

REPORT



Race Bank Offshore Wind Farm

Export Cable Installation Plan Part VI: Cable Burial Risk Assessment

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Race Bank Offshore Wind Farm Export Cable Risk Assessment Update

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Revision Number	Date	Summary of Change
00	04/08/2015	Initial Draft
01	13/11/2015	Updated from Client Comments / Additional Modelling in Wisbech Channel
02	19/11/2015	Updated due to Comments from Port Authorities
03	14/01/2016	Updated due to further comments from client and Port Authorities

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Abbreviations

ABPmer	-	Associated British Ports Marine Environmental Research
AIS	-	Automatic Identification System
ALARP	-	As Low as Reasonably Practicable
CBRA	-	Cable Burial Risk Assessment
CPT	-	Cone Penetration Test
DWT	-	Dead Weight Tonnage
GIS	-	Geographical Information System
GT	-	Gross Tonnage
IACS	-	International Association of Classification Societies
ICES	-	International Council for the Exploration of the Seas
KP	-	Kilometre Point
LAT	-	Lowest Astronomical Tide
MBES	-	Multi-beam Swathe
MMO	-	Marine Management Organisation
nm	-	nautical mile
RYA	-	Royal Yachting Association
UXO	-	Unexploded Ordnance
VMS	-	Vessel Monitoring System

1. Introduction

1.1 Summary

Anatec has been commissioned by DONG Energy to undertake a cable risk assessment for the export cables for the Race Bank Offshore Wind Farm, and the associated inter-array cables. This report contains the analysis associated with the export cables.

The scope of work is to assess the risks associated with natural and anthropogenic hazards, through a combination of hazard workshop discussions, and qualitative and quantitative assessments.

The risks associated with all hazards were reviewed at a Hazard Workshop and ranked in terms of frequency and consequence. For the natural hazards, a qualitative assessment was provided based on information from the client and the results of the hazard workshop. For anthropogenic hazards, the risk was assessed using real-time AIS (Automatic Identification System) shipping data. The risk assessment included an analysis of shipping activity near the cable routes to identify high risk areas of activity for fishing, military, leisure and offshore vessels. In addition, a quantitative risk assessment to analyse risks from vessels dragging anchor or anchoring in an emergency, and from vessels foundering, was also undertaken.

The findings of the risk assessments were used to provide a Cable Burial Risk Assessment (CBRA) for the Race Bank cables, with recommended target burial depths. The methodology for the CBRA follows the guidelines provided by the Carbon Trust (Ref i).

1.2 Objectives

The objectives of the work are as follows:

- Review natural and anthropogenic hazards associated with the export cable
- Analyse the shipping activity using 6 months of AIS data from July to December 2013, and additional 2015 data to account for updated traffic movements within the Wash
- Identify anchoring activity near the cable route
- Carry out hazard workshop to identify hazards, causes, mitigations and rank hazards based on frequency and consequence
- Assess the risk from vessels dragging anchor onto the export cable route
- Assess the risk from vessels anchoring in an emergency onto the export cable route
- Assess the risk from vessels foundering over the export cable route

- Undertake a Cable Burial Risk Assessment to determine minimum burial depths required to afford sufficient protection for the export cable

2. Export Cable Details

This assessment will consider the export cables associated with the Race Bank Offshore Wind Farm. The export cable route is presented in Figure 2.1, relative to the inter-array cables.

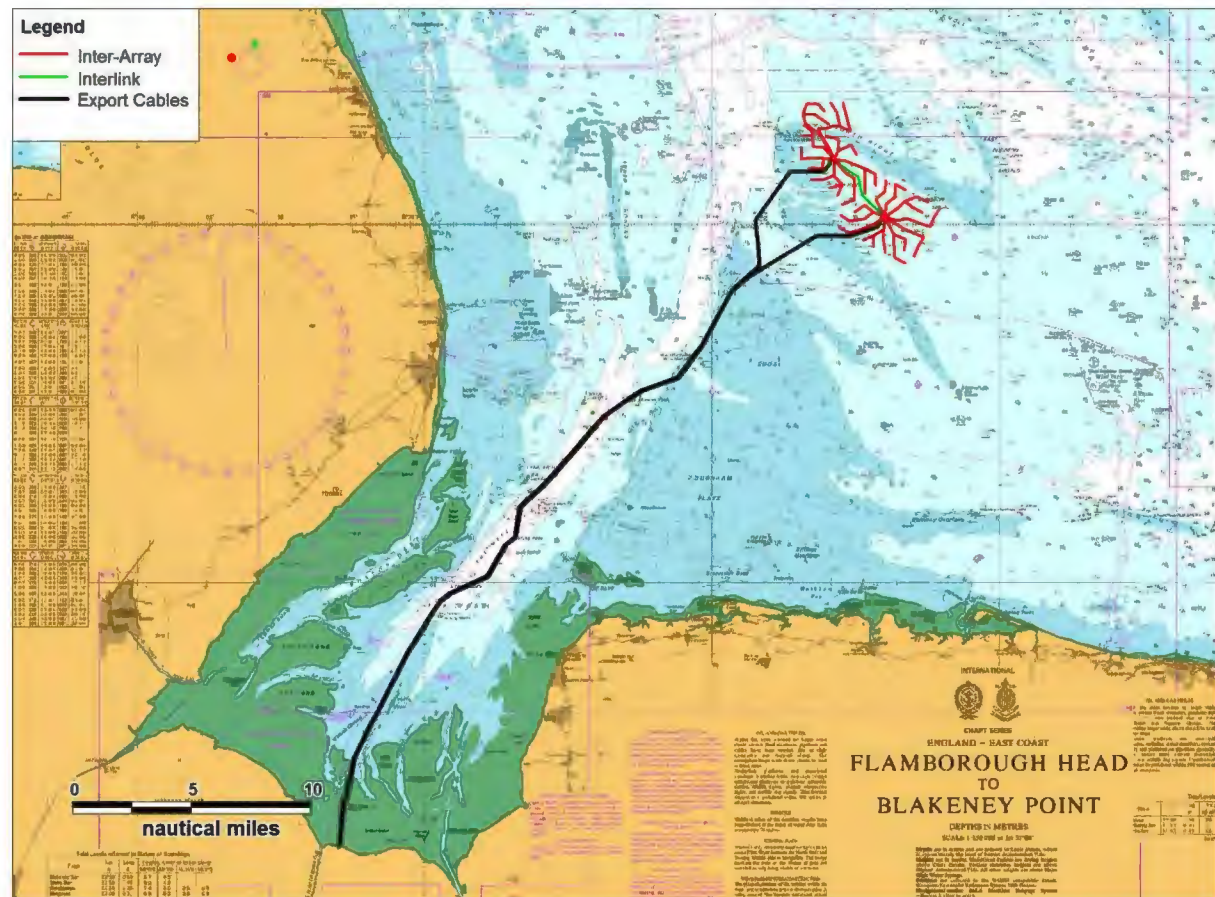


Figure 2.1 Export Cable Overview

For the purpose of the hazard review, the export cable route was divided into five zones, as shown in Figure 2.2. Details of the zones are presented in Table 2.1.

Table 2.1 Cable Route Zone Breakdown

Zone	KP Range	Description
1	1 – 8	Landfall and to end of intertidal flats
2	8 – 22	Within the Wash, passing next to anchorage areas
3	22 - 46	From edge of anchorage areas to edge of Burnham Flats
4	46 – 58	Through Docking Shoal to division of route
5	58 to End	Division of route to Wind Farm.

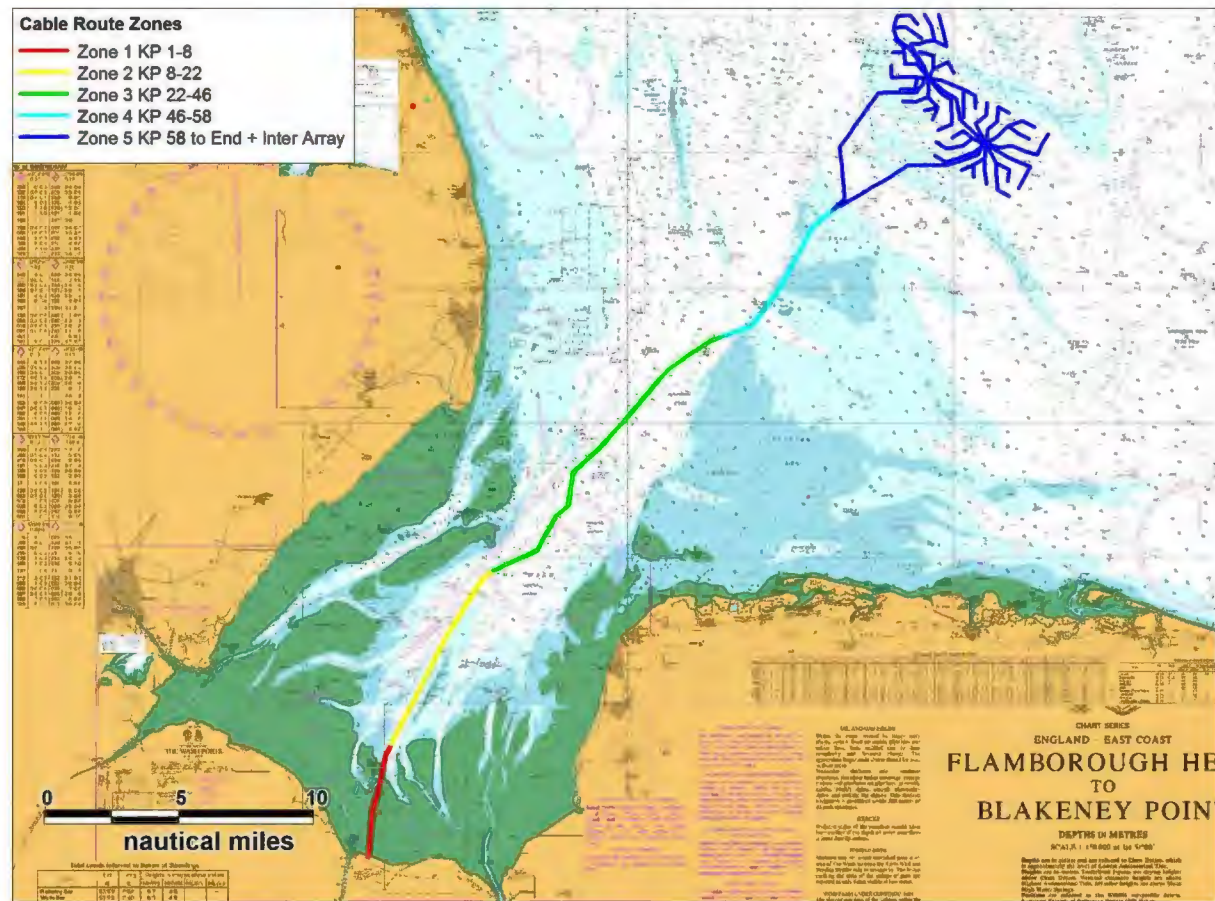


Figure 2.2 Cable Route Zone Breakdown

3. Hazard Description

The hazards to be assessed were identified by DONG Energy and divided into categories of natural and anthropogenic hazards. This section presents a description of each of the hazards to be assessed and the risk that they pose to the export cable.

Natural hazards to be assessed are:

- Sandwaves
- Megaripples
- Rock outcrops
- Boulders and cobbles
- Seabed obstructions
- Inclines
- Seabed stability
- Mass sediment transport in extreme conditions
- Natural migration of the channels into the ports

Information on the natural hazards was obtained from geophysical and geotechnical surveys for the export cable routes. Results of Cone Penetration Tests (CPTs) were used to provide information on the seabed type, including relative density of the seabed and presence of chalk. The geophysical surveys provided details on seabed features and obstructions, using a number of surveying methods e.g. multi-beam echo-sounder, side scan sonar, sub-bottom profiler and magnetometer systems. It is assumed that the results of the surveys were used by the cable installation contractor to identify potential hazards to be avoided for route engineering. Further details of the data sources used for the Cable Burial Risk Assessment are provided in Section 9.2.

Anthropogenic hazards to be assessed are:

- Fishing
- Vessel anchors (anchor dragging, emergency anchoring and inadvertent anchoring)
- Vessel Foundering
- Other commercial activities (Dredging, Oil & Gas operations)
- Military Activities
- Leisure activities

Anthropogenic hazards will be assessed using real-time AIS shipping data. This will be combined with features from the navigation charts to identify high risk areas for fishing vessels, dredging, oil & gas operations, military and leisure activities.

The risk to the export cable from vessel anchors (anchor dragging and emergency anchoring) and from foundering vessels will be quantitatively assessed using Anatec's anchoring and foundering risk models.

A qualitative discussion will be provided on the risk from inadvertent (or negligent) anchoring.

3.1 Natural Hazards

3.1.1 Sand Waves

The term sand wave refers to the larger sand wave features along the cable route. Based on the mobility study carried out by ABPmer (Ref ii), sand waves are defined as having a wavelength of 30-700m, height between 1m and 5m and travel at approximately 10m per year. The information on sand waves along the cable route was provided by the ABPmer report. This is presented in more detail in Section 9.4. Sand waves were seen to be present in zones 1 – 5.

The potential risk posed to the cable by sand waves is that their movement could cause sections of cable buried within them to become exposed or to produce a free span. This could require repair e.g. additional burial/rockdump or cable repair due to fatigue related to the free span.

3.1.2 Megaripples

The term megaripples refers to smaller sand waves, which tend to travel faster than the large sand waves. The ABPmer report (Ref ii) defines megaripples to have a wavelength of 1-3m, height between 0.1m and 1m and travel at approximately 100m per year. The 2015 Fugro survey indicated the presence of megaripples in all five zones of the export cable route, although no height information was available. The ABPmer mobility study identified megaripples with height less than 1m on the east cable at KP58.5-59.5 and at KP68.5-69.5. Existence and locations of megaripples are discussed further in Section 9.4.

The risk to the cable from megaripples is the potential exposure of the buried cable, as for the sand waves. Although megaripples move faster than sand waves, which suggests that exposure of the cable is more likely, their smaller height allows easier burial of the cable to below the base of the megaripple.

3.1.3 Rock Outcrops

Rock outcrops describe the presence of rock within the seabed. The two types of rock considered within this assessment are till and chalk, which are present in zones 2 – 5. Their presence within the seabed sediment has been well established using seabed surveys. This allows careful planning to overcome problems related to rock outcrops e.g. route selection, cable laying equipment. The hazard discussed at the workshop was therefore unidentified till/chalk preventing burial of the cable route to the desired depth or requiring re-routing of the cable or the need for additional tools. This could also lead to operational delays.

3.1.4 Boulders and Cobbles

Boulders and cobbles along the planned cable route could cause problems with the cable installation. The presence of boulders (zones 2 – 5) and cobbles (zones 1 – 5) has been well-documented in the geophysical surveys, allowing selection of the optimal route and suitable equipment. In the event of an unexpected boulder along the cable route, this may require removal of the boulder or re-routeing of the cable, leading to additional costs and operational delays. Cobbles are unlikely to require complete re-routeing but could require removal of the cobbles or additional tools, also leading to additional costs and operations delays.

3.1.5 Seabed Obstructions

The seabed obstructions along all zones of the cable route were divided into magnetic objects, wrecks/debris and UXO (unexploded ordnance). Significant seabed obstructions have been mapped prior to route selection. Unexpected seabed obstructions could require removal or re-routeing of the cable, leading to additional costs and operational delays. UXOs were categorised under anthropogenic hazards.

3.1.6 Inclines

Inclines in the seabed are caused by the Well in zone 2 or by sand waves (zones 1 – 5). Inclines could cause problems with cable burial if the incline is greater than 8-10°. The inclines along the cable corridor have been well-documented by geophysical surveys and the route selection will avoid the Well or other inclines greater than 8-10°.

3.1.7 Seabed Stability

Seabed instability, i.e. slopes or landslides, could cause the cable to become exposed, requiring repair e.g. additional burial/rockdump or cable repair due to fatigue related to the free span. Seabed instabilities are only considered to be a potential risk in zone 2 of the cable route, where the Well is located.

3.1.8 Mass Sediment Transport

Mass sediment transport from the cable route could cause the export cable to become exposed. The main sources of mass sediment transport are sand waves and megaripples, which have been considered under their own sub-categories. The frequency of other cases of mass sediment transport was considered to be negligible.

3.1.9 Natural Migration of the Channels into the Ports

Information from the Port Authorities in the Wash indicated that the entry channels into the ports have been known to move over time due to the natural migration of sediment. In particular, it has been highlighted that the entry channel to the ports of Wisbech and Sutton Bridge have recently moved to the east, to a channel that is traversed by zone 1 of the Race Bank export cable. This could present a risk to the cable from increased vessel traffic or possible requirements for dredging of the channel for larger vessels. This is discussed in more detail in Section 5.3.

3.2 Anthropogenic Hazards

3.2.1 Fishing

Fishing activity in the area poses a potential risk to the cable from fishing gear catching on it. In particular demersal, or bottom-trawling, vessels drag their gear along the seabed and could penetrate to small depths. This could damage the cable directly or cause the cable to become exposed, leading to necessary repairs or additional burial.

In addition, vessels may also ground out for cockle fishing in zone 1. However it is considered that this does not present a significant risk to a buried cable, since cockles are typically located only a few centimetres below the seabed.

3.2.2 Vessel Anchors

Risks to the cable from vessel anchors fall under three categories; anchor dragging, emergency anchoring, and inadvertent (or negligent) anchoring.

Anchor dragging describes the situation where a vessel anchoring near to the cable route drags anchor from the area (due to bad weather, anchor failure, poor holding ground, etc.) and drifts towards the cable. This could potentially damage the cable if the anchor can penetrate to the depth of cable burial. Larger vessels are expected to penetrate further and therefore more likely to cause damage. The majority of anchoring takes place within the Wash port limits, near cable zones 2&3.

Emergency anchoring describes the situation where a vessel suffers engine failure while travelling over the cable route and subsequently drops anchor onto the cable, potentially damaging it. Emergency anchoring could occur anywhere along the cable route.

Inadvertent (or negligent) anchoring refers to a situation where a vessel's crew is not aware of the existence or location of a cable route, and subsequently anchor over the cable, with the potential to cause damage. Inadvertent anchoring is considered more likely within the Wash port limits, near zones 2&3, due to vessels anchoring in the Wash but outwith the planned anchorages.

Damage to the cable from vessel anchors could lead to expensive repairs, delays in production or additional burial requirements.

3.2.3 Vessel Foundering

Vessel foundering describes the situation where a vessel suffers structural failure and sinks. If this occurs along the cable route, the sinking vessel could cause damage to the cable.

3.2.4 Vessel Grounding

There is the potential for vessels to ground on approach to Port Sutton Bridge, near zone 1 of the cable route. This could present a risk to the cable if the vessel was to ground directly over the cable route.

3.2.5 Other Commercial Activities

Other commercial activities considered during the workshop were dredging activities, oil & gas activities and maintenance or repair work on the neighbouring Lincs export cable. Causes of cable damage or exposure from these activities would be due to poor planning and communication, out-of-date navigational charts, faulty navigational equipment on the work vessels etc.

3.2.6 Military Activities

The Holbeach air gunnery and bombing range is located 8 miles north-north-east of Holbeach and less than a mile from the coastline. This could present a risk of cable damage from bombs or gunfire within zone 1 of the cable.

3.2.7 Leisure Activities

There are a number of cruising routes in the Wash area. The main risk to the cable from recreational vessels is from anchoring. The majority of recreational vessels (i.e. those that carry AIS) will be included in the quantitative anchoring risk assessment. Any vessels not included in this assessment will be the smaller vessels. It was considered that the risk to the cable from small recreational vessels is negligible, due to their size.

4. Navigational Features

This section presents an overview of the navigational features in the vicinity of the cable routes.

4.1 Ports and Anchorage Areas

Figure 4.1 presents the overview port limits, anchorage areas and pilot stations in the vicinity of the cable route with Figure 4.2 and Figure 4.3 presenting detailed views. It can be seen that the cable route passes between the three anchorage areas associated with the ports of Boston, King's Lynn and Sutton Bridge/Wisbech.

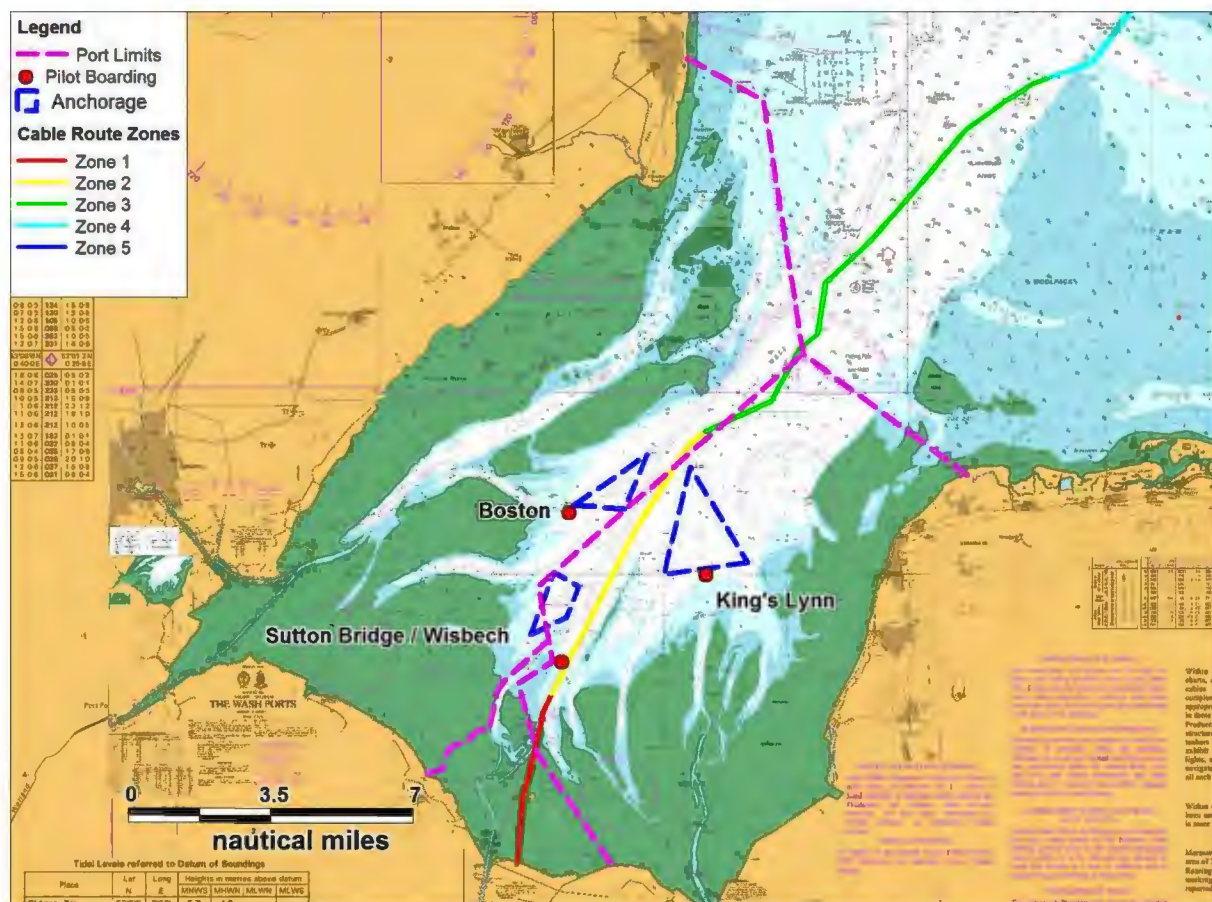


Figure 4.1 Anchorage and Port Limit Overview

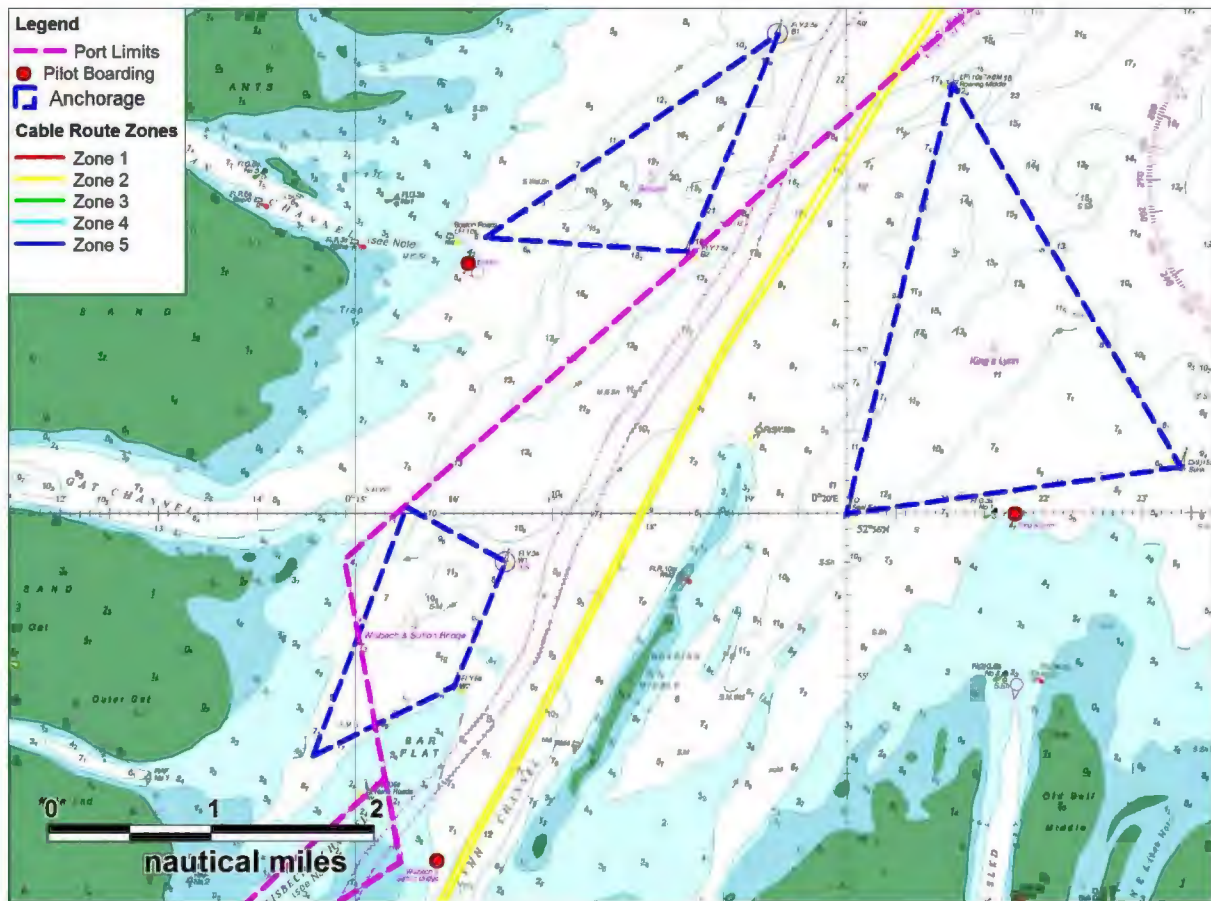


Figure 4.2 Detailed Anchorage Overview

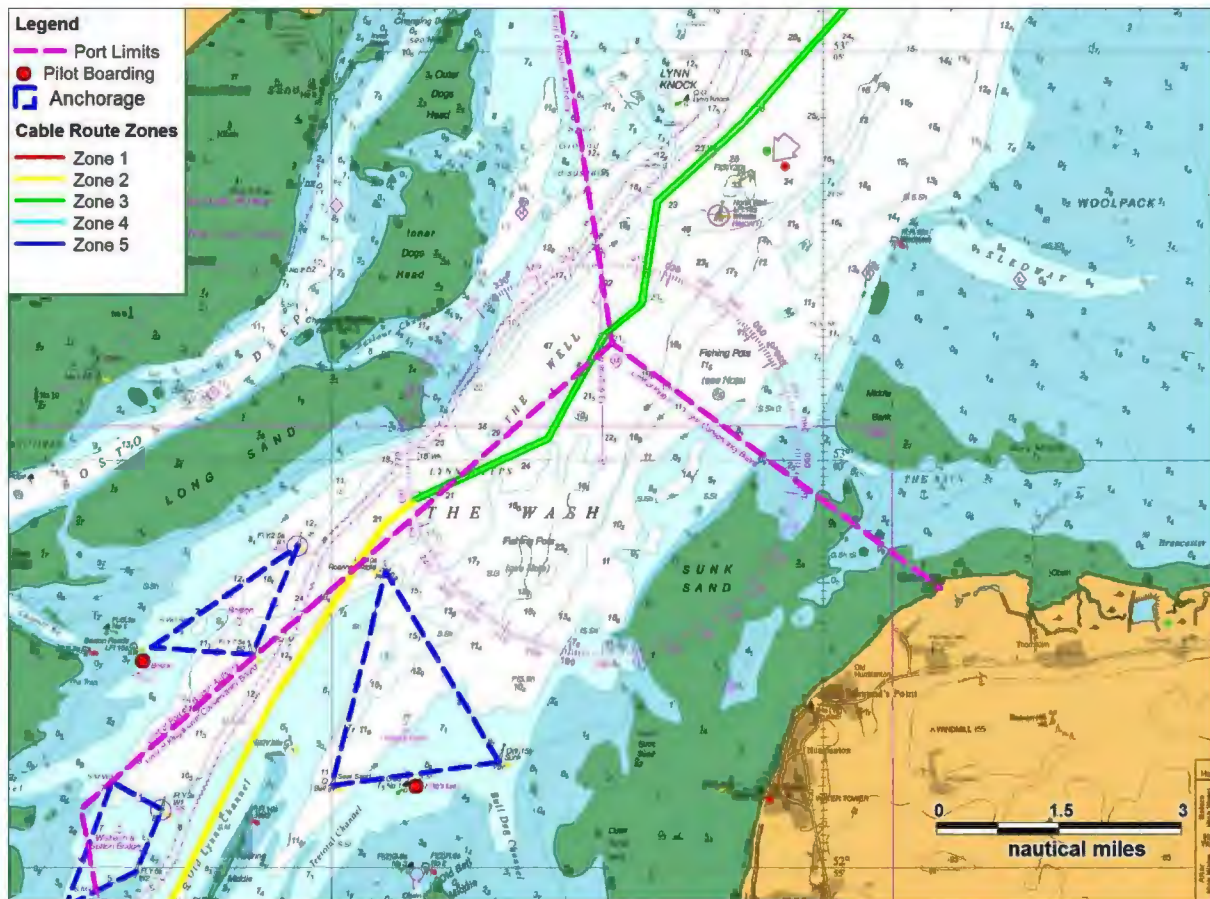


Figure 4.3 Detailed Port Limits Overview

4.2 Wind Farms

Figure 4.4 presents the wind farms and associated export cables in the vicinity of the Race Bank Wind Farm and cable route. It can be seen that the proposed Race Bank export cable route runs in parallel with the Lincs Offshore Wind Farm export cable for the majority of the section in the Wash.

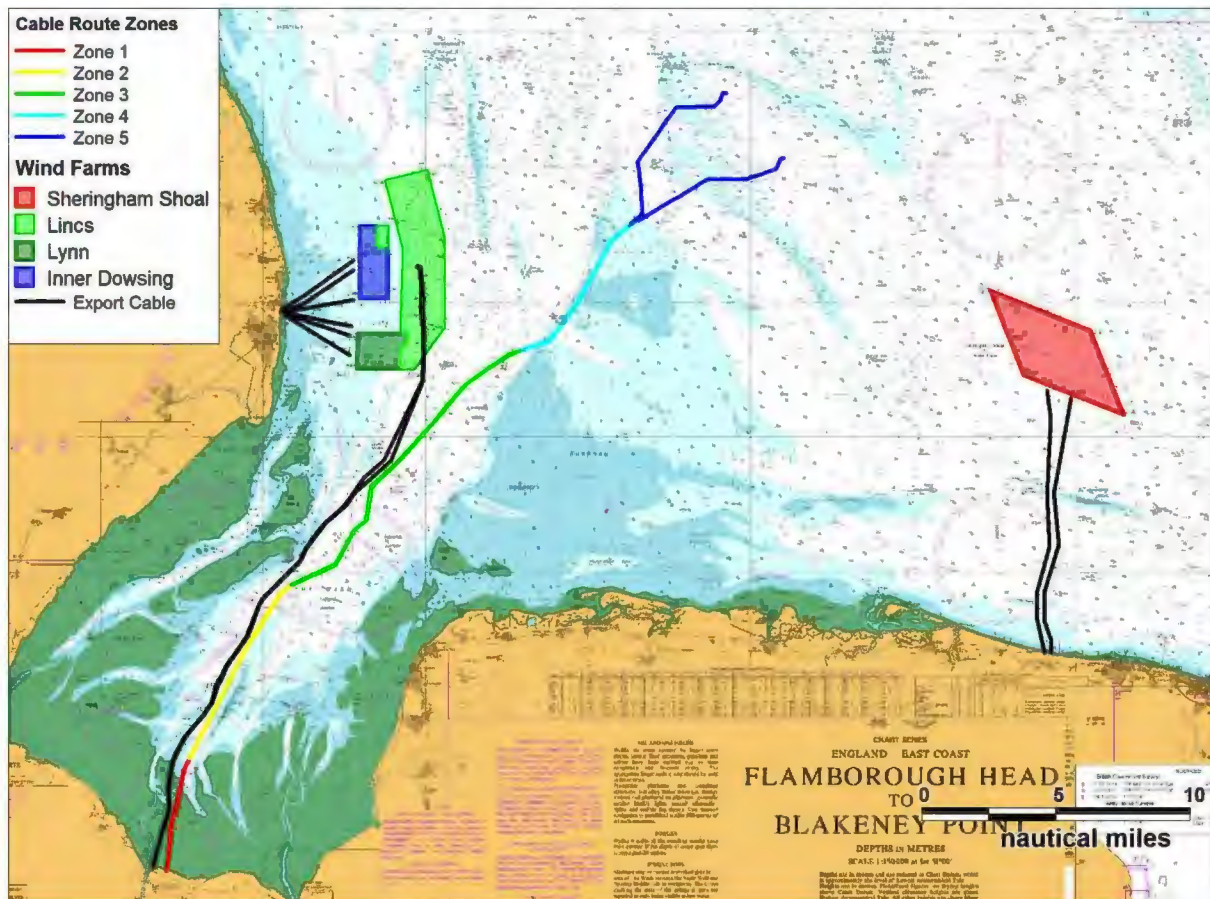


Figure 4.4 Wind Farms

4.3 Aggregates Dredging

Figure 4.5 shows the regions of aggregates dredging near the wind farm. The nearest point of the South Inner Dowsing region is less than 500m northwest of the proposed Race Bank export cable route. Both regions are under application, although the South Inner Dowsing is an application for renewal.

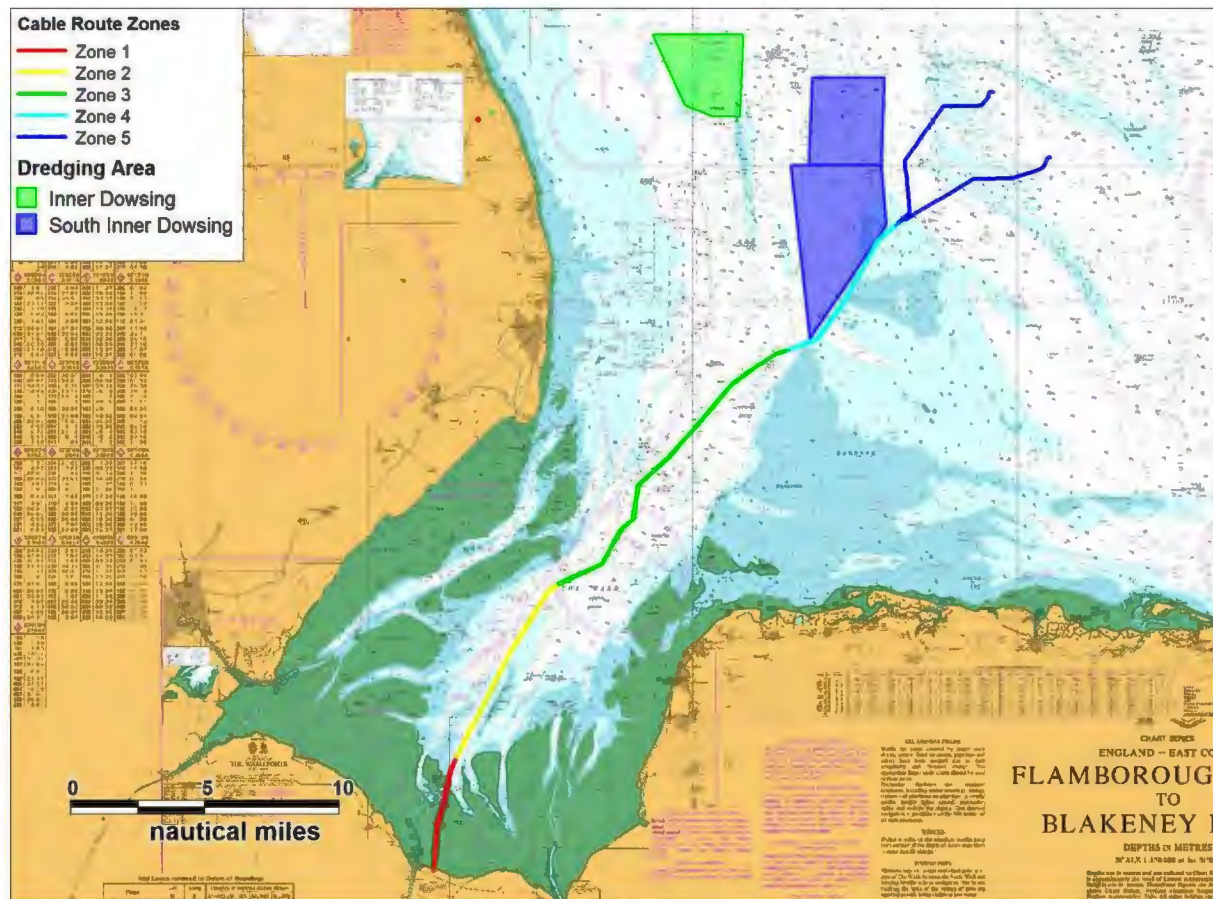


Figure 4.5 Dredging Areas

4.4 Oil & Gas

There are no oil & gas platforms in the vicinity of the cable route. The nearest is the Waveney gas field, over 14nm east of the Race Bank site. However it should be noted that there may be vessels related to the oil and gas industry transiting between the Wash ports and nearby fields.

