DESK STUDY FOR POTENTIAL UXO CONTAMINATION HESSELØ EXPORT CABLE ROUTE

Risk Assessment and Mitigation Strategy

Report Ref: EES1129
Report Number: R-02-01

Desk Study for Potential UXO Contamination – Hesselø Export Cable Route

Rev 01
29th January 2021

Document status

Version	Purpose of document	Authored by	Reviewed by	Approved by	Review date
00	Report	Robert Mills	Kara Stevenson	Victoria Phillips	15/12/2020
01	Client Comments	Robert Mills	Kara Stevenson	Victoria Phillips	29/01/2020

Approval for issue

Victoria Phillips		29 January 2021

ISO Accreditation

RPS Explosives Engineering Services are ISO 9001:2015 accredited to provide Explosives Safety Management Services and Detection of Conventional Explosives WSCS-OCE.

Prepared by:

Robert Mills

RPS Explosives Engineering Services
Unit 14, 2 New Fields Business Park
Stinsford Road
Poole
Dorset
BH17 0NF
Tel: +44 (0)1291 645 011
www.rpsuxo.com

Reviewed & Authorised By:

Victoria Phillips

RPS Explosives Engineering Services
Unit 14, 2 New Fields Business Park
Stinsford Road
Poole
Dorset
BH17 0NF
Tel: +44 (0)1291 645 011
www.rpsuxo.com

CONTENTS

Tables

Figures

Appendices

ABBREVIATIONS

Abbreviation	Definition
ACT	Air Combat Training
ALARP	As Low As Reasonably Practicable
AOI	Area of Interest
CPT	Cone Penetration Test
DGPS	Differential Global Positioning System
EOD	Explosive Ordnance Disposal
EU	European Union
GY	German EMC/EMG mine
HE	High Explosive
ID&C	Identification and Clearance
INS	Inertial Navigation System
kg	Kilogram
kHz	Kilohertz
km	Kilometre
LAT	Lowest Astronomical Tide
m	Metres
MBES	Multibeam Echo Sounder
ML	Muzzle Loading
mm	Millimetres
MoD	Ministry of Defence
MSL	Mean Sea Level
OSPAR	Convention for the Protection of the Marine Environment of the North East Atlantic
PLGR	Pre-Lay Grapnel Run
pUXO	Potential UXO
RAF	Royal Air Force
ROV	Remotely Operated Vehicle
QA	Quality Assurance
QC	Quality Control
SAA	Small Arms Ammunition
SIT	Surrogate Item Trial
SSS	Side Scan Sonar
UK	United Kingdom
UKHO	United Kingdom Hydrographic Office
USBL	Ultra-Short Base Line
UXO	Unexploded Ordnance
WSCS-OCE	Work-Specific Certification Scheme for the Detection of Unexploded Objects
WWI	World War One
WWII	World War Two

EXECUTIVE SUMMARY

Background

RPS has been commissioned by Energinet to conduct a desktop study for potential Unexploded Ordnance Contamination in the vicinity of the Hesselø Offshore Wind Farm and Export Cable Route. This report focuses on the risk posed to the Export Cable Route.

The Area of Interest is the area surrounding the Hesselo Windfarm Export Cable Route in the Kattegat region of the Baltic Sea, between Denmark and Sweden. The Northern tip of the site lies approximately 20 km South East of the island of Anholt. The export cable routes extend south west from the wind farm site, making landfall near the town of Smidstrup, approximately 50 km North of Copenhagen.

The principal aim of RPS, for this report, is to provide the client with an appropriate and pragmatic assessment of the risks posed by Unexploded Ordnance to the Export Cable Route, in order to identify a suitable methodology for the mitigation of any identified risks to an acceptable level in accordance with the 'ALARP' Principle.

UXO Risk Level

Based on the conclusions of the research and the risk assessment undertaken, RPS has found there to be a varying **Low** and **Moderate** risk from encountering Unexploded Ordnance on site. The risk is primarily due to the presence of Allied Mine Fields from World War Two.

RPS also take in to account the category of Unexploded Ordnance both when assessing the probability of the item functioning and the consequence of such an event. This leads to the varying risk levels between munitions with the same installation methodology. The full risk matrices are presented in **Appendix 7** providing an assessment of the risk associated with each activity.

UXO		Risk Zones							
		Zone A	Zone B	Zone C	Zone D	Zone E	Zone F	Zone G	Zone H
Small Arms Ammunition		Low	Low	Low	Low	Low	Low	Low	Low
Land Service Ammunition		Low	Low	Low	Low	Low	Low	Low	Low
≤155 mm Projectiles		Low	Low	Low	Low	Low	Low	Low	Low
≥155 mm Projectiles		Low	Low	Low	Low	Low	Low	Low	Low
HE Bombs	Allied Origin	Low	Low	Low	Low	Low	Low	Low	Low
HE Bombs	Axis Origin	Low	Low	Low	Low	Low	Low	Low	Low
Sea Mines	Allied Origin	Low	Low	Mod	Mod	Low	Mod	Low	Low
Sea Mines	Axis Origin	Low	Low	Low	Low	Low	Low	Low	Low
Sea Mines	Axis Origin (Non-Ferrous)	Low	Low	Low	Low	Low	Low	Low	Low
Torpedoes		Low	Low	Low	Low	Low	Low	Low	Low
Depth Charges		Low	Low	Low	Low	Low	Low	Low	Low
Conventional Dumped Munitions		Low	Low	Low	Low	Low	Low	Low	Low
Dumped Chemical Munitions		Low	Low	Low	Low	Low	Low	Low	Low
Missiles/Rockets		Low	Low	Low	Low	Low	Low	Low	Low

Table 0.1 - Overall Risk Levels

Burial

The seabed sediment noted throughout the site appears to consist mainly of sands and muddy sands, with isolated areas of glacial till. In the softer sediments it is possible for munitions to be scoured by currents and subsequently become buried. This is dependent on the mass, dimensions/shape of the item and the sediments upon which it came to rest as well as the currents affecting the area, however the maximum burial depth due to scour is approximately equal to the diameter of the munition.

An additional potential cause of burial on the Hesselo Export Cable Route is the liquefaction phenomenon, a consequence of the earthquakes that have affected the area, as explained in **Section 2.3.4**. To confirm or discount this process as a burial pathway, RPS would require further geotechnical information such as Cone Penetration Testing data to analyse the seabed sediment and subsurface geology to determine the likelihood of liquefaction causing burial of Unexploded Ordnance.

Recommendations

Based on the identified risk levels, it is recommended that appropriate mitigation is implemented to reduce level of risk associated with identified moderate risk activities, prior to and/or during geotechnical or installation operations. The methods of mitigation that are recommended for the route are outlined in greater detail in the report **(Section 7)**, including both Proactive and Reactive methodologies.

Based on anticipated site conditions and barring unknown factors (for example fishing trawling) bringing Unexplode Ordnance on to site, mobility should be limited. As such, RPS would give an **ALARP validity of 5 years from the date of the mitigation/survey taking place**.

This sign-off would advise whether residual risk mitigation is required, which would be finalised after the mitigation is completed.

1 INTRODUCTION

1.1 Instruction

RPS has been commissioned by Energinet to conduct a desktop study for potential Unexploded Ordnance Contamination in the vicinity of the Hesselø Offshore Wind Farm and Export Cable Route. This report focuses on the risk posed to the Export Cable Route. A site location map has been presented in **Appendix 1**.

1.2 Scope of Work

The following facets will be covered within this report:

- ***UXO Risk Analysis:*** Assessment of the specific military, former military and UXO related activities that have taken place within the vicinity of the project area. Additionally, to review any previous UXO clearance/mitigation operations that have already taken place. Then, to assess the risks which the identified UXO types present to the installation/survey activities.
- ***Recommendations:*** Based on the outcome of the assessment, RPS will recommend appropriate mitigation measures that should be taken to allow works to proceed safely and with minimal disruption. The recommendations will be designed to reduce the risk on site to 'ALARP'.

This report focuses on historical activities that occurred within the proposed Area of Interest and its immediate surroundings, with respect to the likelihood of encountering potential UXO.

1.3 Definitions

The terms 'Site' or Area of Interest ('AOI') refer to the area within the extent of the works associated with the Export Cable Route, illustrated in **Appendix 1**.

Selected terminology referred to throughout this report is documented in **Appendix 2.**

1.4 Aims

The principal aim of RPS, for this report, is to provide the client with an appropriate and pragmatic assessment of the risks posed by UXO to the Export Cable Route, in order to identify a suitable methodology for the mitigation of any identified risks to an acceptable level in accordance with the 'ALARP' Principle. The 'ALARP' Principle is clearly defined in **Appendix 3.**

1.5 Reporting Conditions

This study consists of a desk-based collation and review of available documentation and records relating to the possibility of UXO being present within the AOI. Certain information obtained for the purposes of this study is either classified, restricted material or considered to be confidential to RPS. Therefore, summaries of such information have been provided.

It must be emphasised that this desk study can only indicate the potential for UXO to be present. Further geophysical surveys and target investigation may be necessary to provide confirmation of the presence of UXO and the actual risks involved.

Note: Our appraisal relies on the accuracy of the information contained within the documents consulted. Although the accuracy has been deemed suitable after review. RPS will in no circumstances be held responsible for the accuracy of such information or data supplied.

1.6 Sources of Information

The main sources of information consulted by RPS for this report were obtained from within the public domain. Additional sources reviewed are below:

- RPS Archives;

- Military Archives;
- National Archives;
- Historic Maps, Aerial Photographs and Records;
- Internet Research;
- European Marine Observation and Data Network (EMODnet); and
- United Kingdom Hydrographic Office (UKHO).

1.7 Legislation

Whilst undertaking this desk study, the requirements of various legislation has been considered the details of which can be found within **Appendix 4**

2 SITE DETAILS AND DESCRIPTION

2.1 Area of Interest

The Area of Interest is the area surrounding the Hesselo Windfarm Export Cable Route in the Kattegat region of the Baltic Sea, between Denmark and Sweden. The Northern tip of the site lies approximately 20 km South East of the island of Anholt. The export cable routes extend south west from the wind farm site, making landfall near the town of Gilleleje, approximately 50 km North of Copenhagen.

A site location map has been presented at **Appendix 1***.*

2.2 Proposed Scheme of Work

The exact Export Cable installation methodologies are not known at this time, however they are anticipated to include the following activities:

- Cable Lay;
- Ploughing;
- Vessel Mounted Jetting;
- Tracked Vehicle Jetting;
- Tracked Mechanical Trencher;
- Dredging;
- Anchoring;
- Jack Up Operations;
- Rock Placement;
- Mattress Installation;
- Pre Lay Grapnel Run (PLGR);
- Cone Penetration Testing (CPT);
- Grab Sampling; and
- Snag on Vessel.

2.3 Geology and Bathymetry

2.3.1 Bathymetry

The wind farm will be located on the southern end of a large depression that continues to the north, between the east coast of Sweden and the island of Anholt. Evidence of palaeochannels assumed to be estuaries from the Early Holocene feeding in from the south into the depression are visible in MBES data.

