	0	TDI Brooks
21cs_104	521811	4254310	CPT	0	TDI Brooks
21cs_106	521148	4255070	CPT	0	TDI Brooks
21cs_107	525956	4248347	CPT	0	TDI Brooks
21cs_107_R	525964	4248361	CPT	0	TDI Brooks
21cs_109	525416	4249193	CPT	1	TDI Brooks
21cs_111	524902	4250023	CPT	0	TDI Brooks
21cs_113	524350	4250875	CPT	0	TDI Brooks
21cs_115	523812	4251721	CPT	0	TDI Brooks
21cs_116	523545	4252143	CPT	0	TDI Brooks
21cs_118	520942	4255307	CPT	0	TDI Brooks
21cs_119	520616	4255685	CPT	0	TDI Brooks
21cs_121	519957	4256438	CPT	0	TDI Brooks
21cs_123	519292	4257192	CPT	0	TDI Brooks
21cs_124	518969	4257563	CPT	0	TDI Brooks
21cs_126	518559	4258036	CPT	0	TDI Brooks
21cs_127	518083	4258092	CPT	0	TDI Brooks
21cs_127_R	518054	4258099	CPT	0	TDI Brooks
21cs_129	517067	4258227	CPT	0	TDI Brooks
21cs_131	516095	4258334	CPT	0	TDI Brooks
21cs_132	515586	4258399	CPT	0	TDI Brooks
21cs_134	514585	4258519	CPT	0	TDI Brooks
21cs_134_R	514568	4258522	CPT	0	TDI Brooks
21cs_136	513587	4258629	CPT	0	TDI Brooks
21cs_138	512601	4258767	CPT	0	TDI Brooks
21cs_140	511624	4258865	CPT	0	TDI Brooks
21cs_142	510631	4258986	CPT	0	TDI Brooks
21cs_144	509631	4259123	CPT	0	TDI Brooks
21cs_146	508967	4259516	CPT	0	TDI Brooks
21cs_148	508278	4260228	CPT	0	TDI Brooks
21cs_150	507582	4260938	CPT	0	TDI Brooks
21cs_152	506878	4261657	CPT	0	TDI Brooks
21cs_154	506178	4262367	CPT	2	TDI Brooks

Table A.4: Geotechnical interpretation summary (cont.).

ID	Easting	Northing	Type	t_{soft} (m)	Source
21cs_156	505477	4263088	CPT	0	TDI Brooks
21cs_160	503861	4264431	CPT	0	TDI Brooks
21cs_162	503031	4264964	CPT	2.6	TDI Brooks
21cs_163	502603	4265239	CPT	1.5	TDI Brooks
21cs_165	501765	4265789	CPT	0	TDI Brooks
21cs_167	500941	4266333	CPT	10	TDI Brooks
21cs_170	500180	4267046	CPT	0	TDI Brooks
21cs_172	499465	4267738	CPT	0	TDI Brooks
21cs_174	498746	4268422	CPT	0	TDI Brooks
21cs_175	504700	4263878	CPT	10	TDI Brooks
21cs_177	504568	4264870	CPT	10	TDI Brooks
21cs_179	504431	4265863	CPT	0	TDI Brooks
21cs_181	504298	4266849	CPT	0	TDI Brooks
21cs_183_R	504142	4267844	CPT	0	TDI Brooks
21cs_185	504028	4268825	CPT	0	TDI Brooks
21cs_186	503950	4269345	CPT	10	TDI Brooks
21cs_186_R	503935	4269319	CPT	10	TDI Brooks
21cs_187	503880	4269836	CPT	0	TDI Brooks
21cs_187	503887	4269812	CPT	0	TDI Brooks
21cs_189	503739	4270819	CPT	0	TDI Brooks
21cs_189	503745	4270794	CPT	0	TDI Brooks
21cs_191	503612	4271800	CPT	0	TDI Brooks
21cs_191	503605	4271797	CPT	0	TDI Brooks
21cs_193	503474	4272790	CPT	0	TDI Brooks
21cs_195	503341	4273776	CPT	0	TDI Brooks
21cs_197	503203	4274769	CPT	0	TDI Brooks
21cs_198	503136	4275269	CPT	0	TDI Brooks
21cs_199	503078	4275752	CPT	10	TDI Brooks
21cs_199	503049	4275766	CPT	10	TDI Brooks
21cs_200	503022	4276095	CPT	4.5	TDI Brooks
21cs_200_R	503010	4276088	CPT	4.5	TDI Brooks
21cs_202	502276	4276747	CPT	0	TDI Brooks
21cs_204	501511	4277410	CPT	0	TDI Brooks
21cs_206	500718	4278046	CPT	0.7	TDI Brooks
21cs_206	500745	4278040	CPT	1	TDI Brooks
21cs_206	500731	4278030	CPT	1	TDI Brooks
21cs_209	499845	4278814	CPT	0.4	TDI Brooks
21cs_211	499365	4279695	CPT	10	TDI Brooks
21cs_211	499372	4279685	CPT	10	TDI Brooks
21cs_213	498889	4280567	CPT	10	TDI Brooks
21cs_213	498896	4280571	CPT	10	TDI Brooks
21cs_215	498599	4281105	CPT	10	TDI Brooks
21cs_217	498119	4281979	CPT	10	TDI Brooks
21cs_217	498110	4281986	CPT	10	TDI Brooks
21cs_218	497878	4282423	CPT	1.8	TDI Brooks

Table A.5: Geotechnical interpretation summary (cont.).

ID	Easting	Northing	Type	t_{soft} (m)	Source
21cs_218_R	497858	4282423	CPT	1.8	TDI Brooks
21cs_220	497398	4283303	CPT	0	TDI Brooks
21cs_220_R	497389	4283290	CPT	0	TDI Brooks
21cs_221	497159	4283731	CPT	1.2	TDI Brooks
VC-IRB-05	482447	4271419	VC	10	Alpine
VC-IRB-06	484031	4271394	VC	10	Alpine
VC-IRB-07-ALT	485960	4271859	VC	1.2	Alpine
VC-IRB-08-ALT	486667	4272032	VC	1.6	Alpine
VC-IRB-09-ALT	489063	4272437	VC	10	Alpine
VC-IRB-10-ALT	490397	4272635	VC	10	Alpine
VC-IRB-11-ALT	492079	4272360	VC	10	Alpine
VC-IRB-12	493270	4272066	VC	10	Alpine
VC-IRB-13-ALT	494002	4271737	VC	10	Alpine
VC-IRB-14-ALT	493998	4271708	VC	0	Alpine
VC-IRB-15-ALT	493995	4271676	VC	10	Alpine
VC-IRB-16	493860	4271723	VC	0	Alpine
VC-IRB-17	479991	4271057	VC	2	Alpine
VC-IRB-24	487981	4272285	VC	10	Alpine
21VC_003	498368	4269374	VC	0	TDI Brooks
21VC_007	497645	4271230	VC	0	TDI Brooks
21VC_028_R	498091	4281087	VC	1.4	TDI Brooks
21VC_030	497098	4281069	VC	2	TDI Brooks
21VC_062_R	497398	4272515	VC	1.8	TDI Brooks
21VC_064_R	497246	4273499	VC	0	TDI Brooks
21VC_066_R	497105	4274499	VC	10	TDI Brooks
21VC_069	496887	4275964	VC	10	TDI Brooks
21VC_167_R	500930	4266349	VC	1.6	TDI Brooks
21VC_168	500901	4266359	VC	0.9	TDI Brooks
21VC_171	499822	4267395	VC	10	TDI Brooks
21VC_173	499106	4268096	VC	0	TDI Brooks
21VC_209_R	499852	4278802	VC	0.5	TDI Brooks
21VC_210_R	499606	4279244	VC	1.1	TDI Brooks
21VC_212	499130	4280120	VC	10	TDI Brooks
21VC_213_R	498897	4280560	VC	10	TDI Brooks
21cs_003	498377	4269377	CPT	0	TDI Brooks
21cs_005	498009	4270308	CPT	4.5	TDI Brooks
21cs_007	497651	4271237	CPT	0	TDI Brooks
21cs_029	497581	4281079	CPT	1.6	TDI Brooks
21cs_030	497097	4281060	CPT	0	TDI Brooks
21cs_042	495862	4282343	CPT	10	TDI Brooks
21cs_044	495684	4283319	CPT	0	TDI Brooks
21cs_046	495505	4284306	CPT	2.3	TDI Brooks
21cs_047	495428	4284803	CPT	2.4	TDI Brooks
21cs_061	497468	4272021	CPT	0.6	TDI Brooks
21cs_063	497321	4273006	CPT	0	TDI Brooks

Table A.6: Geotechnical interpretation summary (cont.).

ID	Easting	Northing	Type	t_{soft} (m)	Source
21cs_065	497172	4273993	CPT	0	TDI Brooks
21cs_066	497087	4274485	CPT	0	TDI Brooks
21cs_066_R	497115	4274482	CPT	0	TDI Brooks
21cs_067	497023	4274985	CPT	10	TDI Brooks
21cs_067_R	497008	4274983	CPT	10	TDI Brooks
21cs_069	496869	4275964	CPT	10	TDI Brooks
21cs_084	530122	4241741	CPT	0	TDI Brooks
21cs_087	529314	4243001	CPT	0	TDI Brooks
21cs_089	528789	4243849	CPT	0	TDI Brooks
21cs_091	528257	4244702	CPT	3.2	TDI Brooks
21cs_092_R	527984	4245140	CPT	0	TDI Brooks
21cs_094	527447	4245966	CPT	0	TDI Brooks
21cs_096	526919	4246825	CPT	0	TDI Brooks
21cs_098	526375	4247656	CPT	0	TDI Brooks
21cs_098_R	526387	4247679	CPT	0	TDI Brooks
21cs_100	523119	4252795	CPT	10	TDI Brooks
21cs_102_R	522467	4253536	CPT	0	TDI Brooks
21cs_104	521811	4254310	CPT	0	TDI Brooks
21cs_106	521148	4255070	CPT	0	TDI Brooks
21cs_107	525956	4248347	CPT	0	TDI Brooks
21cs_107_R	525964	4248361	CPT	0	TDI Brooks
21cs_109	525416	4249193	CPT	1	TDI Brooks
21cs_111	524902	4250023	CPT	0	TDI Brooks
21cs_113	524350	4250875	CPT	0	TDI Brooks
21cs_115	523812	4251721	CPT	0	TDI Brooks
21cs_116	523545	4252143	CPT	0	TDI Brooks
21cs_118	520942	4255307	CPT	0	TDI Brooks
21cs_119	520616	4255685	CPT	0	TDI Brooks
21cs_121	519957	4256438	CPT	0	TDI Brooks
21cs_123	519292	4257192	CPT	0	TDI Brooks
21cs_124	518969	4257563	CPT	0	TDI Brooks
21cs_126	518559	4258036	CPT	0	TDI Brooks
21cs_127	518083	4258092	CPT	0	TDI Brooks
21cs_127_R	518054	4258099	CPT	0	TDI Brooks
21cs_129	517067	4258227	CPT	0	TDI Brooks
21cs_131	516095	4258334	CPT	0	TDI Brooks
21cs_132	515586	4258399	CPT	0	TDI Brooks
21cs_134	514585	4258519	CPT	0	TDI Brooks
21cs_134_R	514568	4258522	CPT	0	TDI Brooks
21cs_136	513587	4258629	CPT	0	TDI Brooks
21cs_138	512601	4258767	CPT	0	TDI Brooks
21cs_140	511624	4258865	CPT	0	TDI Brooks
21cs_142	510631	4258986	CPT	0	TDI Brooks
21cs_144	509631	4259123	CPT	0	TDI Brooks
21cs_146	508967	4259516	CPT	0	TDI Brooks

Table A.7: Geotechnical interpretation summary (cont.).

ID	Easting	Northing	Type	t_{soft} (m)	Source
21cs_148	508278	4260228	CPT	0	TDI Brooks
21cs_150	507582	4260938	CPT	0	TDI Brooks
21cs_152	506878	4261657	CPT	0	TDI Brooks
21cs_154	506178	4262367	CPT	2	TDI Brooks
21cs_156	505477	4263088	CPT	0	TDI Brooks
21cs_160	503861	4264431	CPT	0	TDI Brooks
21cs_162	503031	4264964	CPT	2.6	TDI Brooks
21cs_163	502603	4265239	CPT	1.5	TDI Brooks
21cs_165	501765	4265789	CPT	0	TDI Brooks
21cs_167	500941	4266333	CPT	10	TDI Brooks
21cs_170	500180	4267046	CPT	0	TDI Brooks
21cs_172	499465	4267738	CPT	0	TDI Brooks
21cs_174	498746	4268422	CPT	0	TDI Brooks
21cs_175	504700	4263878	CPT	10	TDI Brooks
21cs_177	504568	4264870	CPT	10	TDI Brooks
21cs_179	504431	4265863	CPT	0	TDI Brooks
21cs_181	504298	4266849	CPT	0	TDI Brooks
21cs_183_R	504142	4267844	CPT	0	TDI Brooks
21cs_185	504028	4268825	CPT	0	TDI Brooks
21cs_186	503950	4269345	CPT	10	TDI Brooks
21cs_186_R	503935	4269319	CPT	10	TDI Brooks
21cs_187	503880	4269836	CPT	0	TDI Brooks
21cs_187	503887	4269812	CPT	0	TDI Brooks
21cs_189	503739	4270819	CPT	0	TDI Brooks
21cs_189	503745	4270794	CPT	0	TDI Brooks
21cs_191	503612	4271800	CPT	0	TDI Brooks
21cs_191	503605	4271797	CPT	0	TDI Brooks
21cs_193	503474	4272790	CPT	0	TDI Brooks
21cs_195	503341	4273776	CPT	0	TDI Brooks
21cs_197	503203	4274769	CPT	0	TDI Brooks
21cs_198	503136	4275269	CPT	0	TDI Brooks
21cs_199	503078	4275752	CPT	10	TDI Brooks
21cs_199	503049	4275766	CPT	10	TDI Brooks
21cs_200	503022	4276095	CPT	4.5	TDI Brooks
21cs_200_R	503010	4276088	CPT	4.5	TDI Brooks
21cs_202	502276	4276747	CPT	0	TDI Brooks
21cs_204	501511	4277410	CPT	0	TDI Brooks
21cs_206	500718	4278046	CPT	0.7	TDI Brooks
21cs_206	500745	4278040	CPT	1	TDI Brooks
21cs_206	500731	4278030	CPT	1	TDI Brooks
21cs_209	499845	4278814	CPT	0.4	TDI Brooks
21cs_211	499365	4279695	CPT	10	TDI Brooks
21cs_211	499372	4279685	CPT	10	TDI Brooks
21cs_213	498889	4280567	CPT	10	TDI Brooks

Table A.8: Geotechnical interpretation summary (cont.).

ID	Easting	Northing	Type	t_{soft} (m)	Source
21cs_213	498896	4280571	CPT	10	TDI Brooks
21cs_215	498599	4281105	CPT	10	TDI Brooks
21cs_217	498119	4281979	CPT	10	TDI Brooks
21cs_217	498110	4281986	CPT	10	TDI Brooks
21cs_218	497878	4282423	CPT	1.8	TDI Brooks
21cs_218_R	497858	4282423	CPT	1.8	TDI Brooks
21cs_220	497398	4283303	CPT	0	TDI Brooks
21cs_220_R	497389	4283290	CPT	0	TDI Brooks
21cs_221	497159	4283731	CPT	1.2	TDI Brooks

B. CBRA probability reports - Export cable

B.1. Vessel movement

Vessel movement has been assessed using AIS data as presented in Section 5.1. Tables B.1, B.2 and B.3 provides a summary of the vessels crossing the ECC1 and ECC2 cable segments. Section B.5 and B.6 details the number of vessels crossing each zone for each vessel size over the data set period.

B.1.1. Southern landfall vessel movement

Table B.1: Vessel classifications - southern landfall section

Vessel classification	Number of vessels	Number of crossings	Maximum DWT (t)
Cargo, No additional information	1	88	385
Diving ops	1	1	16
Dredging or underwater ops	1	2	38
Fishing	95	274	1043
High speed craft (HSC), all ships of this type	1	1	411
Other Type, all ships of this type	30	127	2684
Passenger, all ships of this type	21	217	232
Pilot Vessel	1	1	40313
Pleasure Craft	311	474	903
Reserved	1	1	44
Sailing	65	67	138
Search and Rescue vessel	1	3	5035
Towing	120	536	360
Tug	5	8	181
Unknown	2	2	44

A total of 88290 of 519102 data points were ignored from the analysis due to missing vessel length information.

The most common vessels for the southern landfall segment were:

- ST LOUIS RIVER, Passenger, all ships of this type class, 16 tonnes, 178 crossings
- DANIELLE MILLER, Cargo, No additional information class, 385 tonnes, 88 crossings
- DORIS MORAN, Towing class, 271 tonnes, 44 crossings
- BAYOU BRAVE, Towing class, 32 tonnes, 31 crossings
- MAVERICK, Towing class, 32 tonnes, 31 crossings

The largest for the southern landfall segment vessels were:

- NAUTICAST, Pilot Vessel class, 40313 tonnes, 1 crossings

- IRON LADY, Search and Rescue vessel class, 5035 tonnes, 3 crossings
- DODGE ISLAND, Other Type, all ships of this type class, 2684 tonnes, 21 crossings
- PADRE ISLAND, Other Type, all ships of this type class, 2684 tonnes, 13 crossings
- ILLINOIS, Other Type, all ships of this type class, 1363 tonnes, 1 crossings

B.1.2. Main export corridor vessel movement

Table B.2: Vessel classifications - main export corridor section.

Vessel classification	Number of vessels	Number of crossings	Maximum DWT (t)
Cargo, Hazardous category A	4	28	97544
Cargo, Hazardous category B	1	10	73785
Cargo, No additional information	7	17	98473
Cargo, all ships of this type	334	1326	101295
Fishing	192	978	1043
Other Type, Reserved for future use	1	1	32
Other Type, all ships of this type	40	119	3159
Passenger, all ships of this type	27	56	9610
Pleasure Craft	589	892	32058
Port Tender	1	2	2
Reserved	1	3	138
Sailing	132	151	559
Tanker, No additional information	2	2	23856
Tanker, all ships of this type	98	338	75341
Towing	186	1061	467
Towing: length exceeds 200m or breadth exceeds 25m	2	9	65
Tug	4	6	251
Unknown	5	7	69986

A total of 153779 of 984805 data points were ignored from the analysis due to missing vessel length information.

The most common vessels for the main export corridor segment were:

- CAPT JEFF, Fishing class, 44 tonnes, 93 crossings
- DORIS MORAN, Towing class, 271 tonnes, 59 crossings
- ANGELES, Cargo, all ships of this type class, 42436 tonnes, 59 crossings
- CONSTITUTION, Tanker, all ships of this type class, 24988 tonnes, 55 crossings

The largest for the the main export corridor segment vessels were:

- MSC SPAIN, Cargo, all ships of this type class, 101295 tonnes, 6 crossings

- NORTHERN MAGNITUDE, Cargo, No additional information class, 98473 tonnes, 3 crossings
- NORTHERN MAGNUM, Cargo, Hazardous category A class, 97544 tonnes, 4 crossings
- MAERSK MEMPHIS, Cargo, all ships of this type class, 96621 tonnes, 7 crossings

B.1.3. Northern landfall vessel movement

Table B.3: Vessel classifications - northern landfall section.

Vessel classification	Number of vessels	Number of crossings	Maximum DWT (t)
Cargo, No additional information	1	51	385
Cargo, all ships of this type	1	3	19017
Diving ops	1	1	16
Dredging or underwater ops	1	2	38
Fishing	107	323	1043
High speed craft (HSC), all ships of this type	1	1	411
Other Type, all ships of this type	37	362	3159
Passenger, all ships of this type	25	156	232
Pilot Vessel	2	3	40313
Pleasure Craft	371	691	9818
Reserved	1	1	44
Sailing	74	80	138
Search and Rescue vessel	1	2	5035
Tanker, all ships of this type	1	1	12535
Towing	121	560	360
Towing: length exceeds 200m or breadth exceeds 25m	1	12	19
Tug	6	9	197
Unknown	2	3	44

A total of 88290 of 519102 data points were ignored from the analysis due to missing vessel length information.

The most common vessels for the northern landfall segment were:

- PADRE ISLAND, Other Type, all ships of this type class, 2684 tonnes, 122 crossings
- DODGE ISLAND, Other Type, all ships of this type class, 2684 tonnes, 109 crossings
- ST LOUIS RIVER, Passenger, all ships of this type class, 16 tonnes, 56 crossings
- DANIELLE MILLER, Cargo, No additional information class, 385 tonnes, 51 crossings
- DORIS MORAN, Towing class, 271 tonnes, 46 crossings

The largest for the northern landfall segment vessels were:

- NAUTICAST, Pilot Vessel class, 40313 tonnes, 1 crossings
- PANVISION, Cargo, all ships of this type class, 19017 tonnes, 3 crossings
- CHEM POLARIS, Tanker, all ships of this type class, 12535 tonnes, 1 crossings
- PHOENIX, Pleasure Craft class, 9818 tonnes, 1 crossings
- IRON LADY, Search and Rescue vessel class, 5035 tonnes, 2 crossings

B.2. Anchor and ship models for probabilistic anchor strike assessment

One limitation of Carbon Trust guidelines is that soil is only considered as infinitely “soft” or “hard”. This assumption is unrealistic as thin layers of soft sediments overlying more competent strata is often observed in the field. This can lead to over-estimation of anchor penetration and overly conservative depth of lowering requirements. A two-layered soil model is adopted to consider the case where a layer of soft soil is overlying stiffer material. This model does not consider the case where hard soil is overlying soft soil.

Table B.4 shows the anchor model used with upper and lower bounds of penetration and ultimate holding capacity (UHC) shown for infinitely hard and soft soil.

Table B.4: Anchor model.