4.5 Military Activity

Holbeach air gunnery and bombing range is located 8 miles north-north-east of Holbeach. The firing practice area extends into the sand flats, as shown in Figure 4.6.

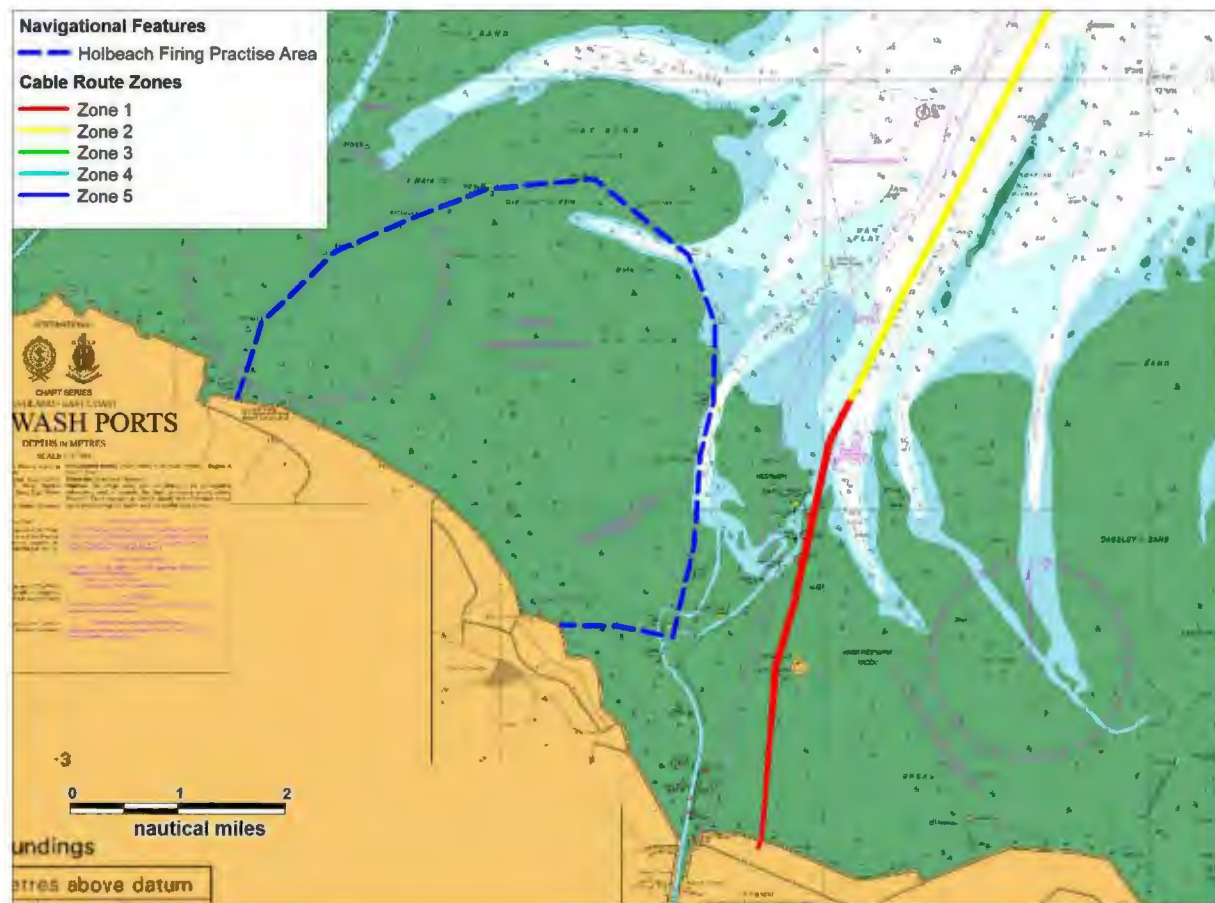


Figure 4.6 Holbeach Firing Practice Area

4.6 Leisure Activities

Figure 4.7 presents the leisure/recreational activities taking place around the Wash area, including marinas and clubs, racing and sailing areas and RYA (Royal Yachting Association) cruising routes.

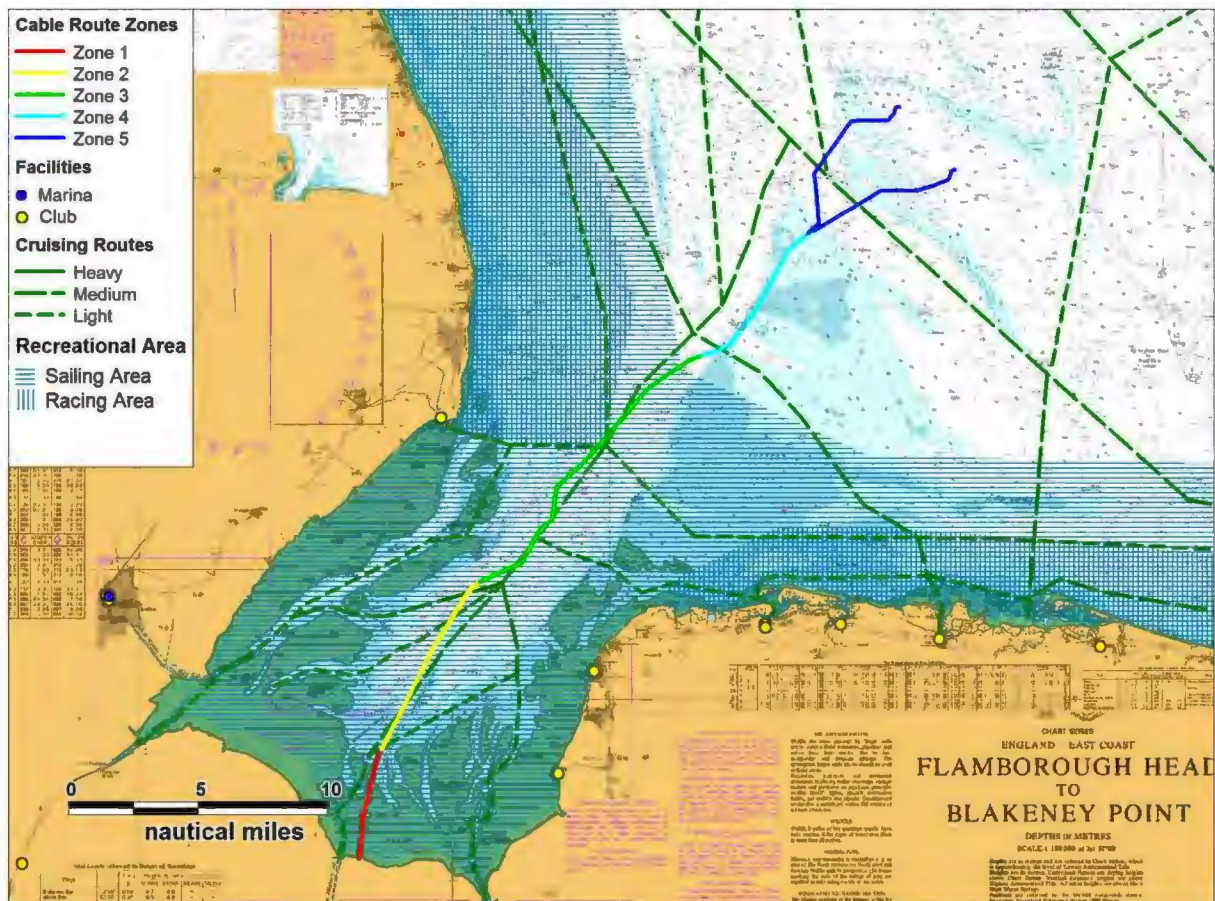


Figure 4.7 Leisure Activities

Figure 4.8 to Figure 4.10 present more detailed views of the export cable in terms of nearby recreational activity.

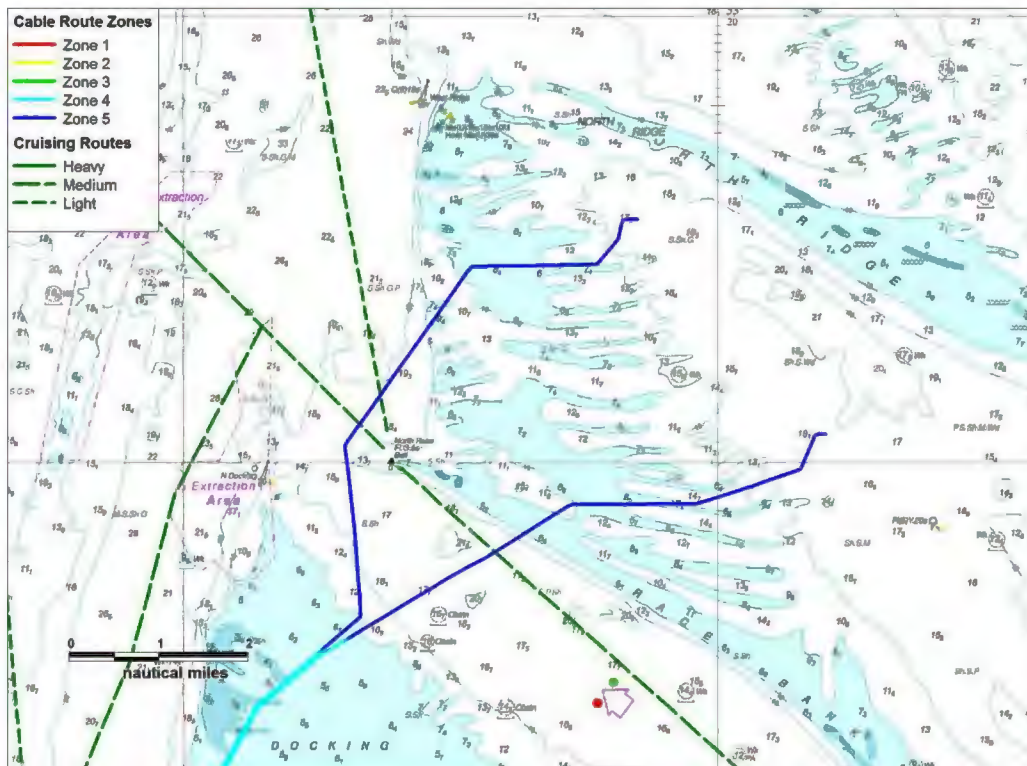


Figure 4.8 Zone 5 Detailed Leisure Activity

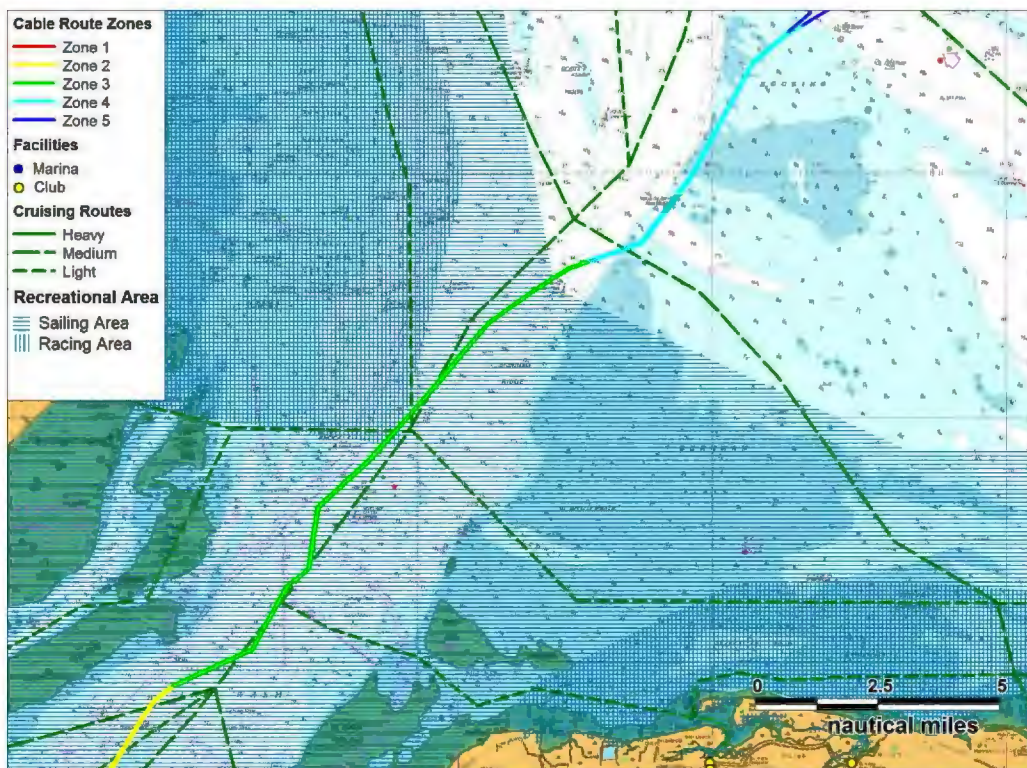


Figure 4.9 Zone 3 and 4 Detailed Leisure Activity

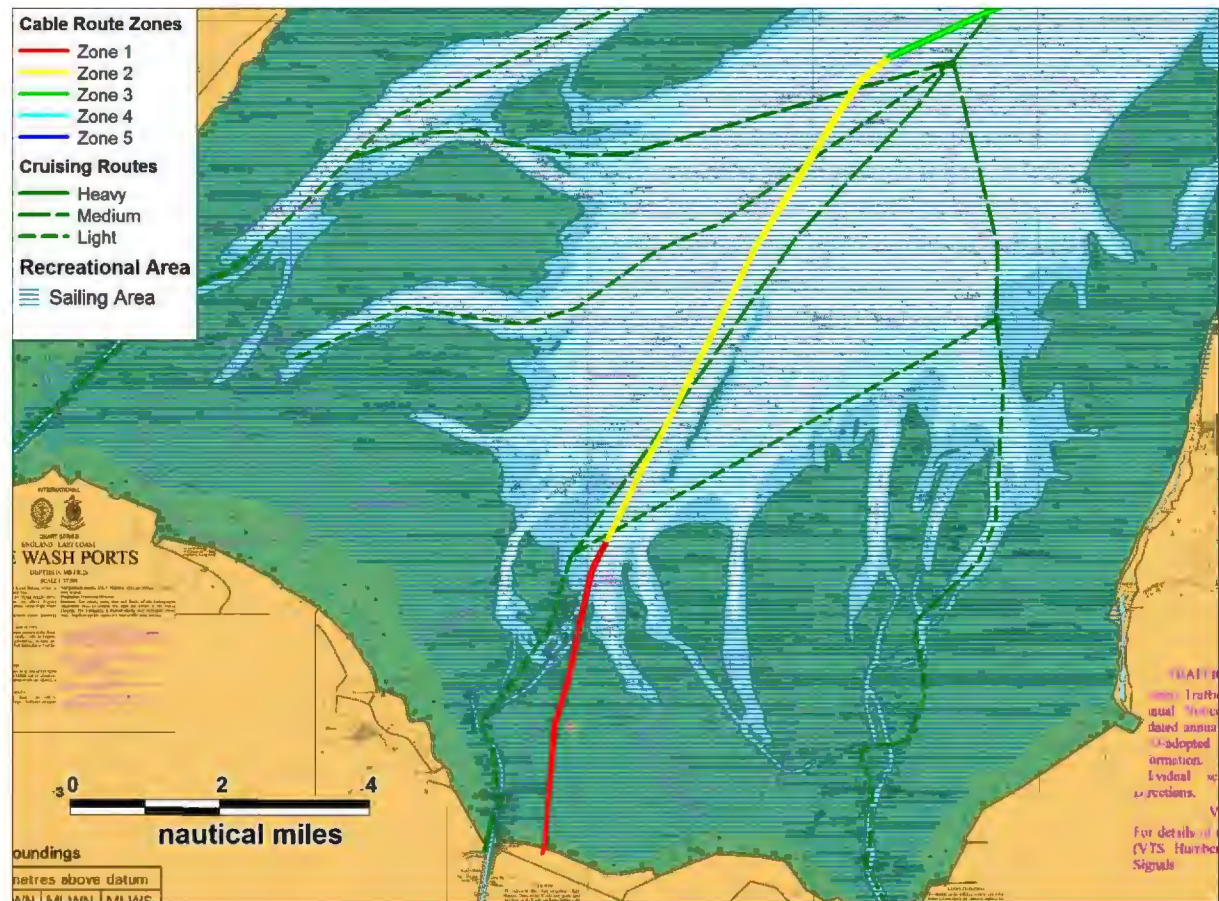


Figure 4.10 Zone 1 to 3 Detailed Leisure Activity

5. Shipping Analysis

5.1 Introduction

As part of the Cable Risk Assessment, a detailed shipping analysis was undertaken on the six months (July to December) of 2013 AIS data used within the assessment. An additional four months of AIS data from 2015 (June to September) was also analysed to assess the impact of the new Wisbech Channel (implemented in May 2015) on shipping within the Wash.

The full analysis is available in Appendix A (Ref iii), with a summary provided below.

5.2 2013 AIS Shipping Analysis

The six months of 2013 AIS data is presented in Figure 5.1, colour coded by vessel type.

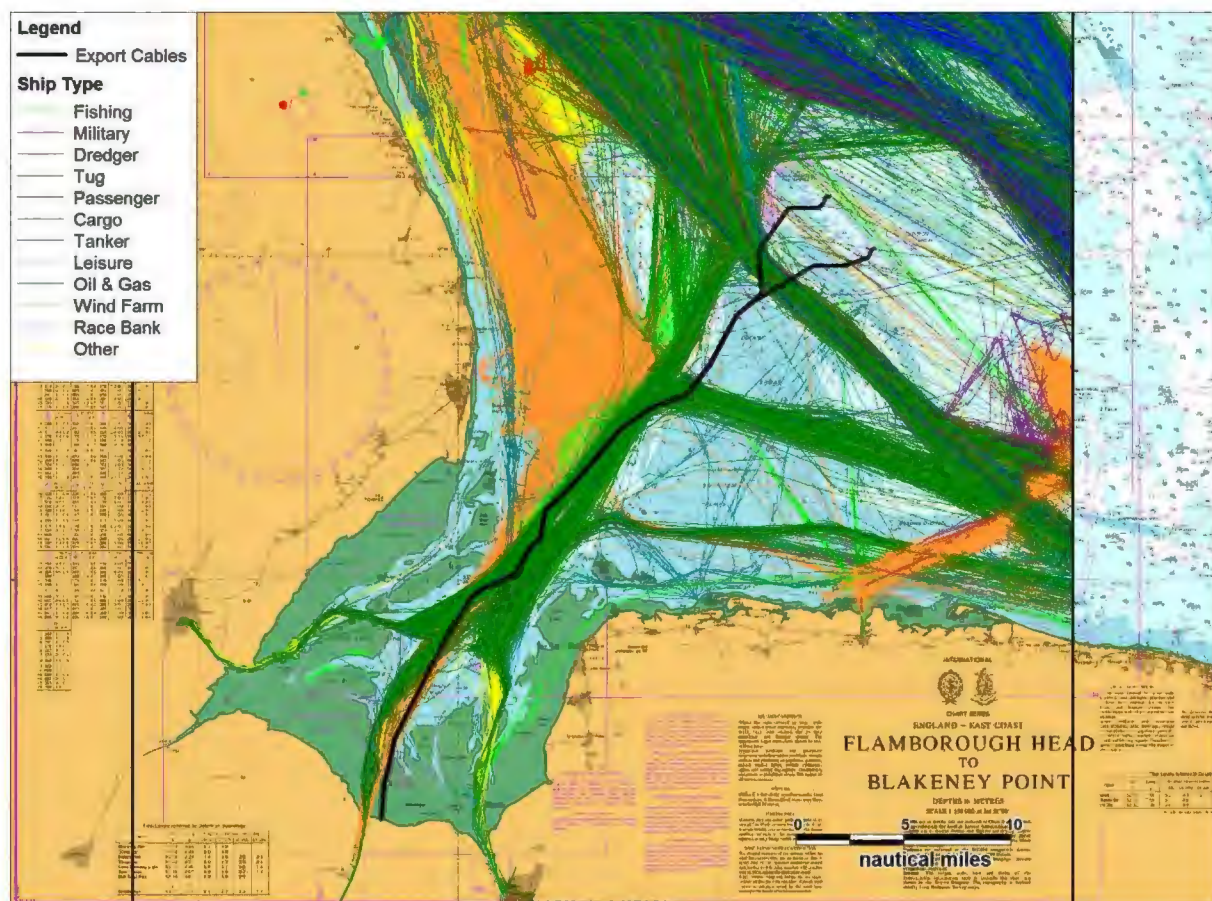


Figure 5.1 2013 AIS Data (July to December 2013)

An average of 82 unique vessels per day passed through the defined study area, with the busiest single day seeing 113 unique vessels compared to 41 on the quietest day. Based on unique vessels per day, approximately 48% of vessels within the study area during the six month period were cargo vessels. A further 16% were tankers, and 18% were associated with wind farms in the area (e.g. Lincs and Sheringham Shoal Wind Farms).

The majority of anchoring activity within the study area occurred within the Wash anchorages. This activity is presented in Figure 5.2.

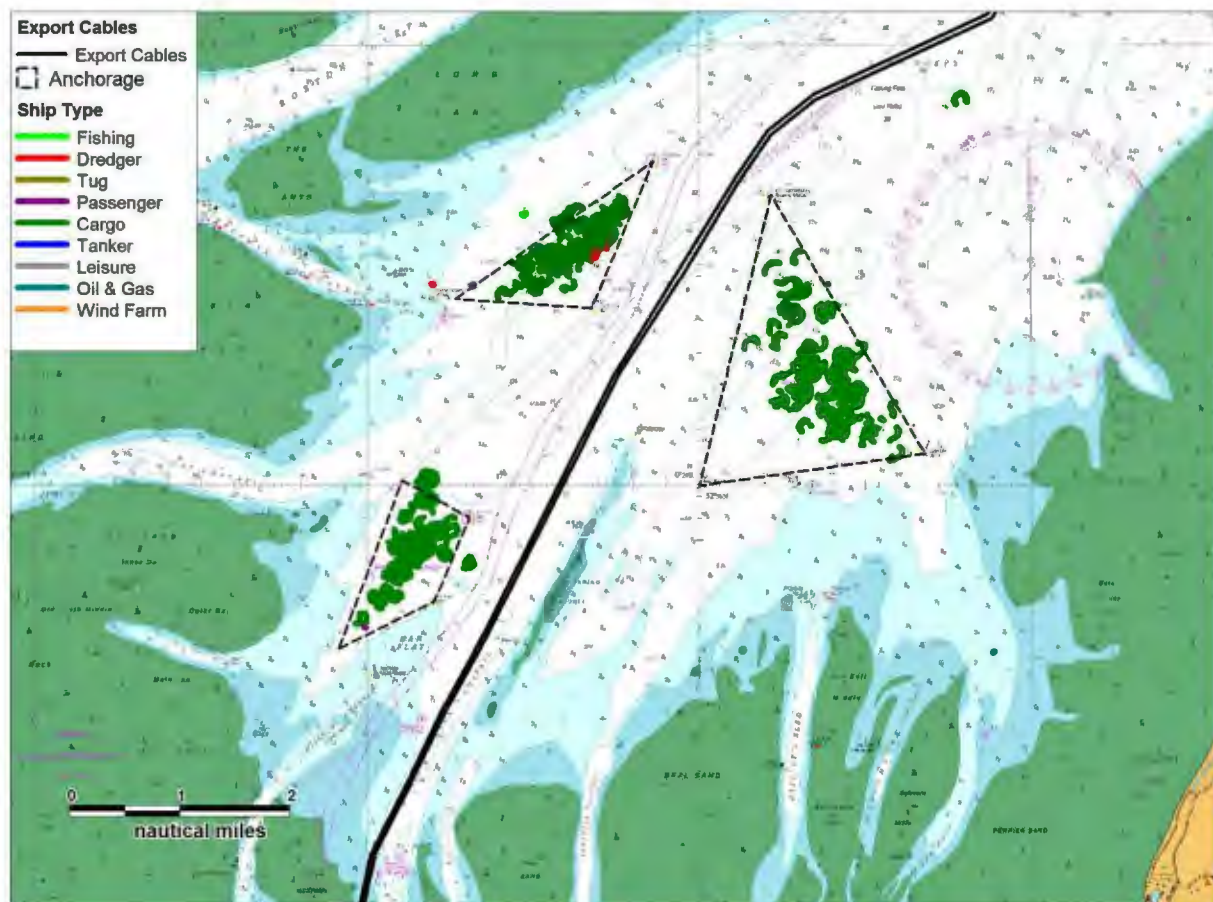


Figure 5.2 2013 AIS Data – Wash Anchoring (July to December 2013)

Approximately 86% of anchoring activity within the study area was from cargo vessels. A further 10% was from vessels associated with wind farms in the area.

5.3 2015 AIS Shipping Analysis

Due to changing water depths within the Wash, access to the ports of Wisbech and Sutton Bridge is via the designated Wisbech Channel. The Channel was shifted approximately 1nm to the east during 2015, and buoys were installed to mark the new channel location. In order to assess the traffic using the new channel, an additional four months of AIS data from the 1st of June to the 30th September 2015 was compared with the 2013 data. The AIS data recorded in 2015 is presented in Figure 5.3 relative to the buoys marking the new channel. The buoy marking the entrance to the old channel has been included in the figure.

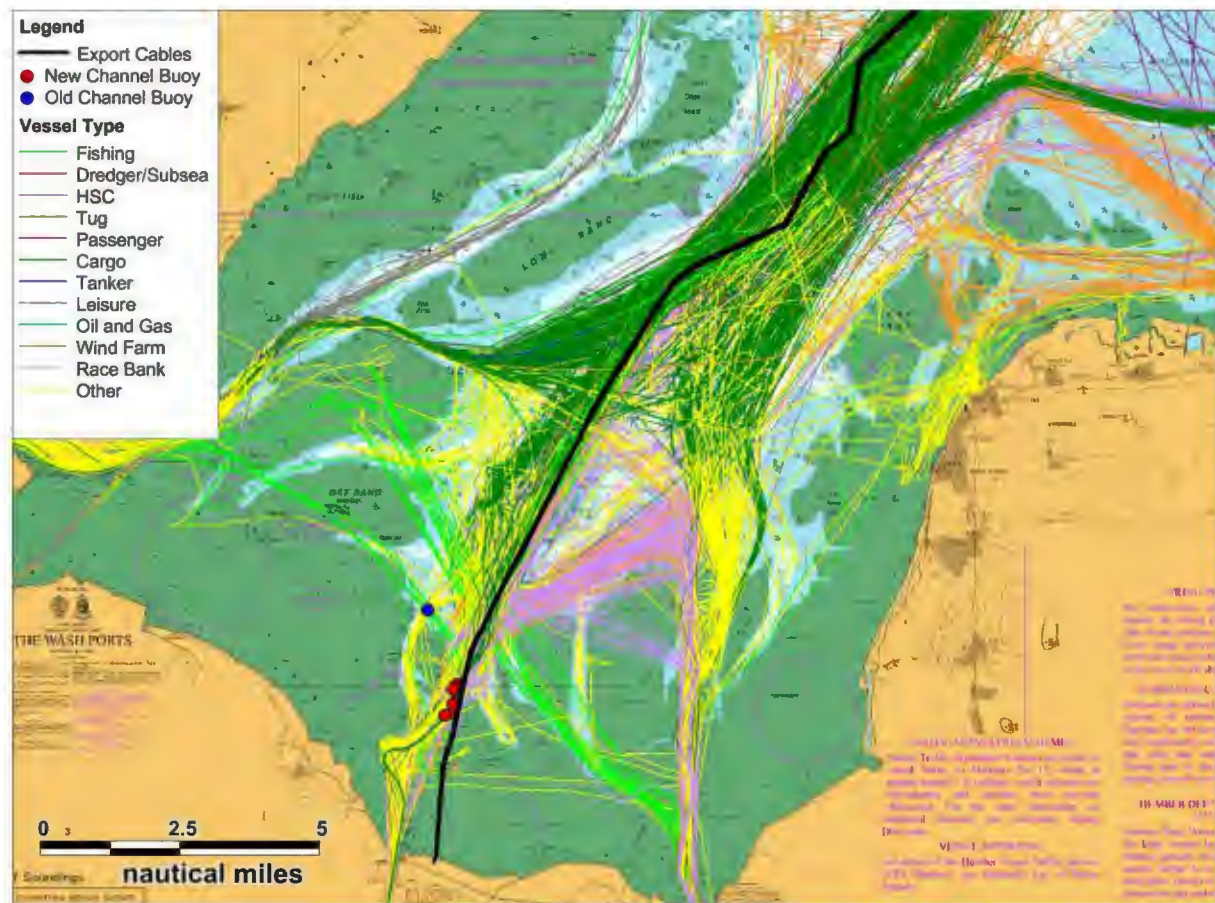


Figure 5.3 2015 AIS Data (June to September 2015)

Small pilot and survey vessels were recorded using the old channel in the 2015 data, however the new channel was clearly being used by the majority of the relevant traffic. It was noted that the main users of the old channel in 2013 and the new channel in 2015 were cargo and pilot vessels. To illustrate the change in vessel routeing, the tracks from cargo vessels only recorded during 2013 and 2015 are presented in Figure 5.4.

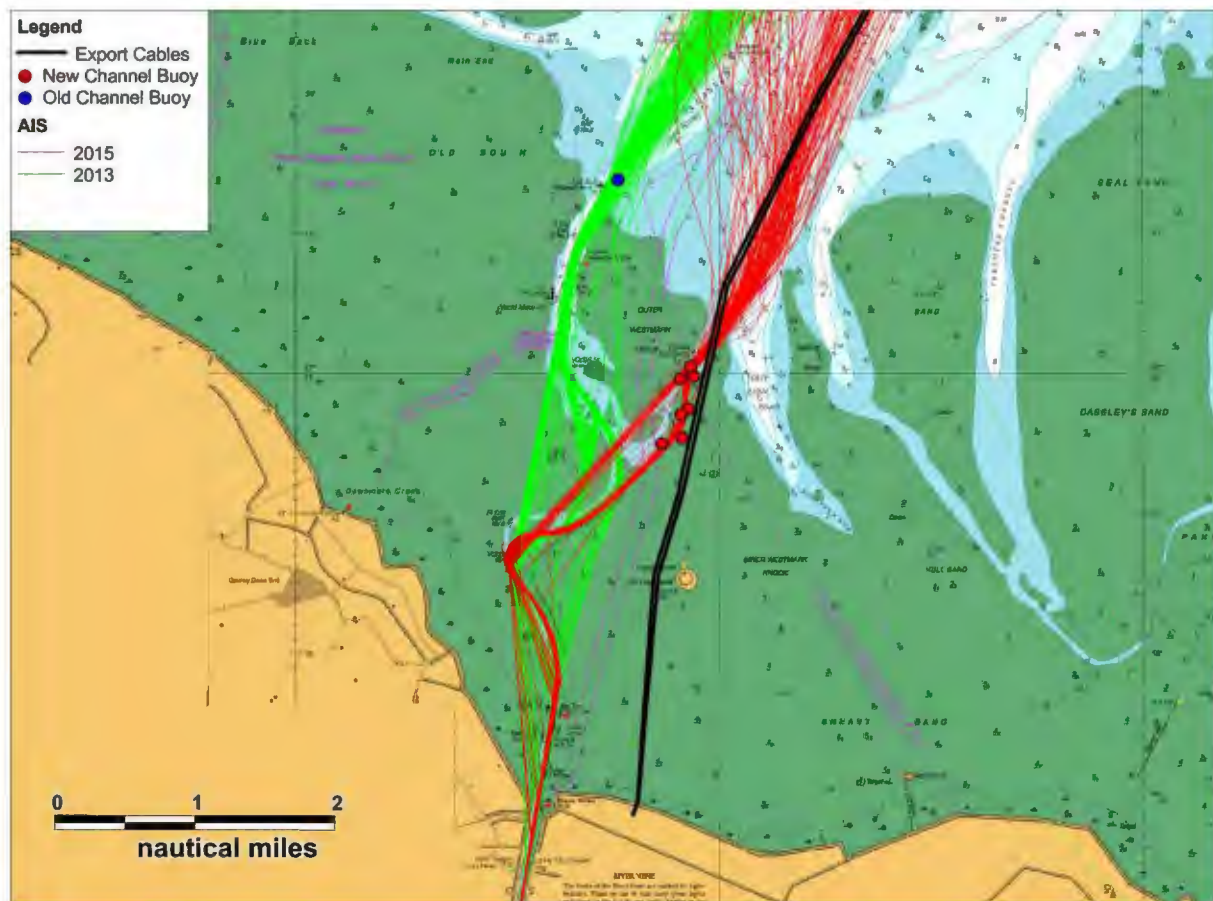


Figure 5.4 Wisbech Channel Comparison (2013 and 2015)

It was observed that the passage of vessels using the new channel resulted in greater exposure of the cable to passing traffic. For this reason 2015 data was incorporated into the emergency anchoring and foundering modelling in Section 8.3 and Section 8.5 to ensure the new shipping patterns within the Wash caused by the channel alteration were accounted for in the risk assessment.

5.4 Port Callings

To validate the AIS data used within the shipping analysis and further anchor dragging and emergency anchoring modelling a comparison was made with port callings for the six month (July to December 2013) study period. The port calling information was provided by the ports of Boston, King's Lynn, Sutton Bridge and Wisbech. Please note that within the AIS analysis port tender vessels have been excluded as these vessels are not counted within typical port callings.

Table 5.1 presents a comparison of Port arrival data with AIS data over the six month survey period.

Table 5.1 Comparison of AIS and Port Callings during Study Period

Port	AIS		Port Report
	Arrival	Departure	Arrival
Boston	179 ⁺	173	181
King's Lynn	103	105	103
Port Sutton Bridge	109	*	109
Wisbech	15	*	15

⁺The small deviation in the Boston count can be attributed to a small portion of downtime as mentioned in Appendix A

*It is not possible to deduce from the AIS data from which port vessels are departing from for these two harbours.

It is noted that the Wash Port authorities indicated that 2013 was a quiet year in terms of port arrivals. For this reason the 2013 anchor dragging, emergency anchoring, and foundering durations used in the risk assessment modelling (see Sections 8.2, 8.3, and 8.5) were factored up by 20%.

6. Hazard Workshop

6.1 Introduction

The workshop was held in the offices of DONG Energy in Copenhagen on 4th April 2014, and was attended by experts on the cable and on the geophysical nature of the seabed, as outlined in Table 6.1.

Table 6.1 Hazard Workshop Attendees

Name	Organisation	Title
Peter Skjellerup	DONG	Geophysicist
Lone Klinkby	DONG (COWI)	Geophysicist
Johan Meincke	DONG	Geotechnical Engineer
Gordon Pedersen	DONG	Cable Lead
Martin Warming	DONG	Cable Installation Manager
Hywel Roberts (phone)	DONG	Fisheries Liaison
Eleftheria Melekou	DONG	Site Investigations Project Manager
Lucy MacNay	Anatec	Workshop Facilitator
Tom Westwood	Anatec	Workshop Facilitator

The key hazards associated with the Race Bank export cable were identified and associated scenarios prioritised by risk level. Hazards were divided into categories of natural hazard and anthropogenic hazard and the cable route was divided into 5 zones, as shown in Table 2.1 and Figure 2.2.