The water depth is at a maximum of 33.5 m on the eastern side of the wind farm site, including the cable route to OSS-1. Due to the various palaeochannels the water depth remains variable from the wind farm until the two cable routes connect, at which point the water begins to shallow steadily to the shore.

2.3.2 Deglaciation

The recent geology of the area is shaped largely by the previous glaciation of the area, and importantly the glacial retreat. The isostatic rebound and eustatic change caused by this retreat has led to variable sea levels, ranging from approximately +37.5 m to -37.5 m below Mean Sea level (MSL) in the last 14 ka. Currently the projection suggests that the sea level in the project area is following a downward trend, having reduced approximately 15 m in the last 4 ka. This reduction in sea level may cause an overall flow of sediment-transporting water from the early Holocene estuaries to the south into the basin. A metocean study of the site completed by RPS shows that there is a net outflow of water from the Baltic Sea through the Kattegat into the North Sea, with the general current direction being described as “Northwest through East”. However, when considering the timescales relevant to this report, any potential sedimentation rate is expected to be negligible.

2.3.3 Seabed Sediment

The majority of the main site is covered with muddy sand, over which the northern cable route to OSS-1 runs. To the south of the site, the mud clears up leaving a small pocket of sand, which reappears along the OSS-2 cable route where the two routes separate, and also closer to the shore where both routes cross a sandy patch.

The route crosses an area of till in the nearshore area up to the Danish coast. This same till is also present for a very short section along the OSS-2 route, although this is only on the very edge of the survey area.

2.3.4 Faults

This area of the Baltic Sea is heavily faulted, with 2 major faults roughly following the offshore half of the export cable routes and another crossing the route striking East-West. These are strike-slip faults, meaning there is fairly frequent earthquake activity. At least three earthquakes with a magnitude >3.0 on the Richter scale have been recorded since WWII. These were in 1985 (M_L= 4.6), 1986 (M_L= 4.2), and 1990 (M_L= 3.3).

Although the major system is strike-slip, some transtensional faulting is observed in the transition area, known as the Sorgenfrei-Tornquist Zone. This type of faulting can cause both uplifted areas (rhomb horsts) or depressions (rhomb grabens), which on a larger scale extend to pull-apart basins. This can further add to the variability of the sea level in this area.

Earthquakes are also known to cause a phenomenon known as ‘liquefaction’, where vibrations cause water-saturated sediments to act as a liquid. In severe cases, this process has been known to cause cars and buildings to ‘sink’ on what was thought to be solid ground. RPS has reviewed CPT data which has helped to ascertain the maximum burial, the potential burial risk caused by this phenomenon is detailed further in **Section 4.2**.

3 UNEXPLODED ORDNANCE RISK ANALYSIS

The AOI is associated with a series of historical military activities that have caused a legacy of UXO-related contamination within the region. Therefore, activities that interact with the seabed are at a potential risk from UXO. Based upon the research carried out, it has been possible to determine the categories of potential ordnance that could have been deployed or are confirmed to have been deployed within the cable routes.

For the sake of completeness, all possible sources of UXO contamination have been considered and are summarised in the subsequent paragraphs.

The figures throughout **Section 3** will only illustrate the individual UXO features being discussed in that figure; additional sources of UXO which may be present in the same area are not necessarily shown. A full UXO Features map, that provides a comprehensive illustration of identified sources of potential UXO is presented at **Appendix 5.**

3.1 Defined Area of Research

The AOI encompasses a geographic surface area that equates to an estimated 2,200 km^2. This area is located in the southern section of the Kattegat Sea and extends to landfall near Gilleleje. This area will be the focus of the research; although, if UXO features at a greater distance are determined pertinent to the Desktop Study, they will be incorporated into the report. On these occasions, the distance between the AOI and the UXO feature will be specified.

3.2 Naval Surface Engagements

The Kattegat Sea did not experience a significant naval battle in either World War One (WWI)(1914 – 1918) or World War Two (WWII)(1939 – 1945). However, it has been identified that the Kattegat was essential in the movement of German U-boats across the periods of conflict. As a result, actions were taken by the Allied Forces (*minelaying*) to restrict this movement and on multiple occasions, confrontation ensued between the alternate parties.

3.2.1 WWII Naval Conflict

An examination of the British Mining Operations 1939 – 1945 (Vol 2) publication (Ministry of Defence, 1977) indicates that a number of German (WWII) military convoy / vessel routes dissect the AOI.

3.2.2 Other Conflicts

No additional historical confrontations are understood to have a significant influence on the UXO-related risk encountered within the site boundaries.

3.3 Naval Mining Operations

The Swedish Maritime Administration, or Sjöfartsverket, has identified that "*The Baltic Sea probably contains the world's largest concentration of munitions (mines, bombs, torpedoes, etc) from the two world wars where mines were the dominant naval weapon*". In the Baltic Sea and adjacent seas, an estimated 165,000 mines were laid. The variants of mine used in the Baltic Sea include contact and remote sensor triggered mines.

With regards to remote sensor triggered mines, "*Around 15-30% (50,000) are reckoned to be still lying on the sea bed mainly in The Quark, the area between Skagen and the Swedish mainland…*" (Sjöfartsverket, 2020).

3.3.1 German WWI Mined Areas

Research by Ostergaard (2020) has identified that Lynaes Fort was established to protect minefields in the Isefjord inlets. The fortification is located within a 0.1 km radius of the AOI. No further information has been sourced to indicate the specifications and location of the mines.

3.3.2 German WWII Mined Areas

The nearest identified German (WWII) offshore minefield is located at the entrance to the Kattegat, between Skagen (Denmark) and Hono (Sweden). The minefield is located an estimated 200 km north of the AOI. Therefore, they are not considered a risk to the site.

A publication by the Bureau of Ordnance (1946) describes how 100 A3 acoustic units (with EMF case) were laid for a test within the Kattegat. *"…Almost all of them simultaneously premature*d" (Bureau of Ordnance Publication, 1946). No further evidence has been found to determine where these test mines were laid, but due to the premature detonations they are not considered a risk to the site.

3.3.3 British WWI Mines Areas

In 1918, the British Royal Navy became aware that the German U-boats were utilising the Kattegat as an alternative to the Bight. Research indicates that the Royal Navy commenced operations to sow minefields in the Kattegat. No additional information has been identified to indicate the exact location of the minefield and the types of mine utilised.

On the other hand, contradictory evidence has been identified to suggest that the Kattegat did not experience a British naval minelaying operation in WWI. A publication by Black (2005) has identified that there was a significant mine shortage after the completion of the Northern Barrage, a minefield in the North Sea. In addition to this shortage, the document cites a political motive to abstain from the mining of the Kattegat. The decision to mine the Kattegat could have antagonised the nation of Sweden, causing them to enter the war.

3.3.4 British WWII Mined Areas

On the 4th May (1940), 50 Mk XVI mines were laid by the HMS Seal (N37) in the southern Kattegat. No information has come to light to indicate the precise location of the minelaying activities.

On the 8th April (1940), submarines of British and French origin laid a number of minefields in the Kattegat, Skagerrak and the North Sea. The minefields were laid to restrict the transfer of iron ore from Norwegian harbours to German dockland. In total, 19 submarines were in operation within the Kattegat and the Skagerrak.

In April (1940), the HMS Narwhal laid a minefield of 50 mines to the north of Læsø Island. The island is located 140 km to the north of the site boundaries. On the 13th April (1940), the HMS Narwhal laid the minefield FD 5 (50 mines) in the Kattegat. The minefield is located an estimated 115 km north west of the site boundaries. On the 1st May (1940), the HMS Narwhal laid the minefield FD 6 (50 mines) in the Kattegat. The minefield is located an estimated 180 km north west of the AOI.

3.3.5 Other Mined Areas

A Sailing Directions (Planning Guide) for the North Atlantic Ocean and Adjacent Seas indicates that there are a number of mined areas within the AOI that have a residual danger of bottom mines (National Geospatial-Intelligence Agency, 2014).

The mined areas that contaminate the AOI have been detailed at *Table 3.1*.

Owner	Period	Area of Contamination	Location	Details
Denmark	Undisclosed	0.5 km^2	7 km to the east of Englandshuse	Residual danger of bottom mines.
Denmark	Undisclosed	6 km^2	13 km north of Rageleje	Undisclosed
Denmark	Undisclosed	33 km^2	18 km north of Smidstrup	Residual danger of bottom mines.
Denmark	Undisclosed	8 km^2	125 km north of the Nodebohuse	Residual danger of bottom mines.

Table 3.1 - Other mined areas that contaminate the AOI.

**Although the National Geospatial-Intelligence Agency data recognises the Danish as the (owner) of the mined areas, it is feasible that the bottom mines could be associated with the Allied forces. This stance is attributed to the fact that the mined areas are located within the greater-Silverthorne mine garden.*

The areas of contamination can be observed in relation to the AOI at **Appendix 5**.

3.4 Aerial Mining Operations

After an examination of the British Mining Operations 1939 – 1945 (Vol 2) publication (MoD, 1977), it is evident that the AOI overlies an estimated 2,000 km^2 of the '*Silverthorne*' air minelaying area, or mine garden. The area of contamination is located in the Kattegat, with minor contamination experienced at the southern section of the AOI. This section includes the Ise Fjord and a significant portion of the Hesselø Bugt.

The Silverthorne mine garden was divided into a number of sub-sections by the Royal Air Force (RAF) Bomber Command. The sub-sections that contaminate the AOI have been detailed in *Table 3.2*.

Name	Period	Area of Contamination	Details
Silverthorne 12	WWII	1,050 km^2	Potential for 1,800 lb bombs Potential for Magnetic / Acoustic Mines (1,500 lb)
Silverthorne 13	WWII	850 km^2	Potential for 1,800 lb bombs Potential for Magnetic / Acoustic Mines (1,500 lb)
Silverthorne 14	WWII	100 km^2	Potential for 1,800 lb bombs Potential for Magnetic / Acoustic Mines (1,500 lb)

Table 3.2 - Sub-sections of the Silverthorne mine garden that contaminate the AOI.

As detailed in *Table 3.4*, OSPAR records indicate that a number of A Mk 1-4 and A Mk 6 ground mines have been identified within the AOI. Additional research has identified that this is just a fraction of the ground mines found within the Area of Interest. Significant concentrations of ground mines have been identified in the north western corner of the AOI and in a consistent across the central section of the AOI. RPS has observed a correlation between the convoy routes discussed at **Section 3.2.1** and the distribution of ground mines.