Vessel category	DWT (1000t)	Disp. (1000t)	Anchor mass (kg)	Fluke length (m)	Fluke pen hard soil (m)	Fluke pen soft soil (m)	UHC hard soil (kN)	UHC soft soil (kN)
1	0-10	18	2878.4	1.4	1.01	3.02	301.1	102.6
2	10-21	36	4799.6	1.7	1.20	3.61	469.7	172.5
3	21-32	54	6243.4	1.9	1.32	3.95	590.4	225.4
4	32-42	71	7448.5	2.0	1.40	4.19	688.3	269.6
5	42-52	89	8653.6	2.1	1.47	4.42	784.2	314.0
6	52-63	107	9858.6	2.2	1.54	4.62	878.4	358.5
7	63-74	125	10950.0	2.3	1.60	4.79	962.4	398.8
8	74-84	143	12000.0	2.3	1.65	4.94	1042.2	437.7
9	84-94	161	13050.0	2.4	1.70	5.09	1121.1	476.6
10	94-105	178	13600.0	2.4	1.72	5.16	1162.0	497.0

DWT is estimated using Equation B.1 (dimensions in metres, DWT in tonnes) (ref [4], Fig 1.3):

$$DWT = (length/5.32)^{(1/0.351)} \tag{B.1}$$

Displacement (Disp) is taken as $1.7 \times DWT$ (ref [4]), adopting container ship parameters.

Anchor mass is estimated from (ref [6], Fig 9.2).

Fluke length is estimated using Equation B.2 from data for stockless anchors from the Dreyfus and Vryhof anchor catalogues (fluke length in metres, anchor mass in tonnes):

$$\text{Fluke length} = 0.9909(\text{anchor mass})^{0.3441} \tag{B.2}$$

Anchor penetration for infinitely soft and hard soil is based on soil type (ref [18]):

$$\text{Fluke pen.} = \begin{cases} 1 \times \text{fluke length} \times sin(45°) & \text{in hard soils} \\ 3 \times \text{fluke length} \times sin(45°) & \text{in soft soils} \end{cases} \tag{B.3}$$

Anchor penetration for the two-layered soil model is calculated using Equation B.4 and the schematic outlined in Figure B.1 considering the thickness of soft soil (t_{soft}) and relative penetration in hard and soft soil.

$$\text{Fluke pen.}_{\text{layered}} = t_{\text{soft}} + \frac{\text{Fluke pen.}_{\text{soft}} - t_{\text{soft}}}{3} \tag{B.4}$$

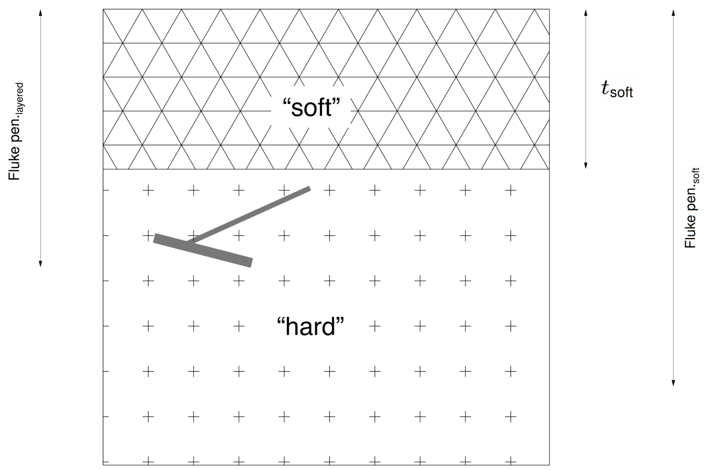


Figure B.1: Two-layered soil anchor penetration calculation schematic.

UHC is based on soil type, (UHC in kN and penetration in metres) and calculated using Equation B.5.

$$UHC = \begin{cases} 294.99 \times \text{Fluke pen.}^{2.5276} & \text{in hard soils} \\ \text{UHC}_{\text{soft}} \times \left(\frac{t_{\text{soft}}}{\text{Fluke pen.}_{\text{soft}}}\right) + \text{UHC}_{\text{hard}} \times \left(\frac{\text{Fluke pen.}_{\text{soft}} - t_{\text{soft}}}{\text{Fluke pen.}_{\text{soft}}}\right) & \text{in layered approach} \\ 3.91 \times \text{Fluke pen.}^{2.9525} & \text{in soft soils} \end{cases} \tag{B.5}$$

Figure B.2 shows the relationship between soft soil thickness, anchor size and anchor penetration. Variation of UHC with soft soil thickness and anchor size is shown on Figure B.3.

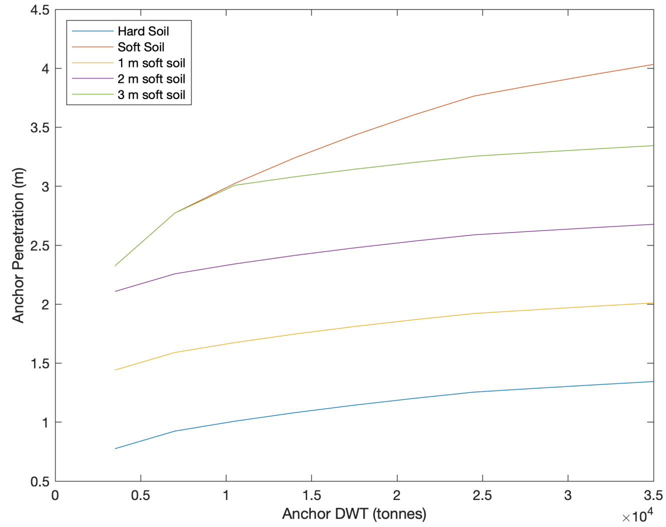


Figure B.2: Anchor penetration for various thicknesses of soft soil.

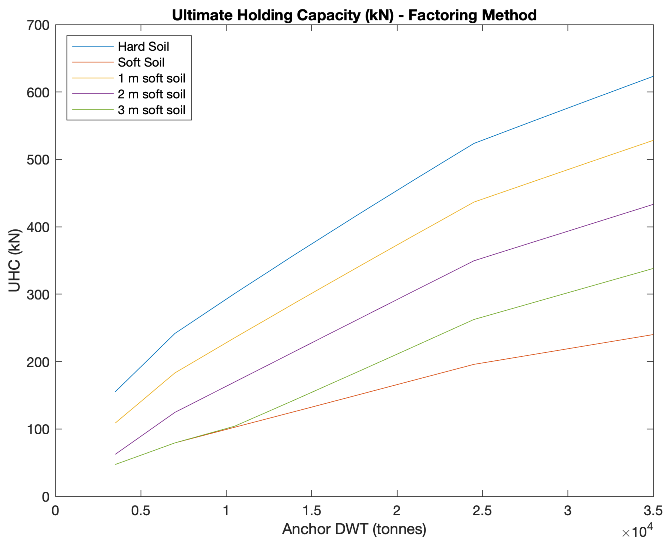


Figure B.3: UHC for various thicknesses of soft soil.

Table B.5 shows the ship model used.

D$_{ship}$, the estimate of distance an anchor is dragged, is calculated using Equation B.6 (ref [5]), D$_{ship}$ in metres, Disp in tonnes, v_{ship} in knots, UHC in kN, 0.51444 kts $>$ m/s:

$$D_{ship} = \frac{\text{Disp} \times 0.51444(v_{ship})^2}{4UHC} \tag{B.6}$$

Table B.5: Ship model

Vessel category	DWT (1000t)	Vship (kts)	Ptraffic (-)	Pwd (-)	Pincident (-)	Dship hard soil (m)	Dship soft soil (m)
1	0-4	4.0	1.0	0.9	0.0100	41.96	132.65
2	4-9	4.0	1.0	0.9	0.0100	58.69	174.74
3	9-14	4.0	1.0	0.9	0.0100	69.33	198.27
4	14-18	4.0	1.0	0.9	0.0100	76.65	212.42
5	18-22	4.0	1.0	0.9	0.0100	82.14	221.82
6	22-27	4.0	1.0	0.9	0.0100	88.72	235.38
7	27-32	4.0	1.0	0.9	0.0100	96.02	251.55
8	32-36	4.0	1.0	0.9	0.0100	102.40	265.18
9	36-40	4.0	1.0	0.9	0.0100	108.06	276.83
10	40-45	4.0	1.0	0.9	0.0100	113.11	286.89

B.3. Probabilistic anchor strike assessment for surface lay

The probability an anchor of a particular vessel size crosses the cable at seabed is estimated as (ref [6]), D$_{ship}$ in m, v$_{ship}$ in kts, 8766 hr/yr, 1852 kts $>$ m/hr:

$$P_{strike} = \frac{p_{traffic} \times p_{wd} \times vessel_{count} \times D_{ship} \times p_{incident}}{v_{ship} \times 1852 \times 8766} \quad \text{(B.7)}$$

Considering the vessel movements as independent, the total probability of an anchor strike over the cable length is (P$_{s.n}$ is the P$_{strike}$ of individual vessel sizes):

$$P_{strike.total} = 1 - (1 - P_{s.1})(1 - P_{s.2})(1 - P_{s.3})...(1 - P_{s.n}) \quad \text{(B.8)}$$

When the probabilities are very small the above method is equivalent to summing the individual probabilities.

Return period (RP) is taken as the inverse of probability of anchor strike. The length of the cable is used to calculate the return period per kilometre of cable.

B.3.1. Southern landfall section

Table B.6 shows the probability of anchor strikes for surface laid cables for the southern landfall section. Full results including vessel categories and counts are shown in Section B.6.

Table B.6: Two-layered soil model summary - southern landfall section.

Cable	Section	t_{soft} (m)	RP	RP per km
USWindECC	SouthKP00toKP03	0	780425 yr	23259088002 yr/km
USWindECC	SouthKP03toKP04	4.5	2354722 yr	263265927716 yr/km
USWindECC	SouthKP04toKP07	0	2140305 yr	70754624995 yr/km
USWindECC	SouthKP07toKP09	10	372224 yr	17140933469 yr/km
USWindECC	SouthKP09toKP10	0	1585411 yr	153988761891 yr/km

Cable	Section	t_{soft} (m)	RP	RP per km
USWindECC	SouthKP10toKP12	2.6	257236 yr	11977833914 yr/km
USWindECC	SouthKP12toEnd	10	468729 yr	38482448859 yr/km

B.3.2. Main export corridor section

Table B.7 shows the probability of anchor strikes for surface laid cables for the main export corridor section. Full results including vessel categories and counts are shown in Section B.6.

Table B.7: Two-layered soil model summary - main export corridor section.

Cable	Section	t_{soft} (m)	RP	RP per km
USWindECC	MainKP13toKP14	10	382041 yr	41438161874 yr/km
USWindECC	MainKP14toKP15	0	1160479 yr	109168703192 yr/km
USWindECC	MainKP15toKP16	2	1098446 yr	109844571976 yr/km
USWindECC	MainKP16toKP35	0	112646 yr	550368383 yr/km
USWindECC	MainKP35toKP36	10	493185 yr	46379180514 yr/km
USWindECC	MainKP36toKP40	0	183448 yr	4676417378 yr/km
USWindECC	MainKP40toKP41	1	363415 yr	39417838517 yr/km
USWindECC	MainKP41toKP45	0	184617 yr	4632823361 yr/km
USWindECC	MainKP45toKP46	3.2	356357 yr	38652375513 yr/km
USWindECC	MainKP46toEnd	0	1596122 yr	319224484112 yr/km

B.3.3. Northern landfall section

Table B.8 shows the probability of anchor strikes for surface laid cables for the northern landfall section. Full results including vessel categories and counts are shown in Section B.6.

Table B.8: Two-layered soil model summary - northern landfall section.

Cable	Section	t_{soft} (m)	RP	RP per km
USWindECC	NorthKP00toKP04	2	266908 yr	5802355237 yr/km
USWindECC	NorthKP04toKP06	10	1230877 yr	65343236504 yr/km
USWindECC	NorthKP06toKP09	1	1238339 yr	39128992363 yr/km
USWindECC	NorthKP09toKP11	0	1334511 yr	65899697251 yr/km
USWindECC	NorthKP11toKP12	10	866538 yr	85804142703 yr/km
USWindECC	NorthKP12toKP18	0	712530 yr	12996484876 yr/km
USWindECC	NorthKP18toKP19	10	1425226 yr	154587518492 yr/km
USWindECC	NorthKP19toKP22	0	1415325 yr	53365928513 yr/km
USWindECC	NorthKP22toEnd	10	528153 yr	32420678545 yr/km

B.4. Probabilistic anchor strike assessment for buried cables

The probability of anchor strike for buried cables has been calculated by removing the vessels from the analysis where the fluke penetration shown in Table B.4 is less than the depth considered. Required burial depths to achieve certain target frequencies are defined as:

- Category 1, $< 10^{-5}$, So low frequency that event considered negligible
- Category 2, $< 10^{-4}$, Event rarely expected to occur
- Category 3, $< 10^{-3}$, Event individually not expected to happen, but when summarised over a large number of cables have the credibility to happen once a year
- Category 4, $< 10^{-2}$, Event individually may be expected to occur during lifetime of the cable
- Category 5, $> 10^{-2}$, Event individually may be expected to occur more than once during lifetime of the cable

Section B.7 shows the anchor strike frequency for buried cables, with zero frequency taken as 10^{-10} for plotting purposes.

B.4.1. Southern landfall section

Table B.9 shows the required burial depth for the southern landfall section.

Table B.9: Burial depths to achieve target frequencies - southern landfall section.

Cable	Section	t_{soft} (m)	1.0e-02	1.0e-03	1.0e-04	1.0e-05
USWindECC	SouthKP00toKP03	0	0.0	0.0	0.0	0.0
USWindECC	SouthKP03toKP04	4.5	0.0	0.0	0.0	0.0
USWindECC	SouthKP04toKP07	0	0.0	0.0	0.0	0.0
USWindECC	SouthKP07toKP09	10	0.0	0.0	0.0	0.0
USWindECC	SouthKP09toKP10	0	0.0	0.0	0.0	0.0
USWindECC	SouthKP10toKP12	2.6	0.0	0.0	0.0	0.0
USWindECC	SouthKP12toEnd	10	0.0	0.0	0.0	0.0

B.4.2. Main export corridor section

Table B.10 shows the required burial depth for the main export corridor section.

Table B.10: Burial depths to achieve target frequencies - main export corridor section.

Cable	Section	t_{soft} (m)	1.0e-02	1.0e-03	1.0e-04	1.0e-05
USWindECC	MainKP13toKP14	10	0.0	0.0	0.0	0.0
USWindECC	MainKP14toKP15	0	0.0	0.0	0.0	0.0
USWindECC	MainKP15toKP16	2	0.0	0.0	0.0	0.0
USWindECC	MainKP16toKP35	0	0.0	0.0	0.0	0.0
USWindECC	MainKP35toKP36	10	0.0	0.0	0.0	0.0
USWindECC	MainKP36toKP40	0	0.0	0.0	0.0	0.0
USWindECC	MainKP40toKP41	1	0.0	0.0	0.0	0.0

Cable	Section	t_{soft} (m)	1.0e-02	1.0e-03	1.0e-04	1.0e-05
USWindECC	MainKP41toKP45	0	0.0	0.0	0.0	0.0
USWindECC	MainKP45toKP46	3.2	0.0	0.0	0.0	0.0
USWindECC	MainKP46toEnd	0	0.0	0.0	0.0	0.0

B.4.3. Northern landfall section

Table B.11 shows the required burial depth for the northern landfall section.

Table B.11: Burial depths to achieve target frequencies - northern landfall section.

Cable	Section	t_{soft} (m)	1.0e-02	1.0e-03	1.0e-04	1.0e-05
USWindECC	NorthKP00toKP04	2	0.0	0.0	0.0	0.0
USWindECC	NorthKP04toKP06	10	0.0	0.0	0.0	0.0
USWindECC	NorthKP06toKP09	1	0.0	0.0	0.0	0.0
USWindECC	NorthKP09toKP11	0	0.0	0.0	0.0	0.0
USWindECC	NorthKP11toKP12	10	0.0	0.0	0.0	0.0
USWindECC	NorthKP12toKP18	0	0.0	0.0	0.0	0.0
USWindECC	NorthKP18toKP19	10	0.0	0.0	0.0	0.0
USWindECC	NorthKP19toKP22	0	0.0	0.0	0.0	0.0
USWindECC	NorthKP22toEnd	10	0.0	0.0	0.0	0.0