6.2 Methodology

The hazards were recorded systematically using Anatec's Hazard Management software. The main information logged by the system is presented in Table 6.2.

It is noted that the nature of the discussion was to consider the worst-case consequences of each hazard and the frequency of such a consequence occurring. This strategy reflects the fact that the majority of natural hazards are well-documented and provisions will be made to avoid or remove the hazard before the cable is installed, with minimal consequence to the

cable. However, in a ‘worst case’ scenario, an unidentified issue may occur with greater consequence to the cable.

Table 6.2 Hazard Log Field Description

Category	Definition
Hazard Title	Title of hazardous event.
Date Recorded	Date the hazard was logged in the system.
Hazard Detail	Description of the hazardous event.
Category	General hazard category, i.e. natural or anthropogenic.
Sub-Category	Hazard sub-category, e.g., sand wave, anchors.
Zone	Zone 1 – 5, as defined above.
Phase	Phase(s) of operation i.e. Construction or Operations.
Possible Causes	List all the potential causes of the hazard.
Embedded Mitigations	List of mitigations that will be in place.
Outcome Description	Description of the likely outcome should the hazard occur.
Frequency	Estimates the frequency of the event occurring.
Consequence	Estimates the outcome should the event occur in terms of consequence to People and Business.
Risk Estimate	Combines the frequency and consequence to estimate risk level for the event.
Risk Reduction Measures	Documents the potential mitigation measures which will aid in the reduction of risk or in the management of the hazardous event.

Based on the discussions at the workshop, the risks associated with each hazard were ranked for each cable route zone. The following frequency and consequence categories were applied.

Table 6.3 Frequency Bands

Rank	Description	Definition
1	Negligible	< 1 occurrence per 10,000 years
2	Extremely Unlikely	1 per 100 to 10,000 years
3	Remote	1 per 10 to 100 years
4	Reasonably Probable	1 per 1 to 10 years
5	Frequent	Yearly

Table 6.4 Consequence Bands

Rank	Description	Definition	
		People	Business
1	Negligible	No injury	<10k
2	Minor	Slight injury(s)	£10k-£100k
3	Moderate	Multiple moderate or single serious injury(s)	£100k-£1M Local publicity
4	Serious	Multiple serious injury(s) or single fatality	£1M-£10M National publicity
5	Major	More than 1 fatality	>£10M International publicity

These were used to determine whether a hazard meets the acceptance criteria, based on the matrix below.

Table 6.5 Risk Matrix

Consequence	5					
	4					
	3					
	2					
	1					
		1	2	3	4	5
		Frequency				

where:

	Broadly Acceptable Region (Low Risk)	Generally regarded as insignificant and adequately controlled. None the less the law still requires further risk reductions if it is reasonably practicable. However, at these levels the opportunity for further risk reduction is much more limited.
	Tolerable Region (Intermediate Risk)	Typical of the risks from activities which people are prepared to tolerate to secure benefits. There is however an expectation that such risks are properly assessed, appropriate control measures are in place, residual risks are as low as is reasonably practicable (ALARP) and that risks are periodically reviewed to see if further controls are appropriate.
	Unacceptable Region (High Risk)	Generally regarded as unacceptable whatever the level of benefit associated with the activity.

The worked example below illustrates the method of ranking hazards:

Hazard Title	Cable becomes exposed due to sand waves
Possible Causes	Sand waves; profile changes in seabed; direction of current
Consequence	Exposure of cable requires repair i.e. additional burial/rockdump; exposure of cable causes free span and damage to cable from fatigue
Embedded Mitigations	Select best option for cable laying; regular inspection of cable; lay cable perpendicular to sand wave; lay cable in suitable seabed type; cable laying vessels use suitable tools; cable burial to suitable depth
Frequency	Reasonably probable (1 to 10 years)
Consequence to People	Negligible
Consequence to Business	Moderate. Repair of cable could cost £100k-£1M.

The following tables present the risk ranking of this hazard.

Table 6.6 Risk Matrix: Cable becomes exposed due to sand waves

Consequence (People)	5						Consequence (Business)	5					
	4							4					
	3							3				X	
	2							2					
	1				X			1					
		1	2	3	4	5			1	2	3	4	5
Frequency							Frequency						

Further potential mitigation measures for this event were logged as follows:

- Bury cable to bottom of sand wave.

This is expected to further reduce the frequency of the cable becoming exposed.

6.3 Results

The results of the hazard workshop are presented in this section. The hazards tended to divide into construction or operational phase. The results assume a certain number of “embedded” mitigation measures that are required for cable installation.

6.3.1 Construction Phase

The majority of hazards during the construction phase were natural hazards leading to problems with cable installation. The following hazards were reviewed:

Natural Hazards

- Difficulties with cable burial due to till in seabed
- Difficulties with cable burial due to chalk in seabed
- Difficulties with cable laying due to cobbles
- Difficulties with cable laying due to boulders
- Difficulties with cable laying due to magnetic objects
- Difficulties with cable laying due to wrecks
- Cable installation unable to occur due to inclines in seabed caused by the Well
- Cable installation unable to occur due to inclines in seabed caused by sand waves

Anthropogenic Hazards

- Difficulties with cable laying due to UXO
- Damage to cable from own installation

Figure 6.1 presents the overall breakdown by tolerability region for the risks to people and to business for the identified hazards.

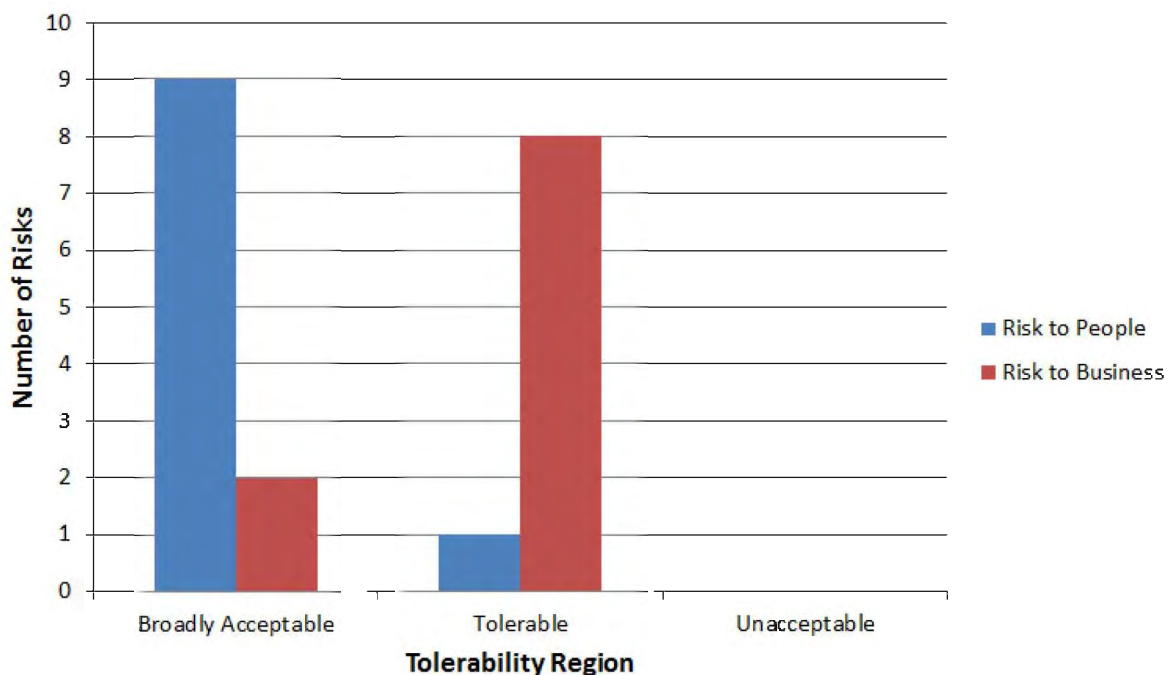


Figure 6.1 Race Bank Cable Risk Ranking Results, Construction Phase

It can be seen that the risk to business was ranked higher than the risk to people. This is generally due to the significant costs associated with repair of the cable in the event that a worst-case scenario occurs.

The hazards ranked as tolerable for the risk to business were:

- Difficulties with cable burial due to till in seabed
- Difficulties with cable burial due to chalk in seabed
- Difficulties with cable laying due to cobbles
- Difficulties with cable laying due to boulders
- Difficulties with cable laying due to magnetic objects
- Difficulties with cable laying due to wrecks
- Difficulties with cable laying due to UXO
- Damage to cable from own installation

Full details of the logged and ranked hazards are given in the Hazard Workshop Report (Ref iv).

6.3.2 Operational Phase

The following hazards associated with the operational phase were reviewed:

Natural Hazards

- Cable becomes exposed due to sand waves
- Cable becomes exposed due to megaripples
- Cable becomes exposed due to seabed instability
- Cable becomes exposed due to mass sediment transport

Anthropogenic Hazards

- Cable damaged by fishing gear
- Cable damaged by Anchor Dragging
- Cable damaged by Emergency Anchoring
- Cable damaged by foundering vessel
- Damage to cable or cable exposed by dredging activity
- Damage to cable or cable exposed by oil & gas activity
- Cable damaged or exposed due to maintenance on Lincs cable
- Cable damaged due to military activity
- Cable damaged due to leisure activity
- Damage to cable from own maintenance

Figure 6.2 presents the overall breakdown by tolerability region for the risks to people and to business for the identified hazards of the operational phase.

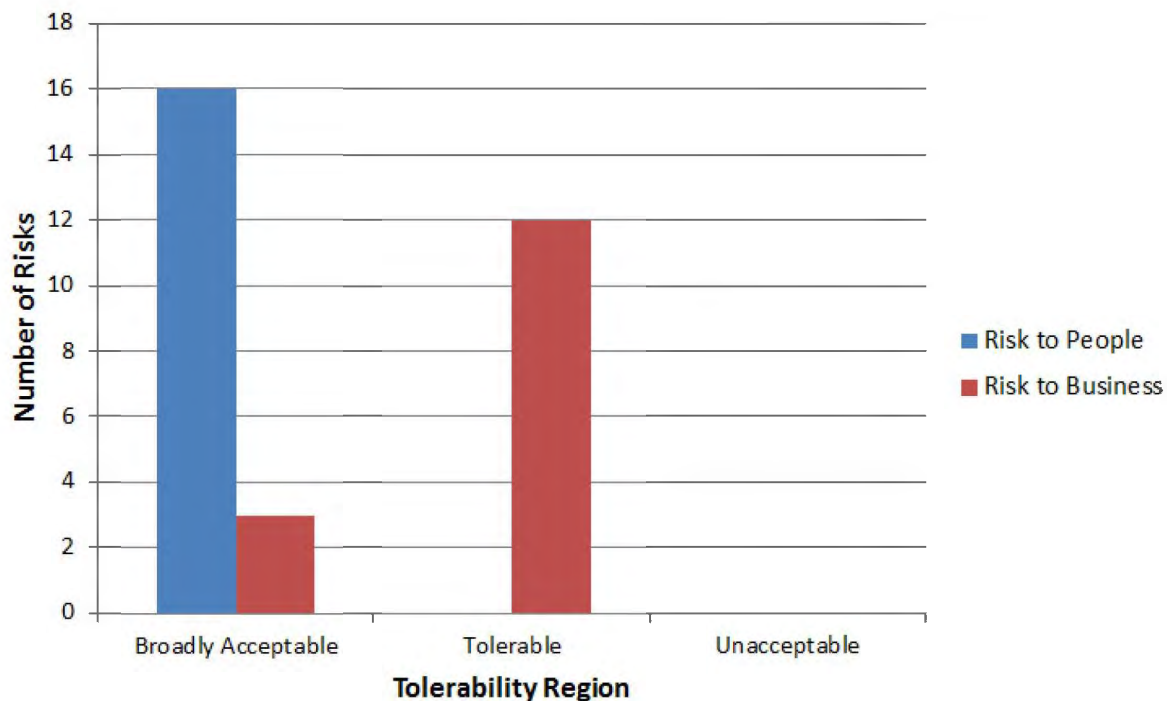


Figure 6.2 Race Bank Cable Risk Ranking Results, Operational Phase

It can be seen that the risks to people were all within the broadly acceptable region. For risk to business, the majority of risks were considered tolerable, with 3 broadly acceptable risks.

The hazards ranked as tolerable for the risk to business were:

- Cable becomes exposed due to sand waves
- Cable becomes exposed due to megaripples
- Cable contains free span due to scour around the turbines
- Cable damaged by fishing gear
- Cable damaged by Anchor Dragging
- Cable damaged by Emergency Anchoring
- Cable damaged by foundering vessel
- Damage to cable or cable exposed by dredging activity
- Damage to cable or cable exposed by oil & gas activity
- Cable damaged or exposed due to maintenance on Lincs cable
- Cable damaged due to military activity
- Damage to cable from own maintenance

Full details of the logged and ranked hazards are given in the report of the Hazard Workshop (Ref iv).

7. Natural Hazards Risk Assessment

The risk from the natural hazards was assessed based on the geophysical and geotechnical information and the discussions from the hazard workshop. This section summarises the findings for each hazard.

7.1 Sand Waves

Sand waves were considered to present a risk of reduced burial depth or exposure of the cable to other hazards if the sand waves cause the sediment to move over time. This risk will be mitigated by optimal route selection to avoid larger sand waves, laying the cable perpendicular to the sand wave, using suitable tools to bury the cable, burying the cable to suitable depths and regular inspection of the cable.

Sand waves are a key factor in determining suitable burial depths for the cable. In particular, it is recommended that the cable is buried to the bottom of the sand wave, or as deep as possible, thereby reducing the frequency that the cable becomes exposed. This is discussed in more detail in the Cable Burial Risk Assessment (Section 9).

The exposure of the cable does not present a safety risk to people, giving negligible consequence to people. The consequence to business is the cost of repair or additional burial, which is expected to be £100k - £1M, giving a consequence ranking of moderate.

7.2 Megaripples

Megaripples were considered to present a risk of reduced burial depth or exposure of the export cable to other hazards. Due to the smaller size of the megaripples, it is assumed that the cable can more easily be buried to the bottom of the megaripples. In addition, the movement of sand due to megaripples is less likely to cause the cable to become exposed. Similarly to the sand waves, the risk will be mitigated by optimal route selection, laying the cable perpendicular to the megaripple, using suitable tools to bury the cable, burying the cable to suitable depths and regular inspection of the cable.

Megaripples are a key factor in determining suitable burial depths for the cable. It is recommended that the cable is buried to the bottom of the megaripple to reduce the frequency that the cable becomes exposed. This is discussed in more detail in the Cable Burial Risk Assessment (Section 9).

The exposure of the cable does not present a safety risk to people, giving negligible consequence to people. The consequence to business is the cost of repair or additional burial, which is expected to be £100k - £1M, giving a consequence ranking of moderate.

7.3 Rock Outcrops

The existence of rock outcrops i.e. till or chalk along the cable route could cause problems with achieving the required depth of burial for the cable.

The existence of till and chalk in the seabed is well-documented by the geotechnical surveys, giving the contract engineers the opportunity to plan the route and the tools required. In the event that previously unidentified till or chalk is discovered during the installation of the cable, this could require re-routeing of the cable or alternative burial methods, leading to operational delays.

Assuming that the contractors have access to geotechnical and geophysical surveys and that they have selected the best route and cable laying equipment, the frequency of encountering unidentified till was considered to be remote, or one event every 10 to 100 years. Chalk in the seabed is not considered to be an issue and the frequency of encountering unidentified chalk was therefore determined to be negligible, or less than one occurrence in 10,000 years.

The consequence to people from encountering previously unidentified till or chalk in the seabed was considered to be negligible. In the event that the discovery requires re-routeing, or re-tooling, leading to operational delays, the consequence to business is considered to be serious, at a cost of £1M - £10M.

The risk to the cable from till and chalk was considered to be **broadly acceptable** for the risk to people and **tolerable** for the risk to business.

Further mitigation measures that could help reduce the risk from rock outcrops to ALARP include additional seabed sampling to provide comprehensive information of rock outcrops and having access to alternative cable laying tools on site, which would reduce operational delays.

Since the existence of till, chalk or bedrock could affect the achievable burial depth of the cable, this is taken into consideration in the Cable Burial Risk Assessment in Section 9.

7.4 Boulders and Cobbles

The existence of boulders or cobbles along the cable route could cause problems with cable installation and achieving the required burial depth. Seabed surveys have mapped out the existence of boulders and cobbles along the cable route. In the event that unexpected cobbles or small boulders are discovered along the cable route, the cobble/boulder will require to be removed. This could lead to operational delays, or the requirement for additional tools. For larger boulders, re-routeing of the cable may be required.

Assuming that sufficient surveys have been carried out in order to carefully select a route that avoids larger boulders and cobbles, that the route has been previously cleared of smaller ones and that suitable tools are available during the cable installation, the frequency of encountering an unexpected boulder or cobble that requires attention is considered to be reasonably probable.

The consequence of such an encounter was considered to be negligible for people and moderate for business, i.e. a cost of £100k - £1M.

The risk to the cable from boulders or cobbles was therefore considered to be **broadly acceptable** for the risk to people and **tolerable** for the risk to business.

Sufficient seabed sampling would help to reduce the risk to ALARP.

7.5 Seabed Obstructions

Seabed Obstructions along the cable route were divided into the categories magnetic objects, wrecks/debris and UXOs. UXOs will be discussed under anthropogenic hazards. Seabed obstructions could cause problems with cable installation.

Seabed surveys have mapped out the existence of magnetic objects and wrecks/debris along the cable route. In the event that unexpected objects are discovered along the cable route, this could require re-routing of the cable or removal of the obstruction. This could lead to operational delays, or the requirement for additional tools.

Since the seabed obstructions are considered to be well known along the cable route, the frequency of encountering an unexpected seabed obstruction that requires attention is considered to be extremely unlikely.

The consequence of such an encounter was considered to be negligible for people and serious for business, i.e. a cost of £1M - £10M.

The risk to the cable from seabed obstructions was therefore considered to be **broadly acceptable** for the risk to people and **tolerable** for the risk to business.

Assuming that sufficient measures have been taken to map and identify all seabed obstructions, this risk is considered to be ALARP.

7.6 Inclines

Inclines in the seabed along the cable route could cause problems with cable burial if the incline is greater than 8-10 degrees. Inclines in the seabed could be caused by the Well in Zone 2 of the export cable or by sand waves.

The proposed cable route is intended to be routed around the Well, thereby avoiding installation problems. The presence of large sand waves is considered to be well documented and, provided the route avoids those with steep inclines, it is considered that the frequency of the selected route encountering inclines greater than 8-10 degrees is negligible.

The consequence of inclines due to the Well was considered to be negligible for the risk to people and moderate for the risk to business, while the consequence of inclines due to sand waves was considered to be negligible for the risk to people and minor for the risk to business.

As a result, the risk to the cable from inclines due to the Well or sand waves was considered to be **broadly acceptable** for the risk to people and business.

7.7 Seabed Stability

Instabilities in the seabed could cause the cable to become exposed over time, leaving it exposed to other hazards. Zone 2 of the export cable was considered to present the highest risk of landslides due to the geographical feature of the Well.

Since the cable will be routed to avoid the Well, the frequency of exposure due to instabilities was considered to be negligible.

In the event that a landslide occurs causing the cable to become exposed, the consequence was considered to be negligible for people and moderate for business, i.e. £100k - £1M.

The risk to the cable from seabed instabilities was therefore considered to be **broadly acceptable** for the risk to people and business.

7.8 Mass Sediment Transport

Since the main sources of mass sediment transport are sand waves and megaripples, which have been considered under their own sub-categories, the frequency of other cases of mass sediment transport was considered to be negligible.

The risk to the cables from other causes of mass sediment transport was therefore considered to be **broadly acceptable** for people and for business.

7.9 Natural Migration of the Channels to the Ports

The natural migration of the entry channel to the ports of Wisbech and Sutton Bridge could increase the risk to the cable from emergency anchoring. This will be mitigated by burying the cable to a suitable depth and regular monitoring of the cable and the channels after burial.

This hazard was not discussed at the hazard workshop, but it should be noted that since the cable route lies directly over the new channel, there may be some requirement from the ports to bury the cable to a certain depth.

8. Anthropogenic Hazards Risk Assessment

8.1 Fishing

An overview of fishing activity in relation to the proposed cables is available in Appendix A (Ref iii). The risk to the cables from fishing gear is from demersal gear types actively fishing along the seabed causing the cable to become exposed or damaged. In the event the cable has been exposed by another hazard and contains a free span, the risk of fishing gear snagging on the cable becomes significant.

It is noted that only bottom trawlers (otterboard or beam trawlers) and dredgers have the potential to penetrate into the seabed and that the penetration depths of fishing gear tend to be small compared to vessel anchors. The maximum penetration depth was shown to be around 30cm. If the cable is buried to a minimum depth of 1m, the likelihood of cable damage from fishing gear is therefore likely to be very small. This is taken into consideration in the Cable Burial Risk Assessment in Section 9.

Fishing gear snagging on a cable could present a safety risk to fishermen, giving a consequence ranking to people of moderate. The consequence to the business was expected to be serious, i.e. £1M - £10M.

8.2 Anchor Dragging

8.2.1 Introduction

This section investigates the potential risk to the cable from vessels routinely anchoring within the Study Area dragging anchor onto the cable.

Anatec's CollRisk Anchor Dragging Model was used to determine the frequency of a vessel dragging anchor over the cable. Calculations are performed within a Geographical Information System (GIS) with relevant shipping and operational data (e.g. wind direction, sea-state etc.) as input.

8.2.2 Methodology

The export cable route was divided into 500m segments and the Study Area encompassing the anchored vessels divided into an exposure grid. The frequency that a vessel drags anchor over a segment of the cable route is calculated by multiplying the frequency that vessels drag anchor from the exposure grid cell, with the probability that the vessel drifts in the direction of the cable route segment (based on wind direction probability) and the probability that the vessel fails to recover in time (based on the time to drift from the cell to the cable and the estimated time for ship recovery).

An overview of the anchor dragging methodology, inputs and results are provided in Figure 8.1.

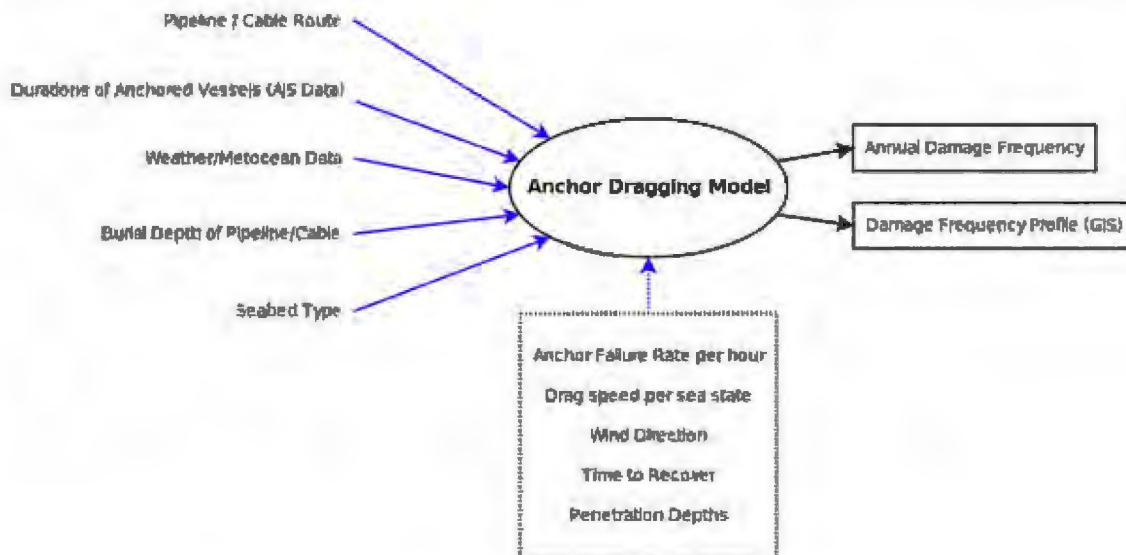


Figure 8.1 Anchor Dragging Methodology

A full description of the anchoring dragging model methodology is provided in Appendix B (Ref v).

8.2.3 Results

To determine the anchor dragging frequency, i.e. the frequency that a vessel drags anchor over the cable route, the CollRisk Anchor Dragging model was run. Calculations were carried out assuming that the cable is surface-laid with no burial/mitigation initially with further analysis carried out to assess the change of risk depending on burial depth.

The annual anchor dragging frequency for the export cable route without mitigation through burial was 3.11×10^{-2} , or one incident every 32 years. Figure 8.2 presents the breakdown of the anchor dragging frequency along the cable route per KP.

In order to avoid over-counting of the anchor dragging incidents, it was assumed that each incident affects only one of the two cable routes, i.e. the one nearest the anchored vessel. However, it is noted that an anchor could potentially drag over more than one cable.

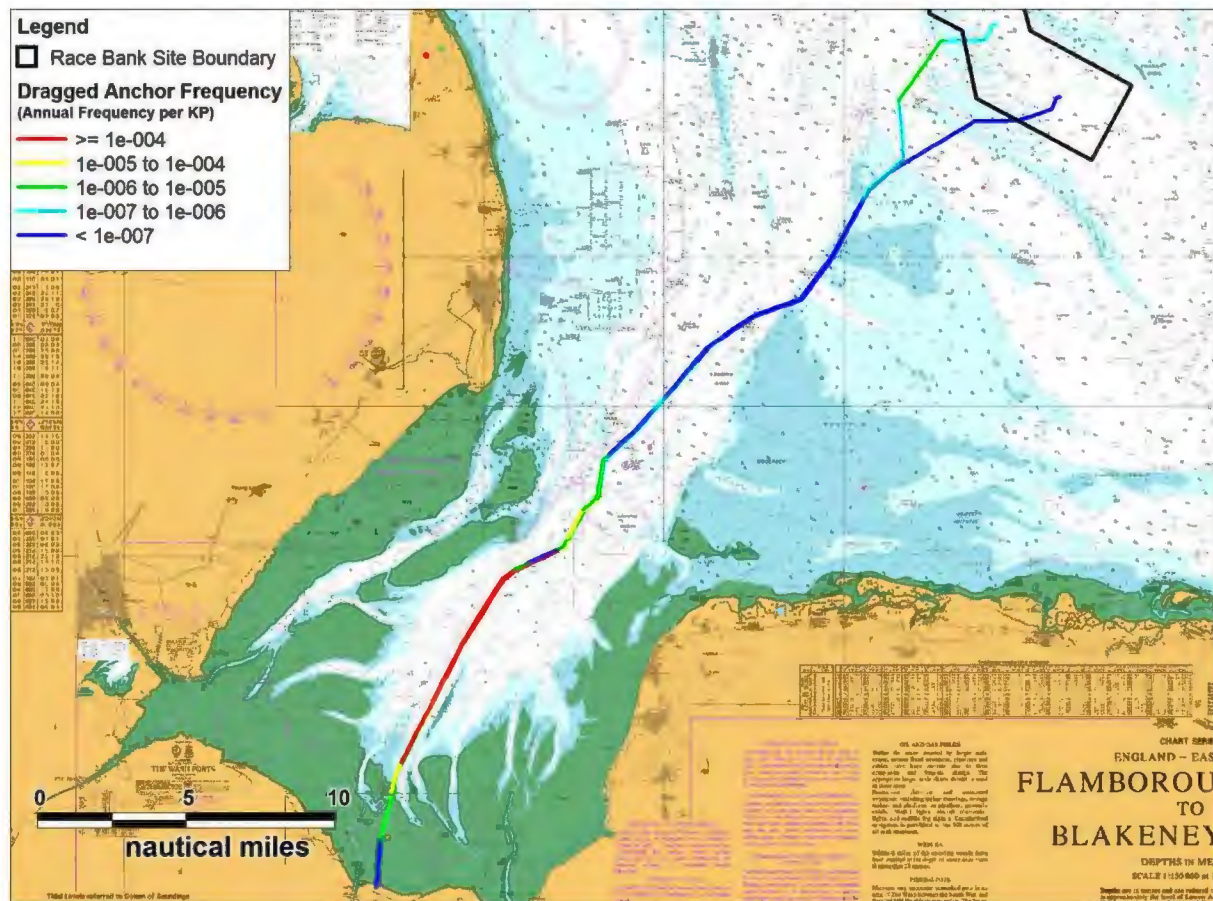


Figure 8.2 Annual Anchoring Dragging Frequency per KP (based on 2013 AIS data)

It can be seen that the highest areas of risk from vessels dragging anchor were the sections of cable between the anchorage areas of Sutton Bridge/Wisbech, Boston and King's Lynn. The vast majority (98%) of this risk was from the cargo vessels anchoring in the anchorage areas within the Wash. A zoomed in plot of the anchor dragging results within the Wash is presented in Figure 8.3.

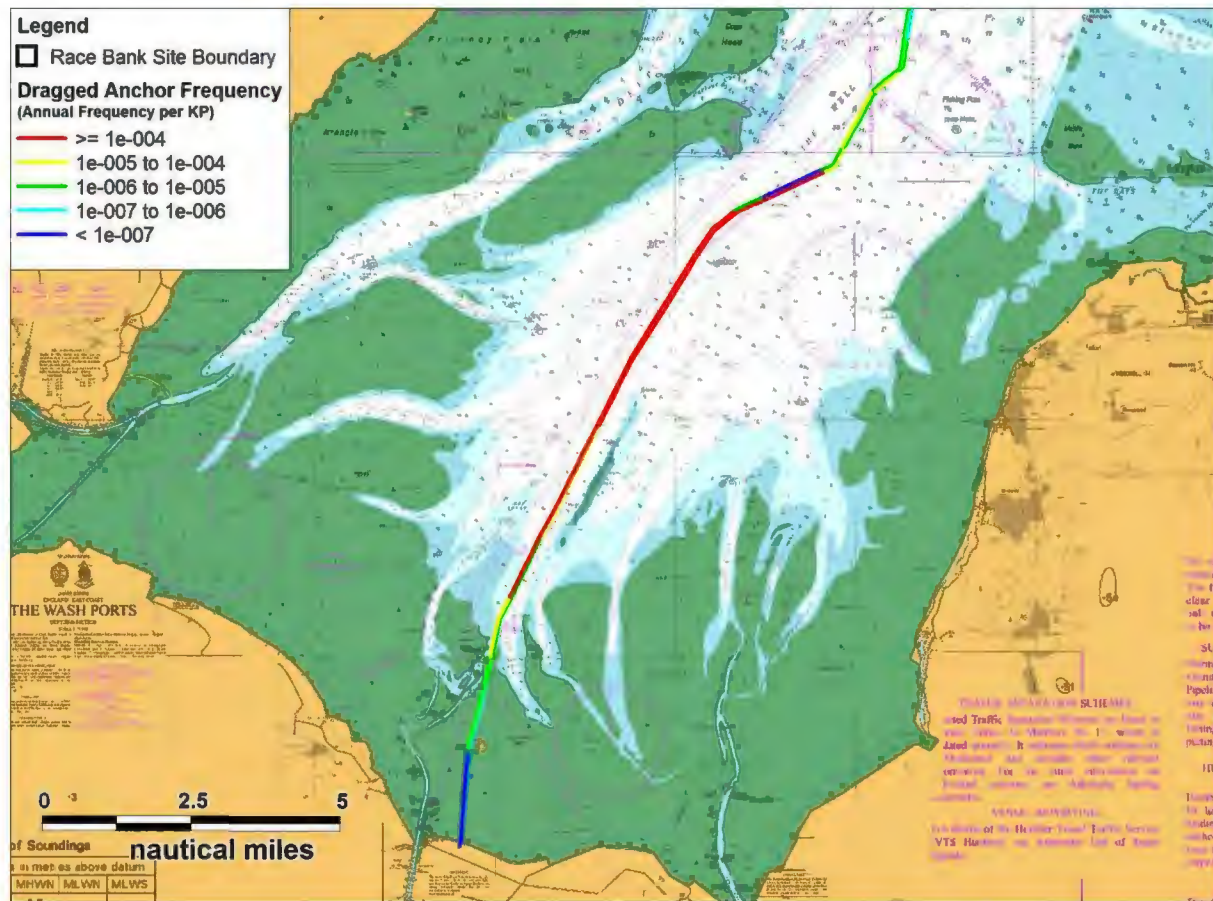


Figure 8.3 Annual Anchoring Dragging Frequency per KP (based on 2013 AIS data) – The Wash

The distribution of anchor dragging frequency by size is presented in Figure 8.4. It should be noted that a logarithmic scale has been used as the vessels with a DWT of 1,500 to 5,000 represent 96% of the risk.

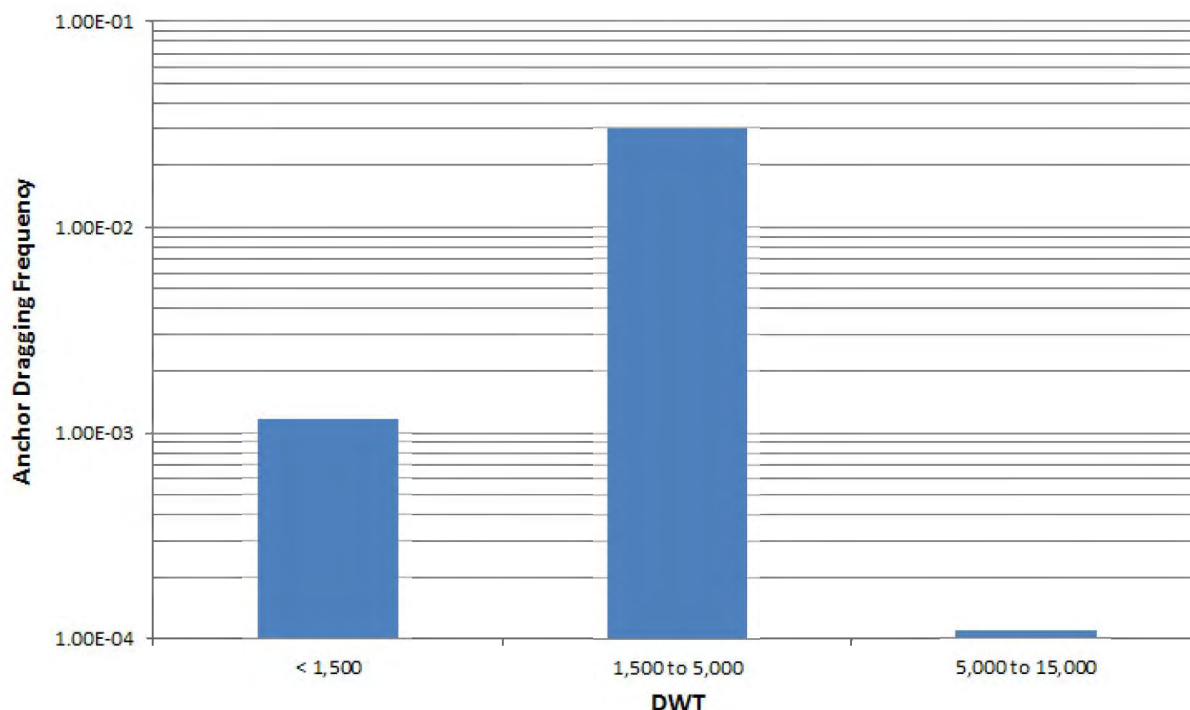


Figure 8.4 Annual Anchor Dragging Frequency Size Distribution (based on 2013 AIS data)

8.2.4 Cable Burial

The burial of subsea cables is the main method of protecting them from dragged anchor incidents. Burying the cable will reduce the number of incidents where the dragging anchor makes contact with the cable. The level of protection will depend on the depth of burial and penetration depths of anchors.

The anchor penetration depths used in the model were researched using a variety of sources. These are presented in Table 8.1 for 15 vessel size categories in an ‘average’ seabed type (e.g. medium dense sand).

Table 8.1 Anchor Penetration Depths

DWT	Anchor Penetration Depths (m)		
	Small	Medium	Large
0 - 1,500	0.8	0.8	0.9
1,500 - 5,000	0.9	1	1.1
5,00 - 15,000	1.2	1.3	1.4

DWT	Anchor Penetration Depths (m)		
	Small	Medium	Large
15,000 - 40,000	1.5	1.6	1.7
40,000 – 60,000	1.8	1.9	2

The penetration depths were then varied according to seabed type using a Seabed Factor, which is applied to increase the penetration depth for softer ground and reduce the penetration depths for harder ground. The seabed information was based on Cone Penetration Test (CPT) results for the export cable route. More details on the seabed type are provided in Section 9.4.