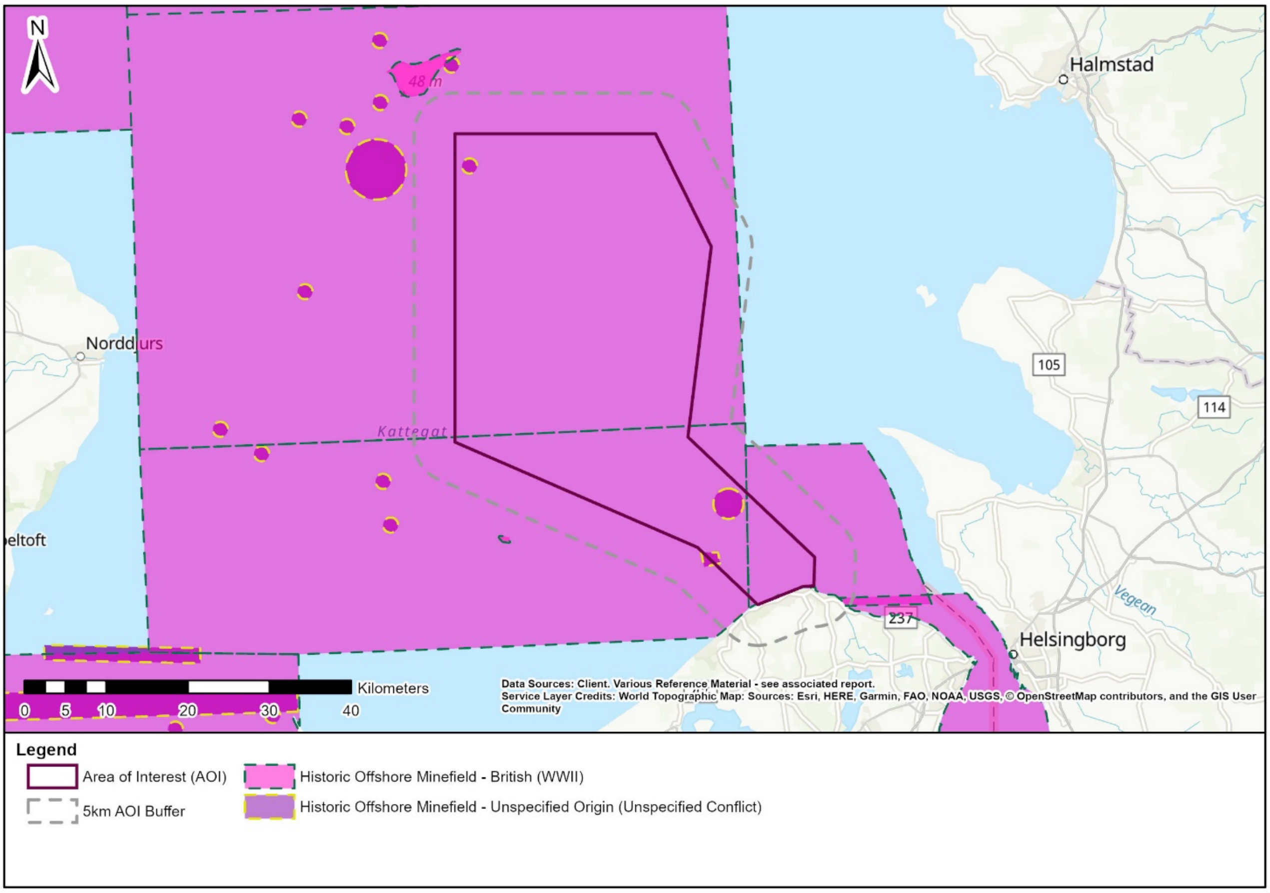


Figure 3.1 - Allied Aerial Mining area

Figure 3.1 shows that the extent of the allied mining areas covers the entirety of the AOI suggesting a mining risk is present throughout the site. However, further detailed research has identified the location of specific locations where mines were dropped. This has been used to massively reduce the size of the risk area and accurately constrain the risk so the smallest possible area of the AOI is affected. The updated extent of the presence of ground mines dropped by the RAF can be observed at **Appendix 5**.

On the 13th December (1944), 6 bomber aircraft of No.166 Squadron and No.103 Squadron deposited mines in the Kattegat. Each aircraft carried 6 x 1,800 lb mines.

On the 4th February (1945), No. 153 Squadron of the RAF participated in an air minelaying operation in the Kattegat. The operation utilised 5 bomber aircraft to drop 6-Airbourne Magnetic / Acoustic Mines at an unspecified area south of the Islands of Anholt and Læsø. The mines deposited were 9 ft in length, with a diameter of 18 in and a weight of 1,500 lb. The explosive charge of the device had a weight of 740 lb.

Research indicates that air minelaying operations were undertaken in the Kattegat on the 13th / 14th March (1943) and the 28th / 29th April (1943). No information has been identified on the variants of mine deposited.

The area of contamination can be observed in relation to the AOI at **Appendix 5**.

3.5 Aerial Conflict

Limited accounts have been identified of aerial combat (between aircraft) above the Kattegat and Denmark in general. However, on a number of occasions, ships and U-boats in the Kattegat were subject to attacks via strafing, rocket-fire and depth charge depositing from military aircraft.

3.5.1 WWI Aerial Conflict

No evidence has been examined to suggest the AOI experienced aerial combat in the period.

3.5.2 WWII Aerial Conflict

On the 19th April (1945), the German submarine (U-251) was sunk by rockets and strafing from British and Norwegian Mosquito aircraft (Squadron 143, 235 and 248). The submarine was equipped with 5 x 21” torpedo tubes, 14 torpedoes, 1 x 3.46” SK C/35 naval gun, 220 rounds and 2 x 0.79” C/30 anti-aircraft guns. Research indicates that the wreck is located in the northern section of the AOI, at: 655025.2 E 6250088.9 N (ETRS 89 UTM Zone 32N) (uboat.net, 2020). The wreck has not been identified in UKHO datasets; therefore, the discovery has been excluded from **Section 3.8**.

On the 5th May (1945), U-534 was attacked with depth charges from a number of British Liberator bomber aircraft. Research indicates that the wreck is located an estimated 15 km north of the AOI, at: 655316.3 6259012.5 (ETRS 89 UTM Zone 32N) (uboat.net, 2020). The wreck has not been identified in UKHO datasets; therefore, the discovery has been excluded from **Section 3.8**.

3.6 Bombing Campaigns

Limited accounts have been identified of scheduled air-raids on the Danish mainland. On these occasions, the significant urban centres of Denmark have been the target e.g. Copenhagen and Aarhus.

3.6.1 WWI Bombing Campaigns

No evidence has been examined to suggest the AOI experienced aerial combat in the period. Demark fostered a neutral status throughout the war.

3.6.2 WWII Bombing Campaigns

On the 31st October (1944), 140 Wing Royal Air Force (RAF) of the 2nd Tactical Air Force participated in an air-raid on the Gestapo Headquarters, University of Aarhus, an estimated 85 km west of the AOI. In total, 25 de Havilland Mosquito aircraft conducted the air-raid, with High Explosive (H.E) and Incendiary Bombs (I.B) deposited in the incident.

At the conclusion of the air-raid, a Mosquito that had significant damage in the 4th wave of the attack on Aarhus traversed the Kattegat with an escort Mosquito and completed an emergency landing in Sweden. The rest of the 140 Wing (RAF) squadron plotted a western course and returned to the UK.

3.7 Anti-Aircraft / Coastal Defences

On the 6th June (1944), an Allied operation with the codename ‘Overlord’ resulted in the capture of a number of beaches in France (German-occupied). The failure prompted the Axis forces to maintain and enhance their coastal defences in the Atlantic Wall, an extensive system of coastal defences and fortifications that extended in excess of 3,000 miles.

Between the Autumn of 1944 and the infancy of 1945, 28 new batteries (light and medium variants) were established in the Kattegat. In addition to the failure outlined above, the spike in construction was attributed to the Axis desire to protect the seaward approaches to the Baltic Sea. If the Allied forces blocked Axis access to the Baltic, the German Kriegsmarine would be unable to dispatch its U-boats to the Atlantic Ocean.

3.8 Shipwrecks & Downed Aircraft Containing Munitions

It is possible that during periods of wartime throughout the 20th Century, vessels may have contained munitions that could have either spilled from ships as they sank and subsequently broke up or remained within holds on the vessel.

Similarly, aircraft which were shot down or otherwise had to ditch into the sea may have also contained unexploded munitions or jettisoned them prior to crashing.

RPS has consulted the UKHO wreck database and located numerous wrecks within a 5 km radius of the proposed route. Each wreck is assigned a Hydrographic Office Identification (HOID) which is used to refer to a wreck when no name is apparent.

The UXO-related wrecks identified within a 5 km radius of the AOI have been presented at *Table 3.3*. and **Appendix 6.**

Vessel	HOID	Date Sunk	Location ETRS 1989 UTM Zone 32N		Details
			Easting	Northing	
August Leonhardt	32554	11-04-40	666105.8	6265116.1	Torpedoed by HMS Sealion (British Submarine)
FV Lynaes (H-654)	52569	05-02-1943	668975.1	6216128.7	Mine
SS Desdemona	32651	04-03-1944	697743	6236134	Mine
Bernlef SS	32694	14-08-1945	693437	6228925.5	Accidental explosion (Confirmed to have carried conventional munitions)
Sigrid	32652	27-06-1943	700887.2	6236420.2	Mine
Valencia	32689	25-10-1942	703902.4	6231336.4	Mine
Alliance (H 156)	32688	26-11-1942	703035	6231893.9	Explosion No additional information has been sourced.
Stutthof Nienstedten	n/a	05-04-1945	663,134.49	6,272,326.74	Air-raid bomb
Helme Sohle	n/a	05-04-1945	663,277.57	6,265,378.05	Air-raid bomb
Emmy	n/a	02-11-1917	680,081.31	6,276,735.08	Gunfire / shelling
Wien	n/a	15-04-1918	694,825.55	6,268,079.88	Gunfire / shelling
Kronprinz Wilhelm	n/a	02-11-1917	696,389.68	6,265,784.61	Gunfire / shelling

Table 3.3 - Identified UXO-related wrecks identified within a 5 km radius of the AOI

3.9 Military Presence

3.9.1 Navy Exercise Areas (Sailing Directions)

In total, 3 naval exercise areas have been identified within the site boundaries. The geographic surface area that is contaminated by the exercise areas is an estimated 723 km^2 (Hesselo: 478 km^2, EK D 52: 286 km^2 and EK D 53: 131 km^2). The activities undertaken at the exercise areas have been determined as firing exercises using 40 mm / 3-inch and 5-inch guns. Additionally, the areas were also used as a testing area for torpedoes, which importantly were without explosives.

The exercise areas can be observed in relation to the AOI at **Appendix 5**.

3.9.2 Firing Exercise Areas (Sailing Directions)

An offshore practice firing area has been identified at Ringenäs, an estimated 27 km east of the AOI. The practice firing area was utilised for surface-to-air missile systems and long-range small arms firing exercises.

3.9.3 Auderød Naval Base

The former-naval base at Auderod was utilised as a Naval Basic Training School until its closure in 1991. The infrastructure associated with the naval base has been sold for commercial purposes. The installation was located an estimated 12.5 km east of the southern Landing Point (LP) of the AOI.