B.5. Vessel movement maps

B.5.1. Southern landfall section

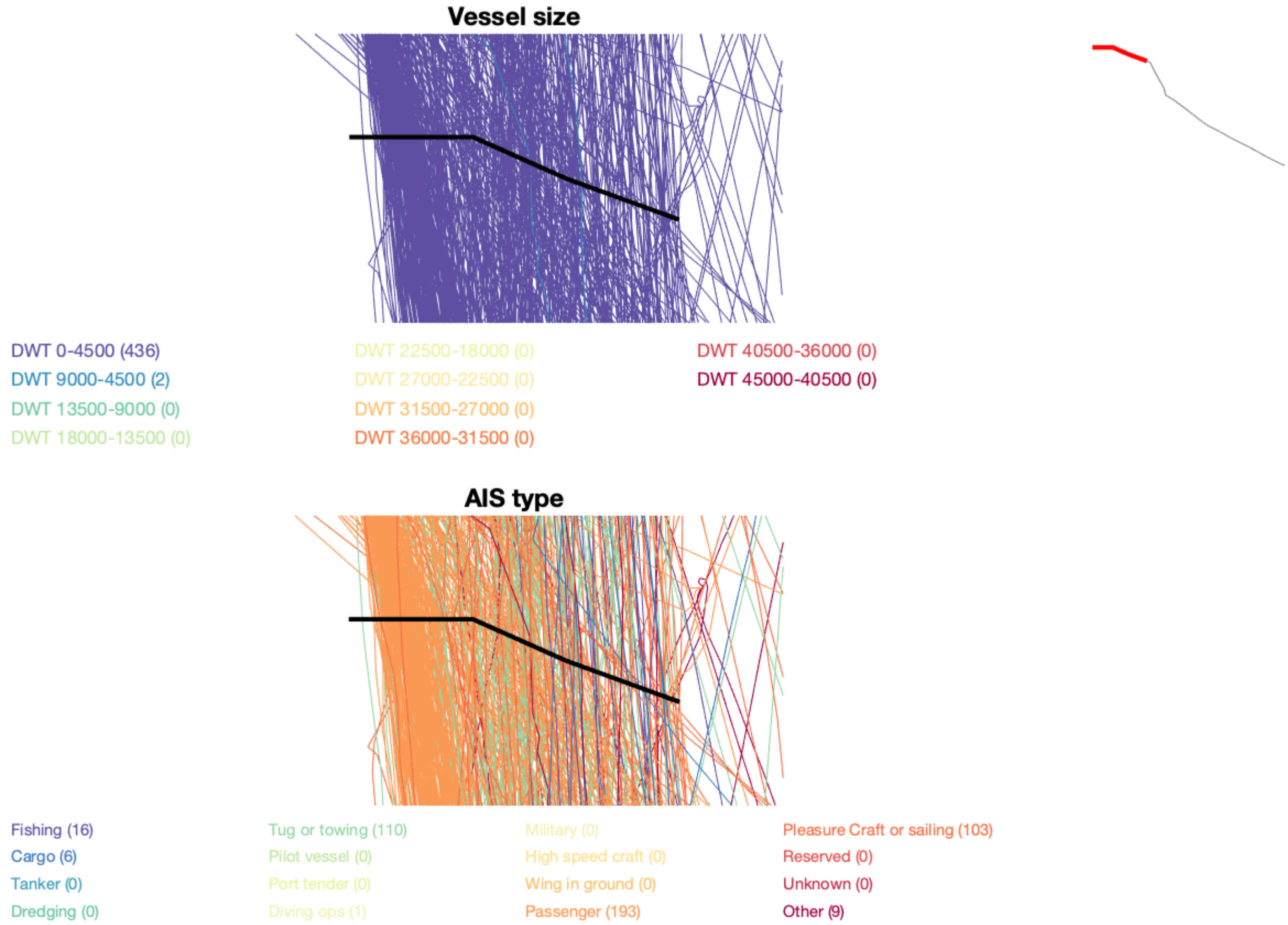


Figure B.4: Vessel movement, Section SouthKP00toKP03

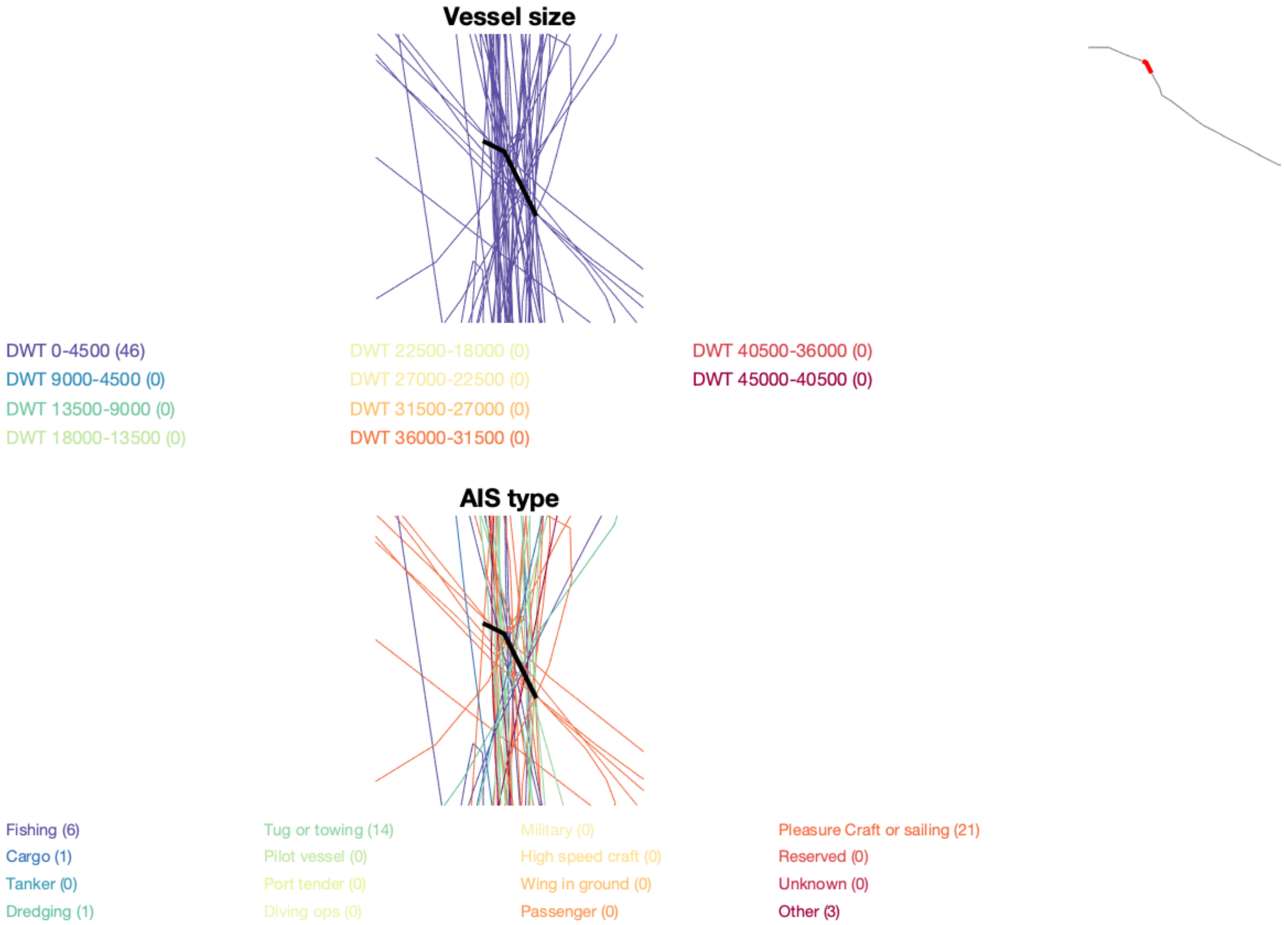


Figure B.5: Vessel movement, Section SouthKP03toKP04

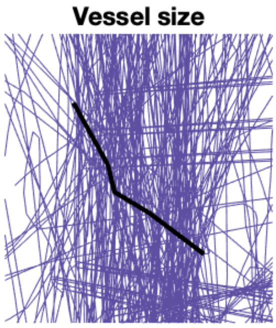


Figure B.6: Vessel movement, Section SouthKP04toKP07

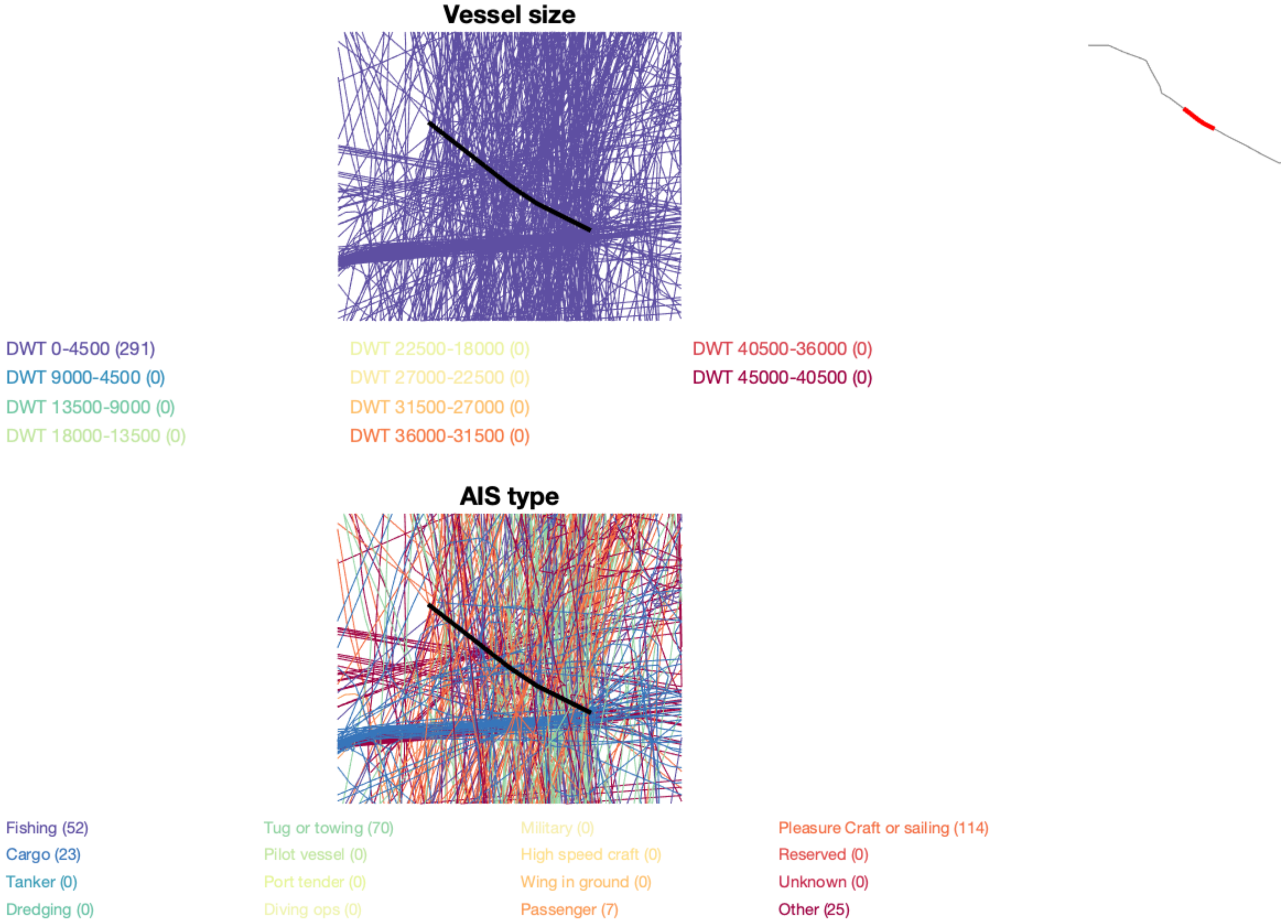


Figure B.7: Vessel movement, Section SouthKP07toKP09

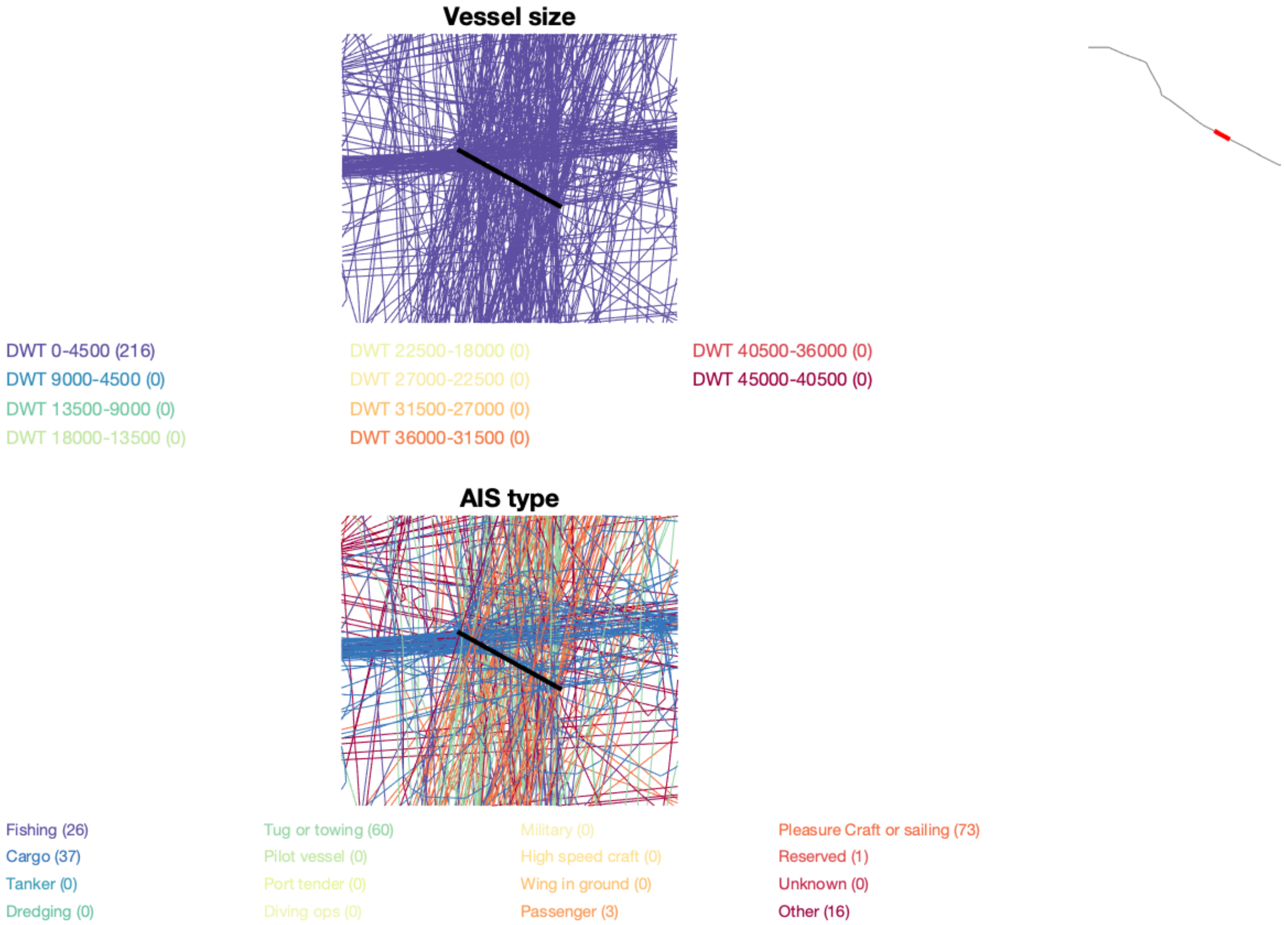


Figure B.8: Vessel movement, Section SouthKP09toKP10

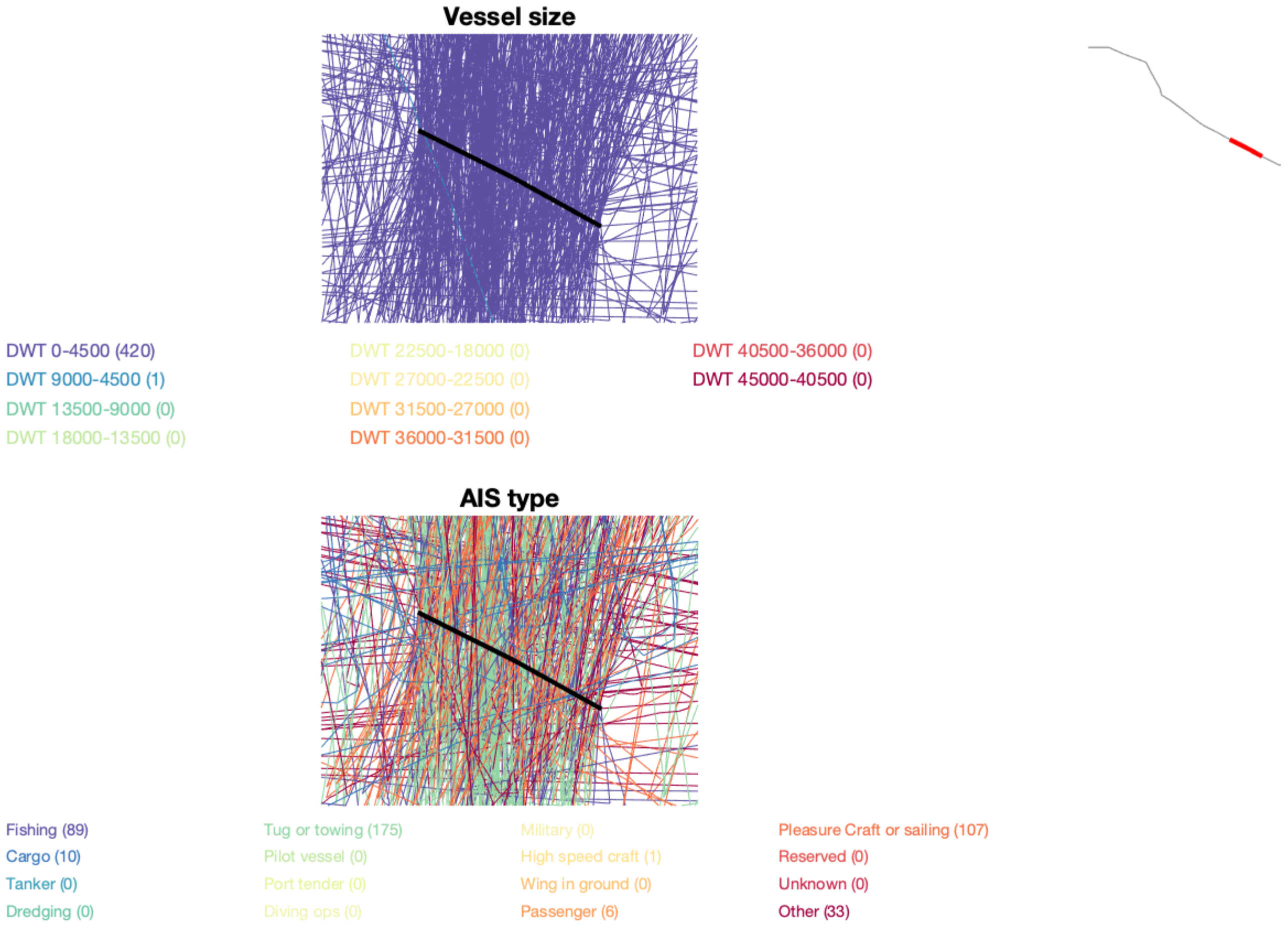
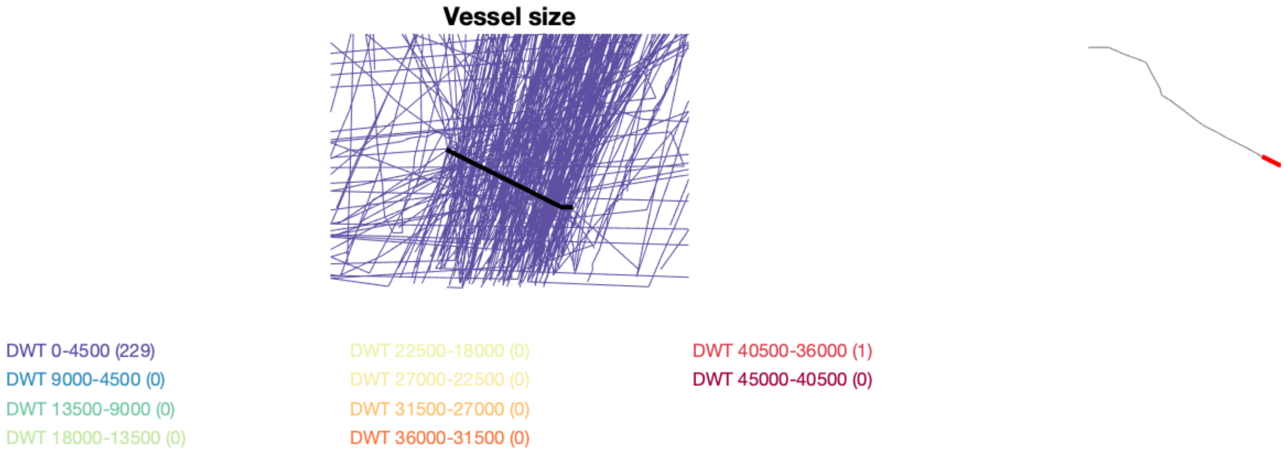