The CollRisk Anchor Dragging model was rerun for 1m, 2m and 3m to assess optimal burial depth. The total annual frequency (and return period) of cable contact due to anchor dragging, according to burial depth, is presented in Table 8.2.

Table 8.2 Annual Anchor Dragging Contact Frequency by Depth (based on 2013 AIS data)

Burial Depth (m)	Eastern Export Cable		Western Export Cable		Total	
	Annual Contact Frequency	Return Period (Years)	Annual Contact Frequency	Return Period (Years)	Annual Contact Frequency	Return Period (Years)
0	4.92E-03	203	2.62E-02	38	3.11E-02	32
1	3.14E-03	318	1.52E-02	66	1.84E-02	54
2	1.01E-03	988	3.61E-03	277	4.62E-03	216
3	3.30E-04	3,027	1.53E-03	654	1.86E-03	538

Table 8.3 presents the annual anchor dragging frequency and return period broken down by the different cable route zones and burial depth.

Table 8.3 Annual Anchor Dragging Contact Frequency by Zone (based on 2013 AIS data)

Burial Depth (m)	Annual Anchor Dragging Contact Frequency (Return Period)				
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
0	1.23E-04 (8,106)	2.99E-02 (33)	1.03E-03 (968)	1.27E-06 (790,293)	1.37E-05 (73,231)
1	6.82E-05 (14,652)	1.79E-02 (56)	4.08E-04 (2,450)	5.68E-07 (1,762,021)	8.20E-06 (121,926)
2	1.38E-05 (72,583)	4.46E-03 (224)	1.45E-04 (6,880)	1.25E-07 (7,990,769)	1.60E-06 (623,138)
3	6.74E-06 (148,282)	1.79E-03 (557)	5.69E-05 (17,565)	6.48E-08 (15,430,241)	7.67E-07 (1,304,239)

8.2.5 Cable Route Sensitivity Analysis

In order to assess the effect of altering the cable route, a sensitivity analysis was run assuming the export cables were positioned at the eastern and western extremes of the survey corridor. A zoomed in plot within the Wash of the extreme case routes relative to the base case is presented in Figure 8.5 to illustrate the difference.

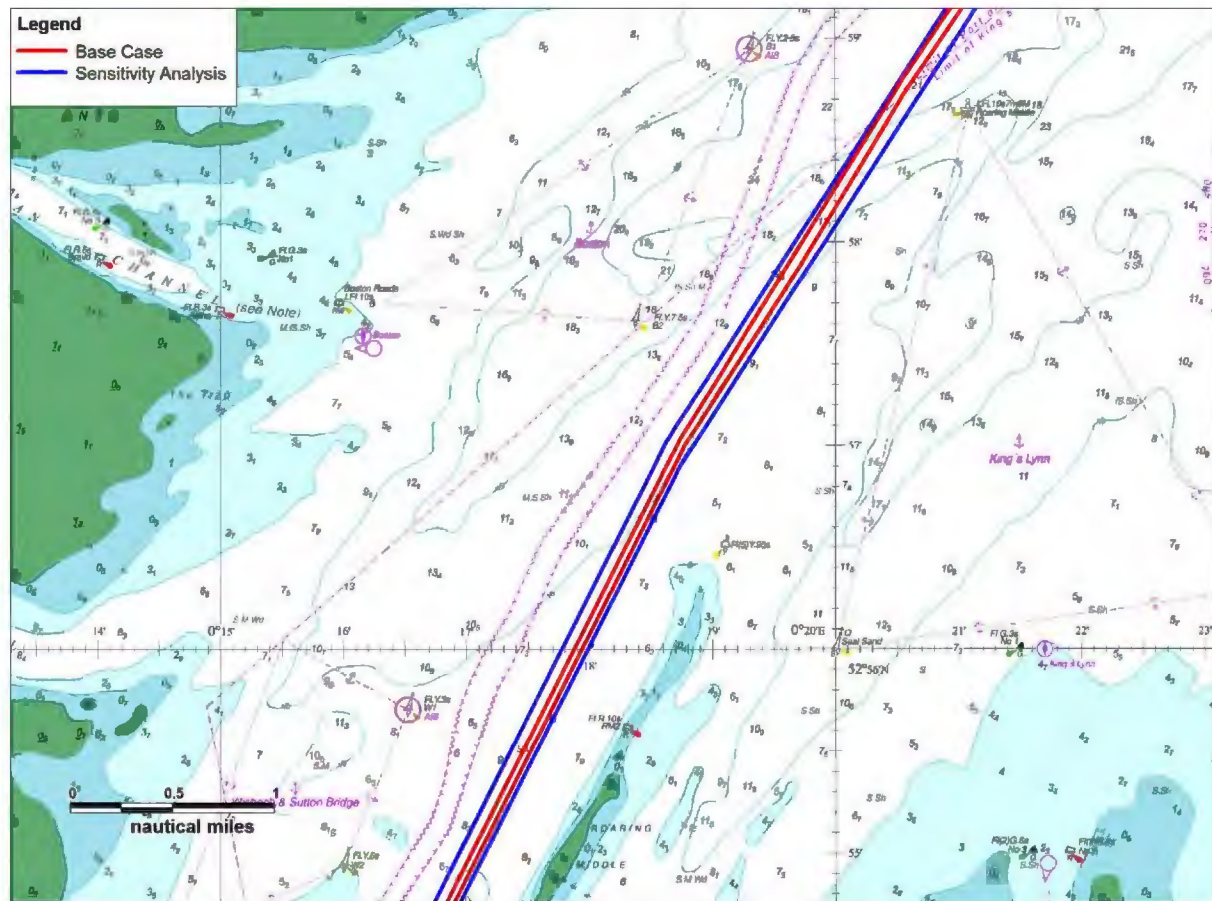


Figure 8.5 Sensitivity Analysis Routes

The anchor dragging model was rerun using the sensitivity analysis cable routes assuming a 0m burial depth. The results of the sensitivity analysis are presented in Table 8.4.

Table 8.4 Anchor Dragging Sensitivity Analysis Results (based on 2013 AIS data)

	Eastern Route		Western Route		Total	
	Annual Contact Frequency	Return Period (Years)	Annual Contact Frequency	Return Period (Years)	Annual Contact Frequency	Return Period (Years)
Base Case	4.92E-03	203	2.62E-02	38	3.11E-02	32
Sensitivity Analysis	5.14E-03	194	2.77E-02	36	3.28E-02	30

It was estimated that moving the export cable to the extreme of the survey corridor would result in an increase to the anchor dragging risk of approximately 6%. Shifting the routes to the extremes of the corridor moves the eastern route closer to the King's Lynn anchorage, and the western route closer to the Boston and Wisbech/Sutton Bridge anchorages which was the

main cause of the increase of risk. The results of the sensitivity analysis are compared per KP with the base case results in Figure 8.6 and Figure 8.7.

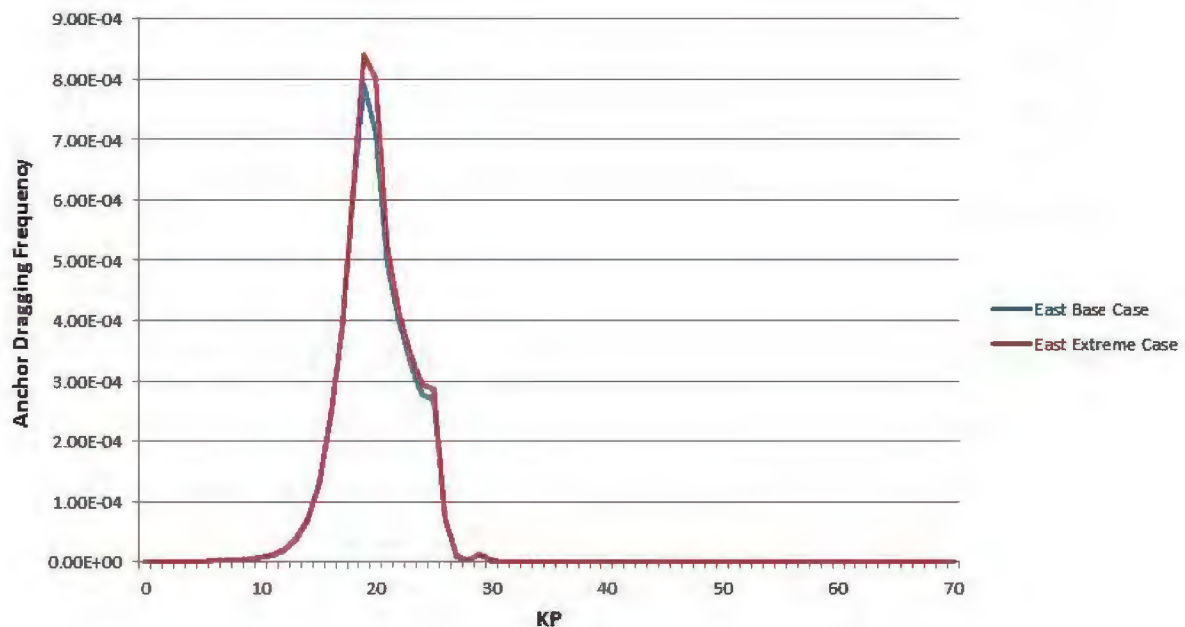


Figure 8.6 East Route Sensitivity Results by KP (based on 2013 AIS data)

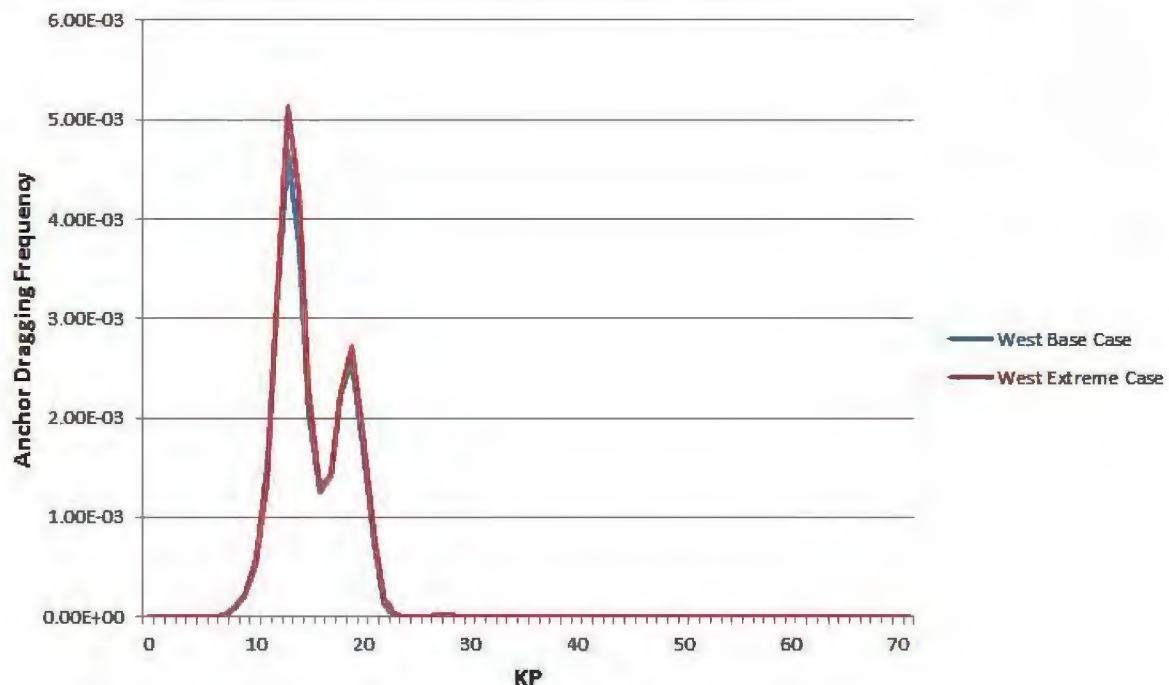


Figure 8.7 West Route Sensitivity Results by KP (based on 2013 AIS data)

It is noted no KP of cable changed frequency rankings in the sensitivity analysis when compared to the base case.

8.2.6 Risk Ranking

For zones 4 and 5 it was seen that the frequency of anchor dragging was negligible, i.e. less than 1 occurrence per 10,000 years.

For zone 1 the frequency was extremely unlikely for the unburied case, reducing to negligible for burial depths of 1m or greater. The frequency for zone 3 was extremely unlikely, reducing to negligible at a burial depth of 3m.

Zone 2 had the highest frequency of anchor dragging. The frequency for this zone was remote for all burial depths. However it should be noted that burying the cable to 3m reduces the frequency of anchor dragging by approximately 95% compared to the unburied case.

The results of the sensitivity analysis showed that moving the cable routes to the extremes of the corridor did not alter the frequency rankings in any of the zones.

The consequences of vessels dragging anchor over the cable route were discussed at the Hazard Workshop. These were considered to be minor for the risk to people and serious for the risk to business.

The risk from anchor dragging plays a key role in the assessment of recommended burial depths for the cables. The results of the anchor dragging risk assessment were therefore used to inform the burial assessment presented in Section 9.

8.3 *Emergency Anchoring Risk Assessment*

8.3.1 Introduction

This section investigates the potential risk to the cable from vessels anchoring in an emergency.

Anatec's Emergency Anchoring model estimates the probability that a vessel sailing over a cable route suffers engine failure and subsequently drops anchor onto the cable. Calculations are performed within a Geographical Information System (GIS) with relevant shipping and operational data (e.g. vessel durations, water depth, distance to shore) as input.

8.3.2 Methodology

The Emergency Anchoring model combines the durations of vessels travelling near the cable route with the probability that a vessel suffers engine failure and the probability that the vessel drops anchor in an emergency (based on water depth and distance from the shore) to calculate the frequency of anchor drop due to emergency anchoring.

An overview of the emergency anchoring methodology, inputs and outputs is presented in Figure 8.8.

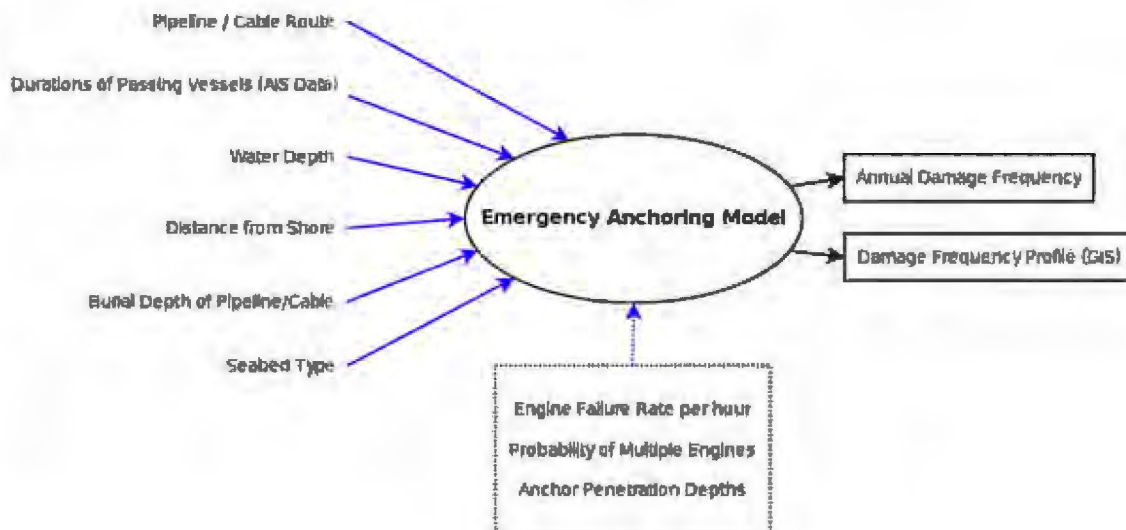


Figure 8.8 Emergency Anchoring Methodology

A full description of the emergency anchoring methodology is provided in Appendix B (Ref v).

8.3.3 Results

To determine the frequency of anchoring onto the cable route in an emergency, the Emergency Anchoring model was run. Calculations were carried out assuming that the cable is surface-laid with no burial/mitigation. Further analysis was then carried out to assess the impact of cable burial for the export cable.

The total emergency anchoring frequency for the east and west export cables was calculated to be 2.75×10^{-3} , or one incident every 364 years.

Figure 8.9 presents the annual emergency anchoring frequency within 100m of the east and west export cable routes presented per KP.

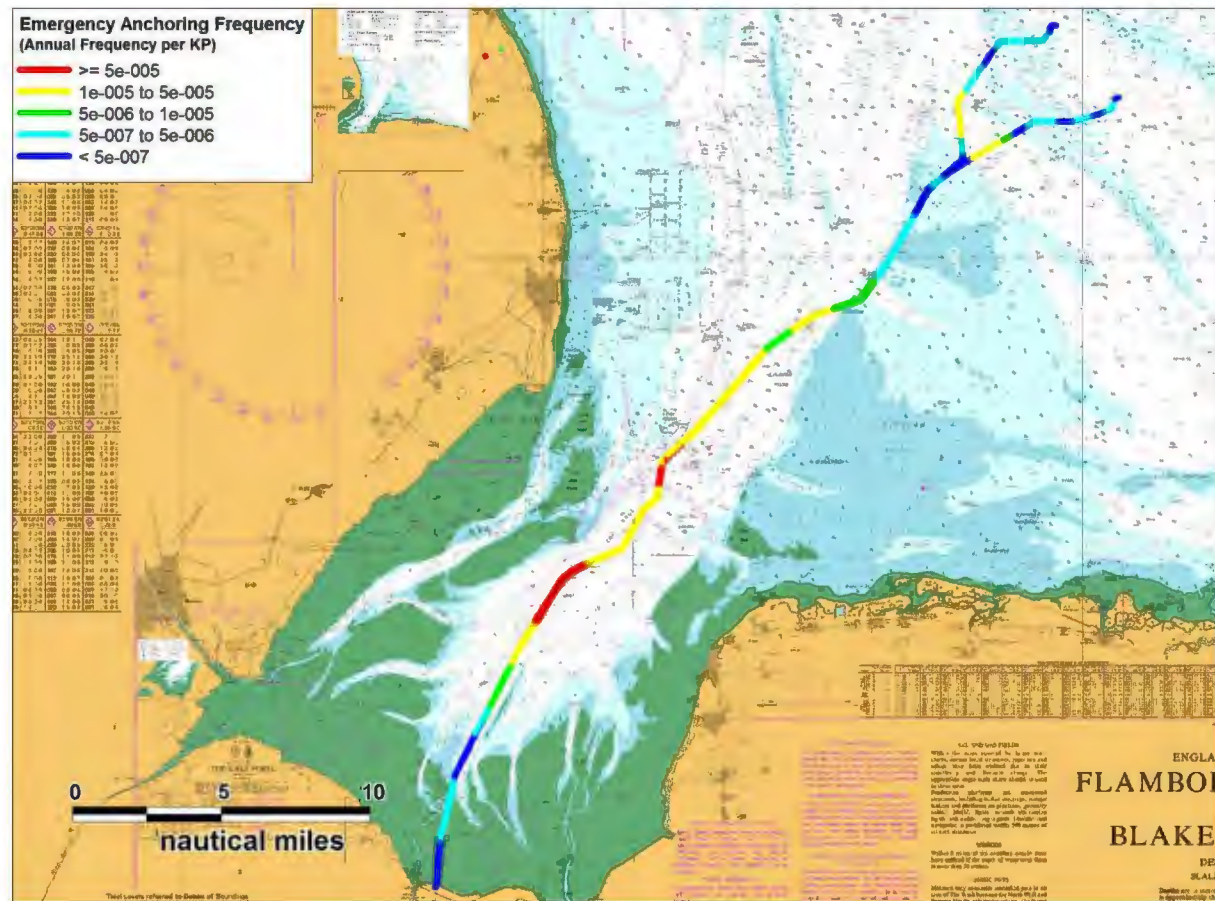


Figure 8.9 Annual Emergency Anchoring Frequency per KP (based on 2013 AIS data)

Detailed plots of the results are presented in Figure 8.10 and Figure 8.11.

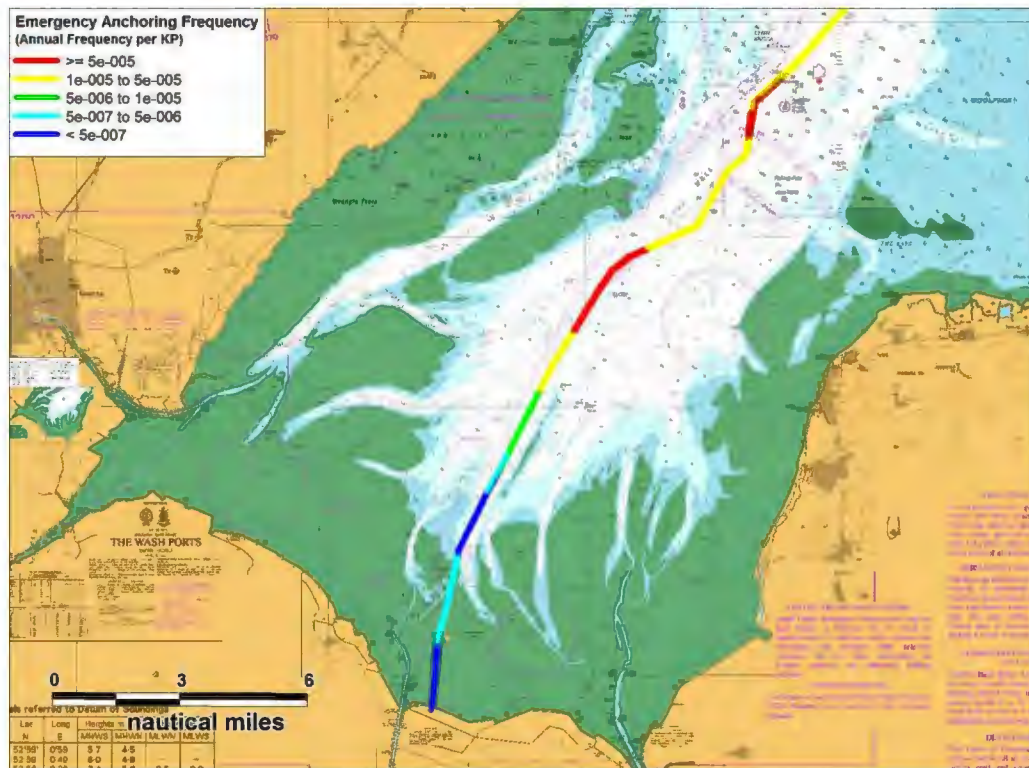


Figure 8.10 Annual Emergency Anchoring Frequency per KP (based on 2013 AIS data) - within the Wash

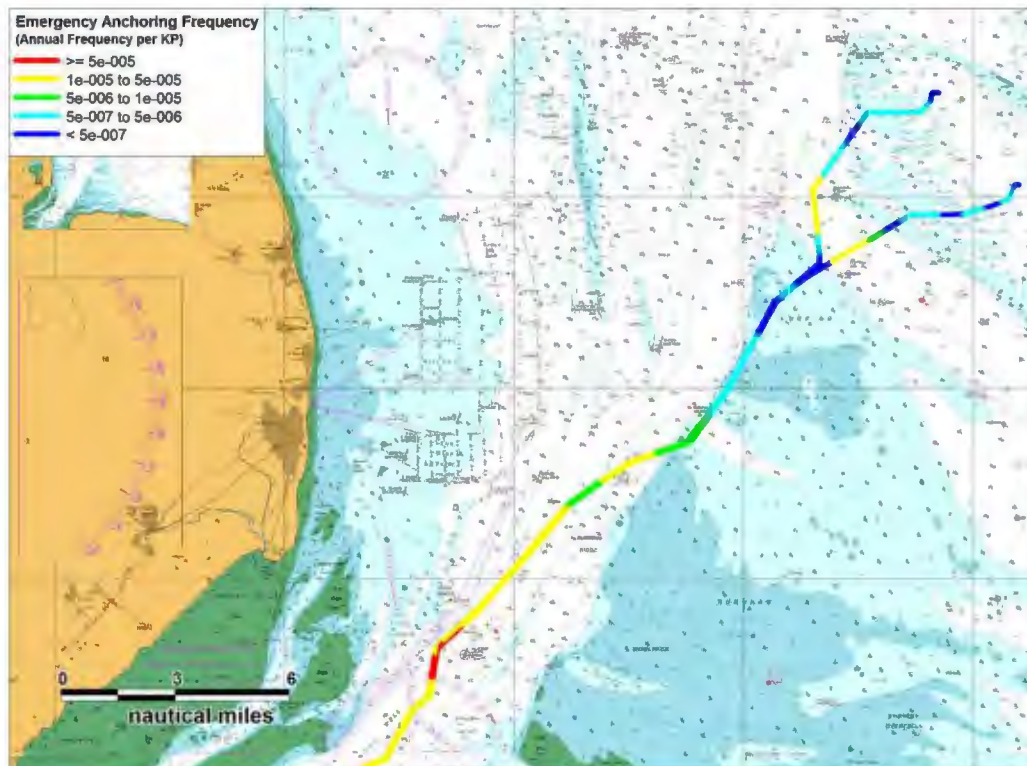


Figure 8.11 Annual Emergency Anchoring Frequency per KP (based on 2013 AIS data) - Offshore

Figure 8.12 presents the type break down of the annual emergency anchoring risk. Those types which amounted to less than 0.5% individually have been grouped into the “Misc” category for clarity. These grouped categories were: Military, Dredging, Tug, Oil & Gas, Wind Farm and Other.

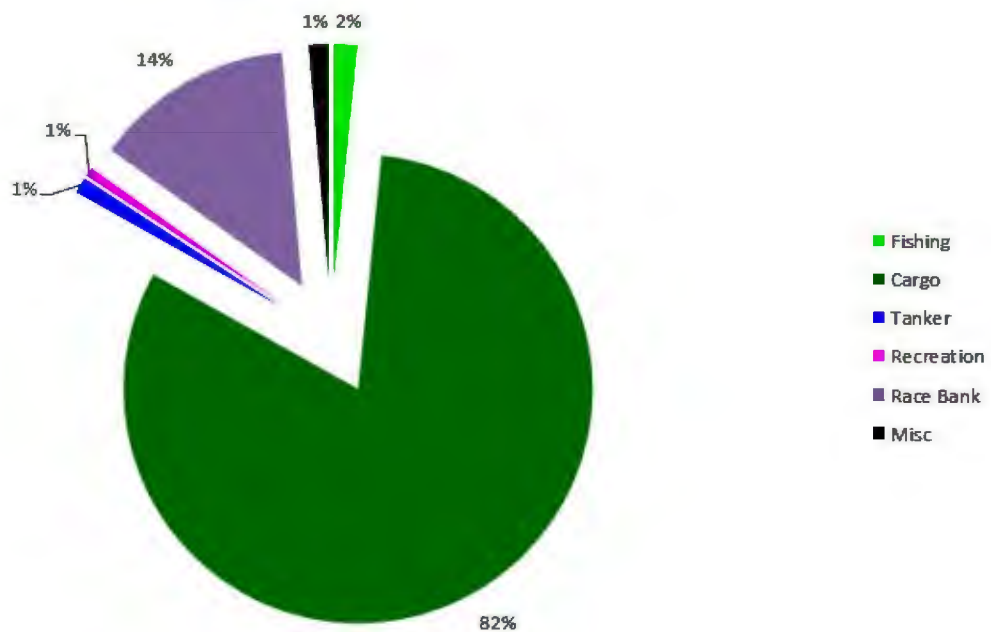


Figure 8.12 Annual Emergency Anchoring Frequency by Vessel Type (based on 2013 AIS data)

The majority of the emergency anchoring risk to the export cable is due to cargo vessels traversing the cable entering the Humber as well as the cargo route south of the Race Bank site through the deeper water corridor.

Figure 8.13 presents the breakdown of emergency anchoring by size.

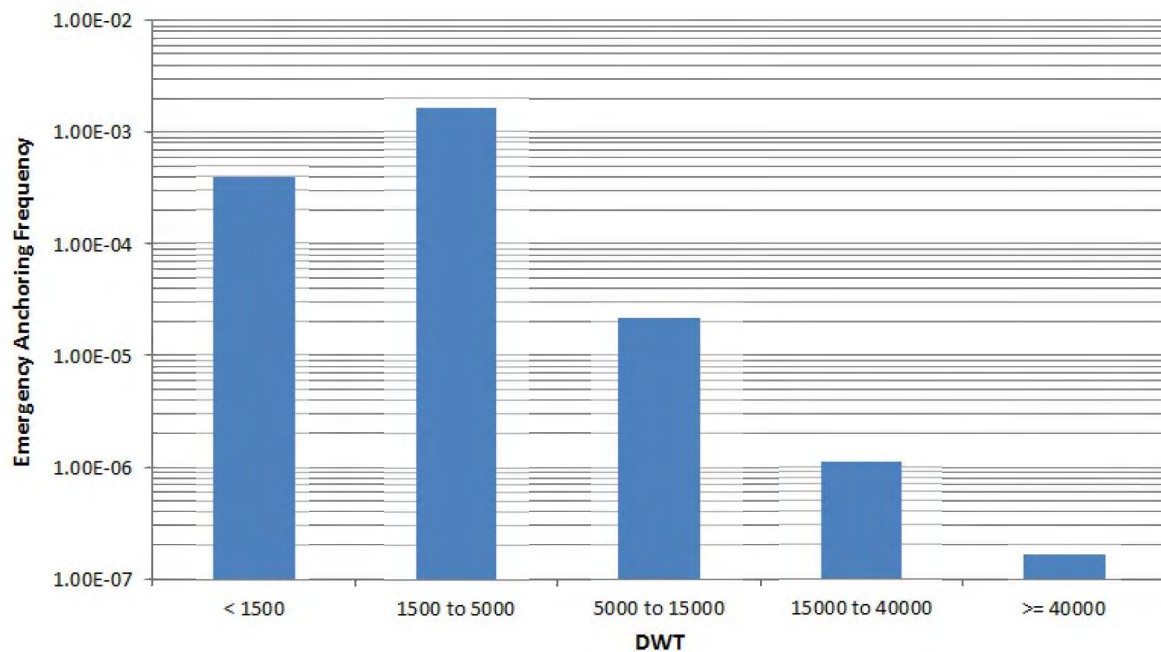


Figure 8.13 Annual Emergency Anchoring Frequency by Vessel Size (based on 2013 AIS data)

A logarithmic scale is used as the vast majority of the frequency (98%) is attributed to vessels with a DWT of less than 5000. Vessels above 15,000 DWT accounted for less than 0.1% of the total frequency.

8.3.4 Cable Burial

The protection provided by burial was investigated for the east and west export cables. The Emergency Anchoring model was rerun assuming depths of 1m, 2m, and 3m. The annual contact frequencies and return periods for the export cables due to emergency anchoring are presented in Table 8.5.

Table 8.5 Annual Emergency Anchoring Frequency with Burial Depth (based on 2013 AIS data)

Burial Depth (m)	Eastern Export Cable		Western Export Cable		Total	
	Annual Contact Frequency	Return Period (Years)	Annual Contact Frequency	Return Period (Years)	Annual Contact Frequency	Return Period (Years)
0	1.34E-03	745	1.41E-03	710	2.75E-03	364
1	6.84E-04	1,462	7.38E-04	1,355	1.42E-03	703
2	2.22E-04	4,504	2.31E-04	4,326	4.53E-04	2,207
3	8.05E-05	12,421	8.46E-05	11,815	1.65E-04	6,055

Table 8.6 presents a breakdown of emergency anchoring risk by cable route zone and burial depth.

Table 8.6 Annual Emergency Anchoring Frequency by Zone, East and West Cables Combined (based on 2013 AIS data)

Burial Depth (m)	Annual Emergency Anchoring Frequency (Return Period)				
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
0	1.07×10^{-5} (93,209)	9.16×10^{-4} (1,092)	1.59×10^{-3} (627)	6.52×10^{-5} (15,339)	1.64×10^{-4} (6,096)
1	5.82×10^{-6} (171,795)	6.69×10^{-4} (1,495)	6.43×10^{-4} (1,556)	2.29×10^{-5} (43,706)	8.15×10^{-5} (12,264)
2	1.18×10^{-6} (850,190)	2.40×10^{-4} (4,174)	1.89×10^{-4} (5,279)	5.75×10^{-6} (173,878)	1.73×10^{-5} (57,917)
3	5.81×10^{-7} (1,719,856)	6.87×10^{-5} (14,566)	8.41×10^{-5} (11,893)	3.15×10^{-6} (317,537)	8.68×10^{-6} (115,150)

8.3.5 Cable Route Sensitivity Analysis

In order to assess the effect of altering the export cable routes, the emergency anchoring model was run assuming that the cables were laid at the extremes of the survey corridor. The resultant grids used as input are presented relative to the base case grids in Figure 8.14. The plot is zoomed in for clarity to illustrate the difference.

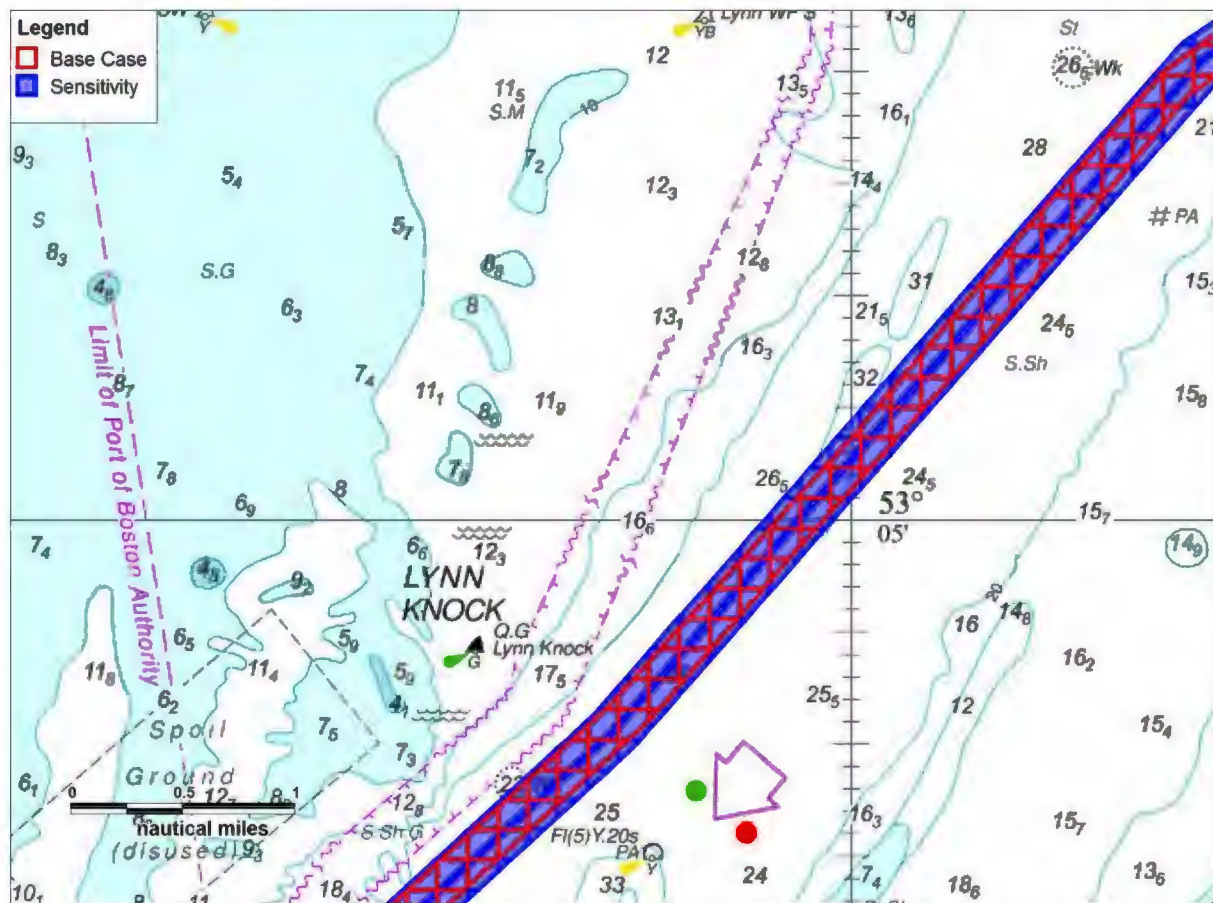


Figure 8.14 Sensitivity Analysis Emergency Anchoring Input Grid

The results of the sensitivity analysis are presented in Table 8.7.