3.10 Conventional Weapon Discoveries

After an examination of an OSPAR (2017) database, it is evident that a number of conventional munitions have been encountered within a 10 km radius of the AOI.

Details of the conventional munitions encountered have been documented in *Table 3.4*.

Date of Encounter	Type of UXO	Location (Coordinates) ETRS 1989 UTM Zone 32N		Location	Action
		Easting	Northing		
30th April (2009)	UK Mine (MK I-IV)	682904.18	6263602.98	Within AOI	Destroyed
22nd June (2009)	UK Mine (Type A M6)	677033.24	6243167.47	Within AOI	Destroyed
30th June (2011)	Part of UK Mine (MK I-IV)	663139.10	6248610.04	Within AOI	Destroyed
01st December (2011)	UK Mine (MK I-IV)	666443.80	6269620.03	Within AOI	Destroyed
04th May (2017)	UK Mk 4 Ground Mine (WWII)	700945.00	6240397.18	5 km E of AOI	Released at Sea
18th May (2017)	UK Mk 4 Ground Mine (WWII)	698745.29	6242601.62	5 km E of AOI	Released at Sea
13th June (2017)	UK Mk 4 Ground Mine (WWII)	706859.77	6236900.62	6 km E of AOI	Released at Sea

Table 3.4 - Details of the conventional munitions encountered in the site boundaries.

3.11 Sea Dumps

On the 14th August (1945), the steamer 'Bernlef' exploded and sunk adjacent to Gillleleje, off the Danish coastline (ETRS 1989 UTM Zone 32N: 693712.8 E, 6229015.9 N). The wreck is attributed to an accident whilst dumping munitions overboard. The British Military Association commissioned the steamer to carry *"…1,200 tons of depth charges and 250 kg of aircraft bombs that had been stored in Denmark*" (Wrecksite.EU, 2020).

Whilst a number of sources detail the wreck with a chemical weapons risk, it has been determined through research that only conventional weapons were stored within the vessel.

4 MARINE UXO MIGRATION / DRIFT AND BURIAL

4.1 Migration / Drift

4.1.1 Migration via Natural Processes

Numerous studies have documented that munitions can migrate across the seafloor; the main force behind this movement is tidal currents. Research by Wilson et al. (2008) highlights that the migration of munitions decreased with burial depth, with munitions in a minimal burial state being particularly susceptible to movement when influenced by a large wave or strong current. Importantly, Wilson's report states that once a munition is completely buried, no further migration occurs unless bottom profile variation allows for re-exposure or there is scour.

The greater the velocity of the tides and currents, the greater the likelihood and rate at which UXO items can migrate. However, larger items of UXO such as mines, torpedoes and larger categories of bombs, are unlikely to migrate as far and frequently as smaller items, as they require significant tidal / current velocities to exceed the minimum energy for them to move. Smaller items of UXO, such as AAA projectiles and Small Arms Ammunition (SAA), are more likely to migrate when subjected to lower levels of energy generated by more benign tides and currents.

Additionally, munitions tend to gather in seabed hollows (they roll in, but tidal action is sometimes insufficient to roll them out again). Shoals of fish tend to congregate in seabed hollows too (as they avoid strong currents in slack water) and fishing trawlers trying to catch them are occasionally prone to snagging UXO in their nets bringing them to the surface. Fishing activity and potential interaction with the seabed is therefore a possible causation for UXO migration.

RPS has considered a report compiled by Menzel, Wranik and Paschen entitled "*Laboratory experiments and numerical simulations on the wave- and flow-induced migration of munition from WW1 and WW2 as a risk assessment for offshore construction*"*.* This report considers the critical velocities needed to move certain objects at various points of burial. The items considered were:

- British Depth Bomb Mark 1;
- British 250 lb General Purpose Bomb;
- German Mine Type GU; and
- German Mine Type GY.

The critical velocities in m/s are presented below for the various statuses of burial:

Item	Critical Velocity @ 5% Burial (m/s)	Critical Velocity @ 15% Burial (m/s)	Critical Velocity @ 30% Burial (m/s)	Critical Velocity @ 50% Burial (m/s)
Mark 1	1.2	1.5	1.9	2.2
250 lb GP	1.6	2	2.4	2.7
GU Mine	1.8	2.1	2.5	3.3
GY Mine	2.2	2.7	2.9	3.9

Table 4.1 - Critical Velocities

The results show scenarios with conservative assumptions and it should be noted that the following assumptions have been made:

- A sandy, non-cohesive seabed is required;

- The objects must be at least partially buried;
- An accumulation area is formed in the wake of the objects;
- Flow through the sediment is neglected;
- The influence of surface waves is neglected;
- Ripples, dunes and the overall shape of the seabed are constant;
- The influence of the water column above the object is neglected; and
- The value of the incident velocity is defined 20 cm above the seafloor in realistic scale.

The results show that as would be expected, the larger an item is and the greater its mass, the larger the velocity must be to move it.

Regarding this site, the results from the GU mine is the closest available ordnance to those present in the AOI due to its shape and is used as a surrogate for migration thresholds throughout the site. In fact, the minimum threat item on this site is significantly larger and heavier than the GU mine, therefore the critical current velocity will be higher than stated here.

Using the above investigations, it is possible to make estimates as to migration rates in the site. RPS carried out a metocean study **(Appendix 10)**, using RPS's HYDROMAP ocean/coastal model. The report shows that the maximum near-surface current velocity is 0.75 m/s. It is expected that the current velocity decreases with increasing water depth, therefore the maximum current velocity on site is considerably lower than the critical velocity of 2.2 m/s. Additionally, the Type A Mk I-VI is larger and heavier than the GU mine, which means the critical velocity is higher still. Therefore, it is concluded that seabed currents are not sufficient to cause the migration of UXO.

4.1.2 Migration via Anthropogenic Activities

It is established that current velocities are insufficient to mobilise UXO, however migration of UXO through anthropogenic activities cannot be discounted. Ecological studies carried out on the area explain how cod stocks have declined to a remnant population over the last two to three decades, after motor trawling was introduced to the Kattegat area in the early 20th century. Whilst fishing of this sort has been banned to the south of the site in the Oresund sea area, the Kattegat has seen no such restrictions. Several OSPAR encounters are recorded in the area, mostly of British Type A Mk I-VI. Some of these were discovered on a Swedish mine hunting expedition in 2017, but others nearer the site are not specified. It is possible, as they were discovered and disposed of at sea, that these were discovered by fishermen.

4.2 Depth of Burial

4.2.1 Burial Via Initial Penetration

When a munition is fired/dropped from height, its velocity upon initial impact provides the potential for the item to penetrate the seabed. In situations where a device impacted into >10 m depth of water, it is likely that penetration would have been retarded significantly by the water and the ordnance would come to rest on or very near the seabed (*within the top 2 m*). Given the water depths located along the route, it is considered unlikely munitions would have become buried when coming to rest on the seabed.

Certain munitions, including those that have either been dumped, placed (*e.g. sea mines*) or have migrated from elsewhere, are likely to have landed on the surface of the seabed rather than penetrating.

4.2.2 Burial Via Natural Processes

The seabed sediment noted throughout the site appears to consist mainly of sands and muddy sands, with isolated areas of glacial till. In the softer sediments it is possible for munitions to be scoured by currents and subsequently become buried. This is dependent on the mass, dimensions/shape of the item and the sediments upon which it came to rest as well as the currents affecting the area, however the maximum burial depth due to scour is approximately equal to the diameter of the munition.

An additional potential cause of burial on the Hesselo wind farm site is the liquefaction phenomenon, a consequence of the earthquakes that have affected the area, as explained in **Section 2.3.4**. To confirm or discount this process as a burial pathway, RPS would require further geotechnical information such as CPT data to analyse the seabed sediment and subsurface geology to determine the likelihood of liquefaction causing burial of UXO.

5 POTENTIAL ORDNANCE DETAILS

5.1 General

Risk Assessment is a formalised process for assessing the level of risk associated with a particular situation or action. It involves identifying the hazards and the potential receptor that could be affected by the hazard. The degree of risk is associated with the potential for a pathway to be present, linking the hazard to the receptor. This relationship is usually summarised as the Source – Pathway – Receptor.

The assessment has utilised information provided in **Section 3** and included the proposed intrusive activities to propose a more specific and detailed mitigation methodology.

5.2 Sources / Hazards

Based on the information collated, RPS considers that the following types of ordnance have the potential to have been utilised on/within the vicinity of the site:

- Projectiles;
- Aerial Delivered Bombs;
- Sea Mines;
- Depth Charges;
- Torpedoes; and
- Missiles / Rockets.

Importantly, whilst the technology in some of these munitions has altered significantly over the years, the composition of the explosives within them generally has not changed. It is the explosives within the devices that pose the risk; therefore, historic munitions can pose as significant of a risk today as more modern devices, especially as bulk explosives may not have degraded since the time the device was assembled.

It should be considered that WWI and WWII munitions which have been identified on or below the sea floor may still be hermetically sealed; with no water ingress having been observed. Other devices are found to have cracked; with the outer casings of some mines having been worn away over time. Therefore, degradation of historic munitions does not significantly reduce the posed risk.

5.3 Pathway

The pathway is described as the route by which the hazard reaches the site personnel. Given the nature of the proposed route the only pathways would be during:

- Cable Lay;
- Ploughing;
- Vessel Mounted Jetting;
- Tracked Vehicle Jetting;
- Tracked Mechanical Trencher;
- Dredging;
- Anchoring;
- Jack Up Operations;
- Rock Placement;
- Mattress Installation;
- Pre Lay Grapnel Run (PLGR);
- Cone Penetration Testing (CPT);
- Grab Sampling; and
- Snag on Vessel.

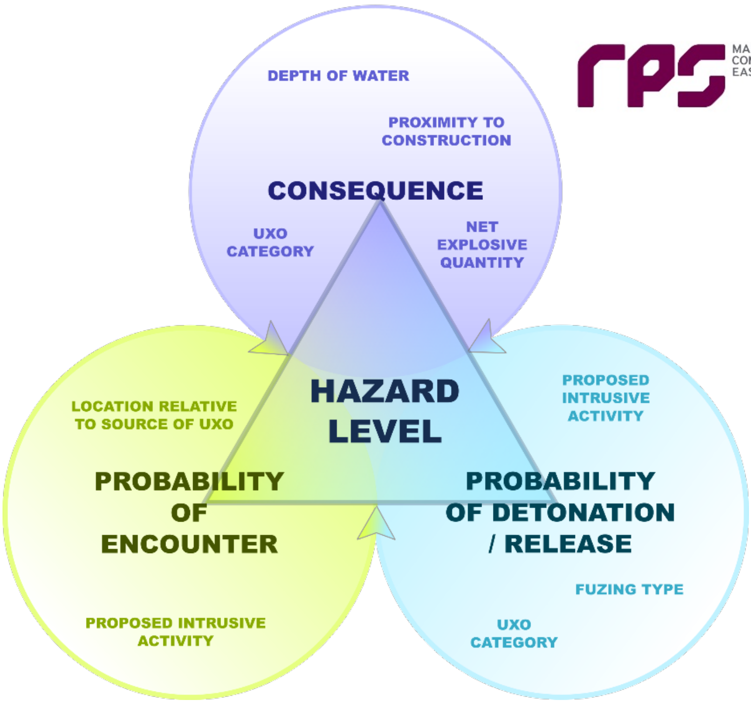
5.4 Receptors

Sensitive receptors applicable to this proposed route would be:

- People (Workers / Engineers and General Public);
- High Value Equipment;
- Infrastructure;
- Vessels (including public); and
- Environment.