Figure B.9: Vessel movement, Section SouthKP10toKP12



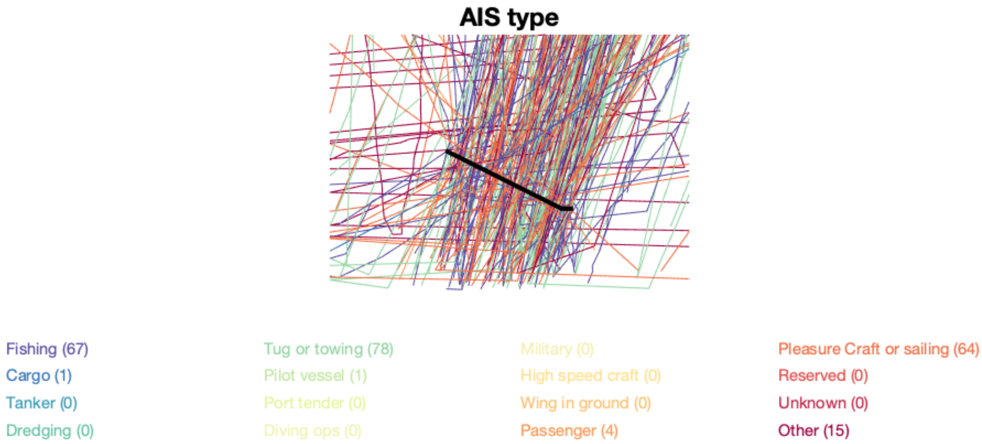


Figure B.10: Vessel movement, Section SouthKP12toEnd

B.5.2. Main export corridor section

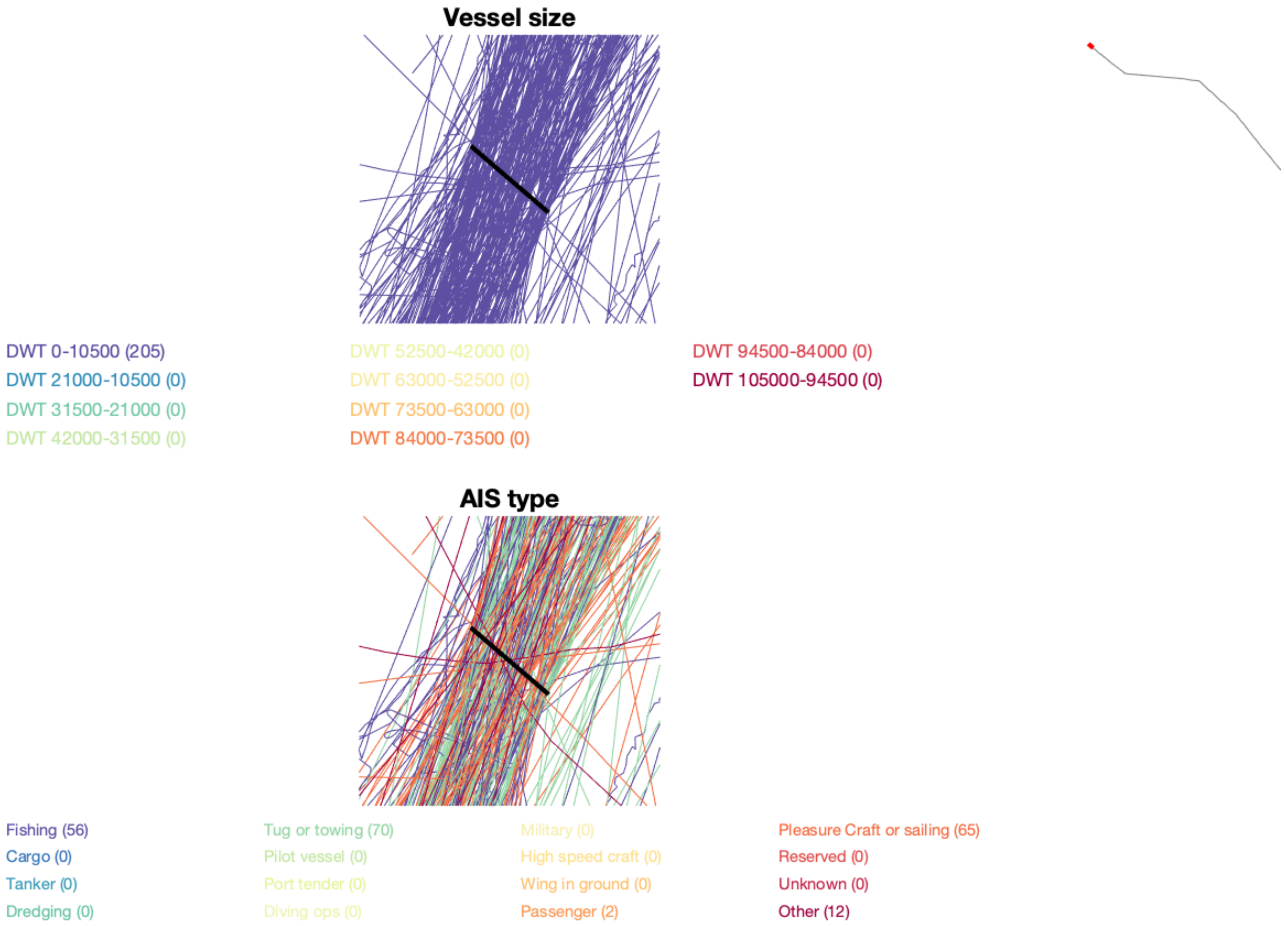


Figure B.11: Vessel movement, Section MainKP13toKP14

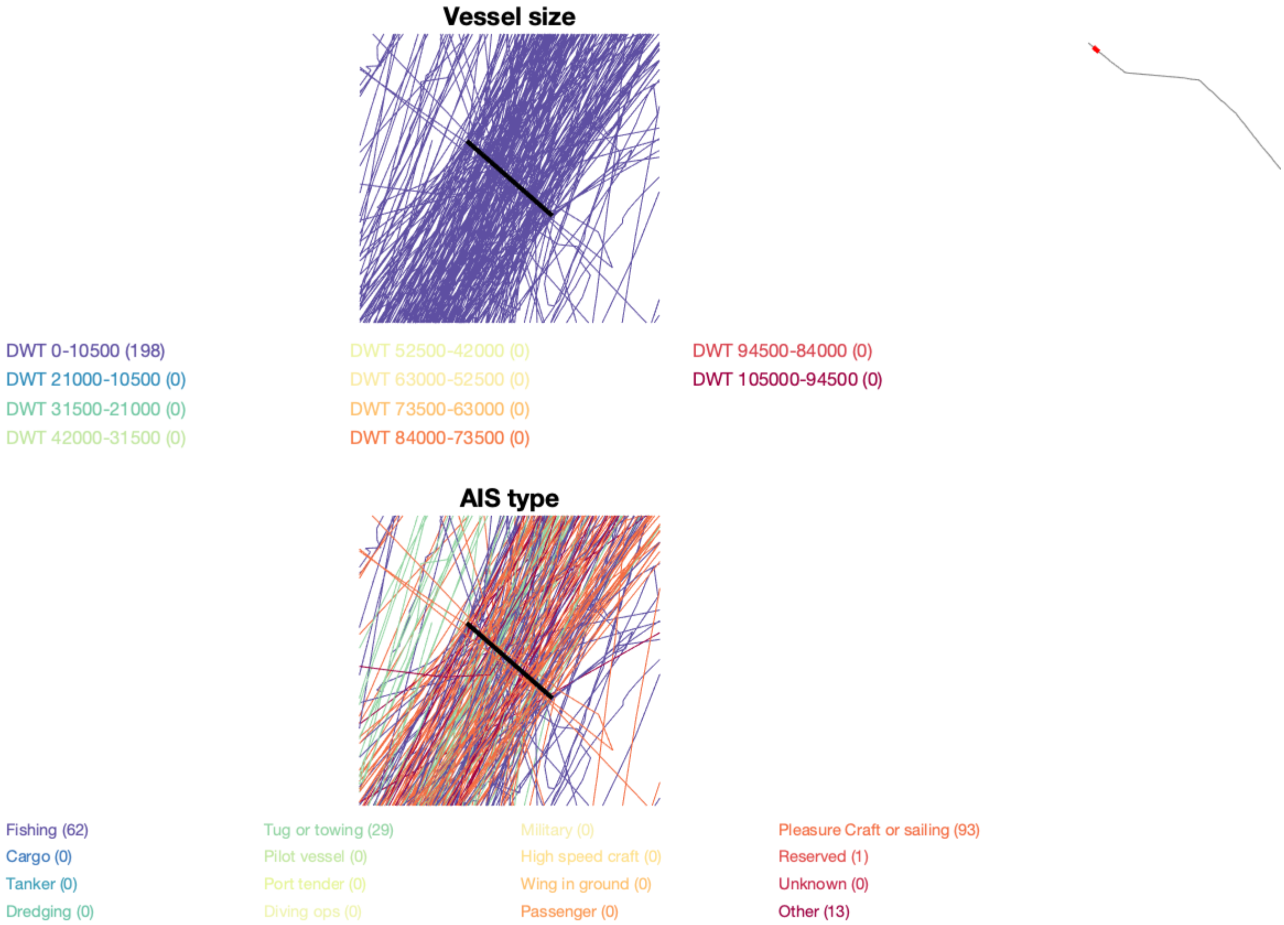


Figure B.12: Vessel movement, Section MainKP14toKP15

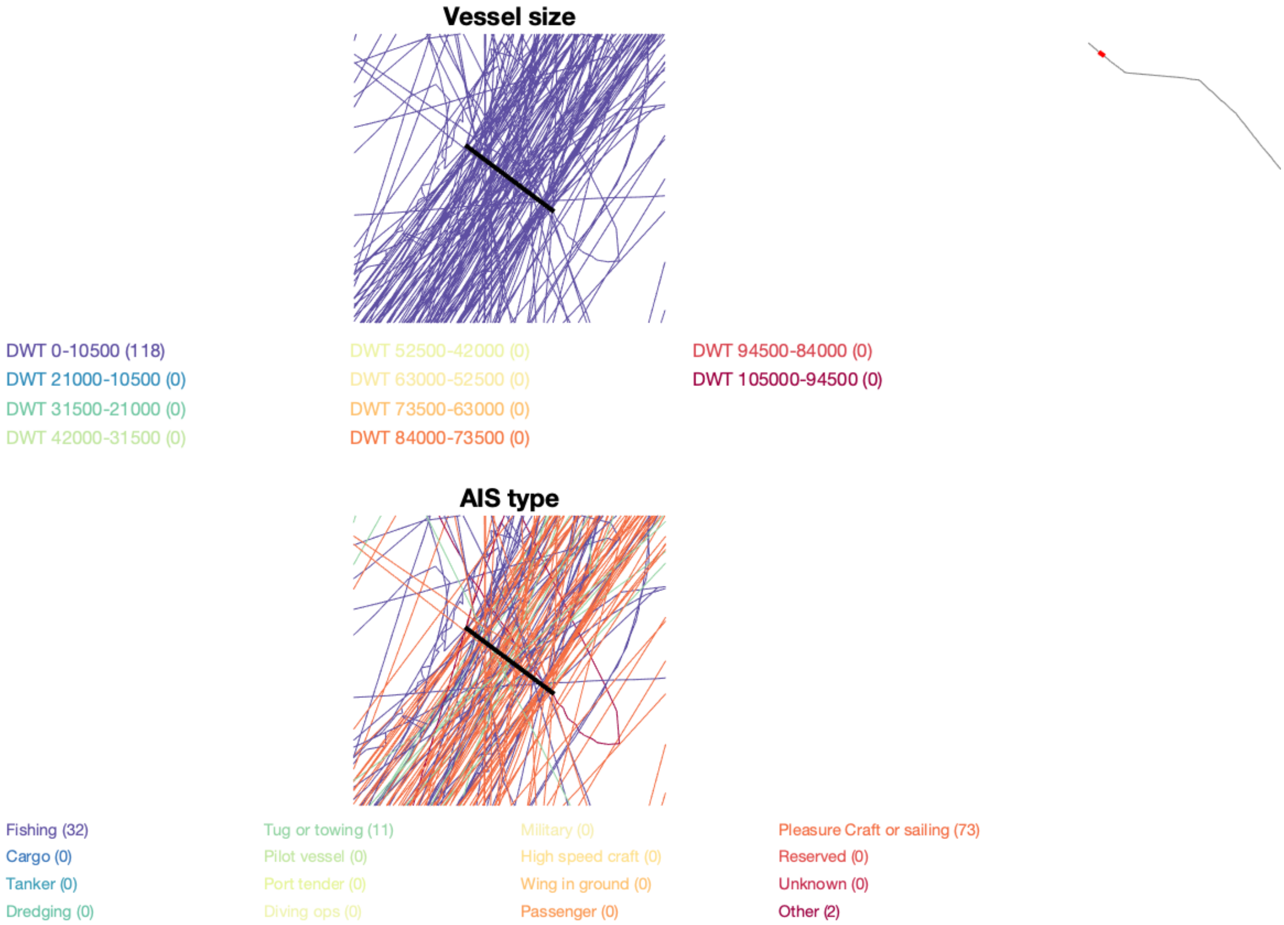


Figure B.13: Vessel movement, Section MainKP15toKP16

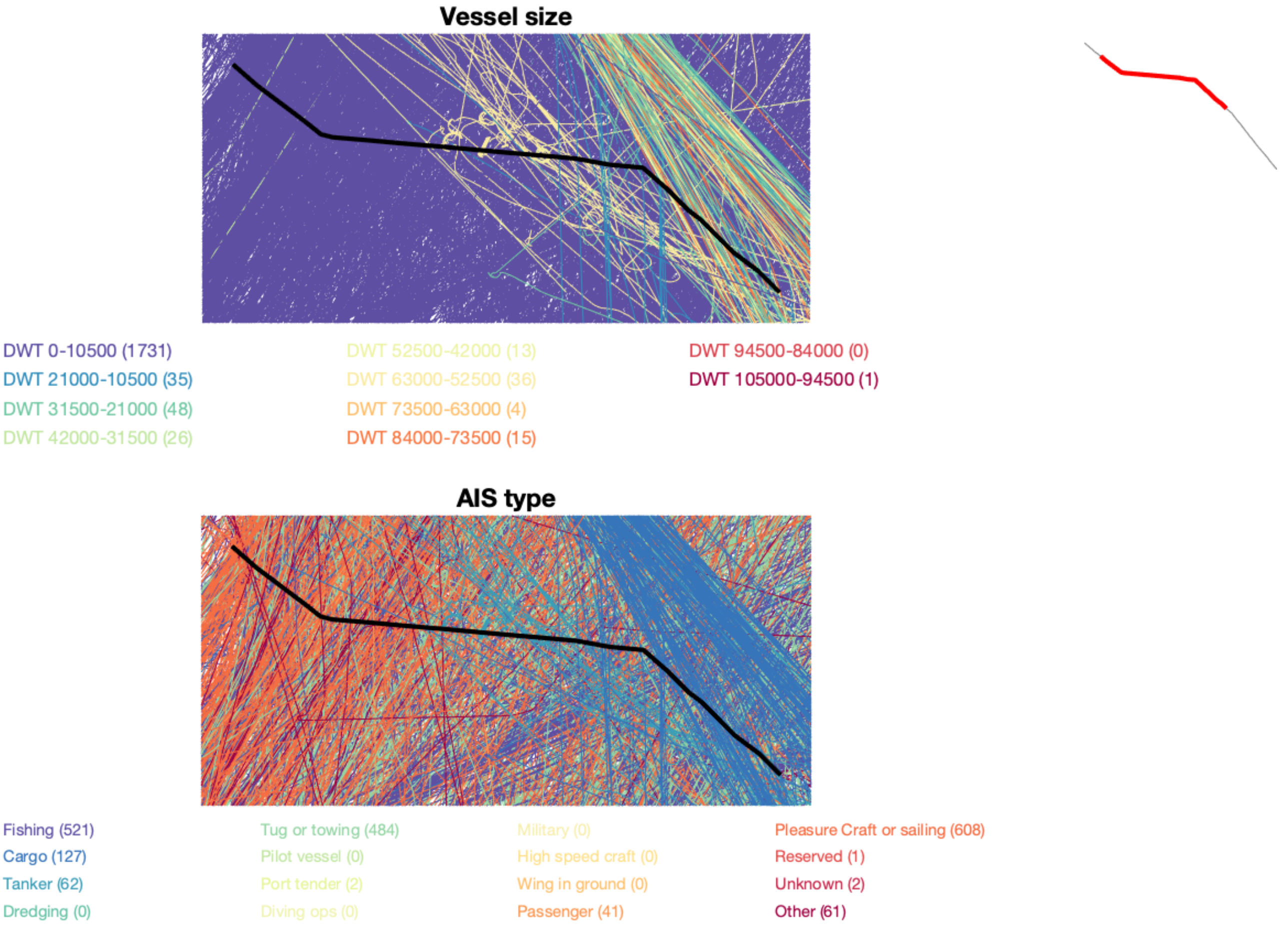
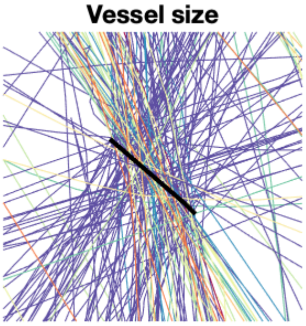


Figure B.14: Vessel movement, Section MainKP16toKP35



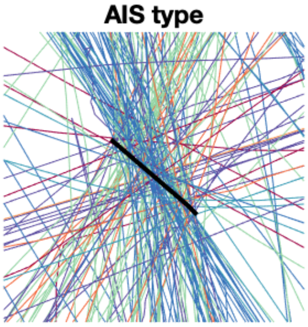
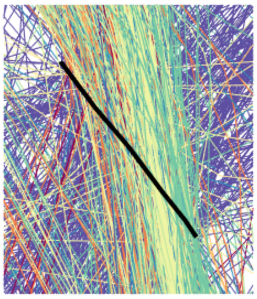


Figure B.15: Vessel movement, Section MainKP35toKP36



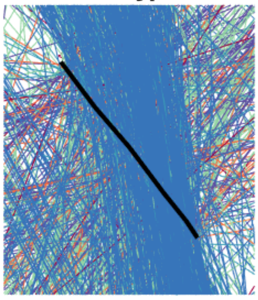
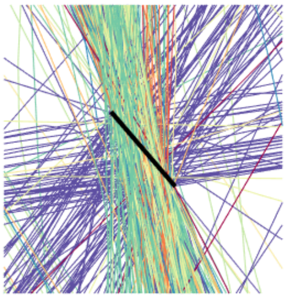
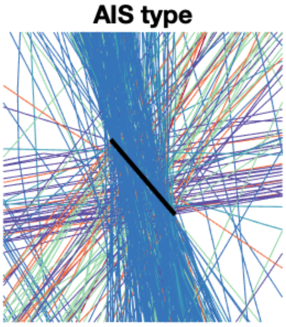


Figure B.16: Vessel movement, Section MainKP36toKP40



DWT 0-10500 (105)
DWT 21000-10500 (21)
DWT 31500-21000 (102)
DWT 42000-31500 (73)
DWT 52500-42000 (22)
DWT 63000-52500 (7)
DWT 73500-63000 (8)
DWT 84000-73500 (12)
DWT 94500-84000 (2)
DWT 105000-94500 (3)



Fishing (42)
Cargo (209)
Tanker (45)
Dredging (0)
Tug or towing (36)
Pilot vessel (0)
Port tender (0)
Diving ops (0)
Military (0)
High speed craft (0)
Wing in ground (0)
Passenger (0)
Pleasure Craft or sailing (22)
Reserved (0)
Unknown (0)
Other (1)

Figure B.17: Vessel movement, Section MainKP40toKP41

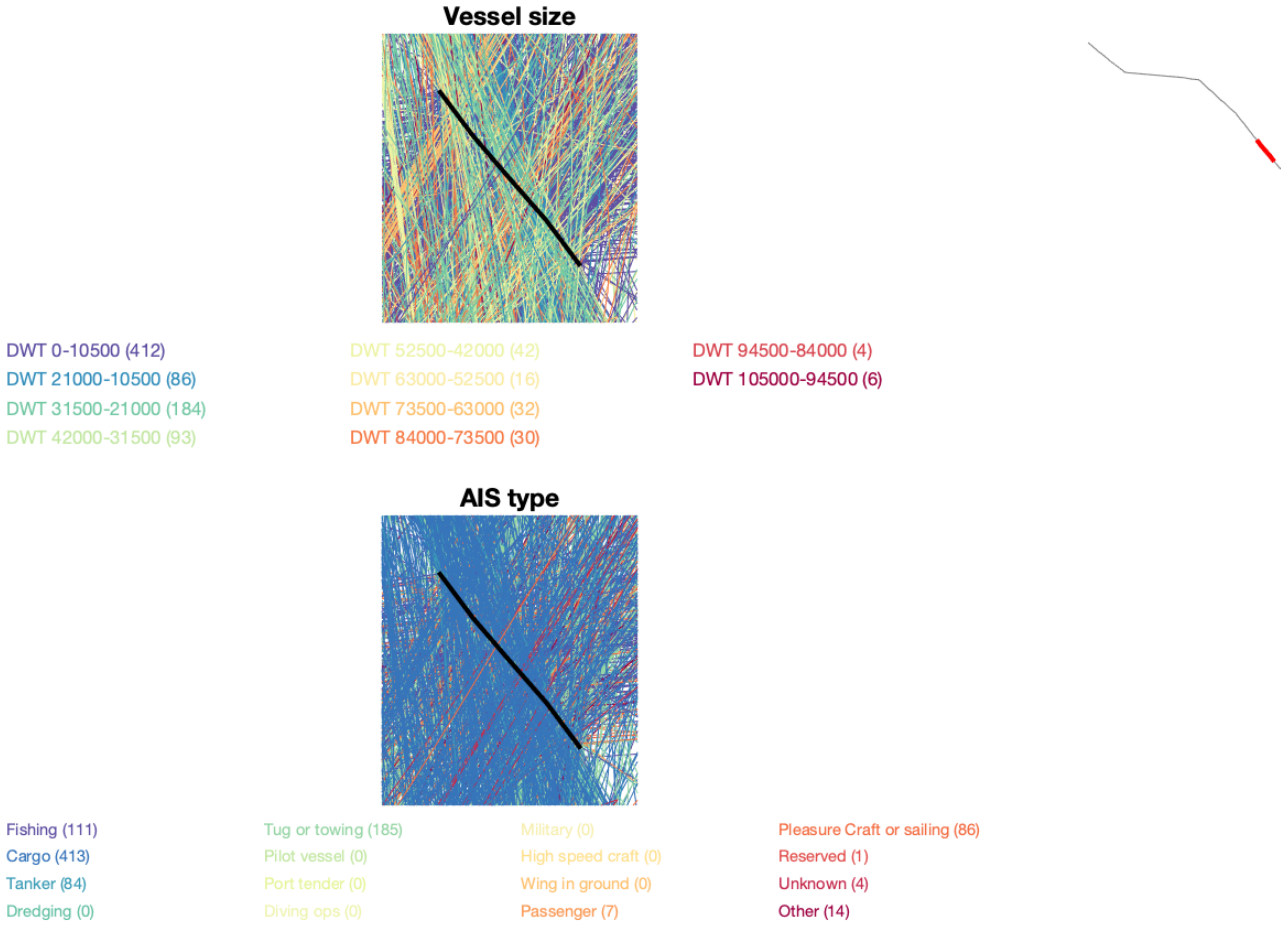
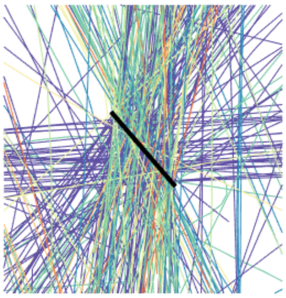