Table 8.7 Emergency Anchoring Cable Route Sensitivity Analysis Results (based on 2013 data)

	East Cable (Rtn Prd in Yrs)	West Cable (Rtn Prd in Yrs)	Total (Rtn Prd in Yrs)
Base Case	1.34×10^{-3} (745)	1.41×10^{-3} (710)	2.75×10^{-3} (364)
Sensitivity Analysis	1.45×10^{-3} (690)	1.29×10^{-3} (776)	2.74×10^{-3} (365)

It was observed that moving the cables to the extremes of the corridor did not have a significant impact on the emergency anchoring risk, as the 100m buffer for each cable would move accordingly. The results are presented by KP for the east and west cable routes in Figure 8.15.

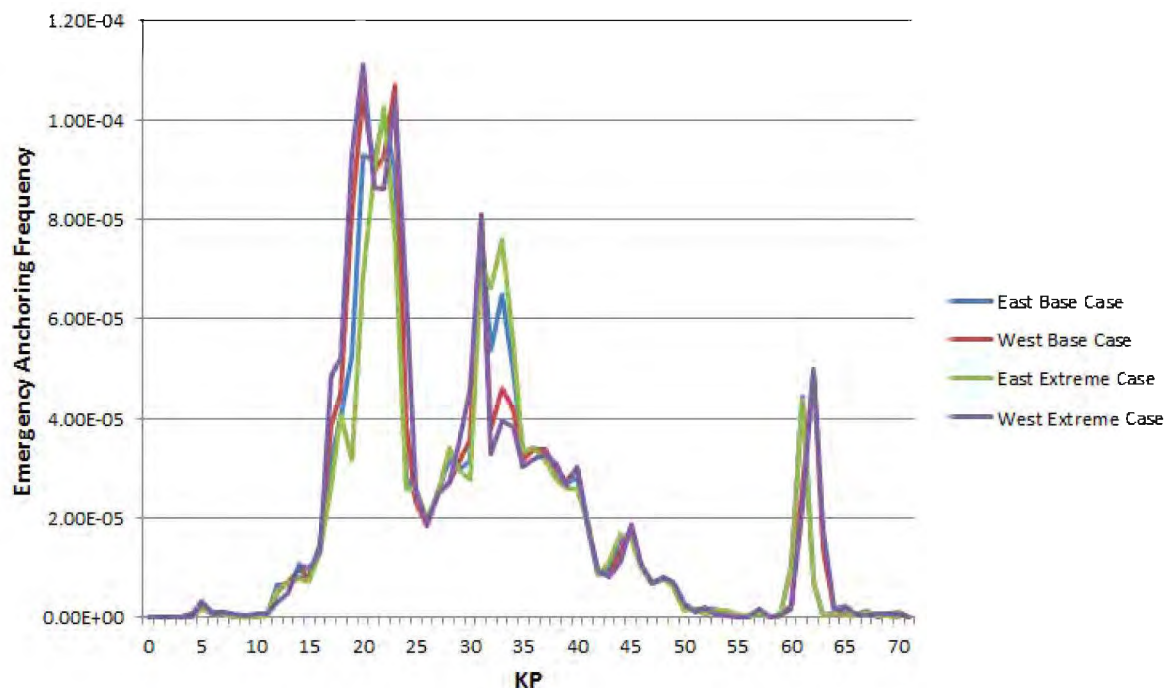


Figure 8.15 Emergency Anchoring Sensitivity Analysis Results by KP (based on 2013 AIS data)

It is seen that the results of the cable route sensitivity analysis by KP did not differ significantly from the base case.

8.3.6 Wisbech Channel Sensitivity Analysis

As discussed in Section 5.3, the location of the Wisbech Channel was altered in May 2015, which resulted in significant changes to the routing of vessel traffic within the Wash. The additional AIS data from 2015 (four months, factored to an annual value) presented in Section 5.3 was used as input to the emergency anchoring model to assess the effect of the new channel on the emergency anchoring risk in the unburied case. All sections of cables within the Wash port limits (KP1 to KP35) were considered.

It was observed that there was a significant rise in vessels associated with the Race Bank wind farm in the 2015 AIS data compared to the 2013 data. The Race Bank vessels were therefore excluded from the following 2015 analysis to allow fair comparison.

The results showed a significant rise in emergency anchoring risk associated with the updated Wisbech Channel boundaries. The emergency anchoring risk profiles from KP1 to KP35 of the updated emergency anchoring results and base case results are presented in Figure 8.16.

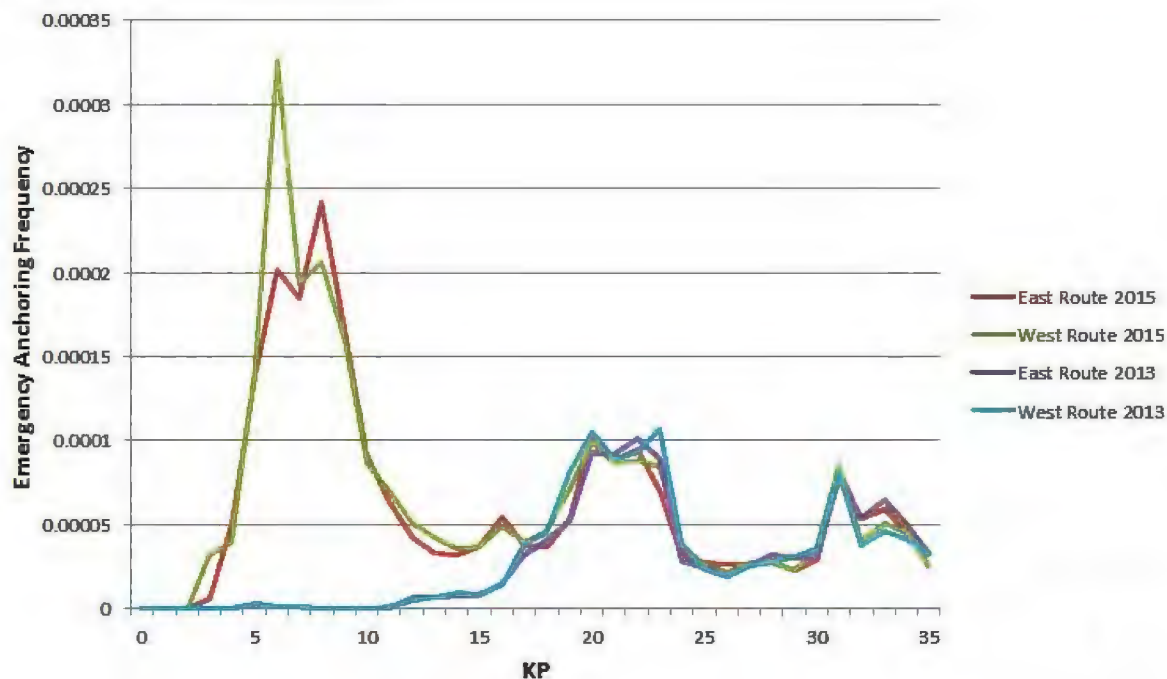


Figure 8.16 Emergency Anchoring – 2013 and 2015 Comparison

The 2013 and 2015 results aligned at approximately KP17. The remainder of the analysis in this section therefore assumes the emergency anchoring results are based on the following:

- KP1 to KP17: 2015 analysis results
- KP17 to KP71: 2013 analysis results

The results of the analysis are summarised in Table 8.8.

Table 8.8 Wisbech Channel Emergency Anchoring Analysis Summary (2013 and 2015 data)

	East Cable (Rtn Prd in Yrs)	West Cable (Rtn Prd in Yrs)	Total (Rtn Prd in Yrs)
2015/2013 Analysis	2.64×10^{-3} (379)	2.83×10^{-3} (354)	5.47×10^{-3} (183)
2013 Only Analysis	1.34×10^{-3} (745)	1.41×10^{-3} (710)	2.75×10^{-3} (364)

The total emergency anchoring frequency associated with the export cable rose from 2.75×10^{-3} (2013 data) to 5.47×10^{-3} (2015 data for KP1 to KP 17, 2013 thereafter). This corresponds to return periods of 183 years for the 2013/2015 analysis and 364 years in the 2013 only data analysis. The significant change is due to the increase of durations over the section of cable intersected by the vessels using the new channel.

The sections of cable in proximity to the altered Wisbech channel account for the highest emergency anchoring frequency. It is noted that there were other areas along the cable route where the traffic durations were higher than in the new channel, however the shallow water depth, proximity to danger and low twin engine probability of the cargo vessels using the channel contributed to the affected area becoming the most significant area of emergency anchoring risk when the 2015 data was taken into account.

The estimated emergency anchoring frequency by burial depth, based on the updated AIS data is presented in Table 8.9, and broken down by zone in Table 8.10.

Table 8.9 Annual Emergency Anchoring Frequency with Burial Depth – 2013 and 2015 Analysis

Burial Depth (m)	Eastern Export Cable		Western Export Cable		Total	
	Annual Contact Frequency	Return Period (Years)	Annual Contact Frequency	Return Period (Years)	Annual Contact Frequency	Return Period (Years)
0	2.64E-03	379	2.83E-03	354	5.47E-03	183
1	1.33E-03	753	1.42E-03	704	2.75E-03	364
2	3.58E-04	2,794	3.77E-04	2,654	7.35E-04	1,361
3	1.49E-04	6,718	1.59E-04	6,309	3.07E-04	3,253

Table 8.10 Annual Emergency Anchoring Frequency by Zone – 2013 and 2015 Analysis

Burial Depth (m)	Annual Emergency Anchoring Frequency (Return Period)				
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
0	1.76×10^{-3} (567)	1.92×10^{-3} (522)	1.59×10^{-3} (627)	6.52×10^{-5} (15,339)	1.64×10^{-4} (6,096)
1	8.49×10^{-4} (1,177)	1.18×10^{-3} (847)	6.43×10^{-4} (1,556)	2.29×10^{-5} (43,706)	8.15×10^{-5} (12,264)
2	1.80×10^{-4} (5,543)	3.56×10^{-4} (2,812)	1.89×10^{-4} (5,279)	5.75×10^{-6} (173,878)	1.73×10^{-5} (57,917)
3	9.16×10^{-5} (10,916)	1.23×10^{-4} (8,120)	8.41×10^{-5} (11,893)	3.15×10^{-6} (317,537)	8.68×10^{-6} (115,150)

In order to account for the updated channel, the results of the emergency anchoring assessment using the 2015 data will be used for KP1 to KP17 in the following risk rankings and in the Burial Assessment in Section 9.

8.3.7 Risk Ranking

For zone 4 it was seen that the frequency of emergency anchoring was negligible, i.e. less than 1 occurrence per 10,000 years. The frequency within Zone 5 was extremely unlikely when unburied, reducing to negligible at 1m.

For zones 1, and 3, the frequency was extremely unlikely for the unburied or 1m and 2m burial depth cases, reducing to negligible at 3m burial depth. Zone 2 fell into the extremely unlikely band at all burial depths.

It is noted that these results take the 2015 AIS data into account.

The consequences of vessels anchoring in an emergency over the cable route were discussed at the Hazard Workshop. These were considered to be minor for the risk to people and serious for the risk to business.

The results of the emergency anchoring risk assessment were used to inform the burial assessment presented in Section 9.

8.4 Inadvertent Anchoring

8.4.1 Introduction

During the consultation process, the Port Authorities highlighted another potential risk to the cable from anchoring, whereby a vessel inadvertently chooses to anchor outside the designated anchorage areas. The cause of this risk is human error, due to the vessel's crew being unaware of the existence or location of the cable, most likely due to the vessel not carrying up-to-date charts.

Due to the random nature of such an event, which is solely dependent on human error, it is not practical to quantitatively assess the risk to the cables from inadvertent anchoring. This section therefore presents a qualitative discussion of the risk of inadvertent anchoring, using AIS data to pinpoint any occurrences within the Wash port limits. The Lincs export cable was used as a reference point for vessels anchoring outside the anchorages, as this cable was installed in 2012 and appears on the navigational charts. Vessels should therefore avoid anchoring close to this cable.

8.4.2 Cases of Inadvertent Anchoring – AIS Data

8.4.2.1 6 Months, 2013

The vessels anchoring near the Race Bank cables were identified using the 6 months AIS data in order to be used as input in the anchor dragging risk assessment. This included all anchored

vessels, within and outside the anchorage areas. Figure 8.17 presents a detailed view of vessels determined to be anchoring within the Wash port limits.

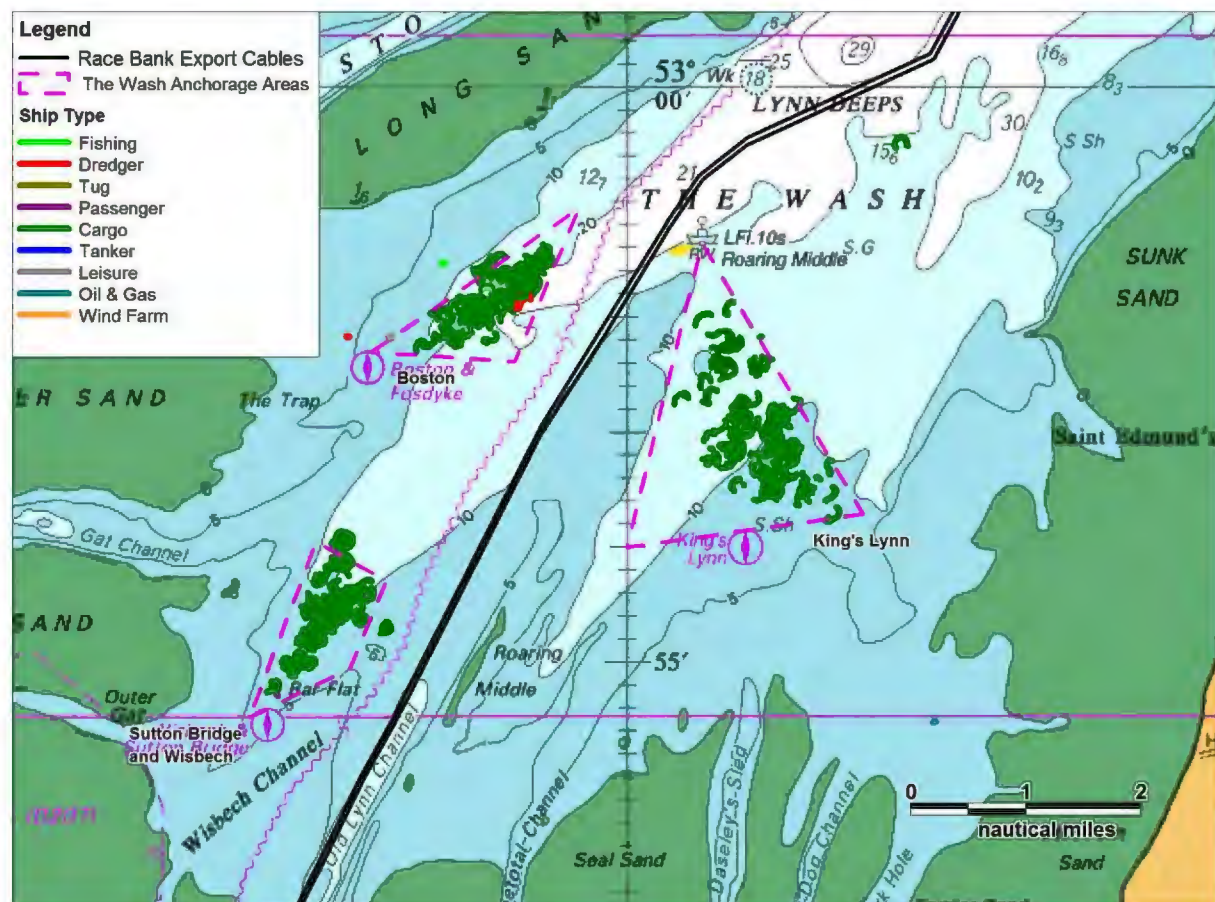


Figure 8.17 Anchoring within the Wash Anchorages (1st July to 31st December 2013)

All vessels anchoring within the anchorages were less than 5,000 DWT, as illustrated in Figure 8.18, which shows the distribution of vessel DWT per anchorage area.

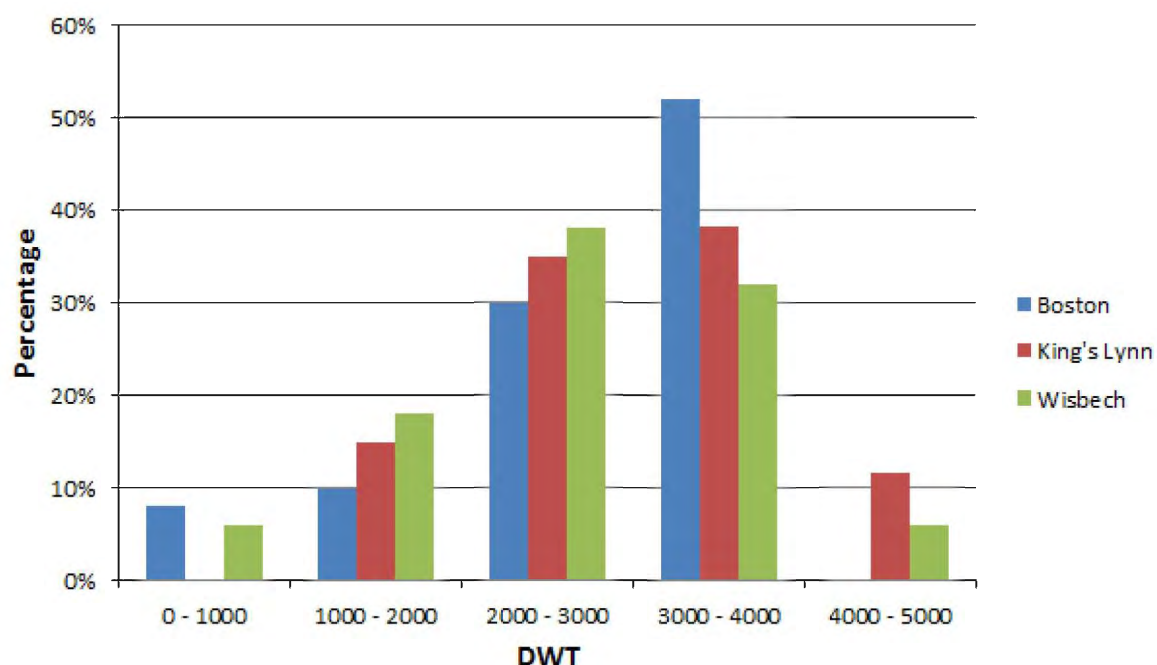


Figure 8.18 Anchored Vessels by Size, The Wash Anchorage Areas

Although the vast majority of anchoring within the wash was within the anchorage zones there are vessels who have anchored outside these limits. Table 8.11 presents the details of vessels anchored outside the anchorage but within the Wash.

Table 8.11 Anchoring Outside Designated Anchorages

Name	Type	DWT	Date	Duration (Hours)	Distance from Anchorage (nm)
Banier	Cargo	3659	29/10/2013	20	1.9
Catzero	Leisure	N/A	01/07/2013	13	<0.1
Douwent	Cargo	1800	28/07/2013	18	<0.1
Elisabeth-S	Cargo	2665	02/11/2013	37	<0.1
Hathor	Cargo	3850	04/11/2013	55	0.1
Humber Guardian	Other	N/A	16/10/2013	15	1.9
Mary Angus	Dredger	582	19/07/2013	21	0.3
Najade	Cargo	3652	02/12/2013	5	<0.1

Name	Type	DWT	Date	Duration (Hours)	Distance from Anchorage (nm)
Onego	Cargo	2090	16/07/2013	44	0.2
Samuel James	Fishing	N/A	17/11/2013	8	0.3

It can be seen that the majority of these vessels anchored very close to the anchorage areas, with the exception of the *Banier*, which anchored approximately 2nm NE of the King's Lynn anchorage and 1.3nm from the charted Lincs export cable, and the Humber guardian, which anchored 1.9nm to the SE of the King's Lynn anchorage. The *Onego* was seen to anchor east of the Sutton Bridge/Wisbech anchorage, positioning it approximately 0.1nm from the Lincs cable.

It is noted that these vessels were taken into consideration in the anchor dragging risk assessment.

8.4.2.2 2014 Incidents

The Wash Port Authorities identified several incidents of vessels anchoring outside the Wash anchorage areas and close to the charted export cable associated with the Lincs Offshore Wind Farm during 2014. These are presented in the following figures.

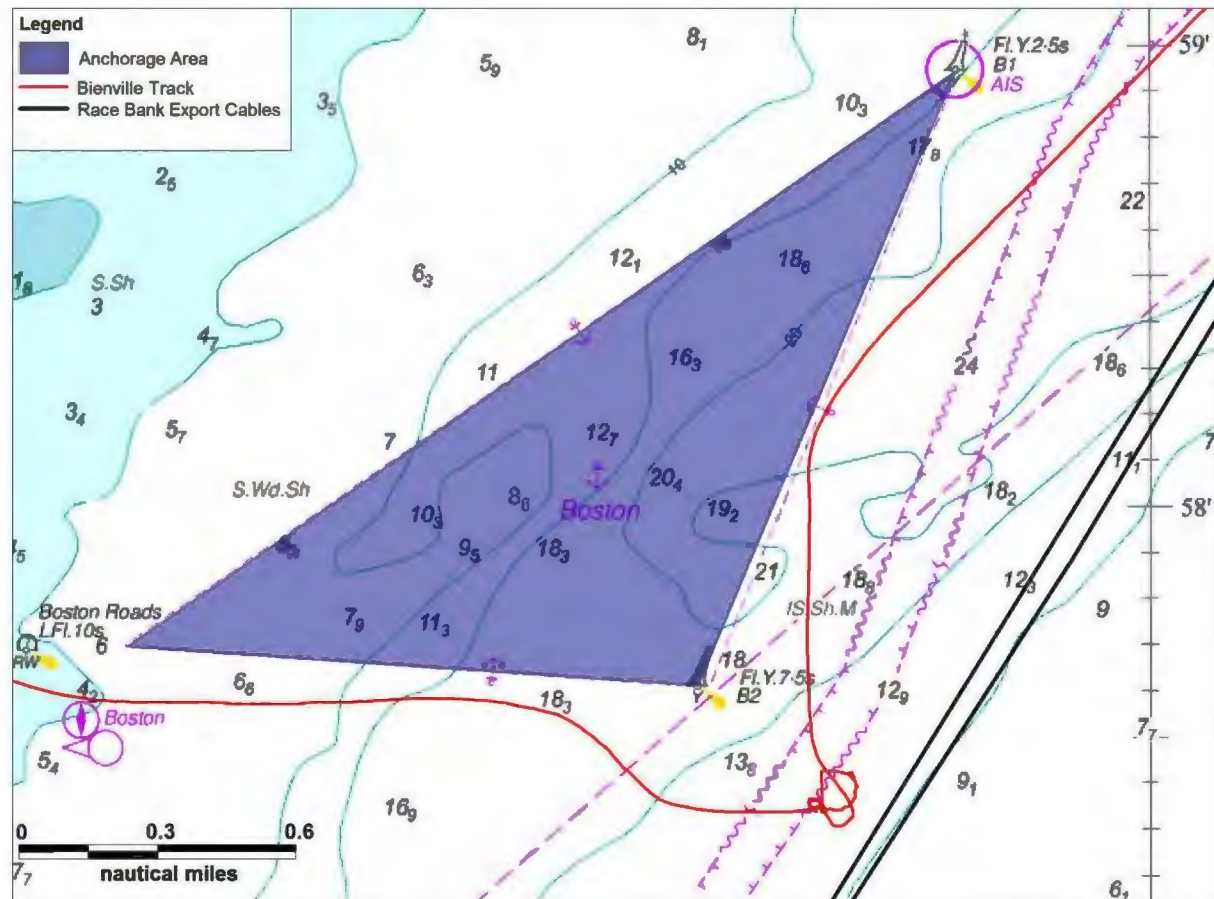


Figure 8.19 Bienville Cargo Vessel Cable Corridor Anchoring Incident

The *Bienville*, a 3,041 DWT cargo vessel, anchored over the Lincs export cable corridor on the 24th of April 2014. The vessel did not have any orders following the previous operation and anchored at the outer end of Freeman Channel. The outward pilot advised the Master to anchor West of the B1 – B2 Anchorage line (shown in east of Figure 8.19). The vessel anchored for a total of 11 hours with four hours spent over the cable corridor.

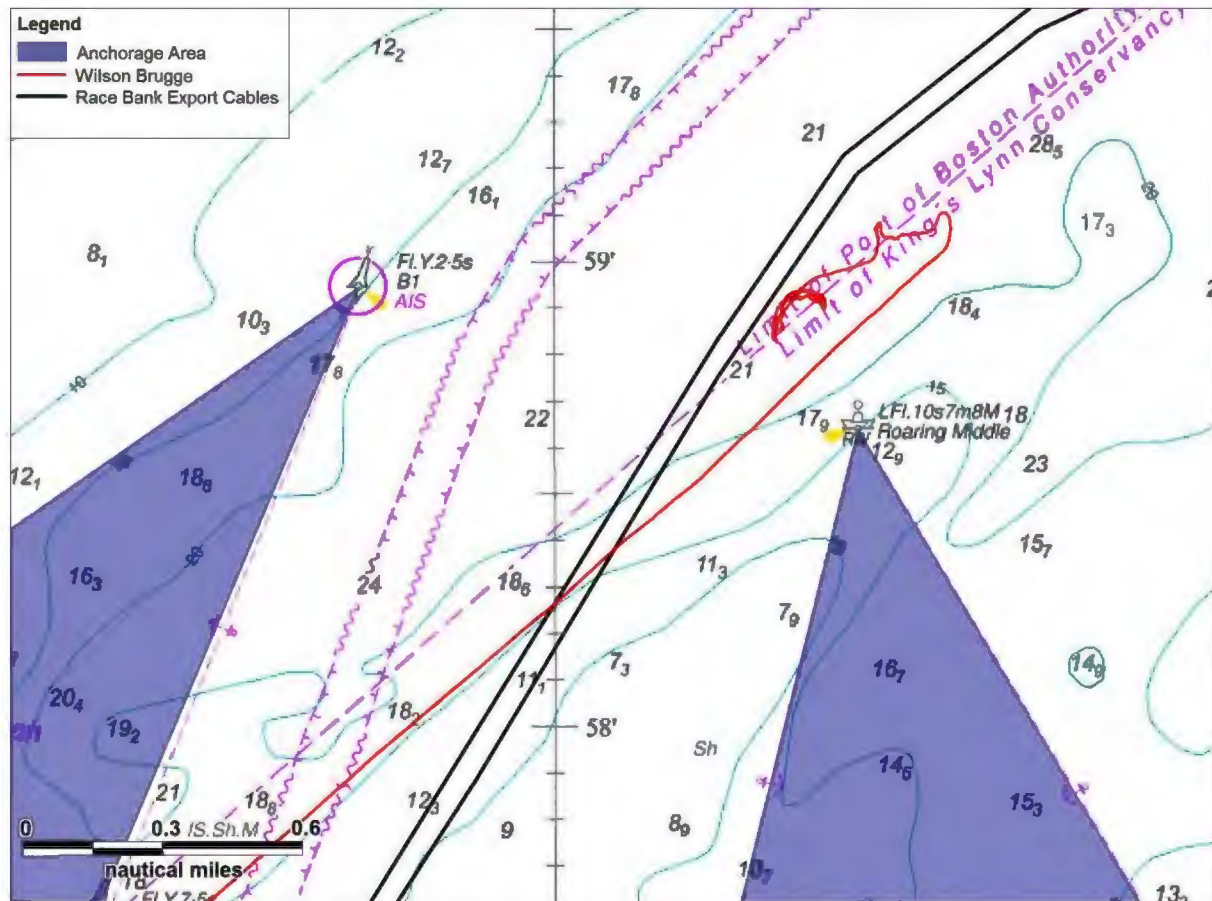


Figure 8.20 Wilson Brugge Cargo Vessel Anchoring Outside Anchorage

The *Wilson Brugge*, a 3,694 DWT cargo vessel, anchored outside the designated anchorages approximately 0.4nm from the charted export cable corridor on the 3rd of June 2014. The vessel was anchored in this location for approximately 18 hours. No more details are available however when the Master was raised and asked why the vessel was not anchored within the anchorage areas the response was “the agent told me to anchor in this position”. This vessel anchored approximately 220m from the proposed location of the Race Bank export cable.

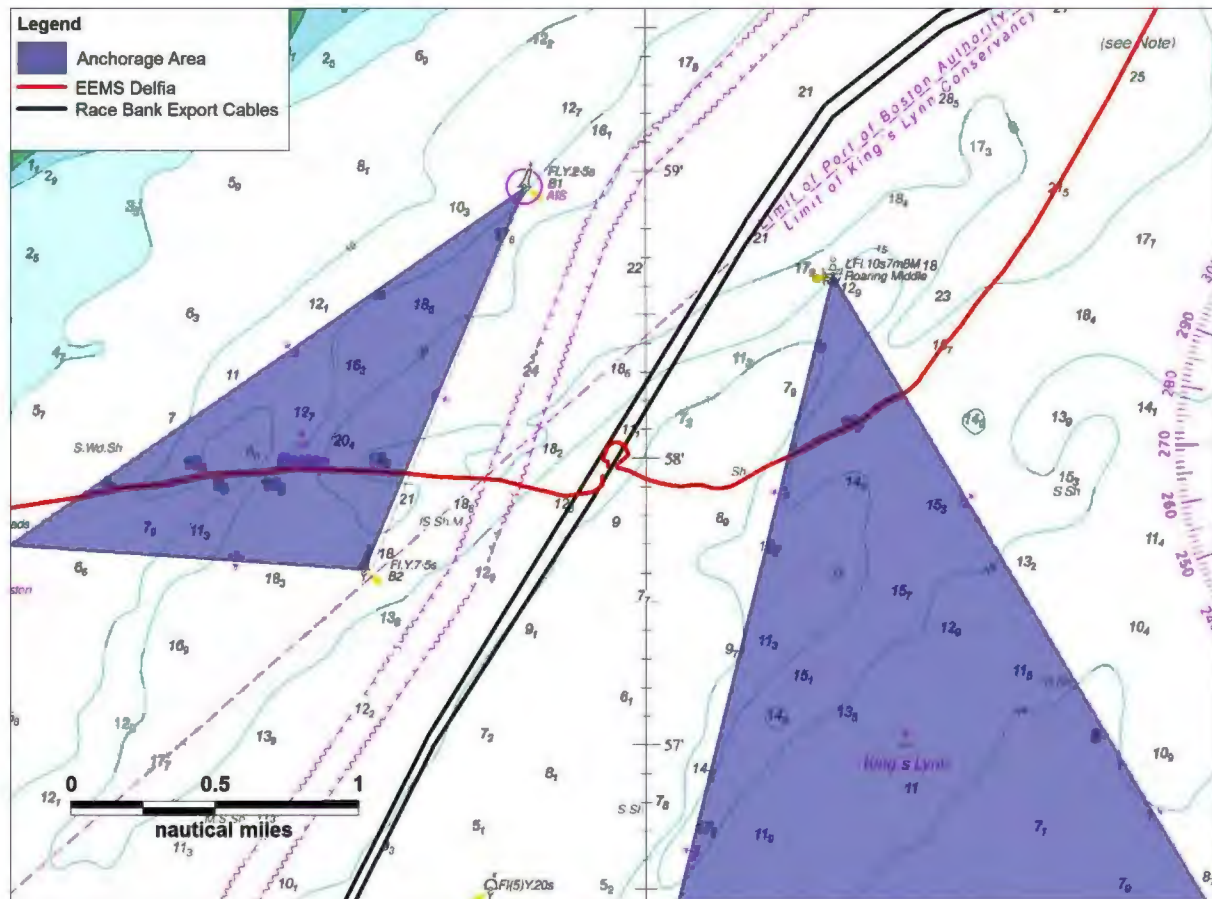


Figure 8.21 EEMS Delfia Cargo Vessel Anchoring Outside Anchorage

A third instance of anchoring was recorded outside the Wash anchorage when the 1,475 DWT cargo vessel *EEMS Delfia* anchored approximately 0.6nm to the west of the King's Lynn anchorage. This vessel was recorded at anchor in this position for approximately 7 hours approximately 0.3nm to the east of the charted cable corridor. No further details are available on this incident. It can be seen that this vessel would have anchored directly over the proposed Race Bank export cable.

It is noted that all vessels identified to be inadvertently anchoring over the cable route were less than 5,000 DWT and, as such, any section of cable identified to be high risk from anchor dragging or emergency anchoring will be buried to a suitable depth to protect against inadvertent anchoring also.

8.4.3 Risk Rankings

For zones 1, 4 and 5 it was considered that the frequency of inadvertent anchoring was negligible, i.e. less than 1 occurrence per 10,000 years.

For zone 2 and the SW section of zone 3, the frequency of a vessel inadvertently anchoring within the Wash was seen to be frequent (i.e. yearly). However it is considered that the

frequency that such an incident occurs directly over the cable route is lower and it was therefore assumed that the frequency that a vessel inadvertently anchors onto the cable route was remote, i.e. one incident every 10 to 100 years.

The consequences of a vessel inadvertently anchoring over the cable route are considered to be similar to the consequences of anchoring dragging or emergency anchoring, i.e. minor for the risk to people and serious for the risk to business.

8.5 Foundering

8.5.1 Introduction

The Foundering model from within Anatec's CollRisk program was run in order to estimate the frequency that a vessel will fail structurally and sink over the cable route. This type of incident has the potential to cause damage to a cable route should the foundering vessel make contact with the cable.

8.5.2 Methodology

Historical accident data was used to determine the probability of different types and sizes of vessels foundering within different weather states. Factors were then assigned to each type and size to weight the results accordingly within the model.

The Foundering model uses as input the durations of vessels by type and size, weather information for the area of the cable route detailing the probability of different weather states, and a grid covering the study area of the cable route.

It is noted that the foundering model only estimates the frequency that a vessel will sink over the cable route. The consequences of such an incident are not taken into account, however it can be assumed that a foundering vessel has the potential to cause notable damage should it make contact with the cable.

8.5.3 Results

The Foundering Model was run using the inputs prepared for the Race Bank Cable Route. Based on the model results, it is estimated that the annual frequency of a vessel foundering over the export cable route is 7.37×10^{-4} , which equates to approximately one incident every 1,357 years.

A general overview of the vessel foundering results is presented in Figure 8.22. It is noted that as with the emergency anchoring results, cropping the grid to the study area of the cable route results in irregular cell areas. The results are therefore presented as frequency over area.

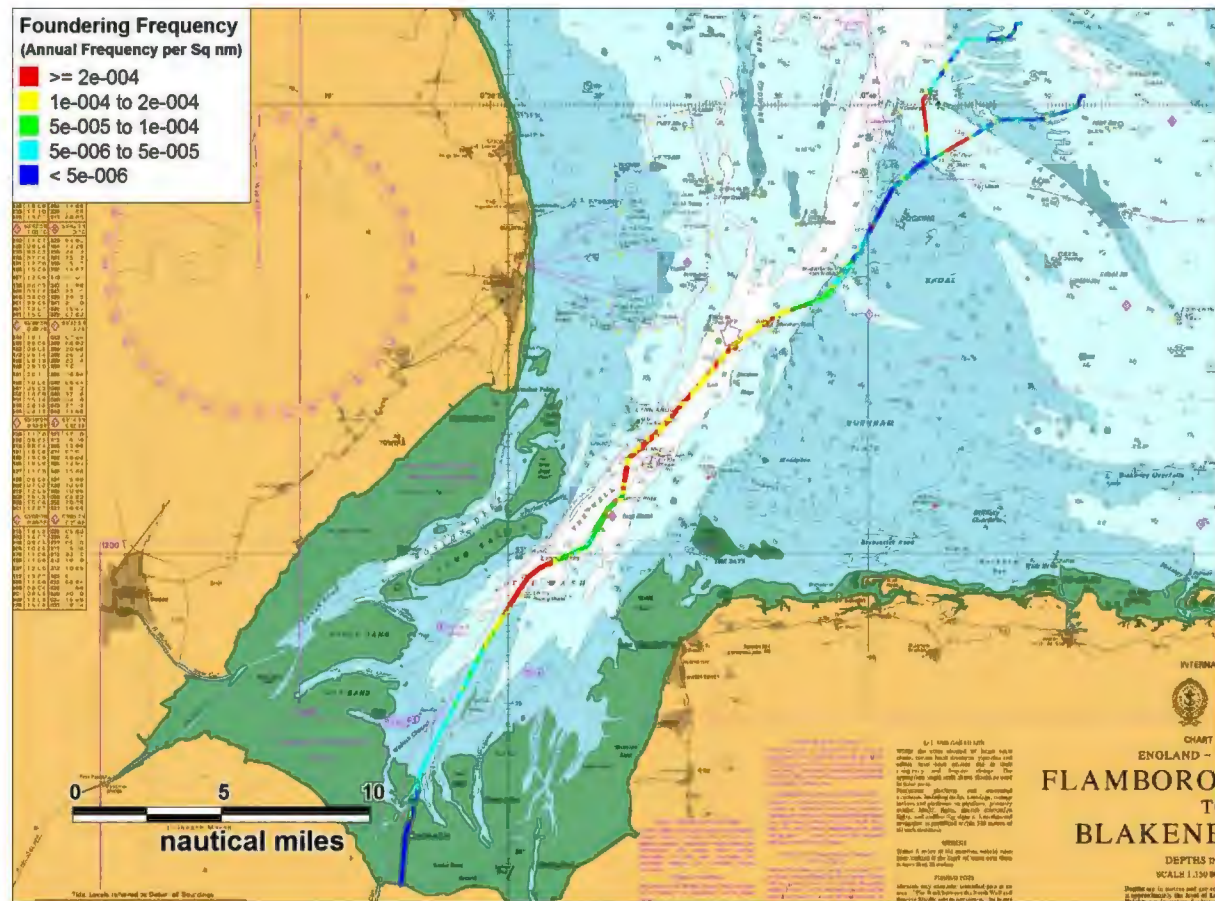


Figure 8.22 General Overview of Foundering Risk (based on 2013 data)

Detailed views of the results are presented in Figure 8.23 and Figure 8.24.