5.5 Risk Evaluation

The following sections contain the Risk Evaluation for the proposed route, prior to the implementation of any risk mitigation measures. For the risk to be properly defined, several factors must be taken into account, including the consequences of initiation, the probability of encountering UXO on the proposed route and the probability of detonating munitions during intrusive activities. The technique used to evaluate level of risk is outlined in the following diagram:



Risk level = Probability of Encounter x Probability of Detonation or Release x Consequence

Figure 5.1 - Hazard Level Considerations

If a significant risk is identified, then an appropriate risk mitigation strategy is necessary for the intended geotechnical investigation and installation works. A semi quantitative assessment is completed below to identify the risk.

5.6 Probability and Consequence Assessment

For the purpose, of this assessment RPS has examined the probability of encounter and detonation and the potential subsequent consequence for the specific proposed works to be undertaken during the project. Only the following main categories of munitions have been included to provide a range of assessment data and it should be noted that other munition types may remain in the area.

The assessment is presented at **Appendix 7** and the process is detailed below.

5.6.1 Probability of Encounter Assessment

An estimate of the likelihood of a UXO risk being present within each route segment is made to assess the probability of encounter, which are ranked A – F, as below.

- Highly Probable
- Probable
- Possible
- Remote
- Improbable
- Highly Improbable

5.6.2 Probability of Detonation Assessment

The probability of encounter is combined with the probability of a certain munition type detonating. The probability of each engineering activity causing each munition type to detonate is assessed and ranked A – F:

- Highly Probable
- Probable
- Possible
- Remote
- Improbable
- Highly Improbable

This is based on the estimated disturbance caused by the installation activity and the likelihood for this to cause a detonation of specific munitions (*which is based on the items initiation systems*).

5.6.3 Consequence Assessment

Finally, the consequence level for each activity and munition type is obtained from the table presented in **Appendix 8**, which provides a consequence rating from 1 to 5, depending upon the severity. The detonation consequence assessment assigns a site-specific consequence level to any potential UXO that may be encountered at the proposed route. This is achieved by combining the UXO impact ranking and the depth of water across the proposed route. A rating system for assigning consequence levels has been derived based on the expected effects of a detonation event during each of the engineering activities, both on the seabed and on the vessel.

5.6.4 Risk Level

The result for each activity, munition type and segment are then presented as:

$\mathbf{P_E \times P_D \times C}$; where:

- $\mathbf{P_E}$ is the Probability of Encounter level, (*A – F*)
- $\mathbf{P_D}$ is the Probability of a Detonation level (*A – F*)

- **C** is the Consequence of a Detonation level (*1 – 5*)

The probability of encounter, probability of detonation/release and consequence of a detonation/release levels are then multiplied to give a risk level for each munition type, segment and engineering activity.

This was determined by assigning the values in the following table to the above results, which were then multiplied to provide a final risk level ranging between Negligible and High.

Prob. of Encounter (*1*)		Prob. of Detonation (*2*)		Consequence (*3*)	
A	Highly Probable (*1 in 1*)	**A**	Highly Probable (*1 in 1*)	**1**	Catastrophic (*1.00*)
B	Probable (*1 in 10*)	**B**	Probable (*1 in 10*)	**2**	Major (*0.1*)
C	Possible (*1 in 100*)	**C**	Possible (*1 in 100*)	**3**	Moderate (*0.01*)
D	Remote (*1 in 1,000*)	**D**	Remote (*1 in 1,000*)	**4**	Minor (*0.001*)
E	Improbable (*1 in 10,000*)	**E**	Improbable (*1 in 10,000*)	**5**	Insignificant (*0.0001*)
F	Highly Improbable (*1 in 100,000*)	**F**	Highly Improbable (*1 in 100,000*)		

Table 5.1 - Probability and Consequence Levels

		Probability of Encounter, P_E					
Consequence Level = 1		**A**	**B**	**C**	**D**	**E**	**F**
Probability of Detonation, P_D	**A**	AA1	BA1	CA1	DA1	EA1	FA1
	B	AB1	BB1	CB1	DB1	EB1	FB1
	C	AC1	BC1	CC1	DC1	EC1	FC1
	D	AD1	BD1	CD1	DD1	ED1	FD1
	E	AE1	BE1	CE1	DE1	EE1	FE1
	F	AF1	BF1	CF1	DF1	EF1	FF1

Table 5.2 - Example Risk Score and Associated Risk Rating (Full details in ***Appendix 8****)*

Risk Level	Definition
High	Indisputable evidence that there is a risk from this type of UXO in the area. Proactive UXO Mitigation is required.
Moderate	Evidence suggests that there is a risk from this type of UXO in the area. Proactive UXO Mitigation is required.
Low	Some evidence suggests that there is a risk from this type of UXO in the area or wider region. Reactive mitigation may be required.
Negligible	No evidence suggesting that there is a risk from this type of UXO in the area or wider region. No further mitigation is required.

Table 5.3 - Risk Level Definitions

The full consequence level matrix can be found in **Appendix 8**.

6 UXO RISK LEVELS

6.1 UXO Risk

Based on the conclusions of the research and the risk assessment undertaken, RPS has found there to be a varying **Low** and **Moderate** risk from encountering UXO on site. The risk is primarily due to the presence of Allied Mine Fields from WWII.

As per *Figure 5.1* RPS also take in to account the category of UXO both when assessing the probability of the item functioning and the consequence of such an event. This leads to the varying risk levels between munitions with the same installation methodology. The full risk matrices are presented in **Appendix 7** providing an assessment of the risk associated with each activity.

The cable route has been split into 8 zones (A-H) dependent on the risk presented and the anticipated installation activities. *Table 6.1* shows the maximum risk for each zone. Descriptions of the zones are given in **Section 6.1.2**.

6.1.1 Risk Levels

UXO		Risk Zones							
		Zone A	Zone B	Zone C	Zone D	Zone E	Zone F	Zone G	Zone H
Small Arms Ammunition		Low	Low	Low	Low	Low	Low	Low	Low
Land Service Ammunition		Low	Low	Low	Low	Low	Low	Low	Low
≤155 mm Projectiles		Low	Low	Low	Low	Low	Low	Low	Low
≥155 mm Projectiles		Low	Low	Low	Low	Low	Low	Low	Low
HE Bombs	Allied Origin	Low	Low	Low	Low	Low	Low	Low	Low
	Axis Origin	Low	Low	Low	Low	Low	Low	Low	Low
Sea Mines	Allied Origin	Low	Low	Mod	Mod	Low	Mod	Low	Low
	Axis Origin	Low	Low	Low	Low	Low	Low	Low	Low
	Axis Origin (Non-Ferrous)	Low	Low	Low	Low	Low	Low	Low	Low
Torpedoes		Low	Low	Low	Low	Low	Low	Low	Low
Depth Charges		Low	Low	Low	Low	Low	Low	Low	Low
Conventional Dumped Munitions		Low	Low	Low	Low	Low	Low	Low	Low
Dumped Chemical Munitions		Low	Low	Low	Low	Low	Low	Low	Low
Missiles/Rockets		Low	Low	Low	Low	Low	Low	Low	Low

Table 6.1 - Overall Risk Levels

6.1.2 Risk Zones

A risk zone map has been presented in **Appendix 9.** A description of each risk zone is given below.

6.1.2.1 Zone A – Low Risk

Zone A is located between the landfall site and the 10 m water depth contour.

Although Zone A is within the designated Allied Minefield from WWII, further research has shown that no mines were laid within the zone. Therefore, Zone A is considered Low Risk.

6.1.2.2 Zone B – Low Risk

Zone B is located from the 10 m water depth contour.

Although Zone B is within the designated Allied Minefield from WWII, further research has shown that no mines were laid within the zone. Therefore, Zone B is considered Low Risk.

6.1.2.3 Zone C – Moderate Risk

Zone C is within the designated allied minefield. Further research has shown that a number of mines were dropped in the area and consequently there is a significant risk of encountering air dropped ground mines. Therefore, Zone C is considered Moderate risk.

There is a residual risk of encountering Projectiles from activities which took place in the vicinity of the zone. However, due to the planned activities and the reduced probability of encounter the risk from these ordnance variants is still considered Low

6.1.2.4 Zone D – Moderate Risk

Zone D is within the designated allied minefield. Further research has shown that a number of mines were dropped in the area and consequently there is a significant risk of encountering air dropped ground mines. Therefore, Zone D is considered Moderate risk.

Additionally, this zone falls within the applied safety buffer on the EK D 53 firing exercise area where 4- and 5-inch projectiles were used for live firing exercises. However, the projectiles used in this area are not considered a threat to the proposed activities.

6.1.2.5 Zone E – Low Risk

Although Zone E is within the designated Allied Minefield from WWII. Further research has shown that no mines were laid within the zone. Therefore, Zone E is considered Low Risk.

Additionally, this zone falls within the applied safety buffer on the EK D 52 and EK D 53 firing exercise areas where 4- and 5-inch projectiles were used for live firing exercises. However, the projectiles used in these areas are not considered a threat to the proposed activities.

6.1.2.6 Zone F – Moderate Risk

Zone F is within the designated allied minefield. Further research has shown that a number of mines were dropped in the area and consequently there is a significant risk of encountering air dropped ground mines. Therefore, Zone F is considered Moderate risk.

Additionally, this zone falls within the applied safety buffer on the EK D 52 firing exercise area where 4- and 5-inch projectiles were used for live firing exercises. However, the projectiles used in this area are not considered a threat to the proposed activities.

There is a residual risk of encountering Torpedoes and Missiles/Rockets from activities which took place in the vicinity of the zone. However, due to the planned activities and the reduced probability of encounter the risk from these ordnance variants is still considered Low.

6.1.2.7 Zone G – Low Risk

Although Zone G is within the designated Allied Minefield from WWII, further research has shown that no mines were laid within the zone. Therefore, Zone G is considered Low Risk.

Additionally, this zone falls within the applied safety buffer on the EK D 53 firing exercise area where 4- and 5-inch projectiles were used for live firing exercises. However, the projectiles used in this area are not considered a threat to the proposed activities.

6.1.2.8 Zone H – Low Risk

Although Zone H is within the designated Allied Minefield from WWII, further research has shown that no mines were laid within the zone. Therefore, Zone H is considered Low Risk.