Figure B.18: Vessel movement, Section MainKP41toKP45



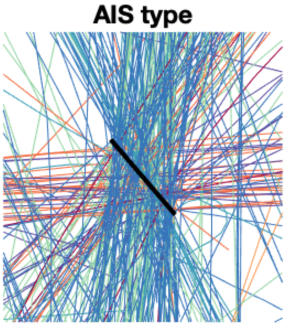


Figure B.19: Vessel movement, Section MainKP45toKP46

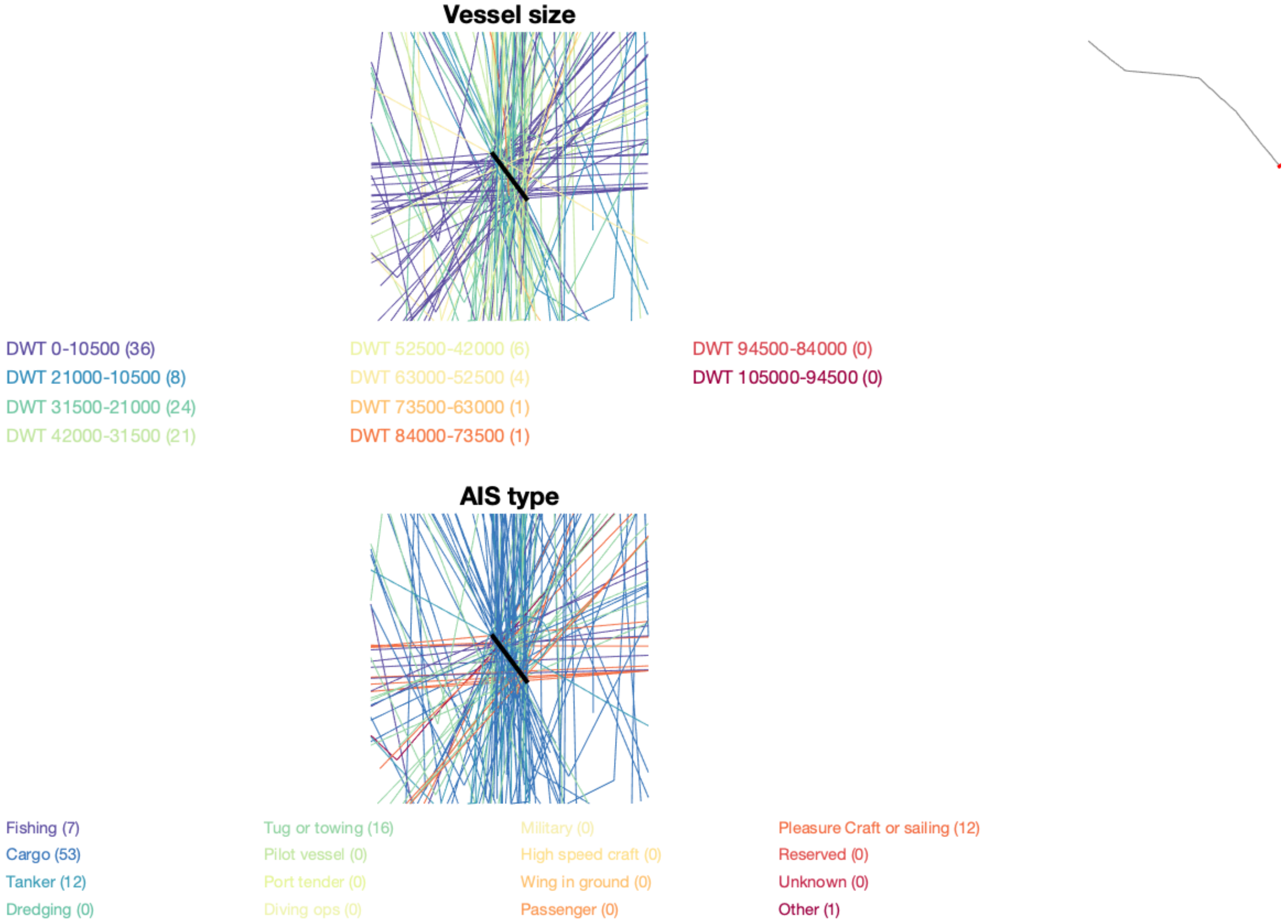


Figure B.20: Vessel movement, Section MainKP46toEnd

B.5.3. Northern landfall section

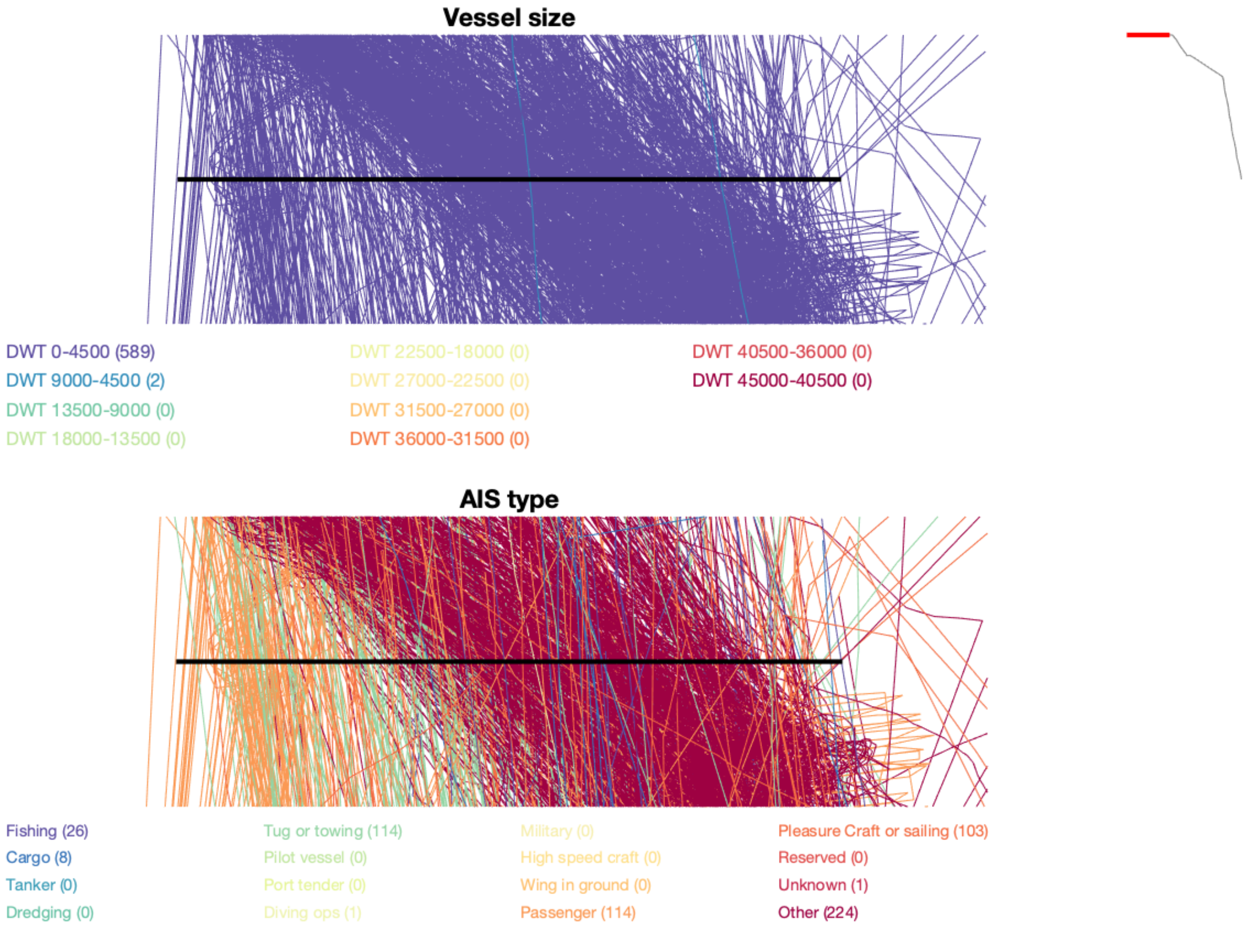
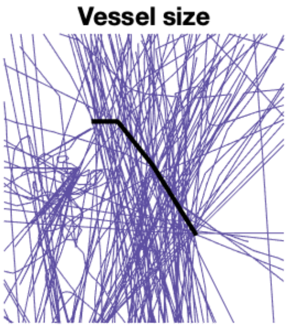
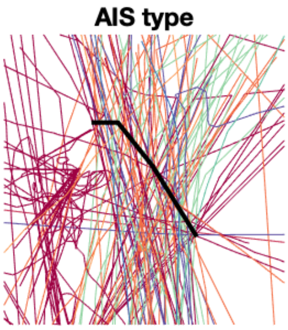


Figure B.21: Vessel movement, Section NorthKP00toKP04



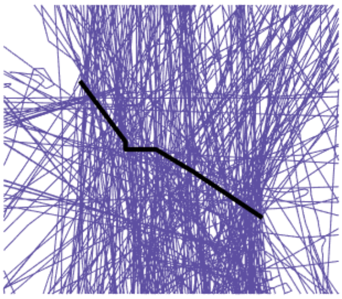
DWT 0-4500 (88)
DWT 9000-4500 (0)
DWT 13500-9000 (0)
DWT 18000-13500 (0)
DWT 22500-18000 (0)
DWT 27000-22500 (0)
DWT 31500-27000 (0)
DWT 36000-31500 (0)
DWT 40500-36000 (0)
DWT 45000-40500 (0)



Fishing (12)
Cargo (2)
Tanker (0)
Dredging (1)
Tug or towing (23)
Pilot vessel (0)
Port tender (0)
Diving ops (0)
Military (0)
High speed craft (0)
Wing in ground (0)
Passenger (4)
Pleasure Craft or sailing (29)
Reserved (0)
Unknown (1)
Other (16)

Figure B.22: Vessel movement, Section NorthKP04toKP06

Vessel size



DWT 0-4500 (202)
DWT 9000-4500 (0)
DWT 13500-9000 (0)
DWT 18000-13500 (0)
DWT 22500-18000 (0)
DWT 27000-22500 (0)
DWT 31500-27000 (0)
DWT 36000-31500 (0)
DWT 40500-36000 (0)
DWT 45000-40500 (0)

AIS type

Fishing (47)
Cargo (2)
Tanker (0)
Dredging (0)
Tug or towing (49)
Pilot vessel (1)
Port tender (0)
Diving ops (0)
Military (0)
High speed craft (0)
Wing in ground (0)
Passenger (3)
Pleasure Craft or sailing (66)
Reserved (0)
Unknown (1)
Other (33)

Figure B.23: Vessel movement, Section NorthKP06toKP09

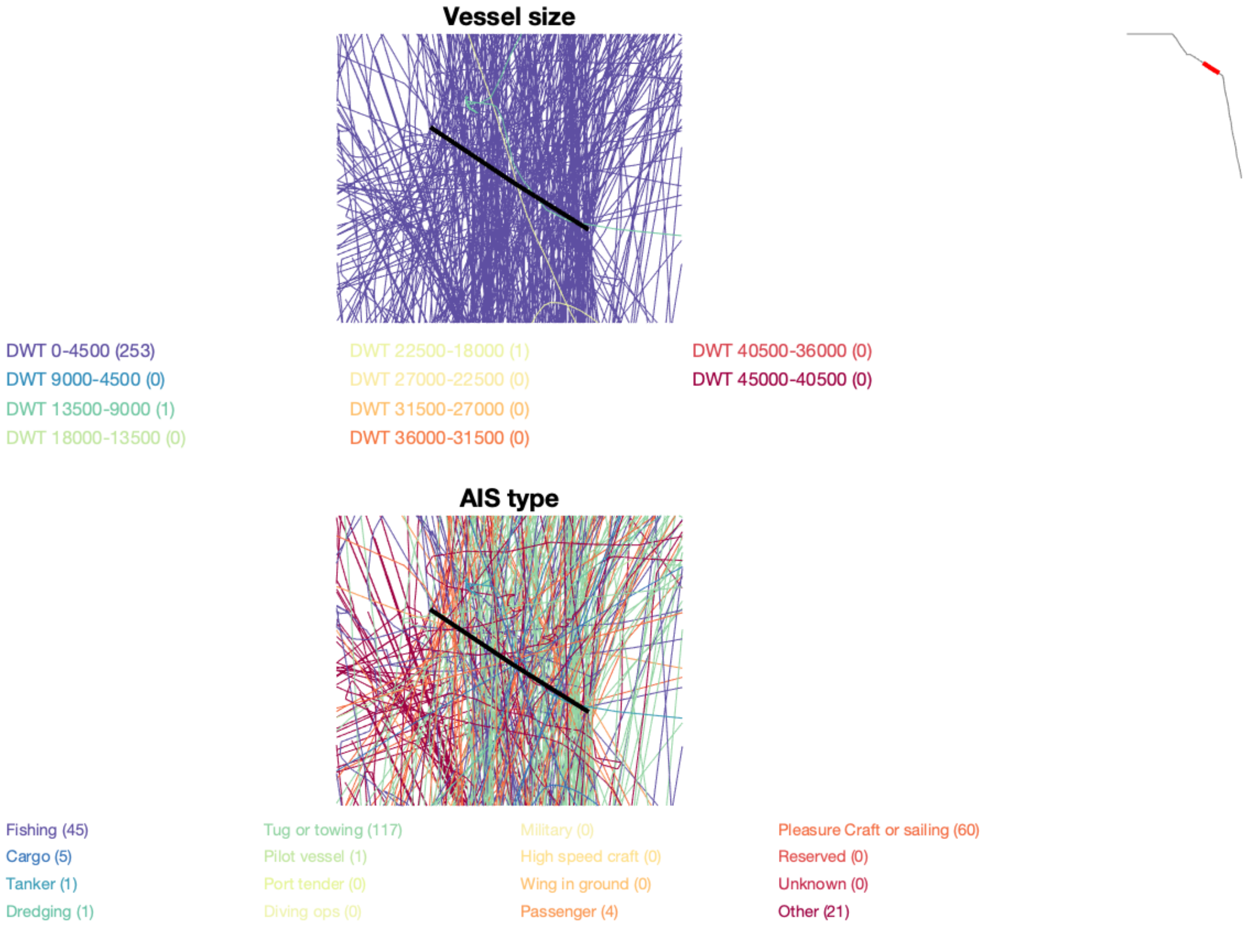


Figure B.24: Vessel movement, Section NorthKP09toKP11

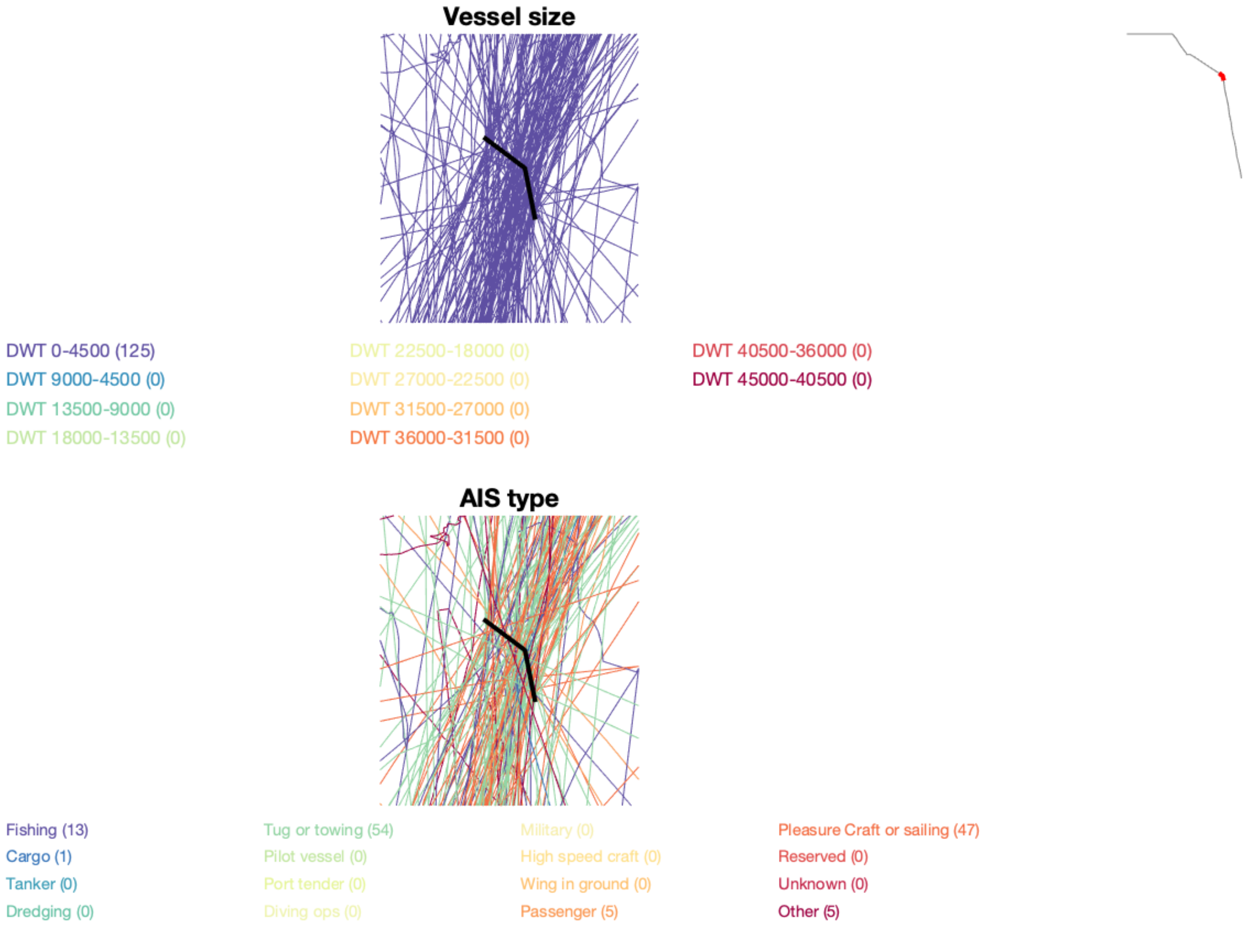
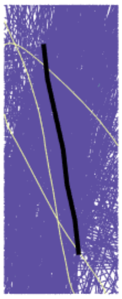


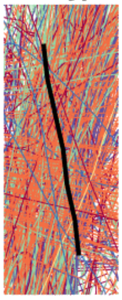
Figure B.25: Vessel movement, Section NorthKP11toKP12

Vessel size



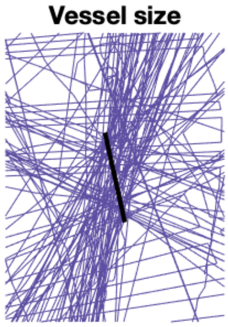
DWT 0-4500 (477)
DWT 9000-4500 (0)
DWT 13500-9000 (1)
DWT 18000-13500 (0)
DWT 22500-18000 (1)
DWT 27000-22500 (0)
DWT 31500-27000 (0)
DWT 36000-31500 (0)
DWT 40500-36000 (0)
DWT 45000-40500 (0)

AIS type

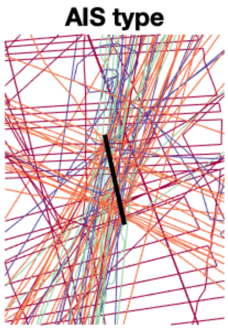


Fishing (68)
Cargo (4)
Tanker (0)
Dredging (0)
Tug or towing (113)
Pilot vessel (0)
Port tender (0)
Diving ops (0)
Military (0)
High speed craft (1)
Wing in ground (0)
Passenger (18)
Pleasure Craft or sailing (258)
Reserved (1)
Unknown (0)
Other (16)

Figure B.26: Vessel movement, Section NorthKP12toKP18

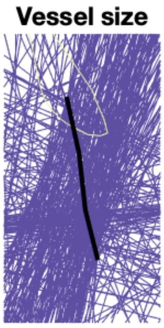


DWT 0-4500 (76)
DWT 9000-4500 (0)
DWT 13500-9000 (0)
DWT 18000-13500 (0)
DWT 22500-18000 (0)
DWT 27000-22500 (0)
DWT 31500-27000 (0)
DWT 36000-31500 (0)
DWT 40500-36000 (0)
DWT 45000-40500 (0)



Fishing (16)
Cargo (0)
Tanker (0)
Dredging (0)
Tug or towing (9)
Pilot vessel (0)
Port tender (0)
Diving ops (0)
Military (0)
High speed craft (0)
Wing in ground (0)
Passenger (2)
Pleasure Craft or sailing (40)
Reserved (0)
Unknown (0)
Other (9)

Figure B.27: Vessel movement, Section NorthKP18toKP19



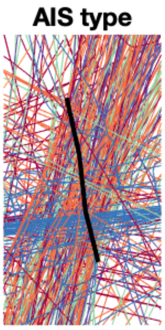
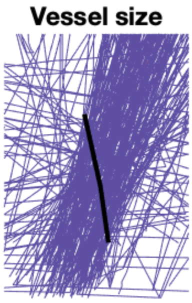


Figure B.28: Vessel movement, Section NorthKP19toKP22



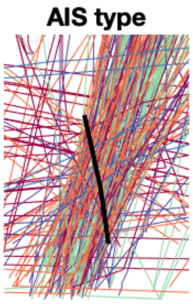


Figure B.29: Vessel movement, Section NorthKP22toEnd

B.6. Full anchor strike assessment for surface lay

B.6.1. Southern landfall section

Table B.12: Surface lay probabilistic assessment (full results - two-layered soil) - southern landfall section.

Cable	Section	Soft soil thickness	Vessel cat.	Anchor penetration (m)	Vessel count	Pstrike (-)	Two-layered soil Total Pstrike (-) Return period (yr) Return period (yr/km)
USWindECC	SouthKP00toKP03	0	1 2 3 4 5 6 7 8 9 10	0.8 1.0 1.1 1.2 1.2 1.3 1.3 1.4 1.4 1.4	436 2 0 0 0 0 0 0 0 0	1.27e-06 8.17e-09 0 0 0 0 0 0 0 0	1.28e-06 780425 yr 23259088002 yr/km
USWindECC	SouthKP03toKP04	4.5	1 2 3 4 5 6 7 8 9 10	2.5 2.9 3.2 3.5 3.7 3.8 3.9 4.1 4.2 4.3	46 0 0 0 0 0 0 0 0 0	4.25e-07 0 0 0 0 0 0 0 0 0	4.25e-07 2354722 yr 263265927716 yr/km
USWindECC	SouthKP04toKP07	0	1 2 3 4 5 6 7 8 9 10	0.8 1.0 1.1 1.2 1.2 1.3 1.3 1.4 1.4 1.4	160 0 0 0 0 0 0 0 0 0	4.67e-07 0 0 0 0 0 0 0 0 0	4.67e-07 2140305 yr 70754624995 yr/km
USWindECC	SouthKP07toKP09	10	1 2 3 4 5 6 7 8 9 10	2.5 2.9 3.2 3.5 3.7 3.8 3.9 4.1 4.2 4.3	291 0 0 0 0 0 0 0 0 0	2.69e-06 0 0 0 0 0 0 0 0 0	2.69e-06 372224 yr 17140933469 yr/km

Cable	Section	Soft soil thickness	Vessel cat.	Anchor penetration (m)	Vessel count	Pstrike (-)	Two-layered soil Total Pstrike (-) Return period (yr) Return period (yr/km)
USWindECC	SouthKP09toKP10	0	1 2 3 4 5 6 7 8 9 10	0.8 1.0 1.1 1.2 1.2 1.3 1.3 1.4 1.4 1.4	216 0 0 0 0 0 0 0 0 0	6.31e-07 0 0 0 0 0 0 0 0 0	6.31e-07 1585411 yr 153988761891 yr/km
USWindECC	SouthKP10toKP12	2.6	1 2 3 4 5 6 7 8 9 10	2.5 2.7 2.8 2.9 3.0 3.0 3.0 3.1 3.1 3.2	420 1 0 0 0 0 0 0 0 0	3.88e-06 9.99e-09 0 0 0 0 0 0 0 0	3.89e-06 257236 yr 11977833914 yr/km
USWindECC	SouthKP12toEnd	10	1 2 3 4 5 6 7 8 9 10	2.5 2.9 3.2 3.5 3.7 3.8 3.9 4.1 4.2 4.3	229 0 0 0 0 0 0 0 1 0	2.11e-06 0 0 0 0 0 0 0 1.93e-08 0	2.13e-06 468729 yr 38482448859 yr/km

B.6.2. Main export corridor section

Table B.13: Surface lay probabilistic assessment (full results - two-layered soil) - main export corridor section.