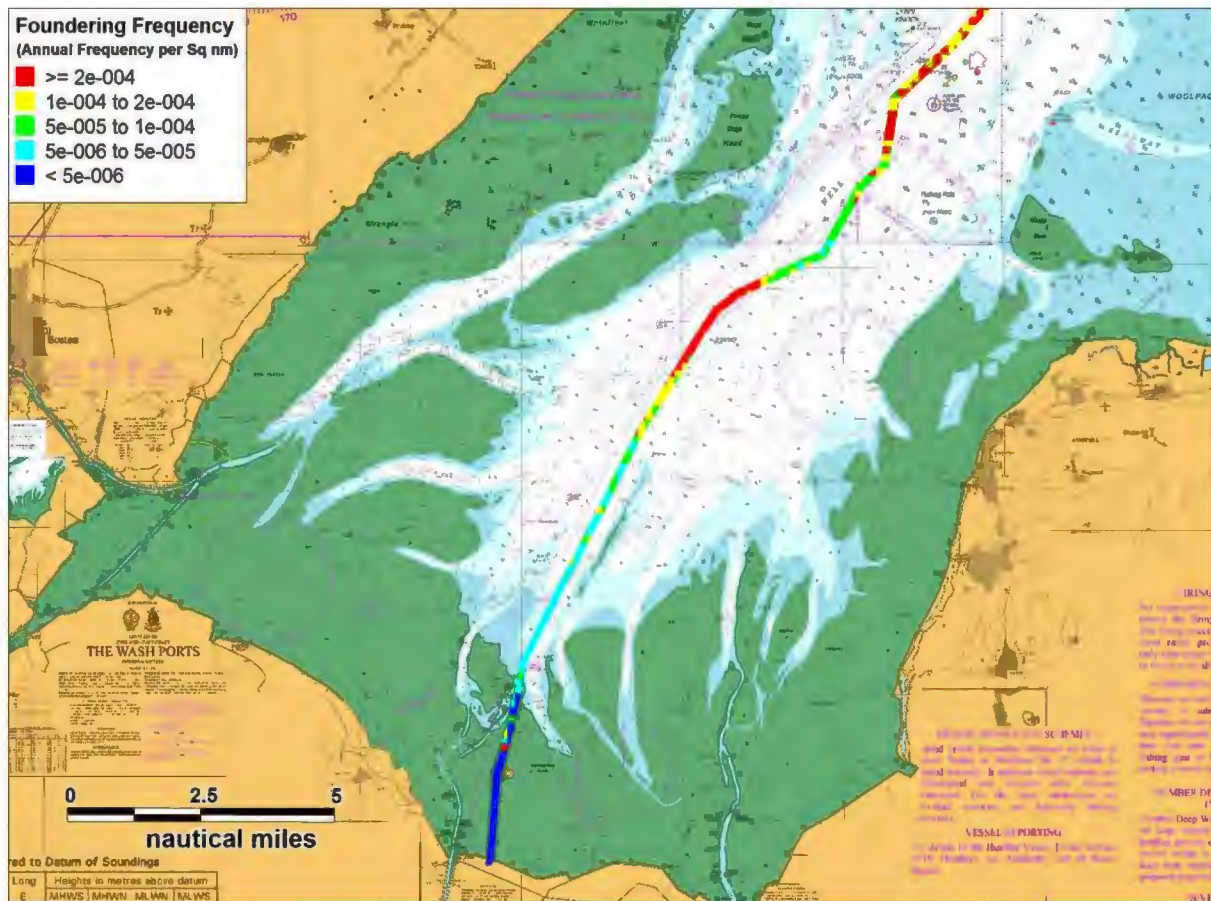


Figure 8.23 Detailed Overview of Foundering Results in the Wash (based on 2013 data)

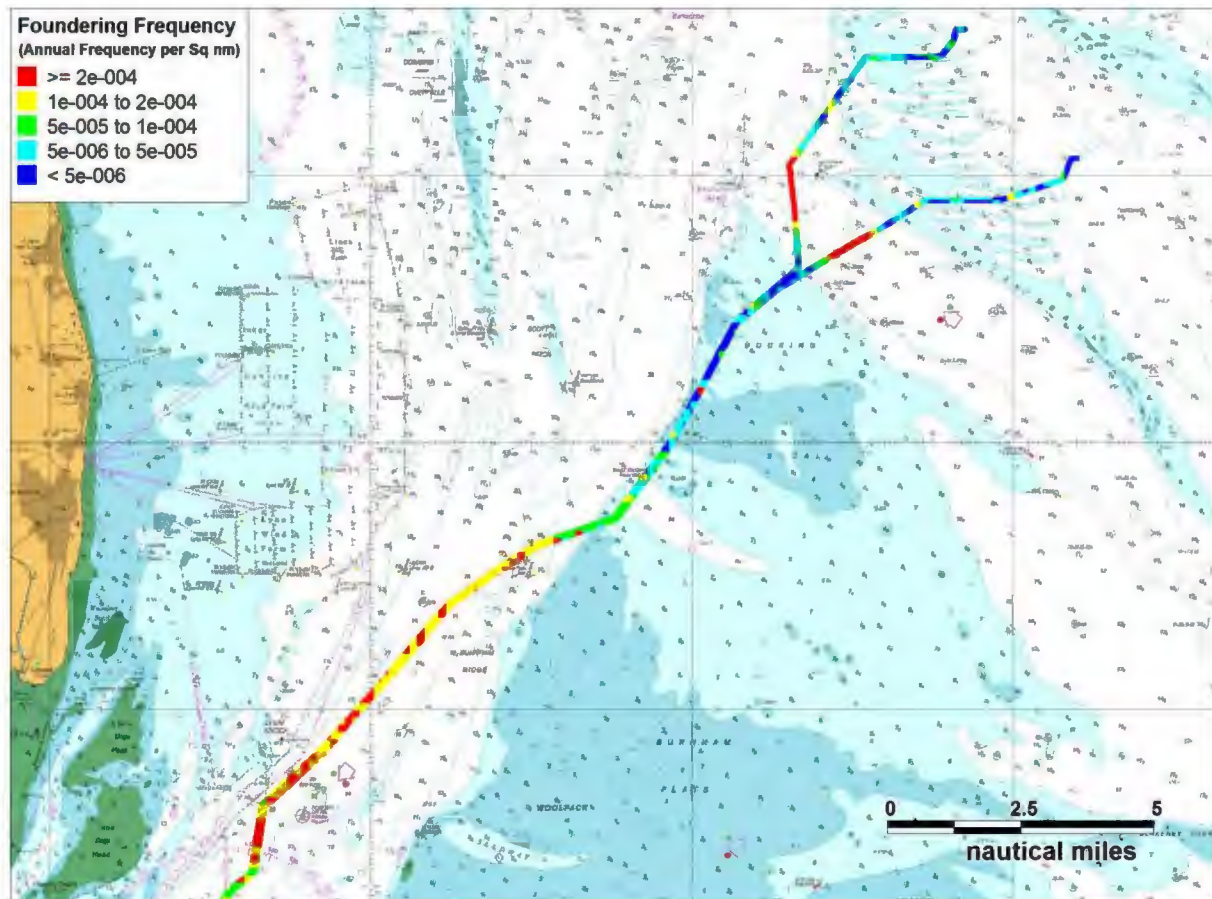


Figure 8.24 Detailed Overview of Offshore Cable Section Foundering Results (based on 2013 data)

The significant areas of risk were seen to be KP17 to KP25 within the Wash, and KP30 to KP47 in the approach to the Wash. The high foundering risk in these sections was caused by the intersection of the cable routes with the traffic associated with the Wash ports.

There was also an area of high risk caused by a merchant shipping route that crossed over both branches of the cable route just after it divides in the approach to the wind farm site. The route was mainly used by cargo vessels, and frequented by vessels travelling to major ports in both the UK and mainland Europe.

In terms of ship type, cargo vessels made up approximately 63% of the foundering risk. The majority of the remaining risk was from smaller “other” vessels. The foundering risk distribution by vessel size is presented in Figure 8.25.

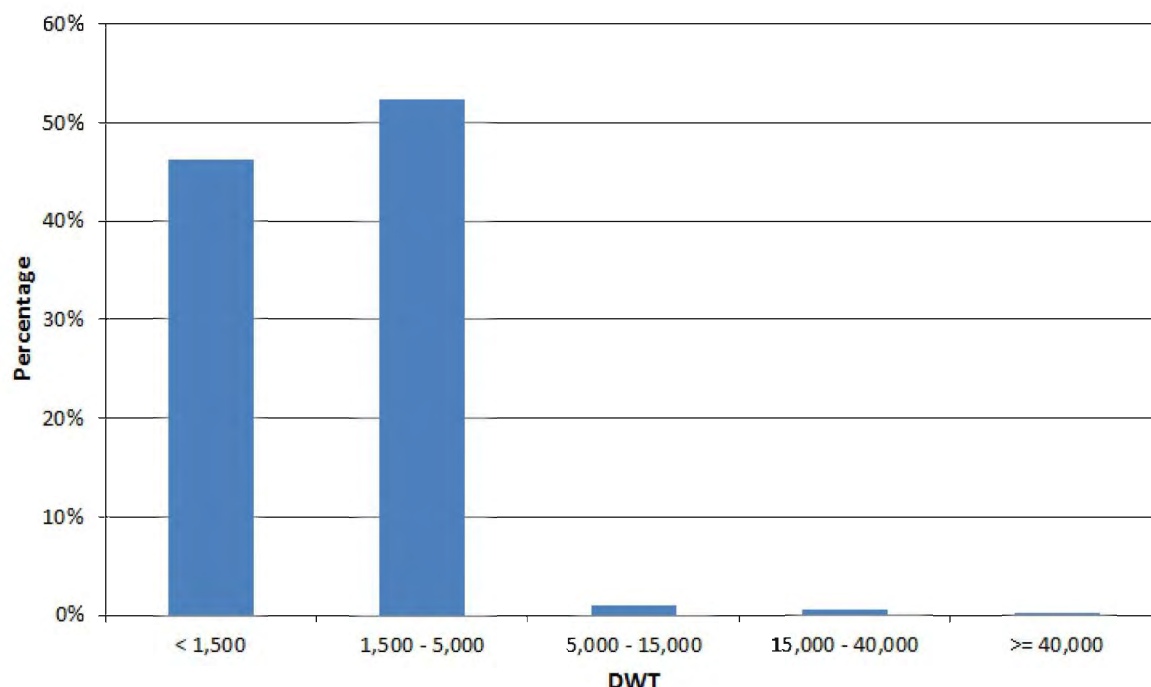


Figure 8.25 Annual Foundering Frequency by Vessel Size (based on 2013 data)

Approximately 46% of the foundering risk was from vessels below 1,500 DWT, with a further 52% coming from vessels between 1,500 and 5,000 DWT. It is noted that larger vessels are more likely to cause damage to a cable should they founder over its route.

The foundering risk broken down by zone is presented in Table 8.12. (See Figure 2.2 for information on the zones).

Table 8.12 Annual Foundering Frequency by Zone (based on 2013 data)

Zone	Frequency	Return Period (Years)
1	1.18×10^{-5}	85,080
2	1.47×10^{-4}	6,804
3	3.59×10^{-4}	2,788
4	3.69×10^{-5}	27,105
5	1.83×10^{-4}	5,468
Total	7.37×10^{-4}	1,357

The zone most at risk was zone 3, due to the busy traffic within The Wash. It contributed approximately 49% of the total foundering risk. Zones 2 and 5 made up 20% and 25% respectively.

8.5.4 Wisbech Channel Sensitivity Analysis

In order to assess the effect of the new Wisbech channel on the foundering risk, the AIS data from 2015 (see Section 5) was used as input to the CollRisk foundering model. The results are presented graphically in Figure 8.26.

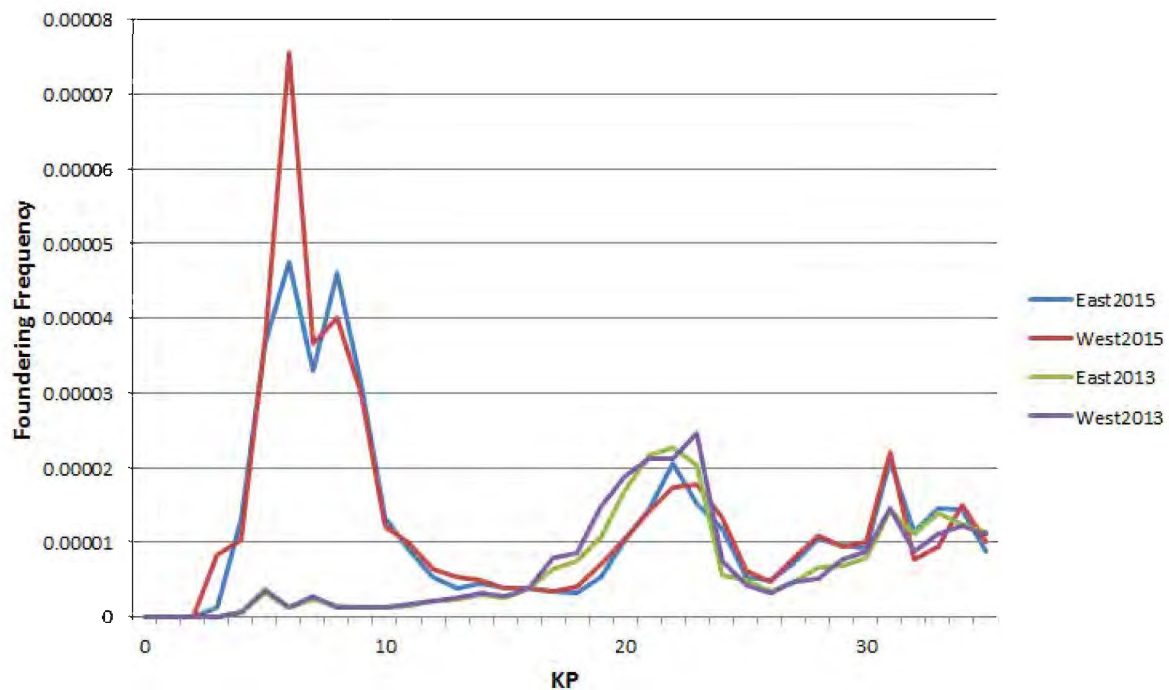


Figure 8.26 Wisbech Channel Foundering Sensitivity Analysis (2013 and 2015 data)

While the results of the 2013 and 2015 analysis were similar from KP17 onwards, they did not align as well as the emergency anchoring result comparison did. For this reason the following analysis assumes that the foundering results are based on:

- KP1 to KP35: 2015 analysis results
- KP35 onwards: 2013 results analysis

It was estimated that the Wisbech channel increased the foundering risk by 40% due to the increased vessel durations over KP3 to KP13. The 2015 results have been used for the foundering risk frequency rankings to account for the updated traffic patterns.

Table 8.13 Annual Foundering Frequency by Zone – 2013 and 2015 Analysis

Zone	2015		2013	
	Frequency	Rtn Prd (years)	Frequency	Rtn Prd (years)
1	2.27×10^{-4}	4,412	1.18×10^{-5}	85,080
2	1.96×10^{-4}	5,110	1.47×10^{-4}	6,804
3	3.90×10^{-4}	2,561	3.59×10^{-4}	2,788
4	3.69×10^{-5}	27,105	3.69×10^{-5}	27,105
5	1.83×10^{-4}	5,468	1.83×10^{-4}	5,468
Total	1.03×10^{-3}	968	7.37×10^{-4}	1,357

8.5.5 Risk Ranking

It is seen from the foundering results that the frequency for zones 1, 2, 3 and 5 was in the extremely unlikely band, i.e. one event per 100 to 10,000 years, while the frequency for zone 4 was seen to be negligible (less than one event per 10,000 years). This is based on the 2013 data combined with the updated 2015 Wisbech Channel analysis.

The consequences of a foundering event causing damage to the cable were considered to be minor for people. For business, the consequence was considered to be serious, i.e. requiring repair costs of £1M-£10M.

The risk to all zones of the cable from foundering was therefore considered to be **broadly acceptable** for people and **tolerable** for business.

It is noted that the risk assessment assumes that a foundering vessel will cause damage to the cable even if buried. This is likely to be a conservative assumption. Burying the cable to suitable depths should further reduce the risk due to foundering.

8.6 Other Commercial Activities

Other commercial activities considered within the risk assessment were dredging, oil & gas and maintenance or repair work on the neighbouring Lincs export cable. Such activities could cause the cable to become exposed to other hazards or to be damaged by the equipment used.

The risk will be mitigated by burying the cable to suitable depths, maintaining good planning and communication and using up-to-date navigational charts.

8.6.1 Dredging

The regions of aggregates dredging near the wind farm are presented in Figure 4.5. It can be seen that there is a region under application less than 500m northwest of the export cable route. The dredging activity tracked on AIS during the survey period is shown in Figure 8.27.

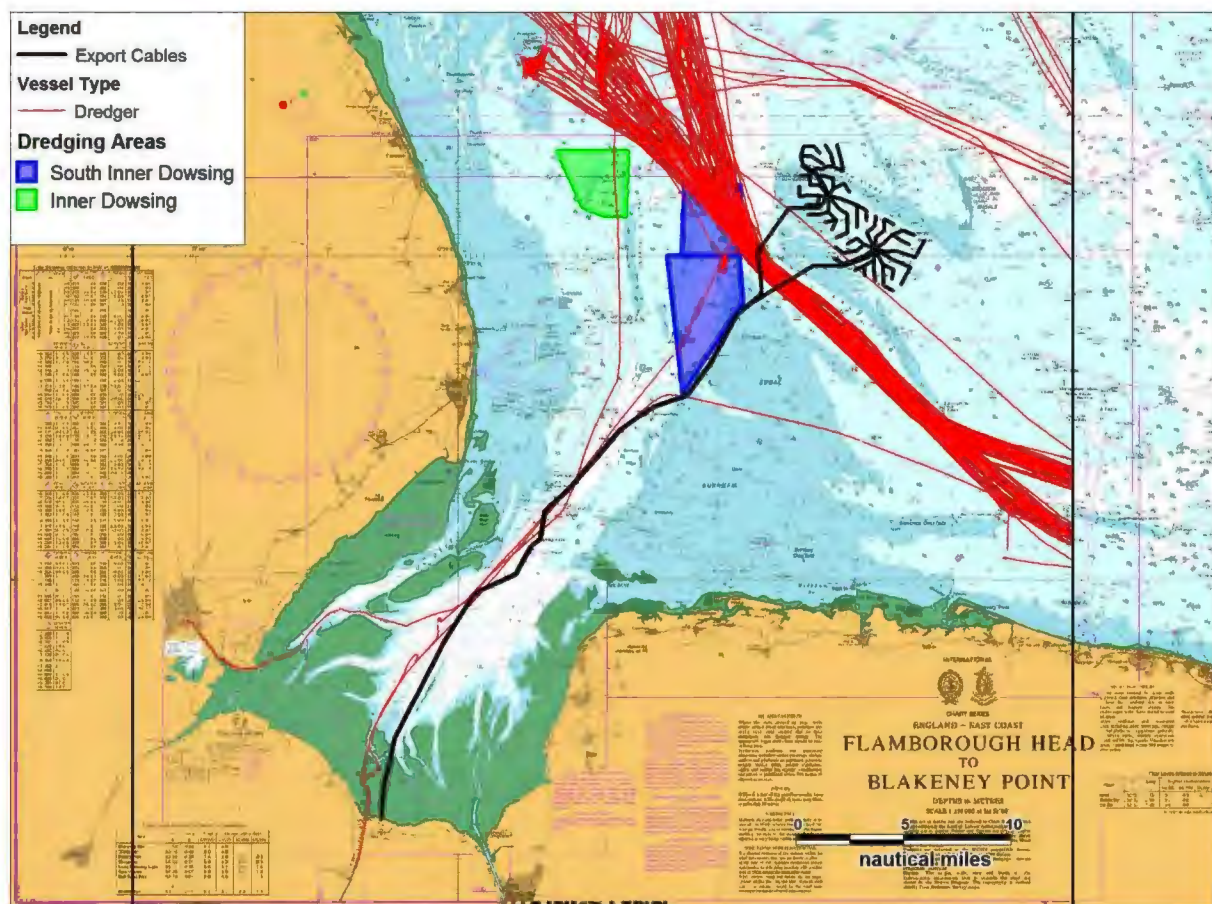


Figure 8.27 Dredging Activity in Study Area

It can be seen that the majority of dredgers appear to be transiting to/from the Wash ports or within the shipping route passing through the deeper water in zone 5 of the cable. Potential dredging activity is identified in the NE corner of the South Inner Dowsing dredging area.

Assuming that all suitable mitigation measures are followed, the frequency of the cable becoming exposed or damaged due to dredging activity was considered to be extremely unlikely, or one case every 100 to 10,000 years.

The consequence to people was considered to be minor. In the event that the cable becomes exposed or damaged requiring remedial burial or repair, the consequence to business is expected to be £1M - £10M, giving a consequence ranking of serious.

The risk to the cable from dredging activities was therefore considered to be **broadly acceptable** for the risk to people and **tolerable** for the risk to business.

In order to reduce the risk from dredging, the recommendation is additional protection of the cable in high risk areas, i.e. rock dump, concrete mattresses, further burial.

8.6.2 Oil & Gas Activity

It was noted in Section 4.4 that there were no oil & gas developments or installations in the vicinity of the Race Bank cables. Figure 8.28 shows a plot of the tracks of vessels working at oil & gas fields outside the study area.

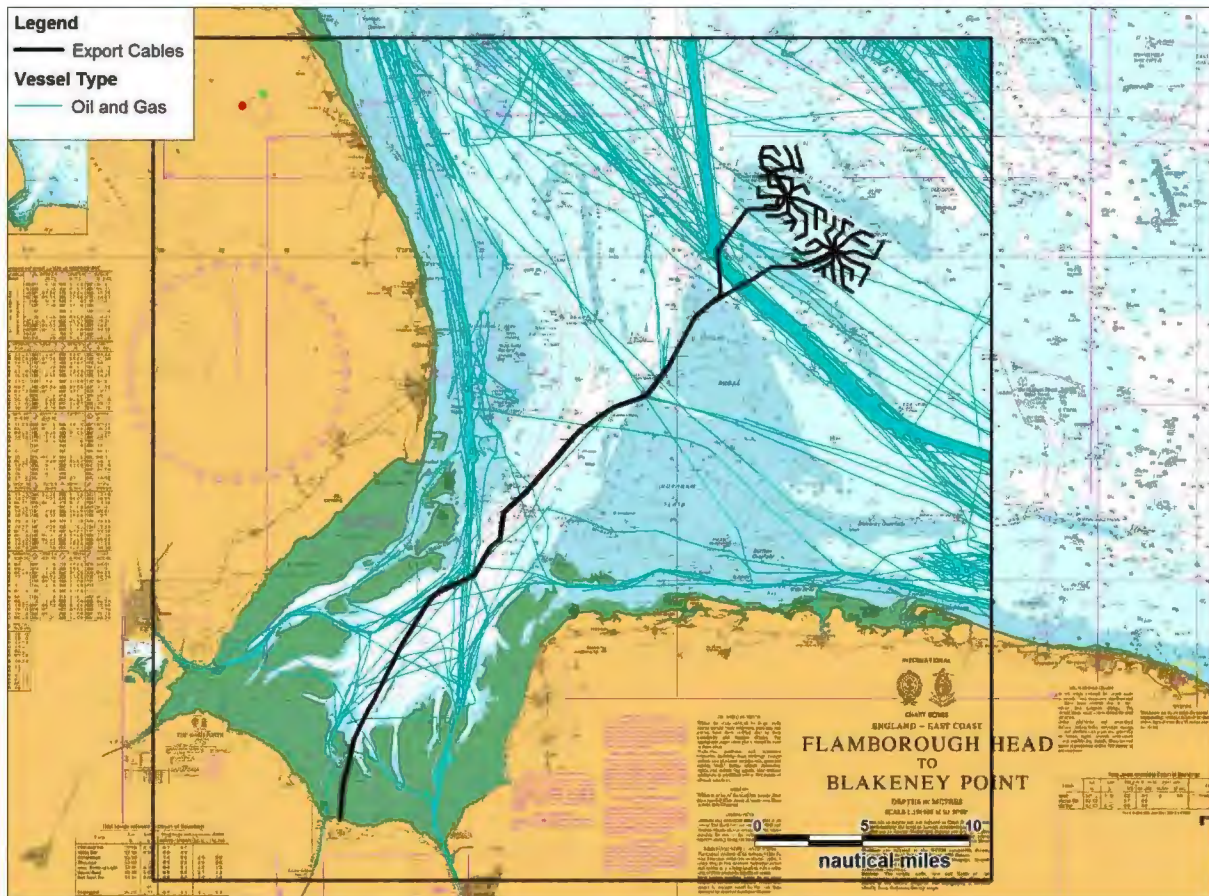


Figure 8.28 Oil and Gas Activity in Study Area

It can be seen that the majority of oil & gas support vessels tracked in the AIS data were transiting between ports and oil or gas fields, with the exception of one vessel possibly engaged in survey/research work north of the Race Bank site at the study area boundary.

Assuming the appropriate risk mitigation measures are implemented, the frequency of the cable becoming exposed or damaged as a result of Oil and Gas vessel activity was considered to be negligible, or less than one occurrence every 10,000 years.

The consequence to people was considered negligible. In the event that the cable becomes exposed or damaged requiring remedial burial or repair, the consequences were considered to have a ranking of serious, with an expected cost to business of £1M - £10M.

The risk to the cable from Oil and Gas activities was therefore considered to be **broadly acceptable** for both people and business.

8.6.3 Maintenance on Lincs Cable

Assuming appropriate risk measures are in place, the frequency of the cable becoming exposed or damaged as a result of maintenance or repair work on the neighbouring Lincs export cable was considered to be extremely unlikely, or one incident every 100 to 10,000 years.

The consequence to people was considered negligible. The consequence to business was considered to be £1M - £10M, a consequence ranking of serious.

The risk to people was therefore considered to be **broadly acceptable**, and the risk to business was considered to be **tolerable**.

In order to reduce the risk from maintenance activity on the Lincs cable, the recommendation is additional protection of the cable in high risk areas, i.e. rock dump, concrete mattresses, further burial.

8.7 Military Activities

The military practice area near the cable's landfall point can be seen in Figure 4.6. Three military vessels were observed in the AIS data. The tracks from these vessels are presented in Figure 8.29.

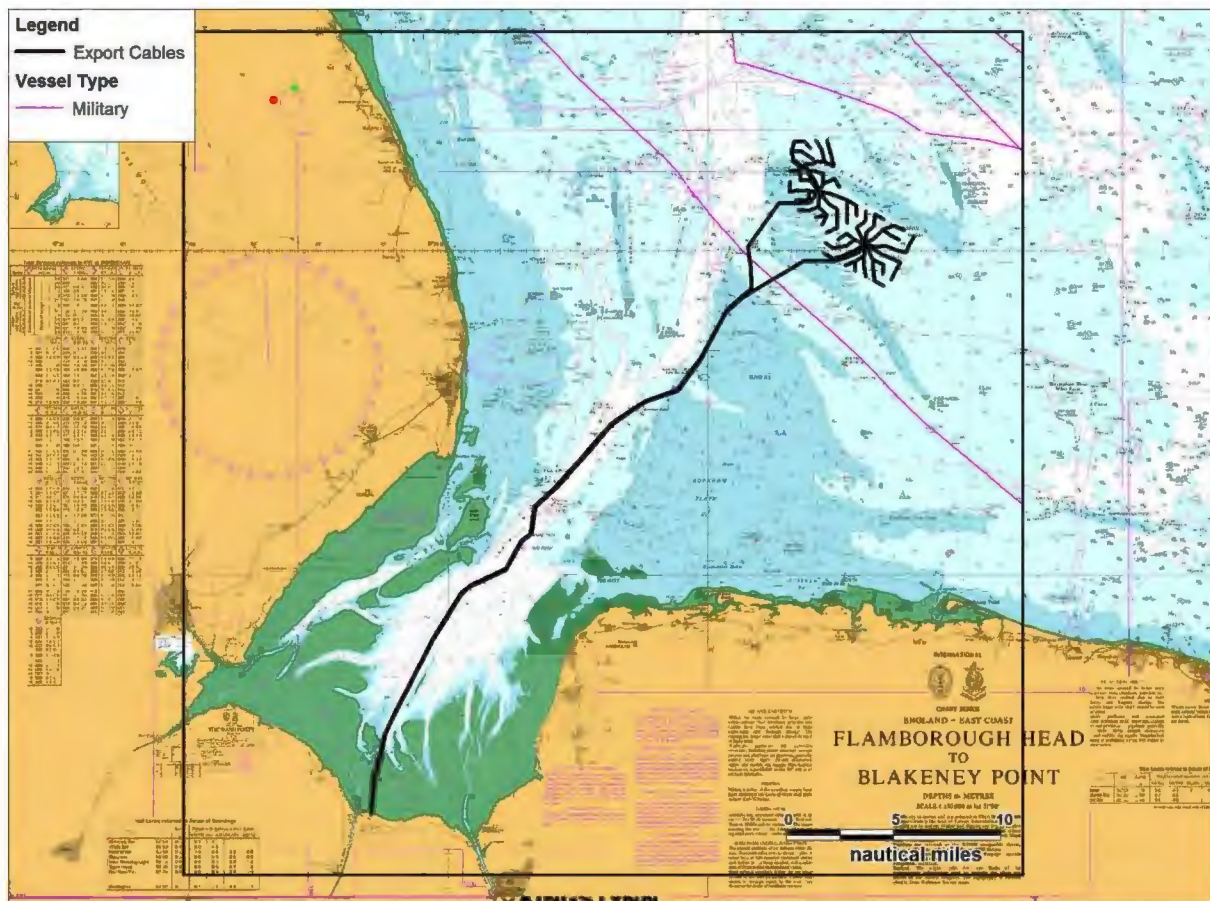


Figure 8.29 Military Activity in Study Area

Any risk from military activities was therefore considered to be due to the Holbeach air gunnery and bombing range described in Section 4.5 The firing practice area extends into the sand flats and is located 0.8nm from the cable route at its nearest point. This could present a risk of cable damage from bombs or gunfire within zone 1 and the beginning of zone 2 of the cable.

With suitable risk mitigation measures in place, the frequency of the cable becoming damaged as a result of military activity was considered to be extremely unlikely, or once every 100 to 10,000 years.

The consequence to people was considered negligible. In the event that military activity damages the cable, the consequences to business were considered to be £1M - £10M, a ranking of serious.

The risk to people from military activity was therefore considered to be **broadly acceptable**. The risk to business from military activity was considered to be **tolerable**.

In order to reduce the risk from military activity to ALARP, the recommendation is additional protection of the cable in high risk areas, i.e. rock dump, concrete mattresses, further burial.

8.8 Leisure Activities

A plot showing the recreational facilities and designated areas within the study area is presented in Figure 4.7. The tracks from leisure craft are presented in Figure 8.30.

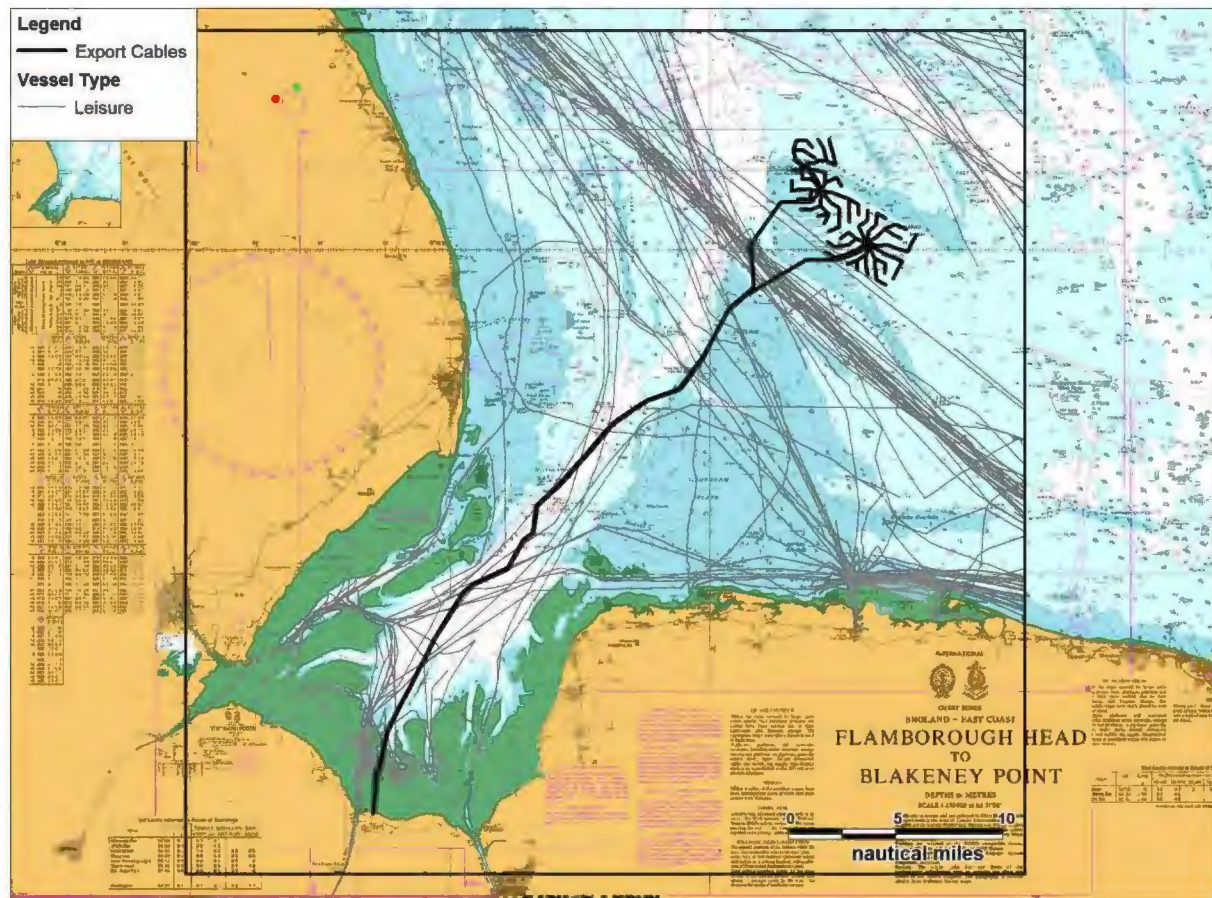


Figure 8.30 Leisure Activity in Study Area

The main risk to the cable from recreational vessels is from anchoring. All recreational vessels carrying AIS were included in the quantitative anchoring risk assessment. Any vessels not included in this assessment will be the smaller vessels. It was considered that the risk to the cable from small recreational vessels is negligible, due to their size.

The frequency of a recreational vessel damaging the cable was considered to be negligible, or less than one occurrence every 10,000 years.

The consequence to people was considered to be negligible, with no injuries expected. The consequence to business was also ranked as negligible, with an expected cost of less than £10k.

The risk to the cable from leisure vessel activity was therefore considered to be **broadly acceptable** for both the risk to people and business.

8.9 UXO

Unexploded ordnances along the cable route could cause problems with cable laying including prevention of achieving the desired burial depth. This could potentially require removal of the UXO, re-tooling or re-routeing of the cable, incurring extra costs and operational delays.

Since the location of UXOs are considered to be well known along the cable route, the frequency of encountering an unexpected UXO that requires attention is considered to be extremely unlikely.