There is a residual risk of encountering Projectiles from activities which took place in the vicinity of the zone. However, due to the planned activities and the reduced probability of encounter the risk from these ordnance variants is still considered Low

7 RISK MITIGATION STRATEGY

7.1 Mitigation Strategy Rationale

RPS' Risk Assessment for Potential UXO contamination has identified a risk from UXO along the Export Cable Route. The research completed established that there is a Moderate UXO Risk within the AOI as the following three components are present:

- ***Source:*** A UXO risk that exists;
- ***Detonation Pathway:*** A mechanism that may cause UXO to detonate; and
- ***Receptors:*** These would be at risk of experiencing an adverse response following the detonation of a munition.

The purpose of risk mitigation is to: Take, action to address one or more of these components to reduce the probability of an incident occurring or to limit the impact of the problem if it does occur; thereby, eliminating the risk or reducing the risk to an acceptable level, or ALARP.

Obviously, the most effective method of mitigation is to remove the source of the contaminant. However, where this is not feasible it may be necessary to look at alternative methodologies; such as, avoiding a suspect item, removing the detonation pathway or minimising the risks to the receptors.

7.2 Recommendations

Based on the identified risk levels, it is recommended that appropriate mitigation is implemented to reduce the risk, where applicable, prior to and/or during the scheduled geotechnical investigation and cable installation operations.

8 PROACTIVE MITIGATION – GEOPHYSICAL UXO SURVEY

The following sections only apply to areas with a Moderate Risk from UXO. Low Risk areas do not require proactive mitigation and therefore all associated stand-off distances are not relevant to Low Risk areas.

8.1 UXO Survey

Where reasonably practicable to do so RPS recommends that a UXO survey is undertaken to identify potential UXO (pUXO) prior to intrusive activities taking place on/below the seabed.

Importantly, although every endeavour can be made to ensure that the seabed is clear of UXO prior to works taking place, it should also be considered that one can never provide 100% clearance as there is always the potential for munitions to be missed during survey due to limitations with the equipment and site conditions (e.g. existing cables) and further for UXO to migrate into the area after the survey is complete.

Table 8.1 details the detection requirements that should be used for UXO Surveys on the Windfarm Site. All geophysical surveys should have 100% coverage as a minimum. RPS recommend using the dynamic coverage technique for magnetometer surveys to ensure this is completed in the most efficient way.

Minimum Threat Item	Ferrous Mass	Dimensions	Depth of Detection below Seabed
British Ground Mine (Type A)	340 kg	4.02 m x 0.45 m	2 m

Table 8.1 - Minimum Detection Requirements

RPS recommend that where feasible High-Frequency Side Scan Sonar (SSS) (600 kHz+ survey with 200% coverage) and / or MBES (minimum 16 hits per metre) data is collected to identify items that are currently situated on the surface or partially buried on the seabed. The high-resolution images that result from these surveys can be used to identify the location and shapes of the items. It should be noted that the SSS survey would only be able to identify larger items that remain at the surface of the seabed, not buried items.

Due to the possibility of burial on site additional sensors such as magnetometry, electromagnetic and sub-bottom imaging could be used to detect UXO; however, if the risk of burial can be discounted then this may not be required. Furthermore, activities that do not significantly penetrate the seabed, such as Rock Dumping can be mitigated through surface detection methods alone such as MBES and SSS.

8.2 Survey Corridor Requirement

The survey corridor width will vary based on the survey accuracy and the installation technique to be used during cable-lay, including the area of potential impact of each installation methodology.

At this stage, RPS doesn't have any specific details of the installation method and therefore, cannot provide specific corridors for the survey. However, the following should be considered in order to identify an appropriate minimum corridor width:

Survey Corridor (*distance +/- RPL*) = **UXO Survey positional Accuracy** + **Half the Tool Footprint** + **Installation positional accuracy** + **Avoidance of UXO**

For example, if the survey positioning is anticipated to be +/- 5 m, the installation tool is 10 m wide (e.g. a Heavy-Duty Plough) with a positional accuracy of +/- 5 m, and the UXO Avoidance is 5 m then the survey corridor will need to be 20 m either side of the RPL as a minimum (i.e. 40 m wide in total). It is important to note that increasing the size of the survey corridor can for rerouting to avoid targets.

8.3 Marine Survey Positioning

Differential Global Positioning Systems (DGPS) positioning (with real time kinematic positioning) in combination with digital compass and mechanical angle sensor information, is recorded and used for sensor positioning and navigational purposes. If the sensors are deployed on a soft tow, as opposed to a fixed boom from the vessel, then an Ultra Short Base Line (USBL) system should be deployed with the magnetometers, to increase positional accuracy, rather than using a straight layback technique. Depth Sensors and altimeters should be deployed with the sensors to show height above sea bottom and depth in water column in real time, to ensure that the sensors are maintained at a constant height above the seabed and assist with data processing.

The underwater accuracy of detected targets should be demonstrated to be approximately +/- 1-2 m.

8.4 Surrogate / Acceptance Trials

For the offshore survey, when using magnetic and / or sub bottom imaging detection methods the Survey Contractor should design a trial to be carried out prior to the survey campaign in order to confirm the suitability of the equipment to be used. The trial should be carried out using the same equipment that will be used during the main survey operations. A client representative should observe the SIT and approve the findings.

The aims of the trials are to:

- Demonstrate that all variants of possible UXO that pose a threat to the site are detectable during the survey.
- Prove that the system has positional accuracy within specified tolerance (±2 m or better) by comparing to results of a separate positioning system. If available SSS and MBES should also be run over surrogate item to verify equipment positioning.
- Determine an appropriate detection range for the system to be used as a basis for coverage throughout the project.

In order to achieve this, the contractor should deploy and recover appropriate surrogate UXO items of known dimensions on a suitable area of seabed free from existing magnetic anomalies. The area needs to be free from ferrous objects to reduce the possibility of ferrous materials affecting the results of the trials.

8.4.1 Surrogate Items

Based on the risk assessment carried out, RPS recommends that the following surrogate items are used during survey trials:

Ordnance Simulant	Dimensions		Ferrous Mass (*kg*)	Construction Material	Maximum Depth of Detection Below Seabed / Ground
	Length (*m*)	Diameter (*m*)			
Mine Explosive Encasement	0.65	0.57	50	Steel	2 m

Table 8.2 - Surrogate Item Specification

Although this Surrogate Item is much smaller than the minimum threat item, it would not be practical to use such a large item. Therefore, a 50 kg item is recommended. This also helps to ensure high data quality and will decrease the number of false positives compared to a survey with a lower specification. Additionally, RPS understand that the magnetometry data collected is also often used to identify debris which may pose a problem to installation; a 50 kg SIT item further facilitates the suitability of the data for this purpose.

The recommended depth of detection is 2 m below the seabed. Although ordnance has been found 30% - 50% buried in areas adjacent to the site, it is important to note that burial by liquefaction cannot be ruled out at this stage.

Additionally, a 2 m depth of detection ensures that the altitude of the sensors is kept low which improves the quality of the data and increases the accuracy of pUXO classification leading to fewer false positives.

8.5 Data Processing

An important stage of the proactive mitigation is the data processing and interpretation. Once the processing is complete the data can be interpreted to identify targets that have the potential to be UXO. Targets will be selected in reference, to the results obtained in the surrogate trials.

Although there are many variations of specialist UXO software, RPS recommends that the data is processed in the Oasis Montaj UXO software package. The survey results will be presented as a contour plot of the magnetic response along the route and the presence of any ordnance should be manifested as anomalous regions on the contour plot. The positional fix data together with the instrument's modelled output can then be presented as a false-colour map. The false colour map shows where magnetic anomalies are located, in the x, y and z planes. Modelled size and depth values to anomalies should be provided.

The modelling process uses various algorithms to identify subsurface anomalies as potential ordnance. The modelling process requires the use of a relatively powerful computer and a suitably trained Geophysicist. The modelling should be undertaken on-site for real-time feedback but also off-site for accurate assessment and/or QC purposes.

Alternative software processing packages, if used, should be able to demonstrate that they filter data, pick targets and rationalise them as potential UXO.

8.6 Stand-Off Distances

The following section outlines some examples of standoff distances which should be adhered to when undertaking activities in Moderate Risk areas.

8.6.1 Cable Burial in Virgin Ground

The following should be considered in order to identify an appropriate corridor width where the cable is being laid along a new route where no cable burial has taken place previously.

Survey Corridor (distance +/- RPL) = UXO Survey Positional Accuracy + Half the Tool Footprint + Installation Positional Accuracy + UXO Extent

This distance would then also be used to avoid any pUXO identified during the survey. This is visualised in *Figure 8.1*.

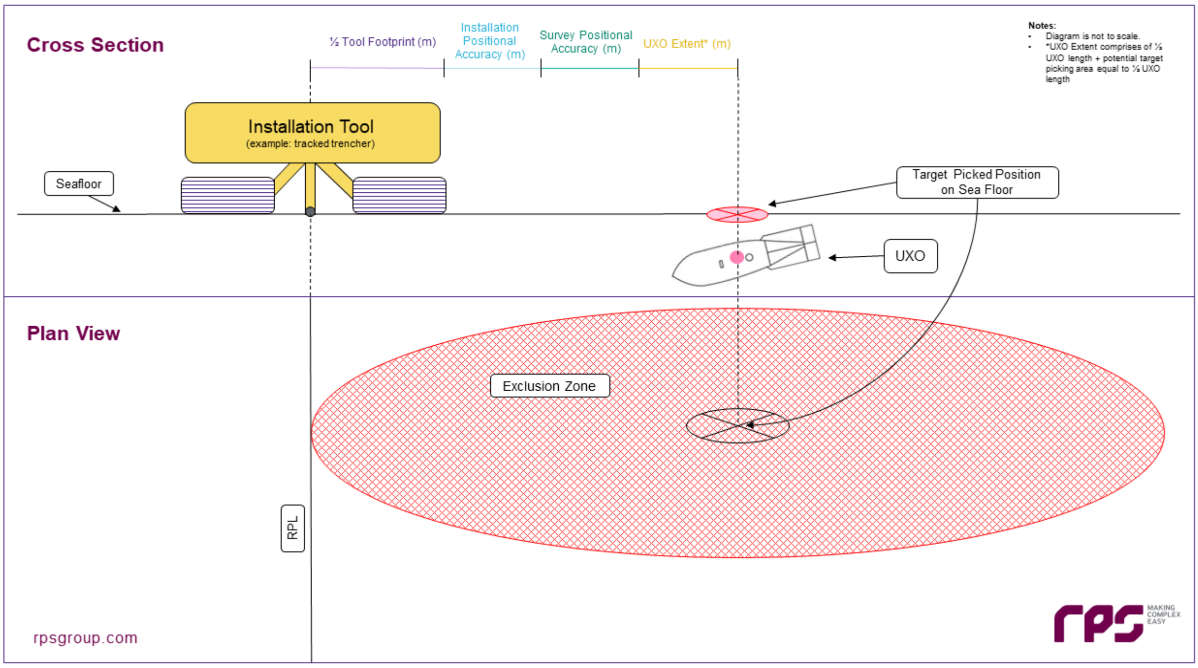


Figure 8.1 - A visualisation of the standoff distance calculation for cable burial.