Cable	**Section**	**Soft soil thickness**	**Vessel cat.**	**Anchor penetration (m)**	**Vessel count**	**Pstrike (-)**	**Two-layered soil** **Total Pstrike (-)** **Return period (yr)** **Return period (yr/km)**
USWindECC	MainKP13toKP14	10	1 2 3 4 5 6 7 8 9 10	3.0 3.6 3.9 4.2 4.4 4.6 4.8 4.9 5.1 5.2	205 0 0 0 0 0 0 0 0 0	2.62e-06 0 0 0 0 0 0 0 0 0	2.62e-06 382041 yr 41438161874 yr/km
USWindECC	MainKP14toKP15	0	1 2 3 4 5 6 7 8 9 10	1.0 1.2 1.3 1.4 1.5 1.5 1.6 1.6 1.7 1.7	198 0 0 0 0 0 0 0 0 0	8.62e-07 0 0 0 0 0 0 0 0 0	8.62e-07 1160479 yr 109168703192 yr/km
USWindECC	MainKP15toKP16	2	1 2 3 4 5 6 7 8 9 10	2.3 2.5 2.6 2.7 2.8 2.9 2.9 3.0 3.0 3.1	118 0 0 0 0 0 0 0 0 0	9.10e-07 0 0 0 0 0 0 0 0 0	9.10e-07 1098446 yr 109844571976 yr/km
USWindECC	MainKP16toKP35	0	1 2 3 4 5 6 7 8 9 10	1.0 1.2 1.3 1.4 1.5 1.5 1.6 1.6 1.7 1.7	1731 35 48 26 13 36 4 15 0 1	7.53e-06 1.95e-07 3.20e-07 1.98e-07 1.09e-07 3.22e-07 3.81e-08 1.51e-07 0 1.13e-08	8.88e-06 112646 yr 550368383 yr/km

Cable	Section	Soft soil thickness	Vessel cat.	Anchor penetration (m)	Vessel count	Pstrike (-)	Two-layered soil Total Pstrike (-) Return period (yr) Return period (yr/km)
USWindECC	MainKP35toKP36	10	1 2 3 4 5 6 7 8 9 10	3.0 3.6 3.9 4.2 4.4 4.6 4.8 4.9 5.1 5.2	86 10 9 9 9 3 2 5 0 1	1.10e-06 1.52e-07 1.57e-07 1.75e-07 1.88e-07 6.58e-08 4.60e-08 1.20e-07 0 2.64e-08	2.03e-06 493185 yr 46379180514 yr/km
USWindECC	MainKP36toKP40	0	1 2 3 4 5 6 7 8 9 10	1.0 1.2 1.3 1.4 1.5 1.5 1.6 1.6 1.7 1.7	335 68 203 90 99 17 17 28 5 9	1.46e-06 3.79e-07 1.35e-06 6.85e-07 8.27e-07 1.52e-07 1.62e-07 2.82e-07 5.26e-08 1.01e-07	5.45e-06 183448 yr 4676417378 yr/km
USWindECC	MainKP40toKP41	1	1 2 3 4 5 6 7 8 9 10	1.7 1.9 2.0 2.1 2.1 2.2 2.3 2.3 2.4 2.4	105 21 102 73 22 7 8 12 2 3	5.84e-07 1.42e-07 8.05e-07 6.50e-07 2.13e-07 7.19e-08 8.69e-08 1.37e-07 2.37e-08 3.80e-08	2.75e-06 363415 yr 39417838517 yr/km
USWindECC	MainKP41toKP45	0	1 2 3 4 5 6 7 8 9 10	1.0 1.2 1.3 1.4 1.5 1.5 1.6 1.6 1.7 1.7	412 86 184 93 42 16 32 30 4 6	1.79e-06 4.80e-07 1.23e-06 7.08e-07 3.51e-07 1.43e-07 3.05e-07 3.02e-07 4.21e-08 6.77e-08	5.42e-06 184617 yr 4632823361 yr/km
USWindECC	MainKP45toKP46	3.2	1 2 3 4 5 6 7 8 9 10	3.0 3.3 3.4 3.5 3.6 3.7 3.7 3.8 3.8 3.9	91 19 54 17 16 3 6 4 0 0	1.16e-06 2.42e-07 7.21e-07 2.42e-07 2.36e-07 4.55e-08 9.39e-08 6.44e-08 0 0	2.81e-06 356357 yr 38652375513 yr/km

Cable	Section	Soft soil thickness	Vessel cat.	Anchor penetration (m)	Vessel count	Pstrike (-)	Two-layered soil Total Pstrike (-) Return period (yr) Return period (yr/km)
USWindECC	MainKP46toEnd	0	1 2 3 4 5 6 7 8 9 10	1.0 1.2 1.3 1.4 1.5 1.5 1.6 1.6 1.7 1.7	36 8 24 21 6 4 1 1 0 0	1.57e-07 4.46e-08 1.60e-07 1.60e-07 5.01e-08 3.58e-08 9.53e-09 1.01e-08 0 0	6.27e-07 1596122 yr 319224484112 yr/km

B.6.3. Northern landfall section

Table B.14: Surface lay probabilistic assessment (full results - two-layered soil) - northern landfall section.

Cable	Section	Soft soil thickness	Vessel cat.	Anchor penetration (m)	Vessel count	Pstrike (-)	Two-layered soil Total Pstrike (-) Return period (yr) Return period (yr/km)
USWindECC	NorthKP00toKP04	2	1 2 3 4 5 6 7 8 9 10	2.2 2.3 2.4 2.5 2.6 2.6 2.6 2.7 2.7 2.8	589 2 0 0 0 0 0 0 0 0	3.73e-06 1.50e-08 0 0 0 0 0 0 0 0	3.75e-06 266908 yr 5802355237 yr/km
USWindECC	NorthKP04toKP06	10	1 2 3 4 5 6 7 8 9 10	2.5 2.9 3.2 3.5 3.7 3.8 3.9 4.1 4.2 4.3	88 0 0 0 0 0 0 0 0 0	8.12e-07 0 0 0 0 0 0 0 0 0	8.12e-07 1230877 yr 65343236504 yr/km
USWindECC	NorthKP06toKP09	1	1 2 3 4 5 6 7 8 9 10	1.5 1.6 1.7 1.8 1.9 1.9 2.0 2.0 2.1 2.1	202 0 0 0 0 0 0 0 0 0	8.08e-07 0 0 0 0 0 0 0 0 0	8.08e-07 1238339 yr 39128992363 yr/km
USWindECC	NorthKP09toKP11	0	1 2 3 4 5 6 7 8 9 10	0.8 1.0 1.1 1.2 1.2 1.3 1.3 1.4 1.4 1.4	253 0 1 0 1 0 0 0 0 0	7.39e-07 0 4.83e-09 0 5.72e-09 0 0 0 0 0	7.49e-07 1334511 yr 65899697251 yr/km

Cable	Section	Soft soil thickness	Vessel cat.	Anchor penetration (m)	Vessel count	Pstrike (-)	Two-layered soil Total Pstrike (-) Return period (yr) Return period (yr/km)
USWindECC	NorthKP11toKP12	10	1 2 3 4 5 6 7 8 9 10	2.5 2.9 3.2 3.5 3.7 3.8 3.9 4.1 4.2 4.3	125 0 0 0 0 0 0 0 0 0	1.15e-06 0 0 0 0 0 0 0 0 0	1.15e-06 866538 yr 85804142703 yr/km
USWindECC	NorthKP12toKP18	0	1 2 3 4 5 6 7 8 9 10	0.8 1.0 1.1 1.2 1.2 1.3 1.3 1.4 1.4 1.4	477 0 1 0 1 0 0 0 0 0	1.39e-06 0 4.83e-09 0 5.72e-09 0 0 0 0 0	1.40e-06 712530 yr 12996484876 yr/km
USWindECC	NorthKP18toKP19	10	1 2 3 4 5 6 7 8 9 10	2.5 2.9 3.2 3.5 3.7 3.8 3.9 4.1 4.2 4.3	76 0 0 0 0 0 0 0 0 0	7.02e-07 0 0 0 0 0 0 0 0 0	7.02e-07 1425226 yr 154587518492 yr/km
USWindECC	NorthKP19toKP22	0	1 2 3 4 5 6 7 8 9 10	0.8 1.0 1.1 1.2 1.2 1.3 1.3 1.4 1.4 1.4	240 0 0 0 1 0 0 0 0 0	7.01e-07 0 0 0 5.72e-09 0 0 0 0 0	7.07e-07 1415325 yr 53365928513 yr/km
USWindECC	NorthKP22toEnd	10	1 2 3 4 5 6 7 8 9 10	2.5 2.9 3.2 3.5 3.7 3.8 3.9 4.1 4.2 4.3	203 0 0 0 0 0 0 0 1 0	1.87e-06 0 0 0 0 0 0 0 1.93e-08 0	1.89e-06 528153 yr 32420678545 yr/km