The consequence of such an encounter was considered to be major for people, i.e. could potentially lead to a fatality, and serious for business, i.e. a cost of £1M - £10M.

The risk to the cable from boulders or cobbles was therefore considered to be **tolerable** for the risk to people and business.

Assuming that sufficient measures have been taken to map and identify all UXOs, this risk is considered to be ALARP.

9. Burial Assessment

9.1 Introduction

This section describes the methodology used to determine suitable burial depths for the cables associated with the Race Bank wind farm. This is in line with guidelines issued by the Carbon Trust (Ref i). An outline of the methodology provided by the Carbon Trust is presented in Figure 9.1.

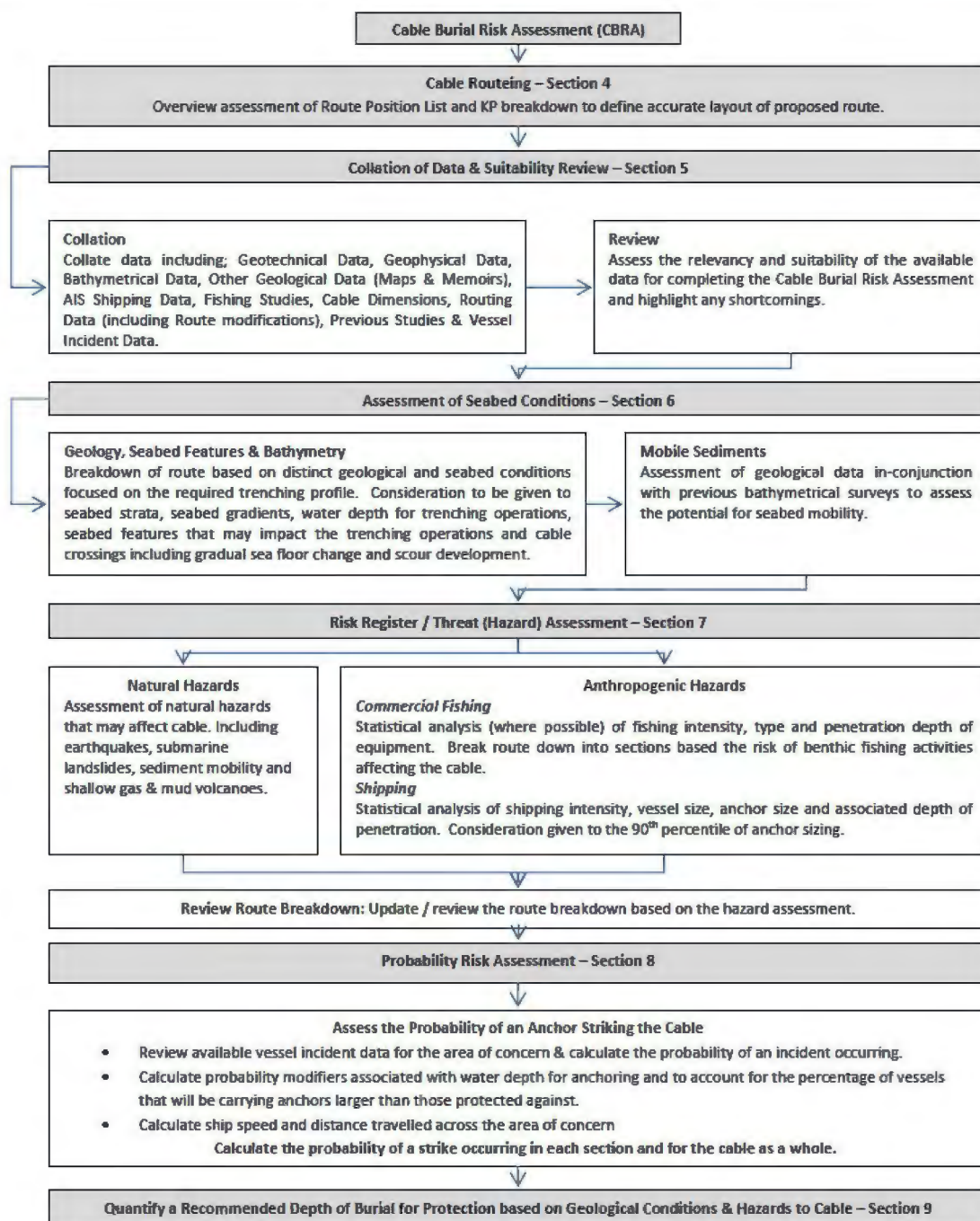


Figure 9.1 Carbon Trust Cable Burial Risk Assessment (CBRA) Methodology

9.2 Cable Routeing

Cable routeing for the export cables has been undertaken by the appointed cable installation contractor, Jan de Nul. It is assumed that the route has been selected based on the geophysical and geotechnical surveys that were carried out in the planning stages and that consideration

has been given to avoiding seabed obstructions which might make burial operations difficult, as well as maintaining a reasonable distance from anchorages and major shipping lanes, where possible.

9.3 Collation of Data & Suitability Review

This section describes the sources of the various data sets along the export cable routes that have been made available to Anatec in order to carry out the CBRA. It is noted that some of the geophysical and geotechnical information has not been updated since the export cable route has been redefined by Jan de Nul. However, it is considered that the new routes do not deviate significantly from the original routes and the original data has therefore been used for the CBRA. The following data has been made available for use in the CBRA.

- Geotechnical Data
 - EGS Geotechnical Survey Report
 - CPT results to 5m depth at approximately 1km intervals along the export cable routes.
- Geophysical Data
 - Gardline Geophysical Survey Report
 - High Resolution Multi-beam Swathe (MBES) Survey
 - Side Scan Sonar
 - Magnetometer survey
- Seabed Mobility Study
- Alignment Charts
- Metocean Data
- Routeing Data (including Route modifications)

In addition, as described in Section 5, six months of 2013 AIS data from 1st July to 31st December, and four months of 2015 AIS data from 1st June to 30th September was used to identify shipping and anchoring activity along the route. Fishing activity was analysed using the AIS data, as well as sightings and satellite data for the area.

The adequacy of the data is discussed in more detail in the sections below.

9.3.1 Geotechnical Data

The main source of geotechnical data available to Anatec was the EGS Geotechnical Survey Report (Ref vi). This includes the results of the Cone Penetration Tests (CPTs) carried out by EGS within the survey corridor in July 2013, which were available at approximately 1km intervals along the export cable routes. These were used to identify the density of the soil sediment (e.g. loose sand, medium dense sand, dense sand, soft clay). It is noted that the CPTs were carried out prior to the redefining of the route by Jan de Nul, and therefore align more closely with the original routes, however it is considered that the new routes do not deviate significantly from the original routes.

In addition, the latest alignment charts (see Section 9.3.4) were used to confirm any areas of hard substance (e.g. chalk, bedrock) by comparing the 2015 bathymetry with the base of the Holocene sand from the 2014 EGS Report (Ref vi) along the cable routes.

9.3.2 Geophysical Data

The 2012 Gardline Geophysical Survey Report (Ref vii) provided details of the geophysical nature of the seabed and the locations of sandwaves, megaripples and other seabed features. However the report is no longer applicable to the cable route, due to the re-routing of the cable leading to a mis-match of KP information. A more recent environmental engineering survey carried out by Fugro (Ref viii) in 2015 was therefore used to provide information on the seabed characterisation. The information was provided in the form of shape files, which were used to identify seabed characteristics along the cable route, including sand type (e.g. shelly silty sand or gravelly sand), outcrops of till, megaripples, sand waves etc.

It should be noted that, based on this characterisation, the majority of the seabed along the cable route was seen to contain megaripples or sand waves. However, the recent ABPmer Seabed Mobility Study (Ref ii), which shows only megaripples or sand waves that are expected to move in the short term future, showed fewer areas with sand waves or megaripples. The mobile sediment information used in the CBRA (i.e. locations and heights of sand waves and megaripples that might move and cause the cable to become exposed) was based on the latter study – see Section 9.3.3.

High Resolution Multi-beam Swathe (MBES), Side Scan Sonar and Magnetometer surveys carried out by Fugro in 2015 were used to determine the bathymetry along the cable route and any seabed features or potential hazards.

9.3.3 Seabed Mobility Study

The Seabed Mobility Study carried out by ABPmer (Ref ii) in October 2015 was used to determine the locations and heights of sand waves and megaripples along the cable route. In addition, this study also provided estimates for the change in seabed level due to erosion and accretion along the cable route.

The key factor for the burial recommendations is any expected decrease in seabed level, causing reduction in burial or, in the worst case, the cable to become exposed and at risk from vessel anchors or fishing gear. Table 6 in Ref ii provides the estimated maximum decrease in seabed level due to erosion or mobile bedforms (i.e. sand waves or megaripples), which will be used as input to the CBRA. This is described in more detail in Section 9.4.

9.3.4 Alignment Charts

The alignment charts prepared by Jan de Nul and Cathie Associates in July 2015 collate the most recent available information on seabed sediment, seabed features, UXOs, bathymetry, location of CPTs and vertical alignment for the export cable routes revised by Jan de Nul during macro-routeing. It is noted that the information on sand waves required for the CBRA was taken from the seabed mobility study, rather than the alignment charts.

9.3.5 Metocean Data

Two sources of metocean data were accessed for the project. The first source was taken from the Metocean Modelling report by HR Wallingford for Race Bank and Docking Shoal Offshore Wind Farms (Ref ix), while the second source was an extrapolation of data from the Holbeach weather station into the Wash, carried out by the Met Office (Ref x). The sources were combined for use in the risk modelling.

9.3.6 Routeing Data

Anatec were provided with the latest Routing Report and Route Engineering Report for the export cable routes prepared by Jan de Nul in July 2015. These reports outline the rationale used to generate the final preferred routes and the proposed methodology for the cable laying operation. Jan de Nul also provided the revised export cable routes in a GIS shape file (dated 1st July 2015). These were used within Anatec's risk models as input to the CBRA.

9.4 *Assessment of Seabed Conditions*

The seabed conditions were assessed using a combination of geophysical and geotechnical data. As discussed, some of the data available was from the original surveys carried out in the planning stages of the cable route and is not specific to the current route proposed by Jan de Nul. However, newer data has been used where available.

9.4.1 Water Depth

The water depth along the export cable route is presented in Figure 9.2. This information was based on the Fugro EMU survey carried out in 2015 (Ref viii).

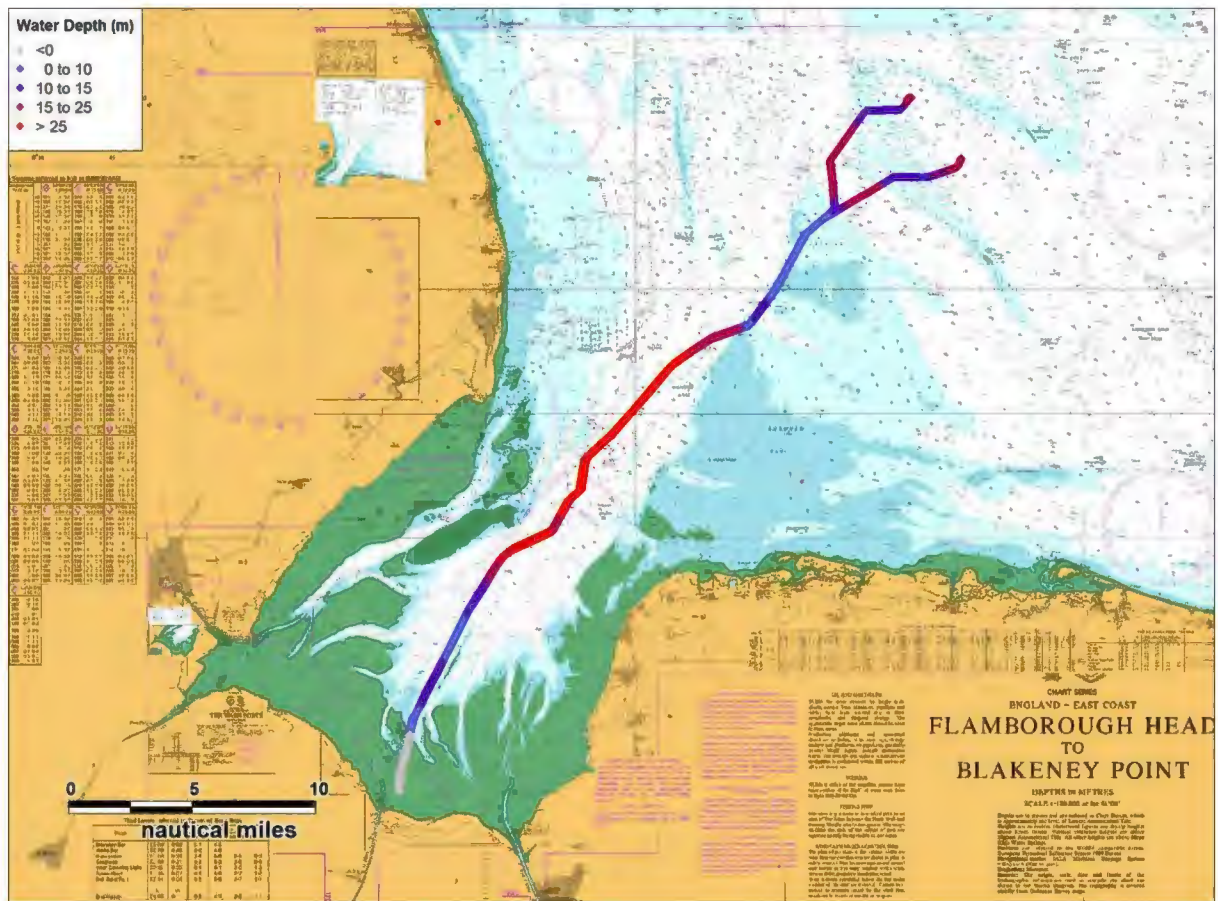


Figure 9.2 Water Depth Along Cable Route

9.4.2 Seabed Characterisation

Figure 9.3 presents the seabed characterisation along the export cable route, based on results of the Fugro Environmental Engineering Survey carried out in 2015 (Ref viii).

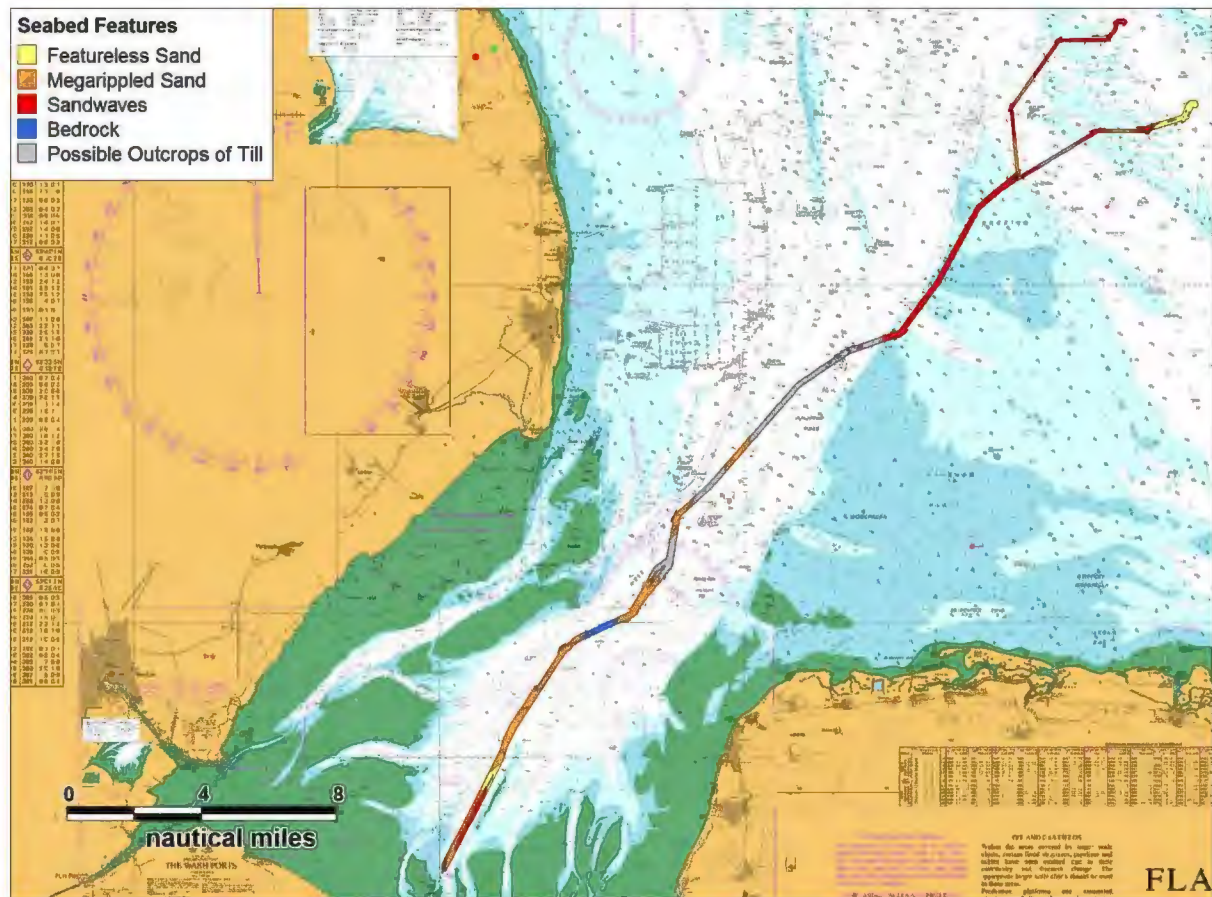


Figure 9.3 Seabed Features Along Cable Routes

It can be seen that there are significant areas containing sand waves, megaripples and possible outcrops of till. This can affect the recommended burial depths for the cable. However it is noted that the information on mobile sand waves / megaripples was based on results of the ABPmer Study, rather than this seabed characterisation, as described below.

9.4.3 Mobile Sediment

The ABPmer mobility study provides results on the potential increase or decrease in the seabed level over time, based on mobile sediments (sand waves, megaripples) and on predicted accretion or erosion. The CBRA is interested in potential reductions in seabed level, as this could cause the cable to become exposed. Figure 9.4 presents the estimated maximum decrease in seabed level between 2015 and 2040, as predicted by ABPmer, due to erosion, sand waves or megaripples.



Figure 9.4 Estimated Maximum Decrease in Seabed Level, 2015 – 2040

This information was used to complete the mobile sediment column in the CBRA spreadsheet. It is noted that there is also the potential for the seabed level to increase (due to accretion or due to mobile sediments moving towards the cable route). However, to be conservative, only the decrease in seabed level is considered (i.e. it is assumed that the bed level has not increased before any reduction).

It is noted that the change in seabed level has a high uncertainty value of 1m applied to the whole cable route, due to limitations of the available data sets. It was therefore assumed that, as suggested in the ABPmer report, any predicted decrease of less than 0.5m could be indicative of little variation in the seabed level. Since such a decrease would be within the Factor of Safety used for anchor penetration, it was assumed that a predicted seabed level decrease of less than 0.5m does not affect the burial recommendations. For any decrease greater than this, 0.5m was subtracted from the given value and the burial depth recommendation increased by the remainder.

9.4.4 Seabed Type

Figure 9.5 presents the seabed type along the export cable route. The seabed types were determined from results of the 2013 Cone Penetration Tests (CPTs) along the route. For each

500m section of cable route, it was assumed that the seabed type information provided by the nearest CPT was applicable for the 500m section.

It is noted that the CPTs were carried out prior to the redefining of the route by Jan de Nul, and the test locations therefore align more closely with the original routes, however it is considered that the new routes do not deviate significantly from the original routes. In addition, the alignment charts were used to confirm any areas of hard substance (e.g. chalk, bedrock) along the cable routes.

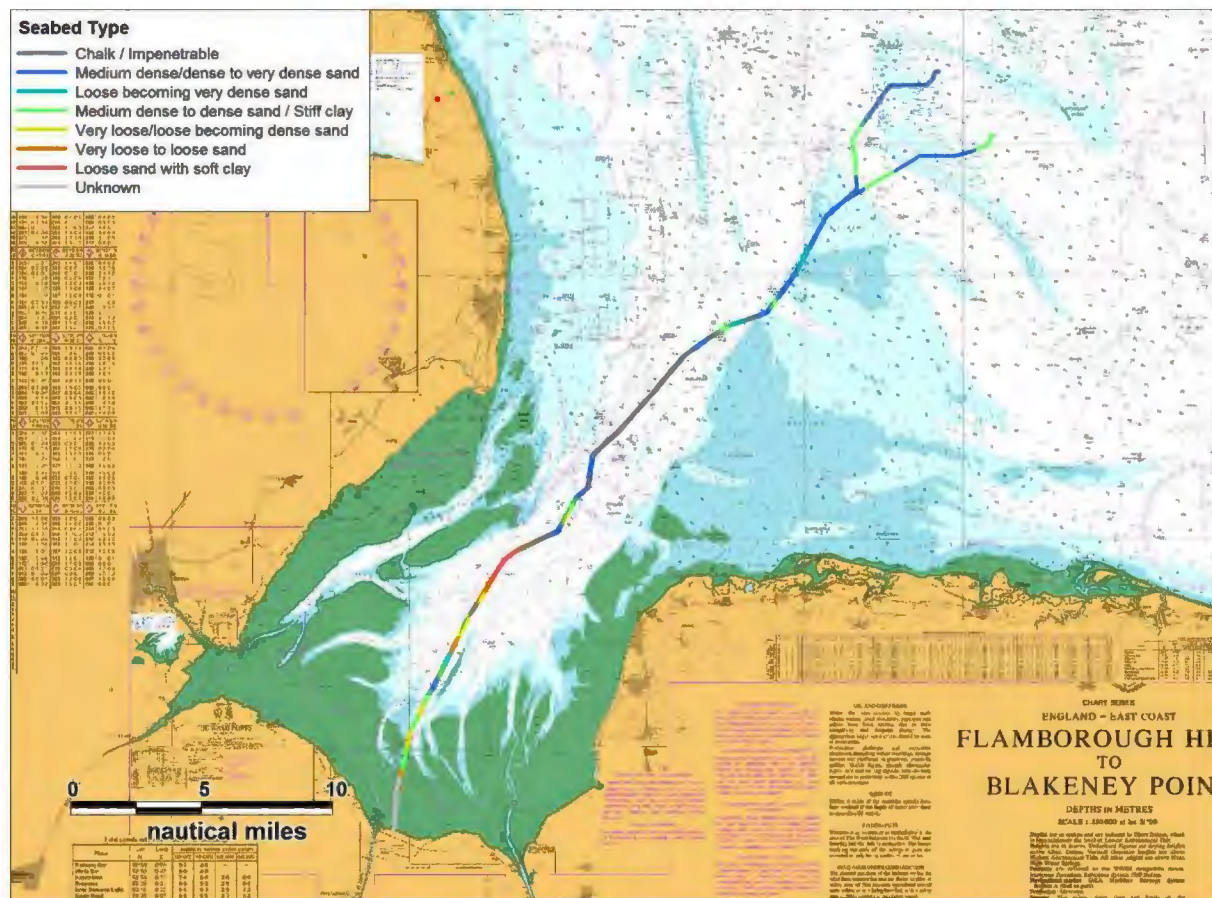


Figure 9.5 Seabed Type Along Export Cable Route

It can be seen that the seabed type along the export cable route was broken down into 7 different types of varying density, e.g. from loose sand to very dense sand. The category Chalk / Impenetrable refers to sections where the seabed contains chalk or the maximum penetration depth achieved by the cone was less than 1m. This category presents the highest resistance to vessel anchors, while anchors are expected to achieve the largest penetration depths in loose sand with soft clay.

Detailed information on the seabed type, seabed features and bathymetry for the export cable route are included in the CBRA spreadsheets (Ref xi and xii).

9.5 Risk Register / Threat (Hazard) Assessment

Table 9.1 provides the results of the threat assessment in the form of a risk register, which considers the Probability (P) and Severity (S) to determine the overall Risk (R) of external threats to the cable. The Probability and Severity are ranked from 1 to 5 and multiplied to give a total Risk between 1 and 25. The findings are primarily based on the results of the Hazard Workshop discussed in Section 6 and Anatec's experience in shipping and navigational hazards.

Table 9.1 Risk Register

Sources	Hazard Description	Cable Burial Risk						
		Risk			Mitigation	Residual Risk		
		P	S	R		P	S	R
NATURAL								
Seabed Instability	Instabilities in the seabed could cause the cable to become exposed	1	3	3	Avoidance of slopes/possible landslides within the Wash and surrounding waters (e.g. the Well); Post installation/in service survey campaigns; Remedial burial campaigns; Concrete mattresses; Further burial in high risk areas identified in geophysical surveys.	1	3	3
Mass sediment transport	Mass sediment transport away from the cable route could cause the cable to become exposed over time	1	3	3	Cable route surveys; Regular inspection of cable, particularly in high risk areas identified in geophysical surveys.	1	3	3
SOIL CONDITIONS								
Sand waves	Sand waves in the region could cause soil to move reducing the burial depth of the cable or causing it to	4	3	12	Select best option for cable laying; Regular inspection of cable; Lay cable perpendicular to sand wave areas identified in geophysical surveys; Lay cable in suitable seabed type; Cable laying	2	3	6

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Sources	Hazard Description	Cable Burial Risk						
		Risk			Mitigation	Residual Risk		
		P	S	R		P	S	R
	become exposed				vessels use suitable tools. Increase recommended burial depth / bury cable to bottom of sand wave. CABLE BURIAL RISK ASSESSMENT			
Megaripples	Megaripples in the region could cause soil to move reducing the burial depth of the cable or causing it to become exposed	3	3	9	Select best option for cable laying; Regular inspection of cable; Lay cable perpendicular to sand wave; Lay cable in suitable seabed type; Cable laying vessels use suitable tools; Accomplish burial beneath depth of active megaripple. CABLE BURIAL RISK ASSESSMENT	2	3	6
ANTHROPOGENIC								
Fishing	Fishing gear snagging on cables or reducing level of burial	3	4	12	Minimum cable burial depth of 0.6m in areas of fishing activity identified in AIS/VMS fishing analysis; Cable marked on charts; Notice to mariners/Liaison with Wash Port authorities. CABLE BURIAL RISK ASSESSMENT	2	4	8
Anchors	Vessels routinely anchoring near to the cable drag anchor and drift over the cable route	3	4	12	Cable burial; cable marked on charts; notice to mariners/Liaison with Wash Port Authorities; Rock dump; concrete mattresses; further burial in high risk areas identified in dragged anchor risk assessment. CABLE BURIAL RISK ASSESSMENT	2	4	8

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Sources	Hazard Description	Cable Burial Risk						
		Risk			Mitigation	Residual Risk		
		P	S	R		P	S	R
Anchors	Vessel travelling over the cable route suffers engine failure and drops anchor onto the cable	2	4	8	Cable burial; cable marked on charts; Notice to mariners/Liaison with Wash Port authorities; Rock dump; concrete mattresses; further burial in high risk areas identified in emergency anchoring risk assessment. CABLE BURIAL RISK ASSESSMENT	2	4	8
Anchors	Vessel inadvertently (or negligently) anchors over the cable route	3	4	12	Cable burial; cable marked on charts; Notice to mariners; Rock dump; Concrete mattresses	3	4	12
Foundering	Vessel suffers technical failure and sinks onto the cable	2	4	8	Cable burial; Rock dump; Concrete mattresses;	2	4	8
Dredging	The cable is damaged or exposed due to nearby dredging activity	2	4	8	Cable burial; Communication with local stakeholders/Wash Port authorities; Cable marked on charts; Rock dump; Concrete mattresses.	2	4	8
Misc. Marine Activities	Oil & gas, military or recreational activities near the cable route damage or expose the cable	2	4	8	Cable burial; Communication with local stakeholders/Wash Port authorities; Cable marked on charts; Notice to mariners; Rock dump; Concrete mattresses.	1	4	4

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Sources	Hazard Description	Cable Burial Risk						
		Risk			Mitigation	Residual Risk		
		P	S	R		P	S	R
Cable Maintenance	Maintenance or repair work on the neighbouring Lines export cable causes damage to the cable	2	4	8	Communication with Lines cable OFTO and Wash Port Authorities; Cable marked on charts; Cable burial; Planning; Rock dump; Concrete matressing.	1	4	4

9.6 Probability Risk Assessment

9.6.1 Risk Frequency

This section summarises the results of the probability risk assessment for the Race Bank cable, which will be used as input to determining suitable Recommended Burial Depths.

The probability risk assessment combines the anchor dragging and emergency anchoring frequencies calculated in Sections 8.2 and 8.3, for the unburied cable, to determine the risk to the cables from all vessel anchors, per KP of cable.

The methodology used in this report for calculating the risk frequency is generally in line with the Carbon Trust guidelines in Ref i for the emergency anchoring frequency, but includes a factor for the distance of vessels from danger. It is also noted that the methodology used here takes into consideration the risk from vessels dragging anchor from nearby anchorage areas (not included in the Carbon Trust methodology), which is a key hazard in the Wash, due to the close proximity of the cables to the designated anchorage areas.

The combined risk is compared with the acceptance criteria defined by DONG Energy. These were defined based on the effort required to repair the cable for each section and on recommendations from the Port Authorities, and are presented in Table 9.2.

Table 9.2 Acceptance Criteria for Export Cable Route

KP Range	Acceptable Risk (Per KP)	Acceptable Return Period (years)
0 – 23	1×10^{-4}	10,000
23 – 26	1×10^{-3}	1,000
26 – 34	1×10^{-4}	10,000
34 to OSS	1×10^{-3}	1,000

For any section of cable where the combined (anchor dragging and emergency anchoring) risk frequency exceeds the acceptance criteria for that section, the frequency per vessel size is investigated in order to determine the maximum vessel size that the cable should be protected against to give an acceptable residual risk to the cable.

Table 9.3 presents the results of the combined anchor dragging and emergency anchoring frequencies per KP, broken down by vessel size category, as defined in Table 8.1. For KP 1 to 17, the emergency anchoring frequency was calculated using the recent AIS data to account for the change in shipping activity in the Wisbech Channel, as described in Section 5.3. Where the total risk exceeds the acceptance criteria, the table cell has been highlighted in red.

Table 9.3 Total Risk Frequency from All Vessel Anchors, Distributed by Vessel Size

KP	Acceptance Criteria	East Cable Total Frequency						West Cable Total Frequency					
		Total	Size 1	Size 2	Size 3	Size 4	Size 5	Total	Size 1	Size 2	Size 3	Size 4	Size 5
0-1	0.0001	1.92E-07	1.08E-08	1.73E-07	8.54E-09	0	0	3.35E-09	0	3.35E-09	0	0	0
1-2	0.0001	3.60E-07	2.05E-08	3.28E-07	1.15E-08	0	0	8.25E-09	0	8.25E-09	0	0	0
2-3	0.0001	5.77E-06	5.31E-06	4.48E-07	2.01E-08	0	0	3.17E-05	3.17E-05	1.23E-08	0	0	0
3-4	0.0001	5.03E-05	4.98E-05	5.38E-07	2.51E-08	0	0	4.22E-05	3.93E-05	2.97E-06	0	0	0
4-5	0.0001	1.41E-04	1.40E-04	8.75E-07	3.89E-08	0	0	1.48E-04	1.42E-04	6.64E-06	0	0	0
5-6	0.0001	2.03E-04	1.62E-04	4.09E-05	5.30E-08	0	0	3.32E-04	2.54E-04	7.81E-05	0	0	0
6-7	0.0001	1.87E-04	9.35E-05	9.33E-05	1.11E-07	0	0	2.06E-04	1.06E-04	1.01E-04	0	0	0
7-8	0.0001	2.45E-04	2.06E-04	3.83E-05	9.79E-08	0	0	2.94E-04	1.88E-04	1.06E-04	2.53E-16	0	0
8-9	0.0001	1.68E-04	1.11E-04	5.74E-05	1.35E-07	0	0	3.78E-04	1.36E-04	2.43E-04	5.49E-16	0	0
9-10	0.0001	9.82E-05	3.72E-05	6.07E-05	3.16E-07	0	0	6.84E-04	7.97E-05	6.04E-04	4.63E-16	0	0
10-11	0.0001	7.43E-05	2.54E-05	4.85E-05	3.98E-07	0	0	1.58E-03	1.19E-04	1.47E-03	2.59E-17	0	0
11-12	0.0001	6.16E-05	1.55E-05	4.53E-05	7.85E-07	0	0	3.18E-03	1.41E-04	3.04E-03	6.97E-16	0	0
12-13	0.0001	7.18E-05	9.83E-06	6.05E-05	1.51E-06	0	0	4.72E-03	1.20E-04	4.60E-03	1.97E-15	0	0
13-14	0.0001	1.02E-04	1.46E-05	8.51E-05	2.40E-06	0	0	3.76E-03	7.55E-05	3.68E-03	4.46E-15	0	0
14-15	0.0001	1.66E-04	1.92E-05	1.43E-04	4.50E-06	0	0	2.07E-03	5.02E-05	2.02E-03	6.50E-16	0	0
15-16	0.0001	2.95E-04	3.79E-05	2.50E-04	7.06E-06	0	0	1.31E-03	6.31E-05	1.25E-03	2.42E-15	0	0
16-17	0.0001	4.26E-04	2.48E-05	3.91E-04	1.04E-05	0	0	1.48E-03	7.99E-05	1.40E-03	1.49E-14	0	0

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KP	Acceptance Criteria	East Cable Total Frequency						West Cable Total Frequency					
		Total	Size 1	Size 2	Size 3	Size 4	Size 5	Total	Size 1	Size 2	Size 3	Size 4	Size 5
17-18	0.0001	6.61E-04	3.15E-05	6.17E-04	1.29E-05	0	0	2.27E-03	1.47E-04	2.13E-03	1.02E-14	0	0
18-19	0.0001	8.43E-04	2.89E-05	8.01E-04	1.28E-05	0	0	2.66E-03	1.62E-04	2.49E-03	2.36E-14	0	0
19-20	0.0001	8.05E-04	2.97E-05	7.64E-04	1.11E-05	0	0	1.82E-03	9.24E-05	1.72E-03	3.66E-14	0	0
20-21	0.0001	5.86E-04	1.92E-05	5.59E-04	7.26E-06	0	0	8.36E-04	3.61E-05	8.00E-04	7.18E-14	0	0
21-22	0.0001	5.01E-04	2.14E-05	4.72E-04	7.83E-06	0	0	2.24E-04	1.34E-05	2.11E-04	7.48E-13	0	0
22-23	0.0001	4.20E-04	3.08E-05	3.83E-04	6.23E-06	0	0	1.11E-04	2.59E-05	8.56E-05	1.01E-12	0	0
23-24	0.001	3.05E-04	1.03E-05	2.90E-04	4.78E-06	3.63E-07	0	3.86E-05	4.61E-06	3.37E-05	2.19E-07	0	0
24-25	0.001	2.94E-04	1.01E-05	2.80E-04	3.70E-06	2.78E-09	0	2.33E-05	2.94E-06	2.03E-05	8.54E-08	0	0
25-26	0.001	8.99E-05	3.27E-06	8.50E-05	1.68E-06	3.48E-07	0	2.00E-05	1.90E-06	1.79E-05	2.17E-07	0	0
26-27	0.0001	3.45E-05	3.92E-06	3.00E-05	5.74E-07	3.22E-07	0	4.29E-05	3.86E-06	3.86E-05	4.17E-07	0	0
27-28	0.0001	3.52E-05	7.63E-06	2.73E-05	2.35E-07	7.87E-08	0	3.98E-05	4.31E-06	3.53E-05	2.57E-07	0	0
28-29	0.0001	4.27E-05	9.38E-06	3.30E-05	3.76E-07	2.45E-09	0	3.22E-05	1.13E-05	2.08E-05	4.80E-08	0	0
29-30	0.0001	3.26E-05	9.91E-06	2.27E-05	2.53E-08	0	0	4.35E-05	1.08E-05	3.26E-05	3.14E-08	0	0
30-31	0.0001	7.83E-05	8.56E-06	6.95E-05	2.67E-07	2.67E-07	0	8.67E-05	8.62E-06	7.78E-05	3.30E-07	0	0
31-32	0.0001	5.37E-05	1.00E-05	4.32E-05	4.82E-07	4.82E-07	0	3.97E-05	8.97E-06	3.03E-05	4.22E-07	0	0
32-33	0.0001	6.51E-05	1.26E-05	5.22E-05	3.05E-07	3.05E-07	0	4.60E-05	9.75E-06	3.59E-05	2.88E-07	0	0
33-34	0.0001	5.02E-05	4.46E-06	4.54E-05	3.58E-07	3.21E-07	0	4.16E-05	4.94E-06	3.65E-05	1.38E-07	0	0
34-35	0.001	3.37E-05	1.72E-06	3.17E-05	3.28E-07	3.19E-07	0	3.16E-05	2.02E-06	2.92E-05	3.12E-07	0	0