8.6.2 Rock Placement

The following should be considered in order to identify an appropriate zone for Rock Placement activities:

Rock Placement Zone (+/- TBC) = UXO Survey Positional Accuracy + Half the Rock Berm width + Fall Pipe Positional Accuracy + UXO Extent

This distance would then also be used to avoid any pUXO identified during the survey. This is visualised in *Figure 8.2*. Consideration would need to be given for scour protection and rock placement where avoidance may not be possible. In this instance the pUXO would require further investigation as detailed in the following section.

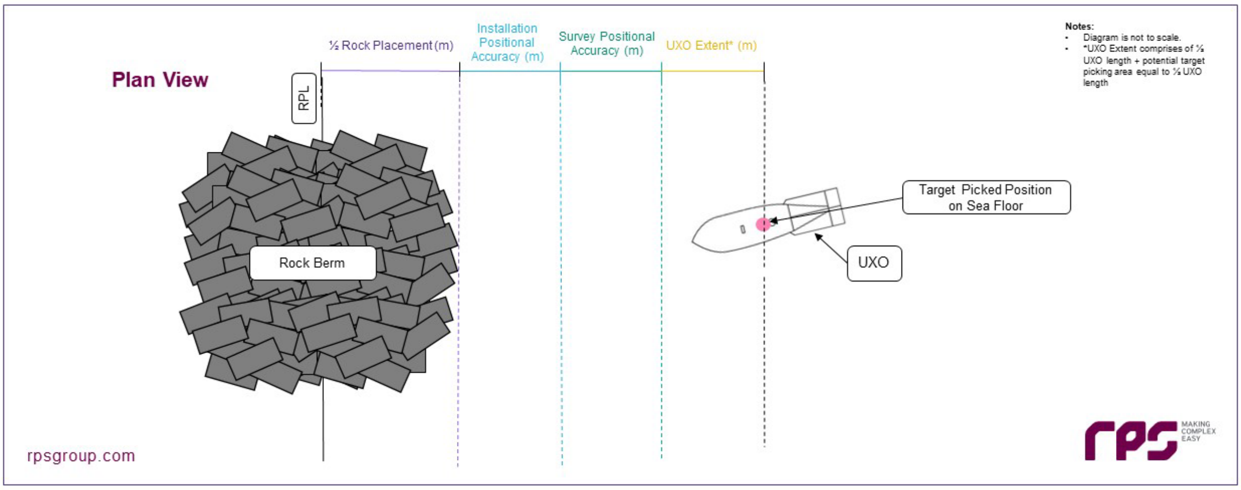


Figure 8.2 - A visualisation of the standoff distance calculation for Rock Placement.

8.6.3 Anchor Placement

The following should be considered in order to identify an appropriate zone for anchoring any applicable installation vessels:

Anchoring zone = Anchor Positional Accuracy + UXO Survey Positional Accuracy + Maximum length of UXO

It should be noted that the line/chain attached to the anchor is not considered a significant risk and therefore is not required to avoid anomalies by any specific distance. This is visualised in *Figure 8.3*.

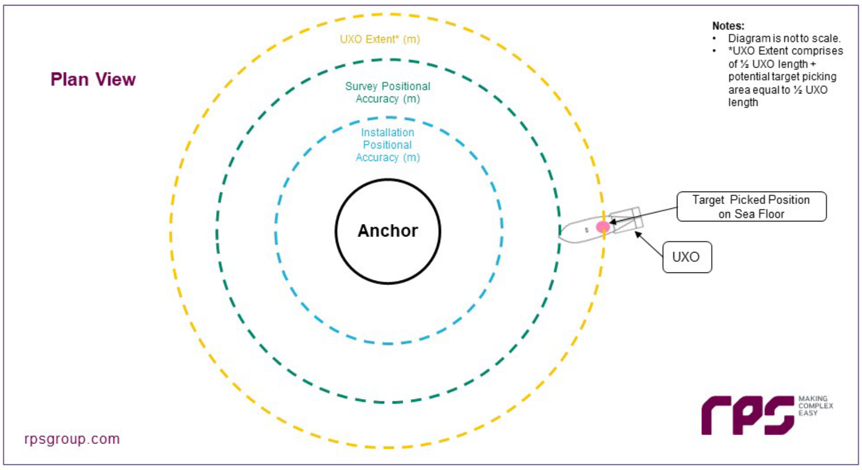


Figure 8.3 - A visualisation of the standoff distance calculation for Anchor Placement.

8.7 Potential UXO Targets

The various surveys across the site will produce numerous data sets and maps, along with lists of anomalies that will require reviewing in order to identify those that are potential UXO targets and those that are considered 'safe'.

Magnetic targets need to be correlated to side scan and multibeam sonar targets (*if available*), and the information used to determine the likelihood of the anomaly being UXO or discounted as pUXO. This would be based on the perceived threat items through the various sections of the site and as such sufficient time should be factored into the schedule to allow for review and analysis of the targets identified during each survey.

All targets should be reviewed by UXO Consultants to determine their likelihood of being UXO. This will possibly reduce the number of pUXO targets that require further mitigation, whilst also confirming that nothing is missed.

8.8 Target Avoidance (*Re-routing*)

Target avoidance is the safest and simplest method of mitigating the risk of encountering UXO during operations by simply relocating works around the target(*s*). However, this is not always possible, for example, if there is no flexibility in positioning i.e. cable route or turbine positioning. Thus, consideration needs to be given to whether avoidance is the best option for mitigation of targets identified during any UXO surveys. Generally, for Geotechnical Investigations (Site Survey) avoidance is the only necessary mitigation method.

The re-routing can be undertaken by initially surveying a wider corridor and then on completion of works the cable is re-routed within the surveyed corridor to avoid as many targets as possible.

Alternatively, the re-routing can be undertaken real-time during the survey. This would require data processing to be undertaken offshore to allow anomalies to be identified immediately and additional survey data gathered where required based on the data processing. This has worked well on previous projects; however, it is critical to have the correct project personnel on board the vessel for this to be successful. The following personnel are recommended:

- Sufficiently trained Geophysicists to processes the data immediately after collection;
- UXO Consultant to identify which targets require avoidance; and
- Client Representative who can confirm re-routing options and authorise additional survey.

The avoidance distance (*i.e. the distance at which the installation activities must be from the target*) is calculated in the same manner as the safety corridor width (see **Section 8.2**) and would apply to most cable installation activities and anchoring (i.e. relatively low energy activities). As such the avoidance distance would be obtained from the following information:

- UXO Extent – an arbitrary distance, based on the judgements and experience of an EOD expert, at which the probability of inadvertent detonation of an unknown item of UXO by the envisaged project activity is negligible;
- Positional error/tolerance of the equipment being used; and
- Positional error during the geophysical survey (including anomaly selection). To be determined from the survey itself but is typically around 2.5m to 5m.

The avoidance distance of high energy activities (such piling) that could cause UXO to detonate through vibration is more complex and requires detailed site information and details of the energy exerted during operations. However, piling is not expected on to take place in the Export Cable Route.

8.8.1 Geotechnical Investigation Avoidances

If geotechnical investigations are to take place before the UXO survey has been completed, RPS recommend boxes of at least 50m x 50m are surveys about the planned investigation site. This size of box then allows for avoidance should any targets appear in the area. The avoidance distance should be calculated as in **Section 8.6.** An example of a typical avoidance distance is given below:

Avoidance distance calculation for CPT	
Half the tool footprint	0.1 m
CPT positional accuracy	+/- 1 m
Survey Positional Accuracy	+/- 2 m
UXO Extent	4 m
Total avoidance distance	**7.1 m Radius**

8.9 Target Investigation

If avoidance is not possible or proves impractical, the target should be investigated to identify whether it is UXO and, if so, the item disposed of. Target investigation is generally conducted by deploying divers or ROV's or a combination of both. Consideration needs to be given as to whether the target is located on the surface or buried and additionally to the visibility on site.

It is important to note that investigation of targets could be employed on targets not considered to be pUXO if they are considered to be items of debris which could cause complications to intrusive activities. However, the investigation techniques shall remain the same.

A lesson learnt from the historic survey campaigns is that the database where all targets and ID&C operations are recorded requires significant attention. The target list is one of the primary deliverables of the UXO survey efforts and it is recommended to put significant attention to professional database management including QA/QC during all UXO survey efforts.

It is important to note that a member of the Danish EOD must be present during all investigation operations.

8.9.1 Investigation by ROV - Marine

Work class ROV's are considered a safe and practical way to investigate targets as they can be equipped with cameras, sonar and survey equipment for relocation and then with dredge pumps for excavation. They additionally keep personnel from physically contacting the UXO.

If ROV's are to be used, RPS recommends the following equipment/requirements should be met during any investigation, as a minimum:

- Work Class ROV as a minimum
- Capable of operating within the following conditions:
  - significant wave height min 2.5 m
  - wind 12 m/s
  - 2 knots current, fully laden (i.e. all equipment operating)
- ROV HD camera system (2 per ROV)
- Inertial Nav System (INS)
- Doppler velocity log

- Digital Edge HD recording system (or equivalent)
- ARIS Sonar (or equivalent)
- Adequate manipulators and grinders to conduct the required operations
- Depth sensor accurate to +/- 1 m
- Ability to carry out excursions at least 200 m from the vessel
- Obstacle avoidance sonars
- USBL system, IXSea Gaps or equivalent
- Dredge pump capable of efficiently excavating sediments given the seabed conditions
- Metal detector (e.g. innovatum/gradiometer (7pin) or TSS pipe tracker (2 m array minimum)) for target relocation

Optional:

- High Resolution Sub-Bottom Imager (e.g. Pangeo SBI)

The configuration of the camera system should allow for variations in view, strobe orientation and focal length in order to maximise data quality with respect to the prevailing conditions. A method of determining scale for the field of view should be evident in the video frame. The video should be supplied with its own source of illumination, which will be no less than 100 W (equivalent) and suitable to provide colour-balanced scene illumination at depth. The video shall be digitally recorded on board the vessel with a means to review, replay, capture and extract data digitally immediately after acquisition.

The TSS 440 or Innovatum system shall be calibrated with a metal test piece (or small surrogate item) at the beginning of the project as a minimum but preferably prior to each dive.

Given the time and cost implications of the ID&C operations and lessons learnt from previous UXO surveys is the importance of efficient, capable dredging, handling and visual inspection instruments for the ID&C operations are to be underlined explicitly. Only with a significant dredging capacity to expose buried targets in as little time as possible and with manipulators and sensors which enable the ID&C ROV to work efficiently and effectively, cost per target can be reduced. Removal of non UXO targets away from the cable route to avoid obstruction to cable installation at a later stage is required simultaneously to reduce overall project costs. An ROV capable of both efficient and effective ID of targets and efficient and effective clearance of debris is therefore recommended.