B.7. Anchor strike probability graphs for buried cables

B.7.1. Southern landfall section

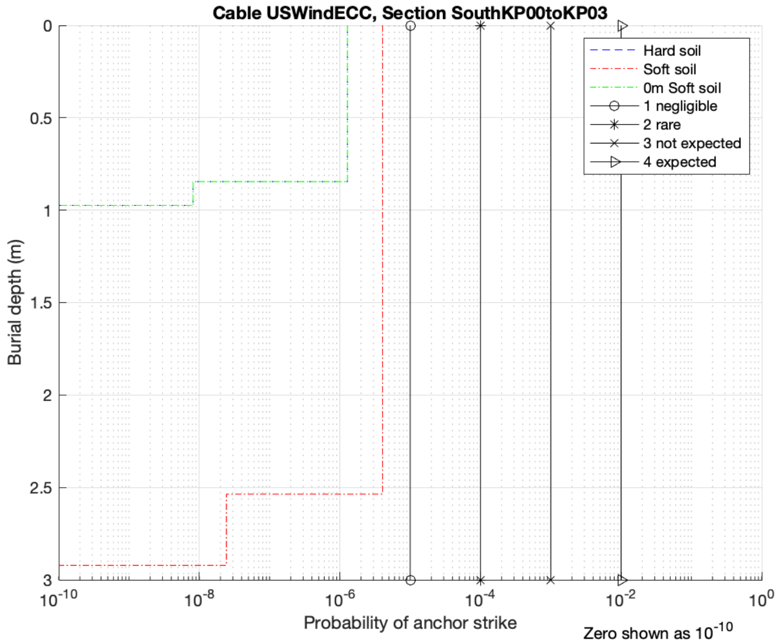


Figure B.30: Anchor strike risk vs burial depth, Section SouthKP00toKP03

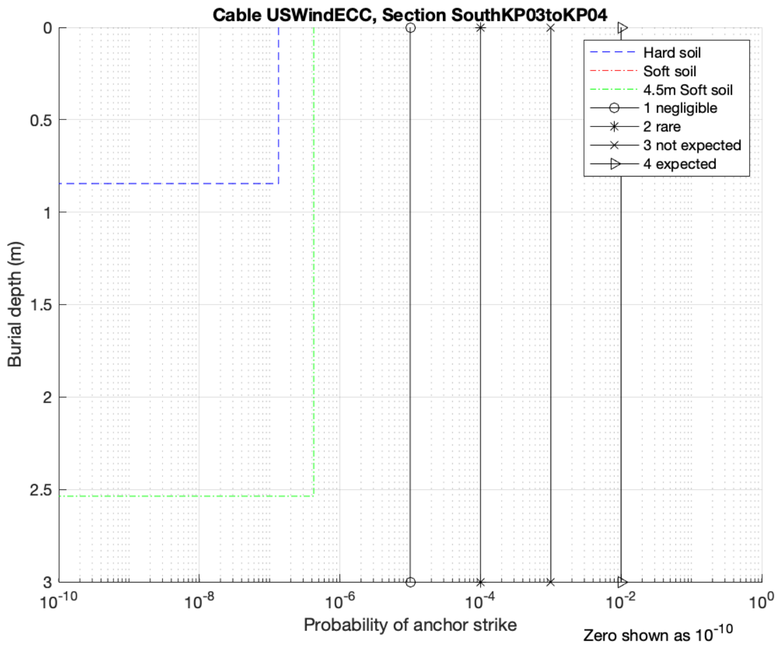


Figure B.31: Anchor strike risk vs burial depth, Section SouthKP03toKP04

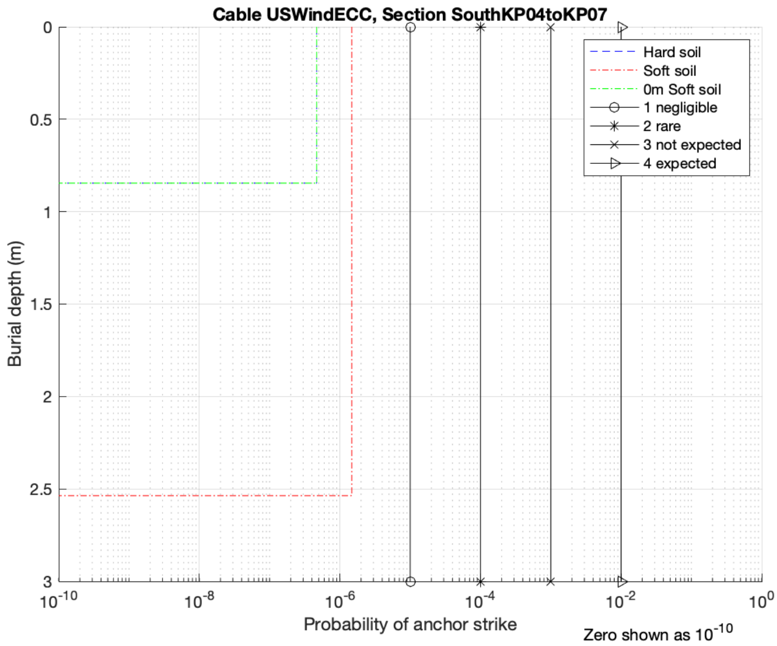


Figure B.32: Anchor strike risk vs burial depth, Section SouthKP04toKP07

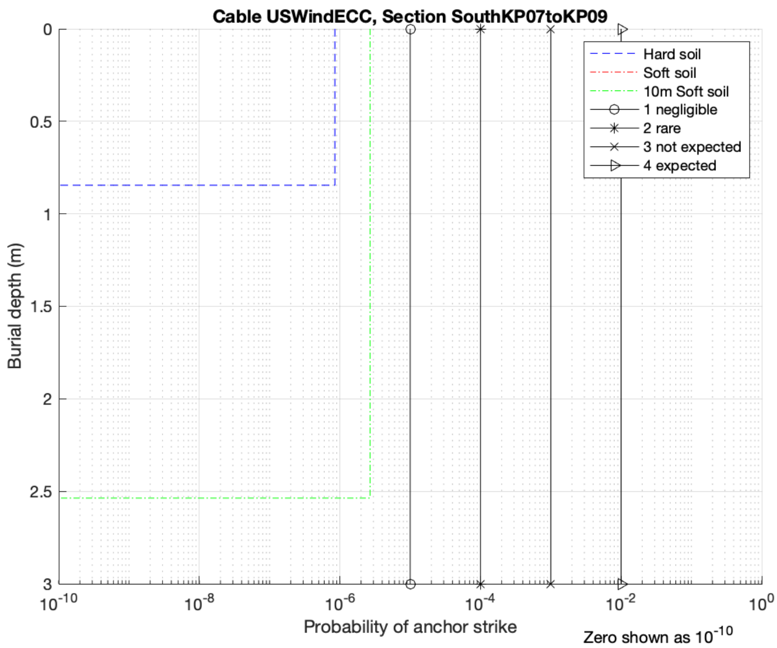


Figure B.33: Anchor strike risk vs burial depth, Section SouthKP07toKP09

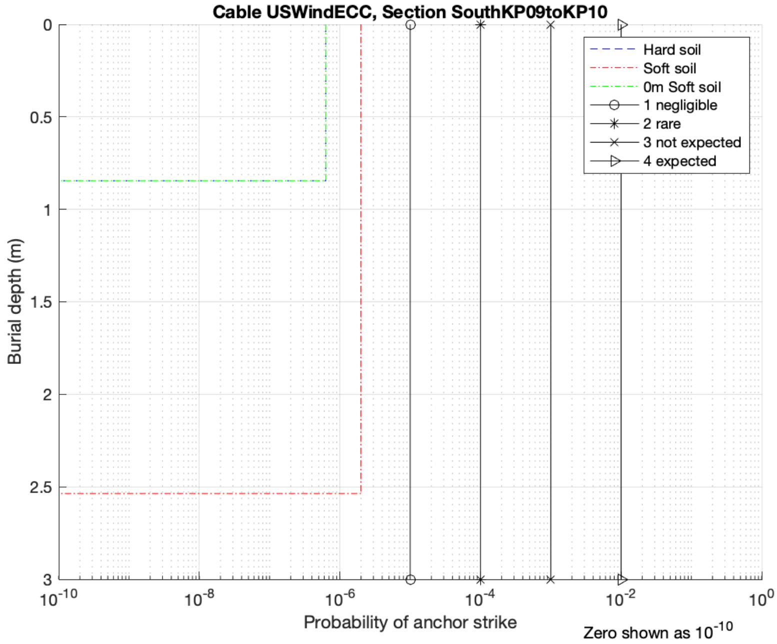


Figure B.34: Anchor strike risk vs burial depth, Section SouthKP09toKP10

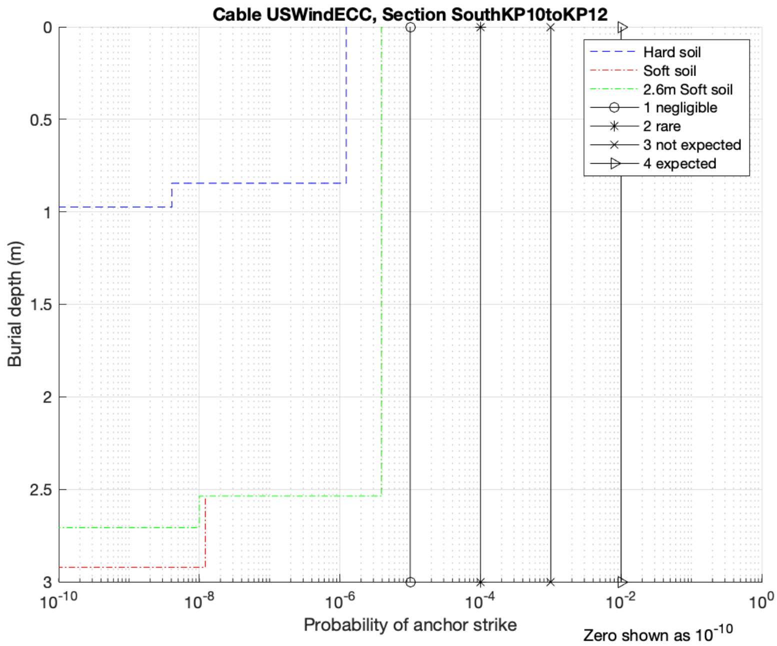


Figure B.35: Anchor strike risk vs burial depth, Section SouthKP10toKP12

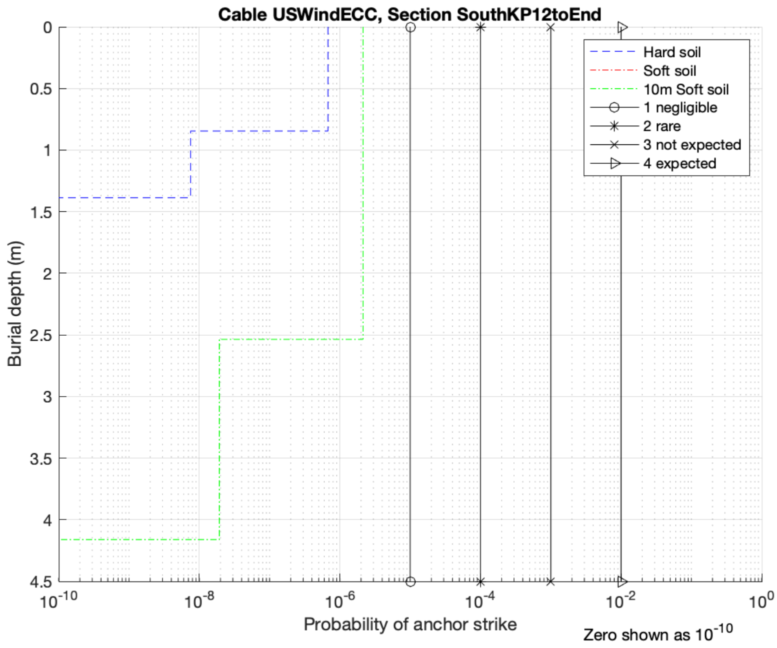


Figure B.36: Anchor strike risk vs burial depth, Section SouthKP12toEnd

B.7.2. Main export corridor section

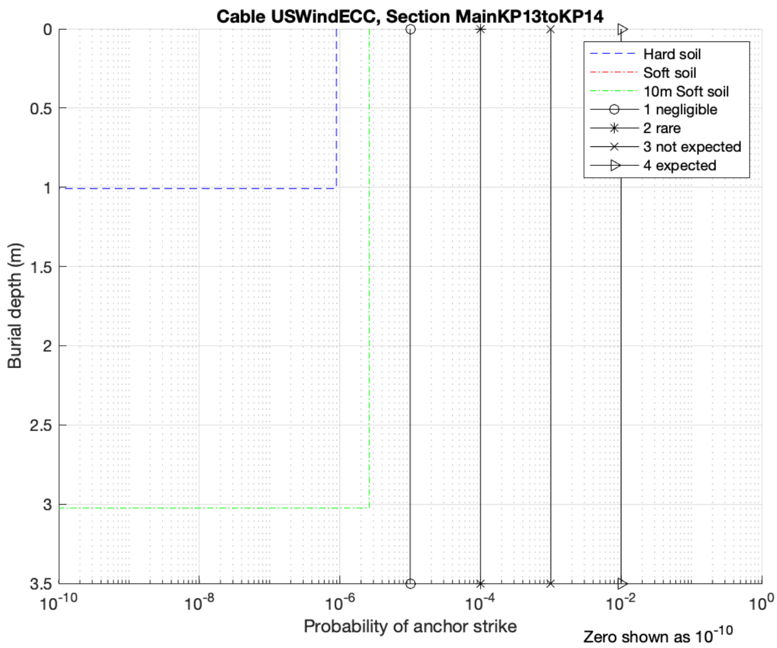


Figure B.37: Anchor strike risk vs burial depth, Section MainKP13toKP14

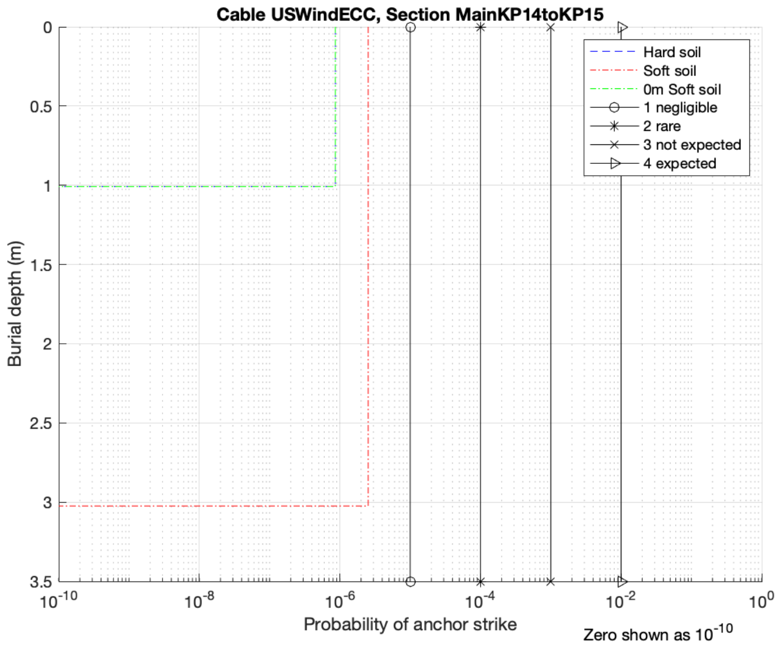


Figure B.38: Anchor strike risk vs burial depth, Section MainKP14toKP15

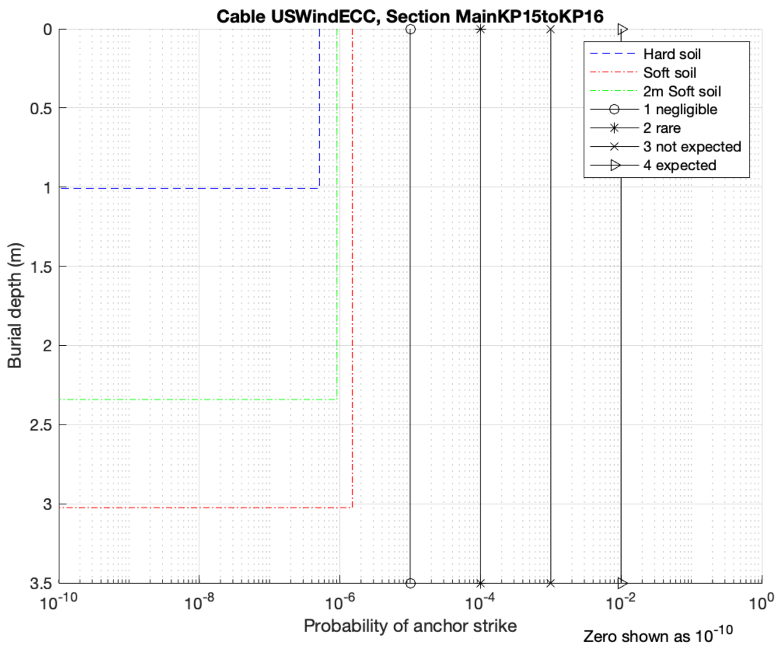


Figure B.39: Anchor strike risk vs burial depth, Section MainKP15toKP16

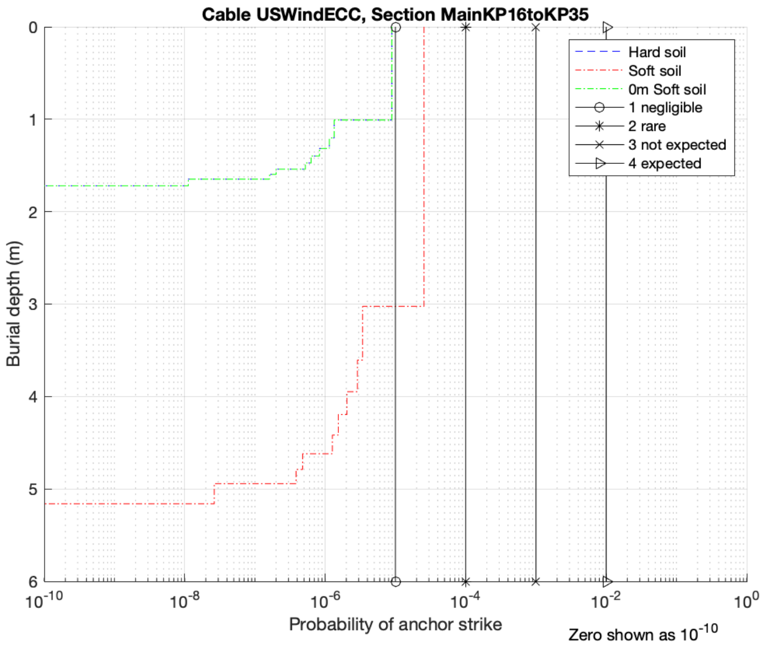


Figure B.40: Anchor strike risk vs burial depth, Section MainKP16toKP35

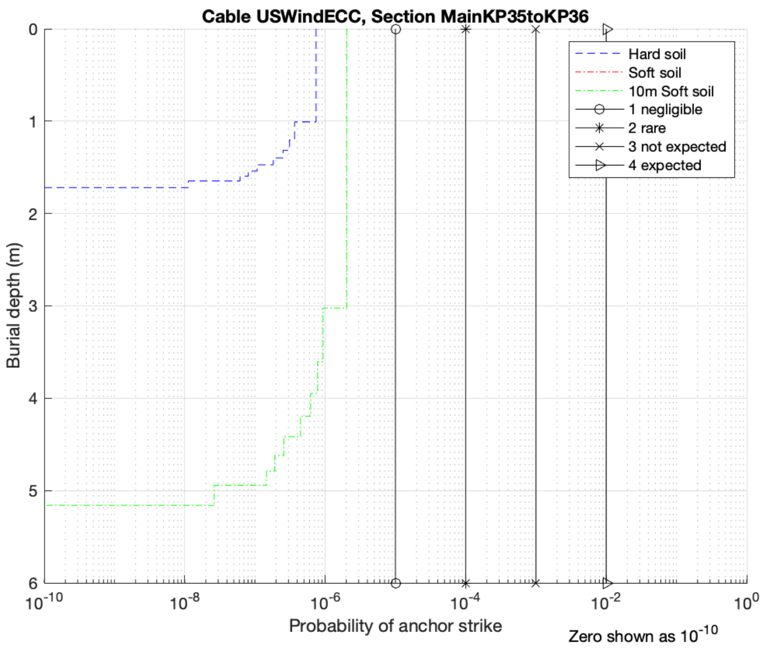


Figure B.41: Anchor strike risk vs burial depth, Section MainKP35toKP36

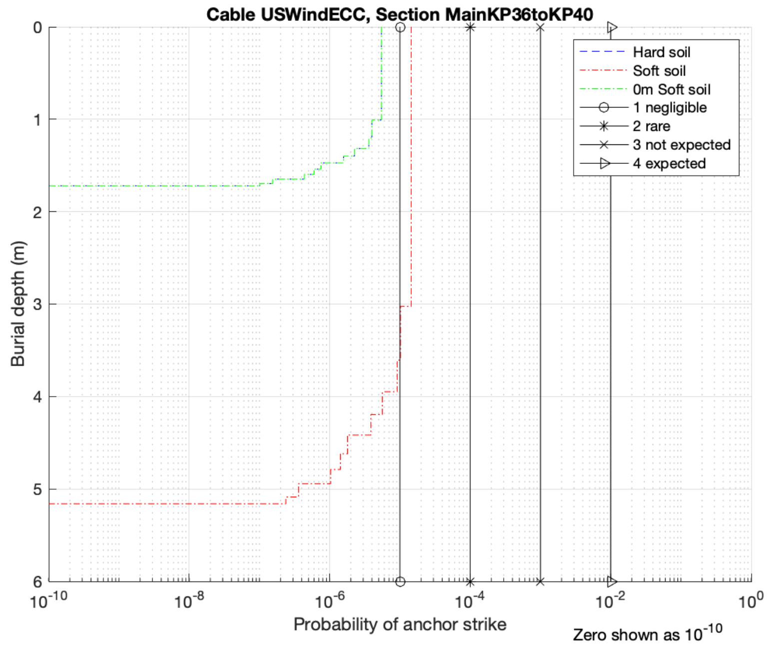


Figure B.42: Anchor strike risk vs burial depth, Section MainKP36toKP40

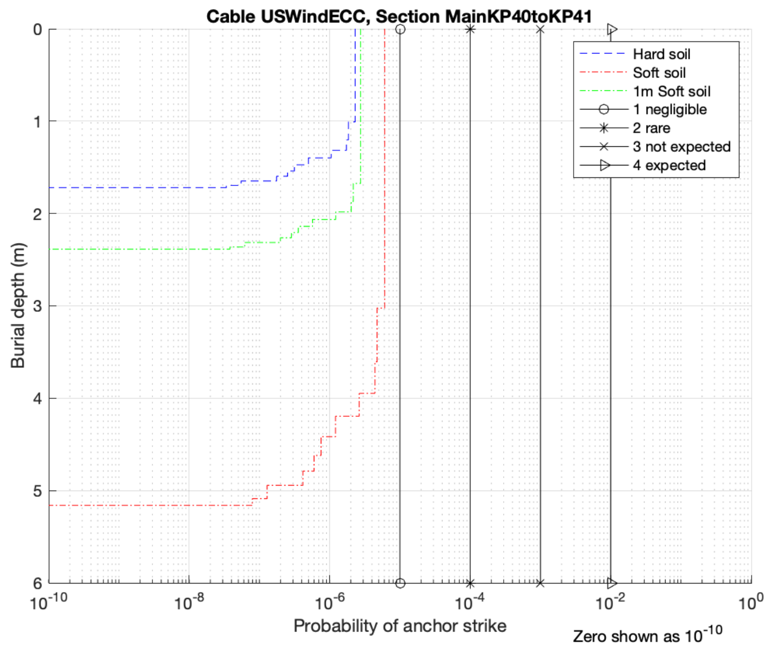


Figure B.43: Anchor strike risk vs burial depth, Section MainKP40toKP41

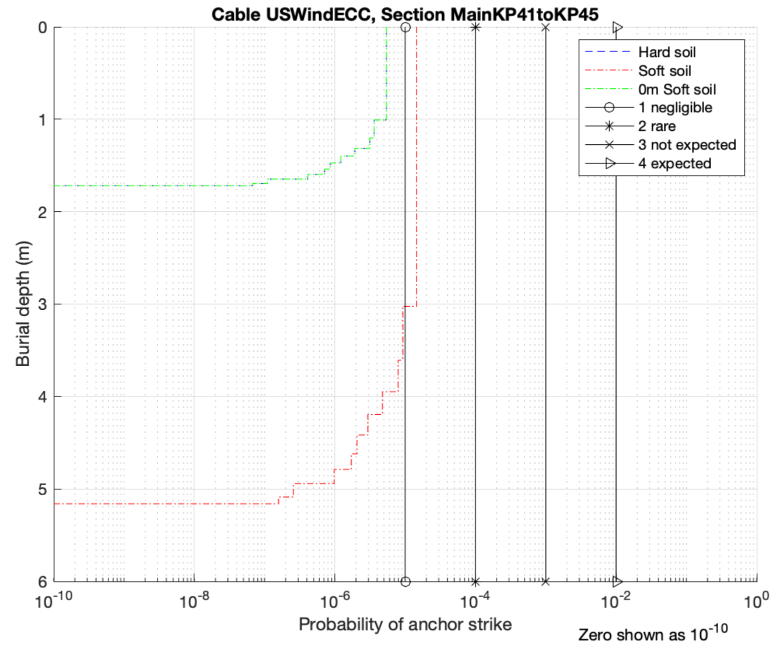


Figure B.44: Anchor strike risk vs burial depth, Section MainKP41toKP45

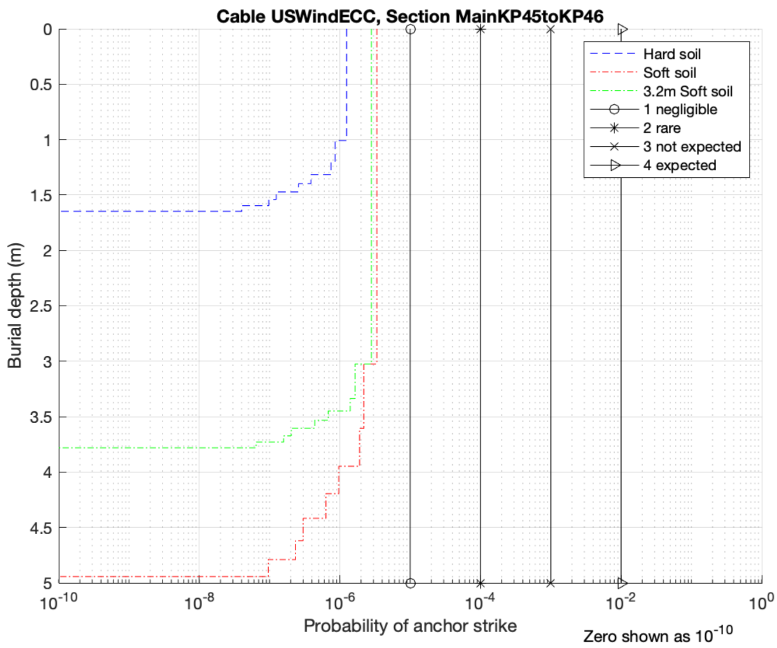


Figure B.45: Anchor strike risk vs burial depth, Section MainKP45toKP46

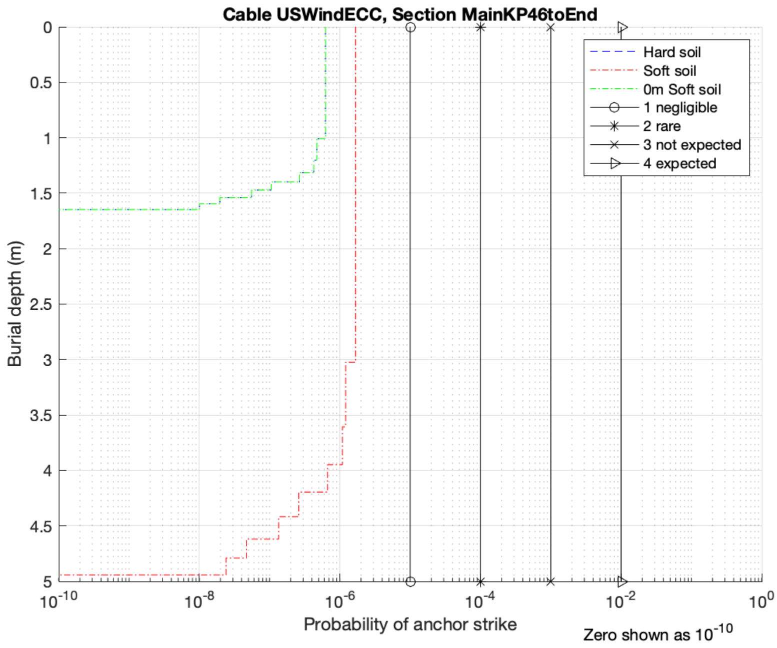


Figure B.46: Anchor strike risk vs burial depth, Section MainKP46toEnd

B.7.3. Northern landfall section

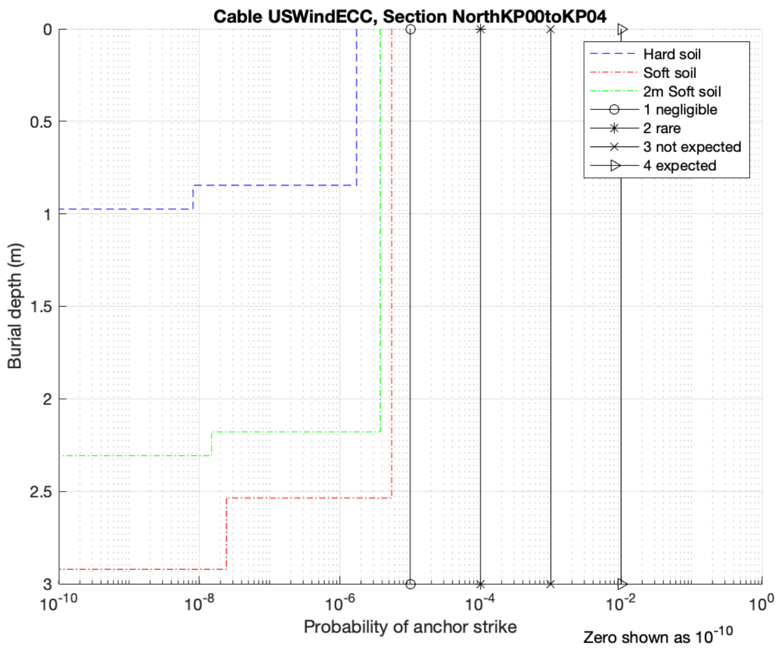


Figure B.47: Anchor strike risk vs burial depth, Section NorthKP00toKP04

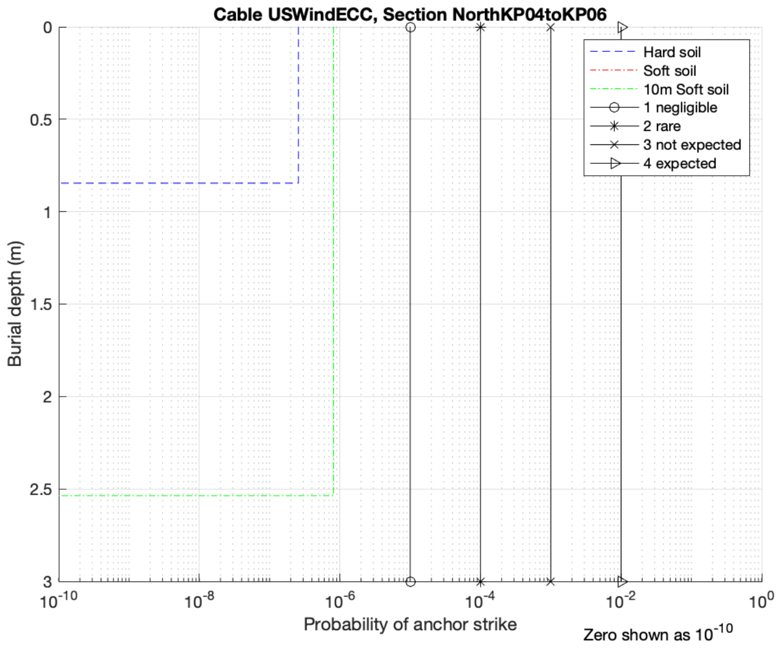


Figure B.48: Anchor strike risk vs burial depth, Section NorthKP04toKP06

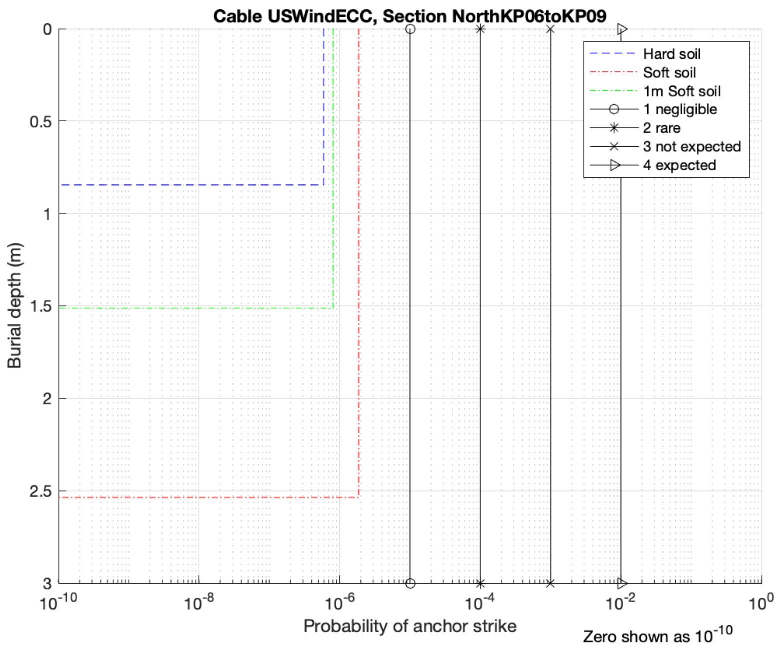


Figure B.49: Anchor strike risk vs burial depth, Section NorthKP06toKP09

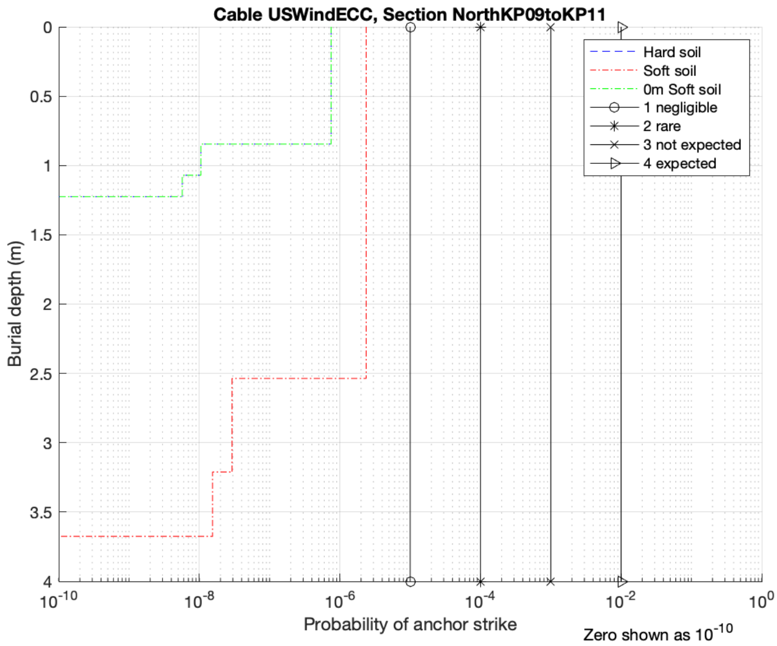


Figure B.50: Anchor strike risk vs burial depth, Section NorthKP09toKP11

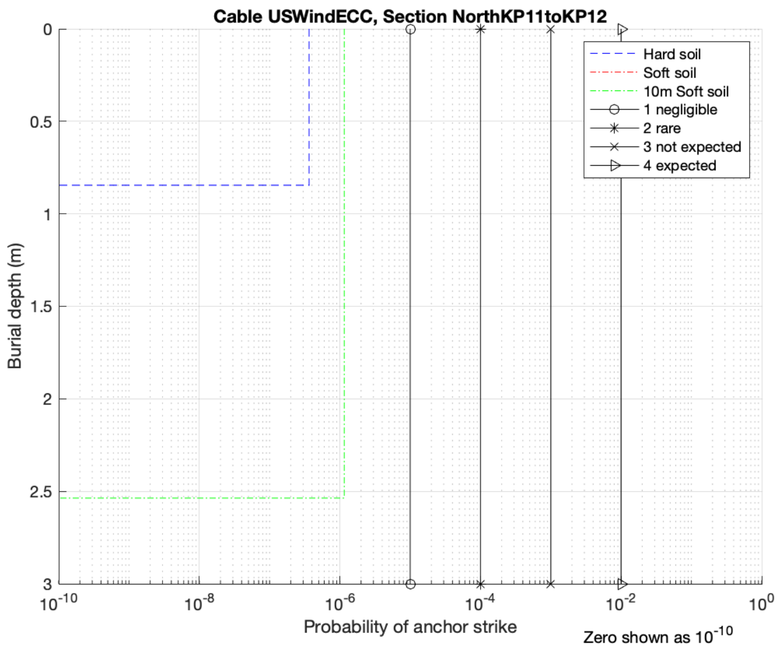


Figure B.51: Anchor strike risk vs burial depth, Section NorthKP11toKP12

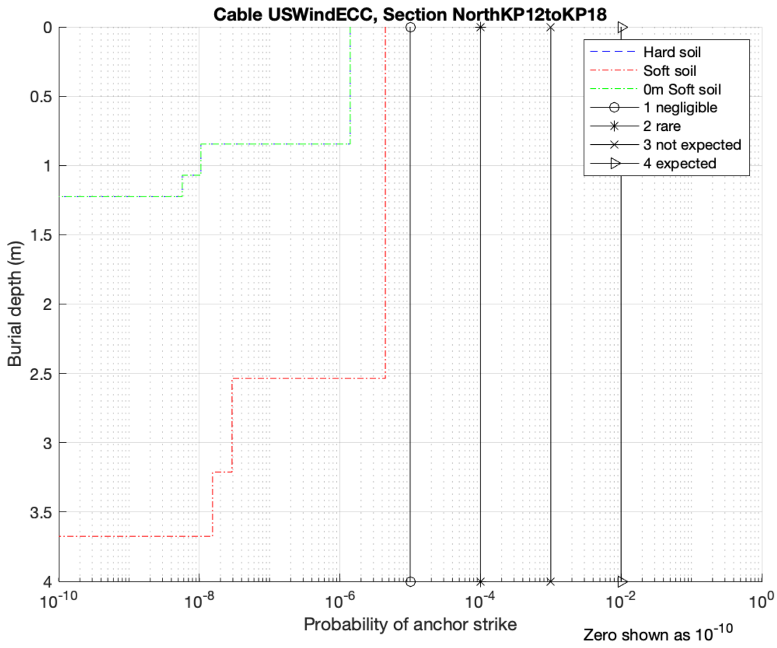


Figure B.52: Anchor strike risk vs burial depth, Section NorthKP12toKP18

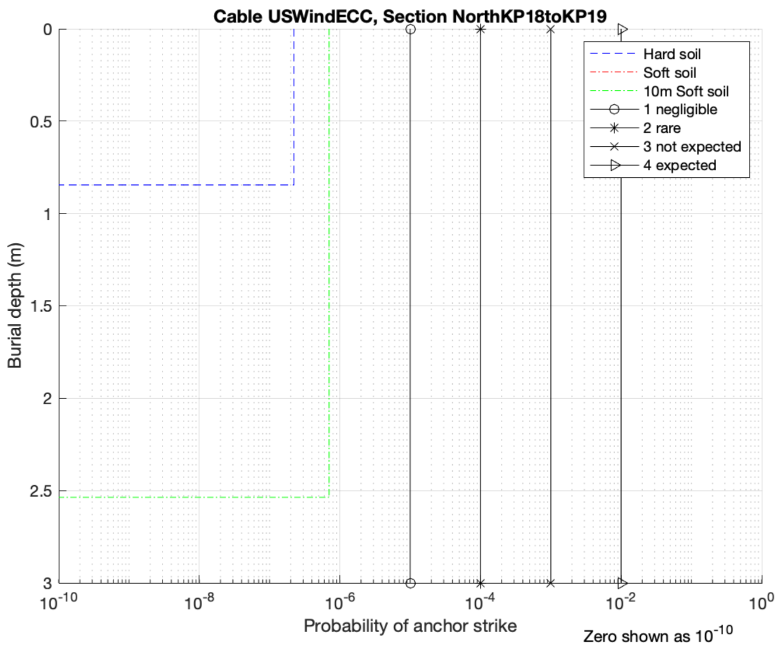


Figure B.53: Anchor strike risk vs burial depth, Section NorthKP18toKP19

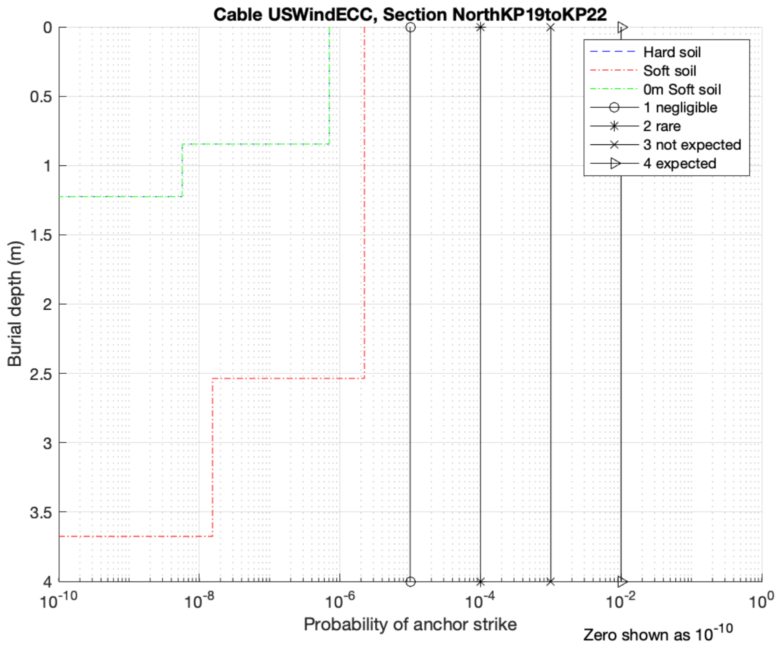


Figure B.54: Anchor strike risk vs burial depth, Section NorthKP19toKP22

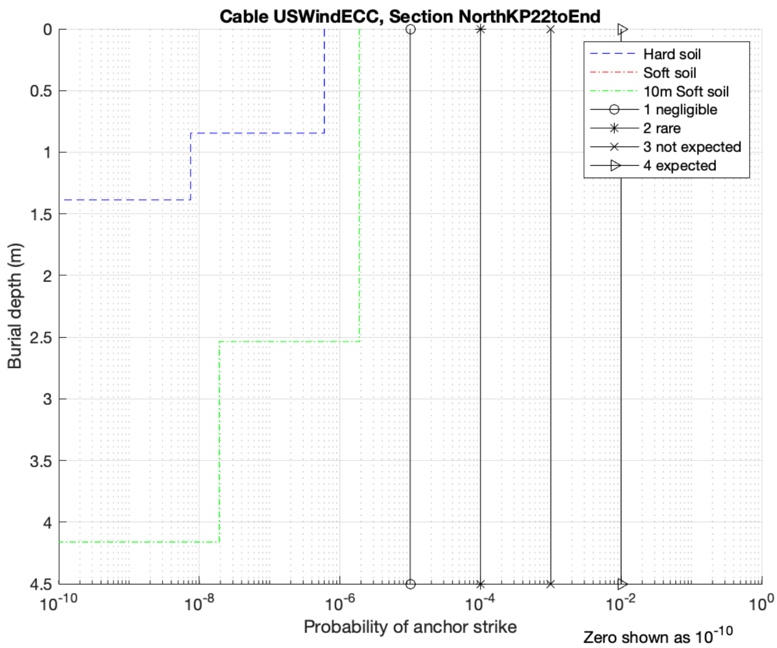


Figure B.55: Anchor strike risk vs burial depth, Section NorthKP22toEnd

C. CBRA PROBABILITY REPORTS - INDIAN RIVER BAY

C.1. Vessel movement

Vessel movement has been assessed using AIS data as presented in Section 5.1. Table C.1 provides a summary of the vessels crossing the IRB area. Section C.5 and C.6 details the number of vessels crossing each zone for each vessel size over the data set period.

Table C.1: Vessel classifications

Vessel classification	Number of vessels	Number of crossings	Maximum DWT (t)
Pleasure Craft	5	44	8
Towing	1	26	1

A total of 69911 of 233535 data points were ignored from the analysis due to missing vessel length information.

The most common vessels were:

- TOW BOAT 'PATRIOT', Towing class, 1 tonnes, 26 crossings
- PADULA 28, Pleasure Craft class, 3 tonnes, 21 crossings
- LEGS II, Pleasure Craft class, 4 tonnes, 10 crossings
- WIRED, Pleasure Craft class, 6 tonnes, 8 crossings
- HER IDEA, Pleasure Craft class, 4 tonnes, 4 crossings

The largest vessels were:

- BAD BEAGLE, Pleasure Craft class, 8 tonnes, 1 crossings
- WIRED, Pleasure Craft class, 6 tonnes, 8 crossings
- LEGS II, Pleasure Craft class, 4 tonnes, 10 crossings
- HER IDEA, Pleasure Craft class, 4 tonnes, 4 crossings
- PADULA 28, Pleasure Craft class, 3 tonnes, 21 crossings

C.2. Anchor and ship models for probabilistic anchor strike assessment

Table C.2 shows the anchor model used.

DWT is estimated using Equation C.1 (dimensions in metres, DWT in tonnes) (ref [4], Fig 1.3):

$$DWT = (length/5.32)^{(1/0.351)} \tag{C.1}$$

Displacement (Disp) is taken as $1.7 \times DWT$ (ref [4]), adopting container ship parameters.

Anchor mass is estimated from (ref [6], Fig 9.2).

Fluke length is estimated using Equation C.2 from data for stockless anchors from the Dreyfus and Vryhof anchor catalogues (fluke length in metres, anchor mass in tonnes):

$$\text{Fluke length} = 0.9909(\text{anchor mass})^{0.3441} \tag{C.2}$$

Anchor penetration is based on soil type (ref [18]):

$$\text{Fluke pen.} = \begin{cases} 1 \times \text{fluke length} \times sin(45°) & \text{in hard soils} \\ 3 \times \text{fluke length} \times sin(45°) & \text{in soft soils} \end{cases} \tag{C.3}$$