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		Total	Size 1	Size 2	Size 3	Size 4	Size 5	Total	Size 1	Size 2	Size 3	Size 4	Size 5
35-36	0.001	3.47E-05	3.12E-06	3.13E-05	2.31E-07	2.17E-07	0	3.36E-05	3.96E-06	2.93E-05	3.14E-07	0	0
36-37	0.001	3.28E-05	3.38E-06	2.94E-05	1.03E-07	9.54E-08	0	3.40E-05	4.20E-06	2.96E-05	1.99E-07	0	0
37-38	0.001	2.84E-05	1.81E-06	2.66E-05	2.54E-08	1.99E-08	0	2.97E-05	2.76E-06	2.69E-05	9.69E-07	0	0
38-39	0.001	2.70E-05	2.25E-06	2.47E-05	2.37E-09	0	0	2.75E-05	2.79E-06	2.47E-05	1.27E-09	0	0
39-40	0.001	2.81E-05	4.81E-06	2.33E-05	1.68E-09	0	0	3.00E-05	6.16E-06	2.38E-05	5.56E-09	0	0
40-41	0.001	1.76E-05	3.15E-06	1.45E-05	5.35E-10	0	0	1.80E-05	3.33E-06	1.47E-05	3.78E-10	0	0
41-42	0.001	8.68E-06	8.95E-07	7.79E-06	1.95E-09	0	0	8.93E-06	7.54E-07	8.18E-06	9.17E-10	0	0
42-43	0.001	9.72E-06	9.64E-07	8.75E-06	4.20E-09	2.89E-09	0	8.44E-06	8.25E-07	7.61E-06	1.43E-09	0	0
43-44	0.001	1.60E-05	1.45E-06	1.44E-05	8.51E-08	8.41E-08	0	1.32E-05	1.14E-06	1.20E-05	9.20E-08	0	0
44-45	0.001	1.66E-05	2.95E-06	1.37E-05	1.18E-08	1.11E-08	0	1.80E-05	2.79E-06	1.52E-05	6.94E-09	0	0
45-46	0.001	1.03E-05	5.31E-06	4.86E-06	1.01E-07	1.00E-07	0	1.03E-05	3.67E-06	6.57E-06	6.66E-08	0	0
46-47	0.001	7.22E-06	2.78E-06	4.39E-06	4.40E-08	4.34E-08	0	6.89E-06	1.46E-06	5.36E-06	8.16E-08	0	0
47-48	0.001	7.96E-06	6.92E-07	7.21E-06	5.50E-08	5.49E-08	0	7.89E-06	4.19E-07	7.40E-06	6.62E-08	0	0
48-49	0.001	6.37E-06	2.39E-06	3.97E-06	3.77E-09	3.76E-09	0	6.86E-06	3.02E-06	3.84E-06	8.81E-09	0	0
49-50	0.001	1.80E-06	1.54E-06	2.61E-07	1.53E-11	0	0	2.70E-06	2.33E-06	3.63E-07	7.85E-09	0	0
50-51	0.001	1.71E-06	1.71E-06	1.56E-09	1.27E-11	0	0	1.34E-06	1.33E-06	5.08E-09	1.27E-08	0	0
51-52	0.001	1.46E-06	1.46E-06	1.56E-09	1.14E-11	0	0	1.89E-06	1.86E-06	4.59E-09	1.95E-08	0	0
52-53	0.001	1.63E-06	1.63E-06	1.22E-09	1.46E-11	0	0	1.14E-06	1.11E-06	4.89E-09	2.77E-08	0	0

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		Total	Size 1	Size 2	Size 3	Size 4	Size 5	Total	Size 1	Size 2	Size 3	Size 4	Size 5
53-54	0.001	7.68E-07	7.67E-07	1.09E-09	1.14E-11	0	0	5.79E-07	5.35E-07	5.96E-09	3.76E-08	0	0
54-55	0.001	3.16E-07	3.15E-07	9.83E-10	9.90E-12	0	0	1.93E-07	1.36E-07	5.62E-09	5.09E-08	0	0
55-56	0.001	2.09E-07	2.08E-07	8.44E-10	1.23E-11	0	0	2.06E-07	9.29E-08	6.44E-09	1.07E-07	0	0
56-57	0.001	1.18E-06	1.18E-06	1.05E-09	1.03E-11	0	0	1.68E-06	1.50E-06	4.93E-09	1.76E-07	0	0
57-58	0.001	1.59E-07	9.85E-08	6.09E-08	1.03E-11	0	0	3.63E-07	7.44E-08	6.30E-08	2.26E-07	0	0
58-59	0.001	2.47E-07	1.75E-07	6.06E-08	1.06E-08	1.06E-08	0	5.18E-07	2.93E-07	3.50E-08	1.91E-07	0	0
59-60	0.001	1.02E-05	1.66E-06	7.55E-06	9.38E-07	9.38E-07	3.80E-08	2.55E-06	7.51E-07	1.39E-06	4.03E-07	8.62E-09	5.63E-10
60-61	0.001	4.43E-05	4.29E-06	3.48E-05	4.78E-06	4.78E-06	0	2.62E-06	2.40E-06	2.07E-05	2.88E-06	2.00E-07	5.81E-08
61-62	0.001	7.08E-06	1.15E-06	5.26E-06	6.21E-07	6.21E-07	3.71E-08	5.02E-05	5.21E-06	3.82E-05	6.31E-06	4.12E-07	2.38E-08
62-63	0.001	2.47E-07	2.08E-07	3.32E-08	1.83E-11	0	5.05E-09	1.50E-05	1.52E-06	1.09E-05	2.57E-06	2.87E-08	0
63-64	0.001	1.04E-06	1.02E-06	1.70E-08	1.89E-11	0	0	3.00E-06	8.09E-07	2.98E-07	1.89E-06	0	0
64-65	0.001	6.42E-07	6.40E-07	2.05E-09	2.33E-11	0	0	4.20E-06	1.95E-06	1.29E-08	2.24E-06	0	0
65-66	0.001	3.72E-07	3.70E-07	2.02E-09	2.77E-11	0	0	2.77E-06	2.06E-07	3.19E-08	2.53E-06	0	0
66-67	0.001	1.29E-06	1.23E-06	5.31E-08	4.09E-11	0	0	2.65E-06	5.45E-07	1.82E-08	2.09E-06	0	0
67-68	0.001	2.19E-07	1.64E-07	5.46E-08	3.58E-11	0	0	1.44E-06	5.30E-07	4.08E-08	8.72E-07	0	0
68-69	0.001	5.46E-07	5.06E-07	3.93E-08	3.36E-11	0	0	9.73E-07	5.39E-07	1.41E-09	4.32E-07	0	0
69-70	0.001	4.05E-08	1.02E-08	3.03E-08	1.06E-11	0	0	1.55E-06	9.37E-07	2.31E-09	6.12E-07	0	0
70-71	0.001	0	0	0	0	0	0	3.71E-07	4.00E-08	1.79E-09	3.29E-07	0	0

It can be seen that, for the West cable, KPs 4 - 23 require additional burial due to the risk from vessel anchors, while KPs 4 – 9 and 13 – 23 require additional burial for the east cable. For these KPs, the burial depth should be sufficient to protect against vessels up to 5,000 DWT (i.e. vessel size categories 1 and 2) as the residual risk for vessels larger than this is smaller than the acceptance criteria.

It is noted that there are some KPs where protection from vessels larger than 1,500 DWT would be sufficient, however it is conservatively assumed that the cable should be protected from vessels larger than 5,000 DWT for all KPs where the anchoring risk is larger than the acceptance criteria.

The results of the probability risk assessment are illustrated in Figure 9.6. Residual risk refers to the risk frequency associated with vessels greater than 5,000 DWT (i.e. size category 3-5).

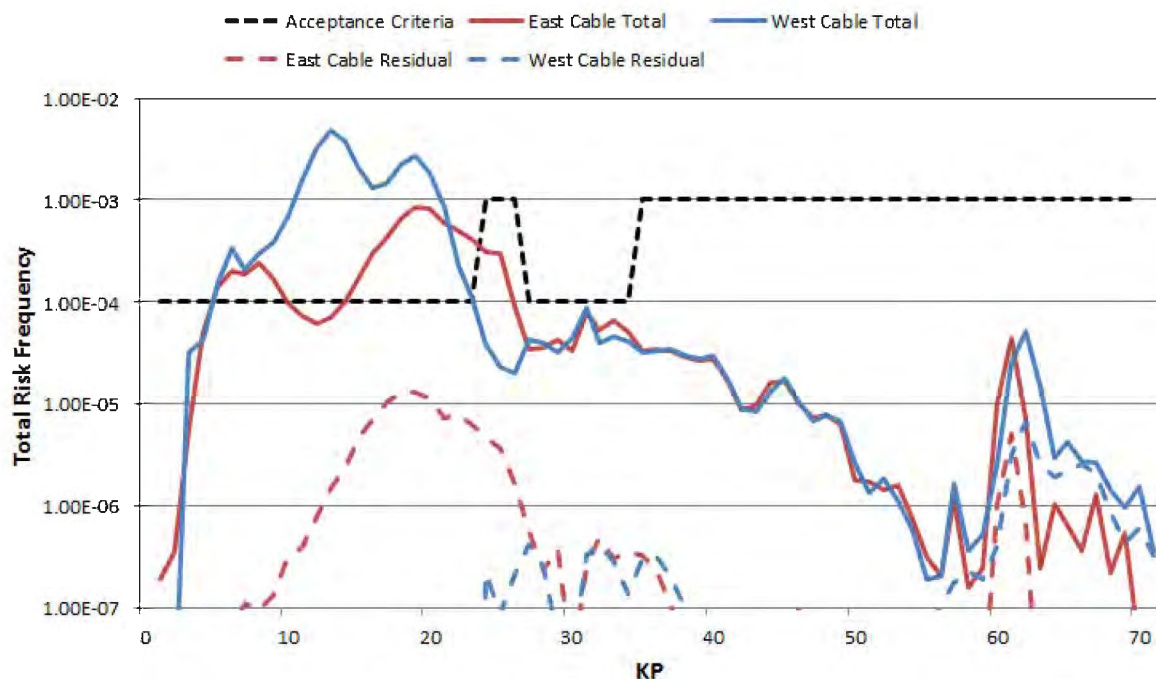


Figure 9.6 Risk Frequency vs Acceptance Criteria

9.6.2 Anchor Penetration Depths

The penetration depth of an anchor depends on the size of the anchor and the seabed type. The size of the anchor generally depends on the size of the vessel. A relationship between vessel DWT and anchor size is provided in Ref i, based on anchor size requirements from the International Association of Classification Societies (IACS). This relationship is presented in Figure 9.7.

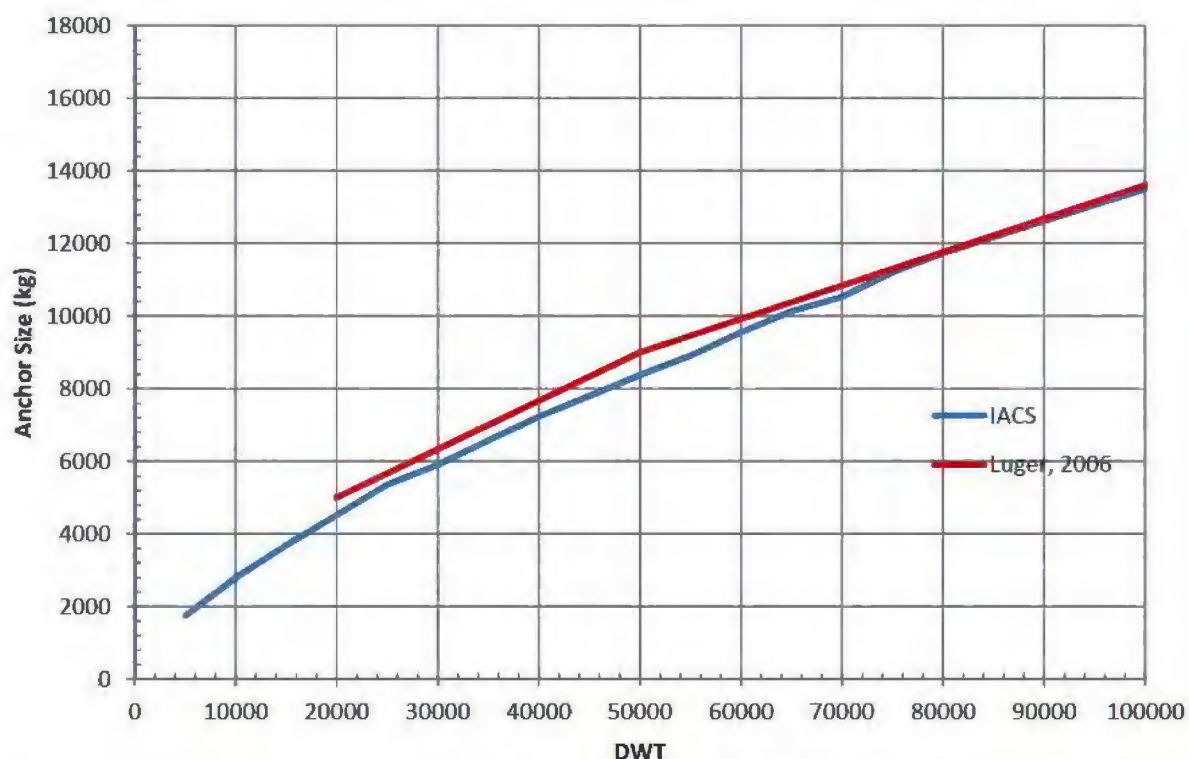


Figure 9.7 Carbon Trust Relationship between DWT and Anchor Size

From this figure, it can be seen that the IACS relationship compares well with anchor sizing proposed by Luger (Ref xiii).

Using information from the manufacturers, the anchor mass can then be used to estimate the fluke length of the anchor, which is closely related to the penetration depth. Figure 9.8 shows a typical anchor design (Ref xiv).

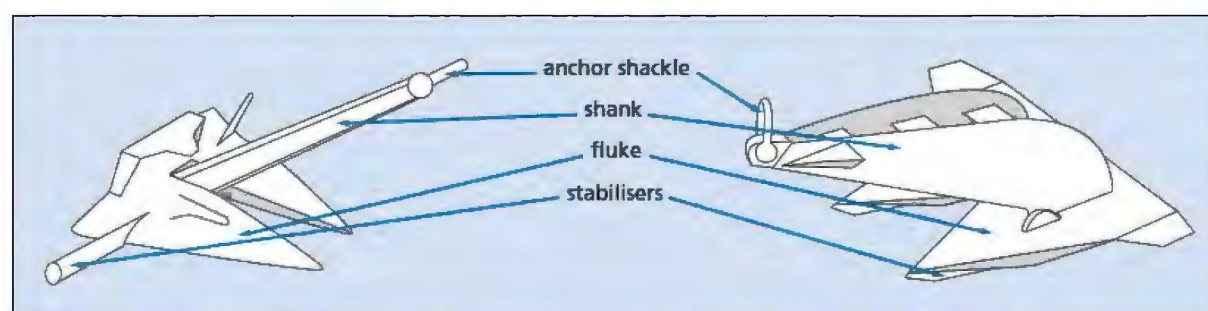


Figure 9.8 Typical Anchor Design

Table 9.4 shows a relationship between vessel DWT, anchor mass and the fluke length for various anchor types. This is based on the Luger relationship and the Vryhof anchor manual (Ref xiv).

Table 9.4 Vessel DWT, Anchor Mass and Fluke Length

Vessel DWT	Anchor Mass (kg)	Fluke Length (m)		
		Vryhof	Danforth	Hall
1,500	2,400	2.1	1.7	1.4
5,000	3,000	2.2	1.9	1.5
15,000	4,500	2.6	2.1	1.7
40,000	7,800	3.1	2.5	2.0
200,000	16,500	3.9	3.1	2.6

The anchor penetration depth depends on the fluke length, the fluke angle and the seabed type. Typical fluke tip penetration depths for an average fluke angle of 32° are presented in Table 9.5.

Table 9.5 Average Fluke Tip Penetration

Vessel DWT	Average Fluke Tip Penetration (m)
1,500	0.7 – 1.1
5,000	0.8 – 1.2
15,000	0.9 – 1.4
40,000	1.1 – 1.6
200,000	1.4 – 2.1

It is noted that, in softer seabed types, the fluke angle may increase to a maximum of 50° (Ref xiv) and the anchor shank may embed into the seabed, giving a larger penetration depth. As discussed in Ref i, work by the US Naval Civil Engineering Laboratory indicates that in sands and stiff clays, the fluke tip penetration is limited to 1 fluke length, while in soft silts and clays, anchor penetration is between 3 and 5 fluke lengths. However it is considered that the suggested penetration depth of 3 to 5 fluke lengths for soft clay is potentially excessive.

Based on the information above, combined with further research on anchor penetration depths, the maximum penetration depths assumed for the CBRA for vessels of size category 1 or 2 (up to 5,000 DWT) are presented in Table 9.6.

Table 9.6 Max Penetration Depths for Varying Seabed Type, Vessels Less Than 5,000 DWT

Seabed Type	Max Penetration (m)
Dense/Very Dense Sand	1.0
Medium Dense Sand	1.2
Loose Sand	1.5
Soft Clay*	2.5

The value for the maximum penetration of vessels up to 5,000 DWT in an average seabed type (i.e. medium dense sand) was assumed to be 1.2, based on the largest fluke tip penetration estimated for average fluke angle of 32°. The penetration depths for denser and looser sands have been assigned taking into account the range of maximum fluke lengths and likely fluke angles, as discussed above.

9.7 Recommended Burial Depths

For the Cable Burial Risk Assessment, the export cable routes were divided into 500m sections, which were subdivided according to the Seabed Features, as presented in Section 9.4. A recommended burial depth was provided for each section, primarily based on:

- Seabed Type, e.g. loose sand/soft clay or dense sand/firm clay
- Existence of mobile sediment (megaripples, sand waves) and likelihood of erosion
- Existence of chalk or bedrock
- Fishing activity
- Shipping Probability Risk Assessment

The burial depth recommendations are presented in the form of a Cable Burial Risk Assessment (CBRA) Spreadsheet for the export cables (Ref xi and xii).

The burial assessment spreadsheets for the export cables provide information on the following, for each section of cable:

- Bathymetry
- Seabed Features
- Seabed Type
- CPT Results
- Shipping Activity
- Fishing Activity
- Anchor Risk

* For areas of seabed identified to contain soft clay, the soft clay was interbedded with loose sand or had a layer of sand above the clay. The penetration depth was therefore assumed to be smaller than soft clay alone

- Threat Line
- Recommended Burial Depth

These are discussed in more detail below.

9.7.1 Bathymetry

This column shows the change in bathymetry along the cable route section based on the bathymetry data supplied by the 2015 Fugro EMU survey, as discussed in Section 9.4.1.

9.7.2 Seabed Features,

The Seabed Features column is based on the results of the Fugro Environmental Engineering Survey carried out in 2015, as described in Section 9.4.2.

9.7.3 Seabed Type

The seabed type column provides a description of the seabed type, which has been determined from the CPT results. For this column, the seabed types have been grouped into 7 categories, as discussed in Section 9.4.4. This information is used to determine the Threat Line for vessel anchors, as discussed below.

The seabed type information is also used to provide information on where there was chalk in the seabed or the maximum penetration depth was less than 1m, as this affects the Recommended Burial Depth for sections without a requirement for protection from vessel anchors.

9.7.4 CPT Results

The CPT results column presents the interpreted results for the CPT that was nearest to the cable route section, which is given in the Nearest CPTs column. Within the CPT Results, the following abbreviations are used:

VL = Very Loose

L = Loose

MD = Medium Dense

D = Dense

VD = Very Dense

9.7.5 Shipping Activity

The Shipping Activity column gives a relative density of shipping based on the number of vessel track intersections per 500m of cable.

The shipping activity descriptions were based on the following definitions:

Low	Less than 20 vessels crossing the cable per 500m per year
Moderate	20-100 vessels crossing the cable per 500m per year
High	100-200 vessels crossing the cable per 500m per year
Very high	More than 200 vessels crossing the cable per 500m per year

The 2015 AIS data was used for KP 0-17, while the 2013 data was used beyond this. Both were factored to an annual value.

This column also gives information on whether the cable section is close to any of the Wash anchorages.

9.7.6 Fishing Activity

The fishing activity descriptions were based on a qualitative analysis of the various sources of fishing data.

9.7.7 Anchor Risk

The ‘Total Anchor Risk Frequency Per KP (Unburied)’ column provides the anchor risk frequency per KP from anchor dragging and emergency anchoring in the unburied case. This is based on the results of the Shipping Probability Risk Assessment in Section 9.6. The ‘Protection from Anchors Required?’ column provides information on whether the cable requires to be buried deep enough to protect against vessel anchors, based on the results of the anchor risk frequency and the acceptance criteria. This is discussed in Section 9.6.

9.7.8 Threat Line

These columns provide the Threat Line associated with fishing, vessel anchors and mobile sediment.

The fishing threat line was assumed to be 0.3m for all sections of cable based on the typical penetration depths of fishing gear.

The Vessel Anchors threat line is 0m for sections of cable that do not require protection from anchors. For cable sections requiring protection from anchors, this depends on the seabed type. The following assumptions were made:

Table 9.7 Vessel Anchor Threat Line Assumptions

Seabed Type	Vessel Anchor Threat Line (m)
Loose sand with soft clay	2.5
Very loose to loose sand	1.5
Very loose/loose becoming dense sand	1.5
Loose becoming very dense	1.5
Medium dense to dense sand / Stiff clay	1.2
Medium dense/dense to very dense sand	1
Chalk / Max penetration less than 1m	1

For the mobile sediment threat line, this information was based on the ABPmer report. The value in the Mobile Sediment threat line column is based on the Estimated Maximum Decrease in Seabed Level, which is subtracted by 0.5m, as discussed in Section 9.4.3.

9.7.9 Recommended Burial Depth

In line with the Carbon Trust guidelines (Ref i), the recommended burial depths are determined based on the risk from fishing, shipping and mobile sediments, following the rules below.

1. The minimum recommended burial depth for the majority of the cable route will be 1m. This is sufficient to protect from fishing gear and a significant proportion of vessel anchors, based on the types and sizes of vessels transiting the area. Exceptions to this rule are sections where the maximum penetration achieved in the CPT was less than 1m (due to chalk or bedrock close to the seabed), where the minimum recommended burial depth is 0.6m.
2. The Recommended Burial Depth is calculated as:

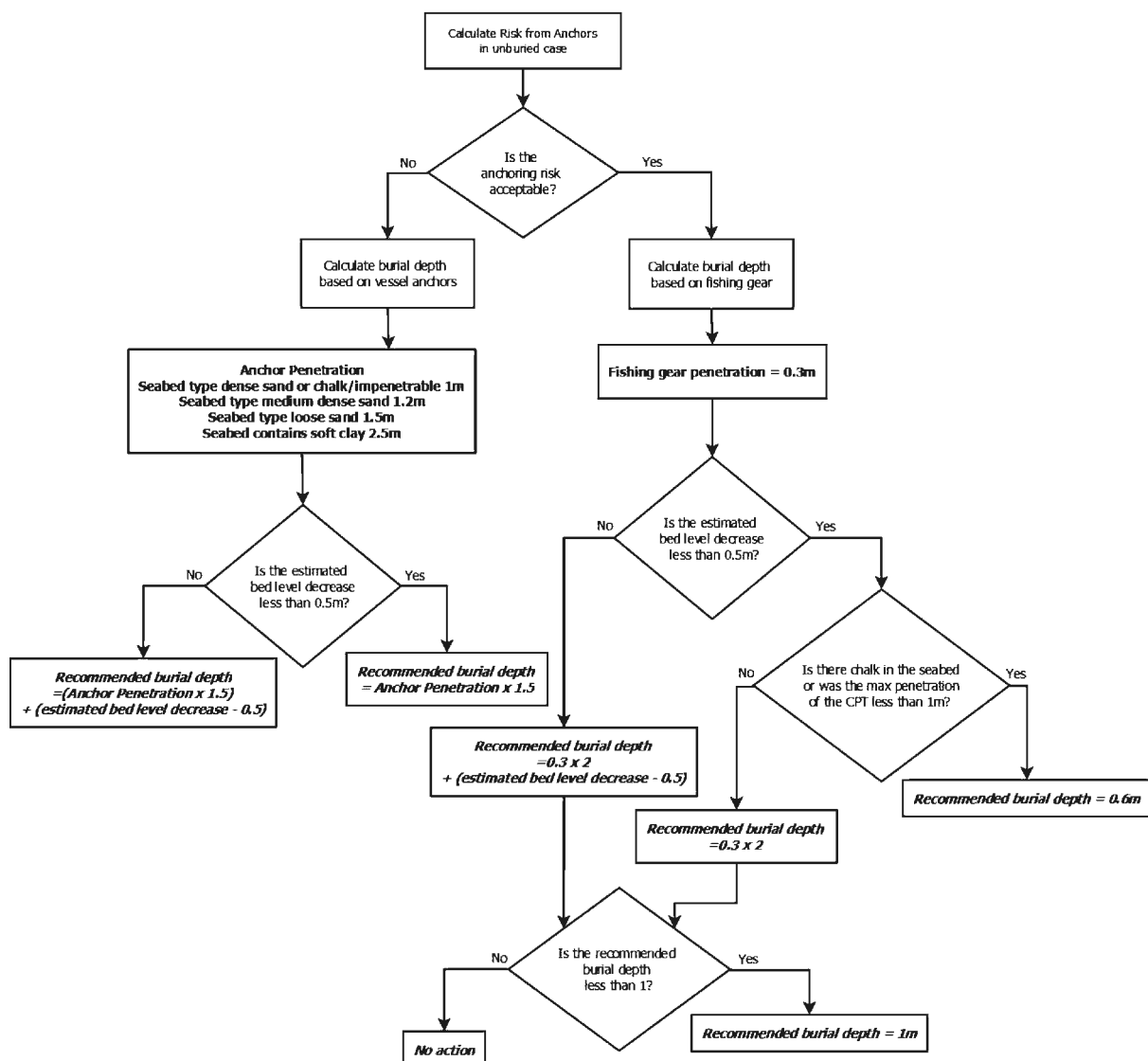
$$\text{Max}[\text{anthropogenic hazard} \times \text{FoS}] + \text{mobile sediment}$$

3. The burial depth required to protect against fishing vessels is 0.3m. Since fishing activity could reduce the level of cover by repeated trawling over the cable, the Factor of Safety (FoS) for fishing risk is assumed to be 2, i.e. minimum recommended burial depth for fishing is 0.6m.
4. The recommended burial depths for sections of cable requiring protection from vessel anchors (for vessels up to 5,000 DWT) are given in Table 9.7. The Factor of Safety for vessel anchors is 1.5.

5. To account for mobile sediment (sand waves, megaripples and erosion), the burial depth, as decided based on fishing and anchoring, should be increased by the maximum estimated decrease in seabed level predicted by ABPmer.*

It should be noted that the target burial depth of the cable within the port limits is required to be agreed with the port authorities of Boston, Sutton Bridge, Wisbech and King's Lynn before cable laying operations begin.

The following diagram illustrates how the Recommended Burial Depth is determined for a cable route section.



* Note that the value given by ABPmer (Table 6) is subtracted by 0.5m to account for the high level of uncertainty and since this is covered by the Factor of Safety used for anchor penetration

An overview of the results of the Cable Burial Risk Assessment is presented in Figure 9.9. For details, refer to the spreadsheets (Ref xi and xii).

It is noted that the CBRA does not impose a maximum limit on the recommended burial depths and therefore, due to the predicted changes in bed level, burial depths of up to 7.5m are recommended. There may be alternative options for such sections of cable, e.g. micro-route the cable to avoid mobile sediment, lower the burial depth and undertake regular monitoring to assess any reduction in burial over time, consider alternative protection measures for the cable.

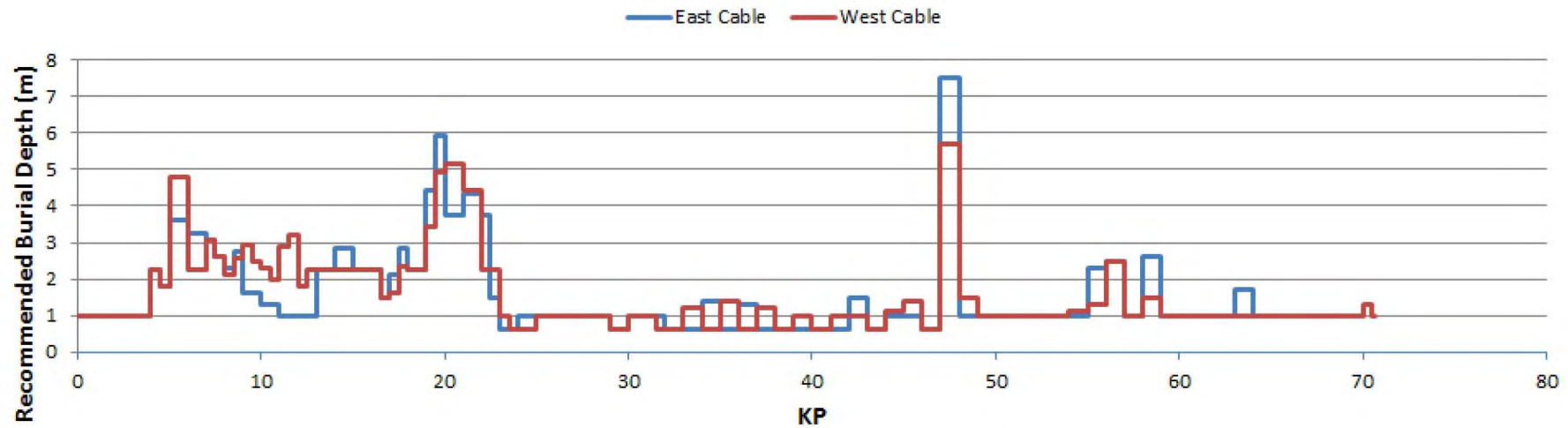


Figure 9.9 Recommended Burial Depths, East and West Export Cable Routes

10. Conservatism

It has been noted throughout this report that there were a number of conservatisms used in the burial risk assessment. These are described in the following table.

Parameter	Conservatism
Factoring of Shipping Data	The anchoring risk assessments were based on a combination of 2013 and 2015 shipping data. At the request of the Port Authorities, the 2013 data was factored by 20% to account for this being a quiet year.
Anchor Dragging – Time to Recover	Anatec's model uses a default of 15 minutes. For this report it was increased to 30 minutes, at the request of the Port Authorities.
Soft Clay	It was assumed that the penetration depth for soft clay was 2.5m. However, for all areas of seabed identified to contain soft clay, there were shallow layers of soft clay interbedded with sand of varying density. It is therefore considered that the penetration depths are likely to be lower than this.
Threat Line for Anchors	For areas where the anchoring risk was deemed to be unacceptable, based on the acceptance criteria, it was recommended that the cable be buried to a depth that gives protection from vessels up to 5,000 DWT. This is conservative in some of areas (e.g., KP 4-8), where the anchor risk for vessels greater than 1,500 DWT was acceptable, indicating that the cable would only require protection from vessels smaller than 1,500 DWT in these areas.
Acceptance Criteria	Initial acceptance criteria provided by DONG Energy of 1 in 1,000 years were increased to 1 in 10,000 years based on requirement from the Port Authorities

11. Conclusions and Recommendations

This report has presented a detailed assessment of the risks to the export cables associated with the Race Bank Offshore Wind Farm. The assessment considered a range of natural and anthropogenic hazards.

The risks associated with all hazards were reviewed at a Hazard Workshop and ranked in terms of frequency and consequence, assuming embedded mitigations were in place. The results of the hazard workshop are presented in Section 6.

11.1 Natural Hazards

For the natural hazards, information from geophysical and geotechnical surveys, as well as the results of the hazard workshop, were used to provide a qualitative assessment of risks to the cables, as described in Section 7.

The information on mobile sediments (including erosion, as well as sand waves and megaripples) and existence of chalk or bedrock were used as input to the Cable Burial Risk Assessment (CBRA) for the Race Bank cables.

The information on natural hazards was based on the latest available geophysical and geotechnical surveys and other relevant studies, as discussed in Section 9.3.

11.2 Anthropogenic Hazards

For anthropogenic hazards, the risk was assessed using real-time AIS (Automatic Identification System) shipping data. The risk assessment included an analysis of shipping activity near the cable routes to identify high risk areas of activity for fishing, military, leisure and offshore vessels. In addition, a quantitative risk assessment to analyse the frequency of risk from vessels dragging anchor or anchoring in an emergency, and from vessels foundering, was also undertaken.

The results of the quantitative assessments showed that the majority of the risk to the cable is from vessels dragging anchor over it. The total annual frequency of a vessel dragging anchor over any part of the export cable, if the cable is unburied (i.e. worst case scenario), was 3.11×10^{-2} , or one incident every 32 years. If traffic using the new Wisbech Channel was taken into account, it was estimated that an incident of a vessel anchoring over the cable in an emergency would occur once per 262 years. A vessel foundering over the cable was estimated to occur once every 968 years based on the updated Wisbech traffic patterns. The frequency of contact was seen to depend on the burial depth of the cable.

The total risk from anchor dragging and emergency anchoring by vessel size per KP along the cable routes is provided in Table 9.3.

The consequences of anthropogenic hazards were determined based on hazard workshop discussions. It was seen that the anthropogenic hazards generally presented a moderate to serious consequence for the risk to business i.e. the cable.

The results of the anthropogenic risk assessments were used to inform the burial assessment, in order to recommend target burial depths along the export cable.

11.3 Cable Burial Risk Assessment (CBRA)

A comprehensive CBRA was undertaken for the Race Bank export cables, as described in Section 9. The methodology was in line with guidelines issued by the Carbon Trust and takes into consideration various factors, including seabed type, sand waves, megaripples, shipping and fishing activity, nearby anchoring, etc. Detailed results of the assessment are presented in the appendices, Ref xi and xii, and the recommended burial depths per KP are summarised in Figure 9.9.

A number of conservatisms were assumed for the CBRA, mainly based on discussions with the Port Authorities. These are described in Section 10.

11.4 Recommendations

Based on the results of the risk assessment, the following recommendations are made:

- The burial depth recommendations are based on the best data available to Anatec at the time, however there are some limitations to the data. This should be taken into account during cable installation, with consideration given to updated surveys and accessibility to suitable installation equipment.
- The export cable should avoid being routed close to The Well.
- The target cable burial depths should take into consideration the CBRA provided in Section 9 and Refs xi and xii.
- Target burial depths within the Wash port limits should be agreed with the Port Authorities.
- Alternative options for sections of cable with large recommended burial depths may be considered, e.g. micro-routeing the cable to avoid mobile sediment, lowering the burial depth and undertaking regular monitoring to assess any reduction in burial over time, consideration of alternative protection measures for the cable.
- Where the proposed burial depth has not been achieved, e.g. due to till or chalk in the seabed, seabed obstructions, etc., consideration should be given to alternative protection methods, e.g. rock dump, concrete mattresses.
- Consideration should be given to applying additional protection measures, e.g. rock dump, concrete mattresses or further burial, to sections of cable considered to present a significantly high risk.

12. References

- i “Cable Burial Risk Assessment Methodology, Guidance for the Preparation of Cable Burial Depth of Lowering Specification”, Carbon Trust, February 2015.
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- iii “Race Bank Cable Risk Assessment Rev01, Appendix A – Shipping Analysis”, A3656-DONG-RA-01, Anatec Ltd, November 2015.
- iv “Race Bank Offshore Wind Farm Cable Risk Assessment, Hazard Workshop Report”, A3398-DONG-HL-01, Anatec Ltd, April 2014.
- v “Race Bank Cable Risk Assessment Rev01, Appendix B – Anchoring Assessment Methodology”, A3656-DONG-RA-01, Anatec Ltd, November 2015.
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- ix “Race Bank and Docking Shoal Offshore Wind Farms, Metocean Modelling”, HR Wallingford, August 2010.
- x “Met Office Weather Data Holbeach 34 Year Period”, Spreadsheet dated October 2014.
- xi “Race Bank CBRA East Cable”, A3656-DONG-APP-01, Anatec Ltd, November 2015.
- xii “Race Bank CBRA West Cable”, A3656-DONG-APP-02, Anatec Ltd, August 2015.
- xiii “Developments in Anchor Technology and Anchor Penetration in the Seabed; Anchoring and Anchor Protection”, Luger, D., Delft Hydraulics, 2006.
- xiv “Anchor Manual 2010, The Guide to Anchoring”, Vryhof Anchors, 2010.