Ultimate holding capacity is based on soil type, (UHC in kN and penetration in metres):

$$UHC = \begin{cases} 294.99 \times \text{Fluke pen.}^{2.5276} & \text{in hard soils} \\ 3.91 \times \text{Fluke pen.}^{2.9525} & \text{in soft soils} \end{cases} \tag{C.4}$$

Table C.2: Anchor model

Vessel category	DWT (1000t)	Disp. (1000t)	Anchor mass (kg)	Fluke length (m)	Fluke pen hard soil (m)	Fluke pen soft soil (m)	UHC hard soil (kN)	UHC soft soil (kN)
1	0-0.50	0.85	191.8	0.6	0.40	1.19	28.6	6.5
2	0.50-1	2	383.6	0.7	0.50	1.51	52.2	13.2
3	1-2	3	575.5	0.8	0.58	1.74	74.2	20.0
4	2-2	3	767.3	0.9	0.64	1.92	95.3	26.8
5	2-2	4	959.1	1.0	0.69	2.07	115.8	33.6
6	2-3	5	1150.9	1.0	0.74	2.21	135.7	40.4
7	3-4	6	1342.8	1.1	0.78	2.33	155.1	47.3
8	4-4	7	1534.6	1.1	0.81	2.44	174.2	54.2
9	4-4	8	1726.4	1.2	0.85	2.54	193.0	61.1
10	4-5	8	1872.1	1.2	0.87	2.61	207.1	66.3

Table C.3 shows the ship model used.

D_{ship}, the estimate of distance an anchor is dragged, is calculated using Equation C.5 (ref [5]), D_{ship} in metres, Disp in tonnes, v_{ship} in knots, UHC in kN, 0.51444 kts $>$ m/s:

$$D_{ship} = \frac{\text{Disp} \times 0.51444(v_{ship})^2}{4UHC} \tag{C.5}$$

Table C.3: Ship model

Vessel category	DWT (1000t)	Vship (kts)	Ptraffic (-)	Pwd (-)	Pincident (-)	Dship hard soil (m)	Dship soft soil (m)
1	0-0.50	4.0	1.0	0.9	0.0100	31.51	137.38
2	0.50-1	4.0	1.0	0.9	0.0100	34.49	135.87
3	1-2	4.0	1.0	0.9	0.0100	36.36	134.99
4	2-2	4.0	1.0	0.9	0.0100	37.75	134.38
5	2-2	4.0	1.0	0.9	0.0100	38.86	133.90

Vessel category	DWT (1000t)	Vship (kts)	Ptraffic (-)	Pwd (-)	Pincident (-)	Dship hard soil (m)	Dship soft soil (m)
6	2-3	4.0	1.0	0.9	0.0100	39.80	133.51
7	3-4	4.0	1.0	0.9	0.0100	40.61	133.18
8	4-4	4.0	1.0	0.9	0.0100	41.32	132.90
9	4-4	4.0	1.0	0.9	0.0100	41.96	132.65
10	4-5	4.0	1.0	0.9	0.0100	43.45	135.74

C.3. Probabilistic anchor strike assessment for surface lay

Table C.4 shows the probability of anchor strikes for surface laid cables. Full results including vessel categories and counts are shown in Section C.6. The highest risk (per km) cables are:

- Onshore ECC1, IRB, RPhard 17357613146 yr/km, RPsoft 3981748270 yr/km

The probability an anchor of a particular vessel size crosses the cable at seabed is estimated as (ref [6]), D_{ship} in m, v_{ship} in kts, 8766 hr/yr, 1852 kts $>$ m/hr:

$$P_{strike} = \frac{p_{traffic} \times p_{wd} \times vessel_{count} \times D_{ship} \times p_{incident}}{v_{ship} \times 1852 \times 8766} \quad \text{(C.6)}$$

Considering the vessel movements as independent, the total probability of an anchor strike over the cable length is ($P_{s.n}$ is the P_{strike} of individual vessel sizes):

$$P_{strike.total} = 1 - (1 - P_{s.1})(1 - P_{s.2})(1 - P_{s.3})...(1 - P_{s.n}) \quad \text{(C.7)}$$

When the probabilities are very small the above method is equivalent to summing the individual probabilities.

Return period (RP) is taken as the inverse of probability of anchor strike. The length of the cable is used to calculate the return period per kilometre of cable.

Table C.4: Surface lay probabilistic assessment

Cable	Section	Hard soil return period	Soft soil return period	Rank
Onshore ECC1	IRB	6441630 yr, 17357613146 yr/km	1477677 yr, 3981748270 yr/km	1

C.4. Probabilistic anchor strike assessment for buried cables

The probability of anchor strike for buried cables has been calculated by removing the vessels from the analysis where the fluke penetration shown in Table C.2 is less than the depth considered. Table C.5 shows the required burial depths to achieve certain target frequencies, defined as:

- Category 1, $< 10^{-5}$, So low frequency that event considered negligible
- Category 2, $< 10^{-4}$, Event rarely expected to occur
- Category 3, $< 10^{-3}$, Event individually not expected to happen, but when summarised over a large number of cables have the credibility to happen once a year

- Category 4, $< 10^{-2}$, Event individually may be expected to occur during lifetime of the cable
- Category 5, $> 10^{-2}$, Event individually may be expected to occur more than once during lifetime of the cable

Section C.7 shows the anchor strike frequency for buried cables, with zero frequency taken as 10^{-10} for plotting purposes.

Table C.5: Burial depths to achieve target frequencies

Cable	**Section**	**Hard, 1.0e-02**	**Soft, 1.0e-02**	**Hard, 1.0e-03**	**Soft, 1.0e-03**	**Hard, 1.0e-04**	**Soft, 1.0e-04**	**Hard, 1.0e-05**	**Soft, 1.0e-05**
Onshore ECC1	IRB	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

C.5. Vessel movement maps

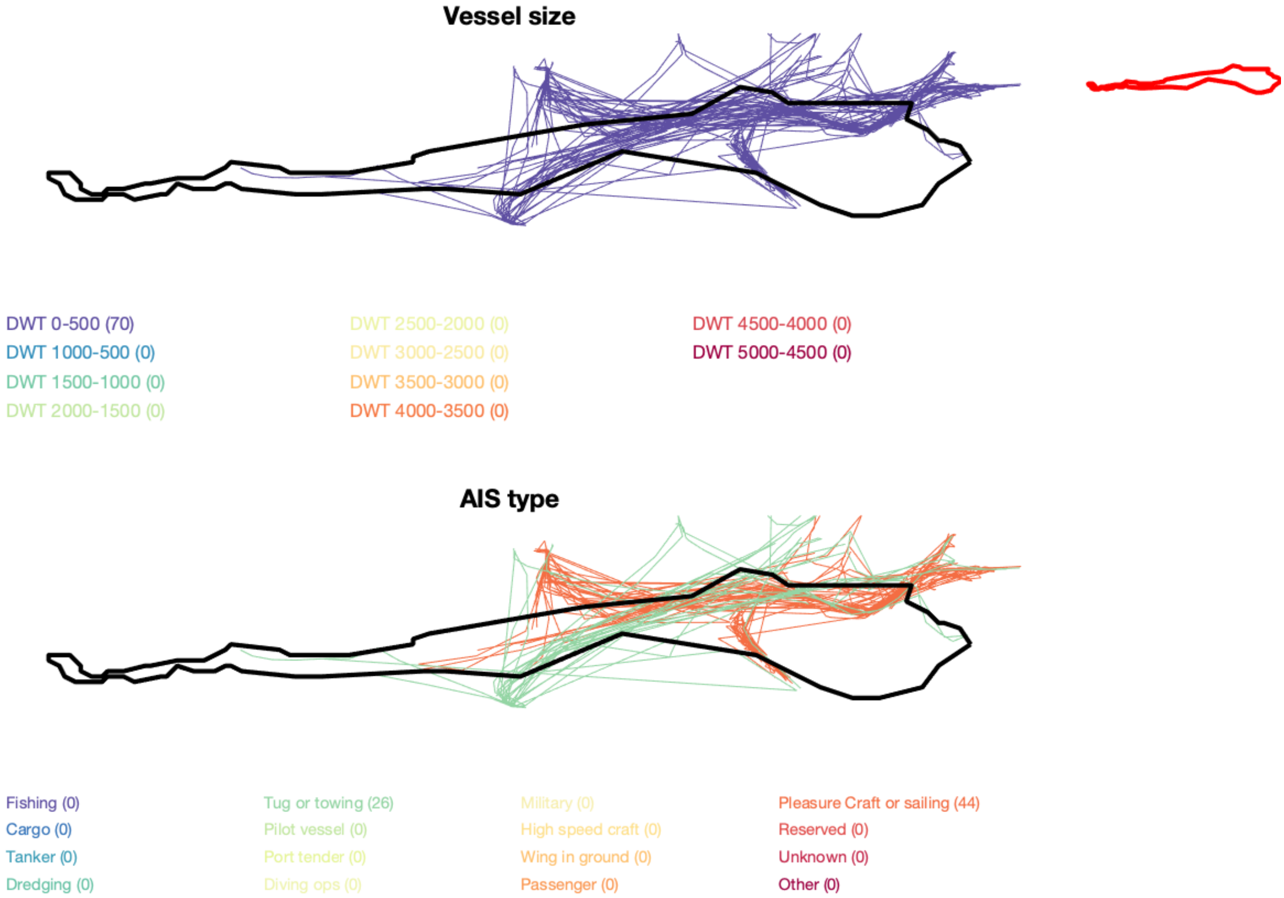


Figure C.1: Vessel movement, Section IRB

C.6. Full anchor strike assessment for surface lay

Table C.6: Surface lay probabilistic assessment (full results)

Cable	Section	Vessel cat.	Vessel count	Pstrike hard soil (-)	Pstrike soft soil (-)	Hard soil Total Pstrike (-) Return period (yr) Return period (yr/km)	Soft soil Total Pstrike (-) Return period (yr) Return period (yr/km)
Onshore ECC1	IRB	1 2 3 4 5 6 7 8 9 10	70 0 0 0 0 0 0 0 0 0	1.55e-07 0 0 0 0 0 0 0 0 0	6.77e-07 0 0 0 0 0 0 0 0 0	1.55e-07 6441630 yr 17357613146 yr/km	6.77e-07 1477677 yr 3981748270 yr/km

C.7. Anchor strike probability graphs for buried cables

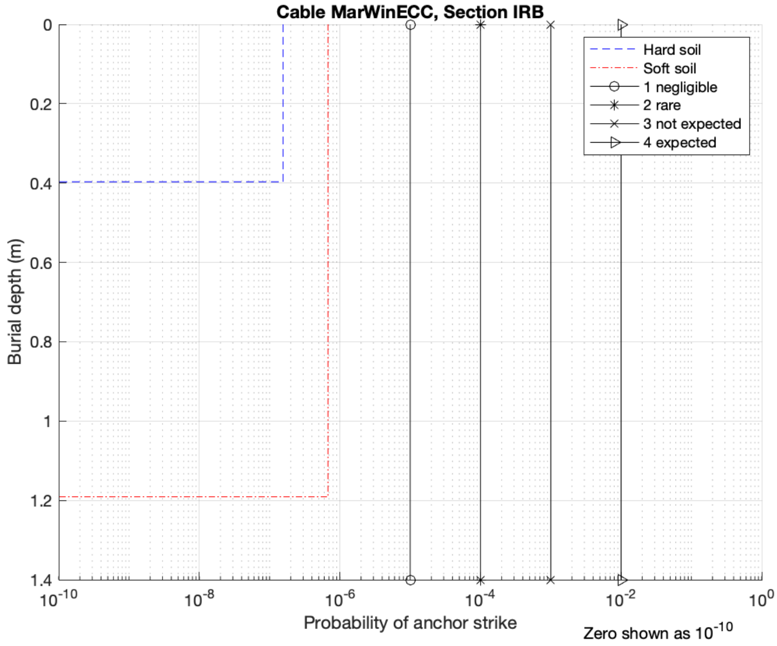


Figure C.2: Anchor strike risk vs burial depth, Section IRB