8.9.2 Investigation by Diving - Marine

If there is poor visibility, EOD trained divers are more often used for investigation. The advantage of using divers in this environment is that they can perform a tactile investigation where the visibility would prevent a positive identification being conducted visually. The divers would use hand-held locators (*metal detectors*) to relocate the target and diver operated air lifts to expose buried objects. However, if targets are buried deeply i.e. more than ~1 m then it may be preferable to use remote operated excavation equipment due to the safety implications of diving near excavations and the risk of hole collapse.

If divers are to be used, RPS recommends the following equipment to be deployed during the investigations as a minimum:

- Divers must have UXO familiarisation and search training/experience
- Surface Supplied Diving (as opposed to SCUBA). If SCUBA is proposed, justification for this method should be provided
- Diver to surface communications
- Diver to vessel live and recordable video link, via the diver's helmet
- Diver held metal detectors capable of detecting to 2 m below seabed (*DX200 or better*)
- Digital Edge HD recording system (*or equivalent*)
- USBL system (*IXSea Gaps or better*)

- Handheld sonars (*optional, if available*)

A method of determining scale for the field of view should be evident in the video frame. The video should be supplied with its own source of illumination, which will be no less than 100 W (*equivalent*) and suitable to provide colour-balanced scene illumination at depth. The video shall be digitally recorded on board the vessel with a means to review, replay, capture and extract data digitally immediately after acquisition.

8.10 Confirmed UXO

If a target is positively identified as UXO an assessment of the likelihood of the object moving prior to installation activities would need to be made to determine whether it can be avoided or whether it would need to be disposed of.

If the confirmed UXO requires disposal it would be dealt with by the Danish EOD, possibly with the assistance of the contractor.

Alternatively, if the UXO is not disposed of then it will need to be avoided. The avoidance distance should obviously be as large as possible; however, as a minimum the avoidance distance (i.e. the distance at which the activities must be from the confirmed UXO) is calculated in the same manner as the survey corridor width / avoidance distance (see previous sections). For example, the same distance as the edge of your survey corridor to the RPL (e.g. if your minimum survey corridor is +/-20 m from the RPL then your avoidance distance will also be +/-20 m from the UXO position, as a minimum).

8.11 ALARP Sign-Off

Based on the outcome of the survey and subsequent avoidance and/or investigation activities, ALARP sign-off would be provided for the site, which would demonstrate that appropriate mitigation has been implemented in order to reduce the risks from UXO to installation activities to an acceptable level i.e. As Low As Reasonably Practicable.

Based on the anticipated site conditions across all project sites RPS would anticipate there is at least some level of burial of UXO due to scour and potentially liquefaction.

The probability of an item of UXO migrating along the seabed due to water flow (tidal stream/current) is a function, among others, of seabed composition, firmness and morphology (slopes, ripples, troughs, boulders etc.); the current strength, duration and persistence of direction; and the weight, shape and orientation of the UXO. The tidal stream flowing through a project site will vary with location but is generally greater closer inshore. As such offshore it is unlikely that UXO will move due to normal tidal currents within the project areas **(See Section 4.1).**

In terms of wave action moving UXO in deeper waters (>10 m LAT) it is considered unlikely and would require extraordinary conditions for the UXO to moved such as significant storm events. Even then, due to the size of the risk items, migration is still considered extremely unlikely.

Therefore, based on anticipated site conditions and barring unknown factors (for example fishing trawling) bringing UXO on to site, mobility should be limited. As such, RPS would give an **ALARP validity of 5 years from the date of the mitigation/survey taking place**. However, the site conditions would need to be continually monitored and periodically reviewed by RPS to ensure this validity and to potentially carry it past the 5-year period.

This sign-off would advise whether residual risk mitigation is required, which would be finalised after the mitigation is completed. However, the likely possible requirements are detailed in the following sections.

9 REACTIVE MITIGATION

9.1 General

The following section outlines in more detail the recommended methods of reactive mitigation that can be implemented on site to further reduce the risks associated with UXO encounters. These are recommended for zones assessed as Low risk and potentially for the Moderate Risk areas once the proactive Mitigation is completed.

Even after reactive mitigation measures are implemented there will always remain a possibility, albeit, it should be Low, that UXO could be encountered or potentially brought on board the vessels working in the area. Surveys can never provide 100% certainty that all munitions will be detected. Smaller munitions may not be picked up during the survey and due to limitations in equipment and site conditions there is the potential for items to be missed or to migrate after the survey works are complete.

Due to the residual risk it is therefore recommended that UXO safeguarding be implemented to manage any inadvertent UXO encounters.

Importantly this level of safeguarding should be reviewed on completion of the proactive mitigation. Based on the findings of the survey and dependent on the levels of potential UXO identified, this may not be required.

9.2 Explosives Safety Awareness

In areas where a proactive survey and avoidance strategy was not practicable, for example in areas where survey data was inconclusive, RPS would recommend that an ***Explosives Safety Engineer*** (*Explosives Ordnance Disposal trained*) be based on board the vessel(*s*) during operations, in order to reduce the risks to personnel and equipment and avoid unnecessary delays and associated costs.

Importantly, this method should not replace any survey and should only be used where survey was not possible.

Not all apparent UXO items contain energetic material. A qualified Explosives Safety Engineer can often determine which items are considered UXO and deal with them accordingly. In some cases, it may not be possible to visually determine what the item is due to corrosion or encrustation and therefore whether it is UXO or something benign, such as an oil drum. The EOD Engineer would therefore be able to carry out ordnance recognition and minimise delays due to items that do not turn out to be UXO.

The EOD support would include but not be limited to:

- Attendance at risk assessment meetings, such as HIRA's,
- Carrying out Explosive Ordnance Safety and Awareness Briefings for all personnel. The Briefings would be given to all operational personnel working for the Client on site during cable lay operations,
- Development of Emergency Response Plans,
- Monitoring works in order to identify potential UXO items if they are uncovered as works progress,
- Inspecting the equipment (grapnel and trenching equipment) when it is brought back on board the vessel to ensure no ordnance are brought back on board.
- Assist in liaison with relevant authorities / personnel should ordnance be identified and present an explosive hazard,
- Where it is not practical or safe to observe the intrusive works, the Explosives Engineer will be on-call and immediately available to respond to a request for assistance,
- Provide on-call services to immediately respond to suspected ordnance that has been discovered by other site staff,
- Identify an area to which safe-to-move ordnance may be stored prior to recovery by the appropriate authorities.

The main aim would be to avoid interaction with UXO and consider the mitigation that will have already been undertaken in Moderate risk areas and therefore the resulting reduced risk, the risk of encounter should be Low. However, should an item of ordnance be discovered then the following action will be taken:

a. If an item is identified as ordnance, the Explosives Safety Engineer will carry out an ordnance risk assessment. He will assess the nature of the item, its initiation system as well as determining the explosive content. He will assess the requirement and size of any exclusion zone around the item,

b. The Explosives Safety Engineer will inform the Client as to the nature of the item and the conclusions of the risk assessment,

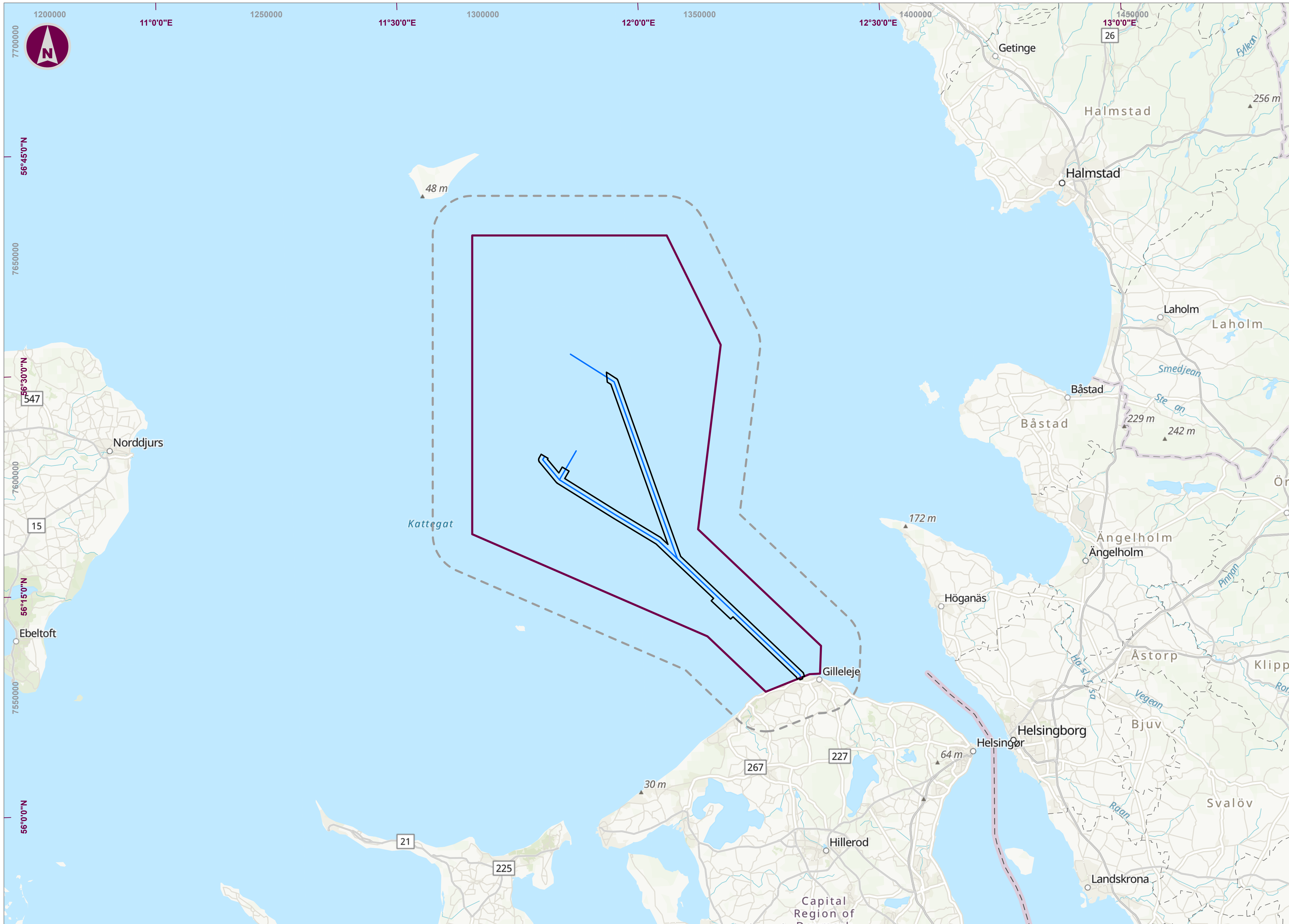
c. If the item does not contain any hazardous components, the Explosives Safety Engineer may remove it from the area of works, or if on the seafloor inform the client that works can continue,

d. If the item is deemed to pose a risk and cannot be moved, the Explosives Safety Engineer will contact the relevant authorities to dispose of the item.

9.3 Explosives Engineer On-Call for Offshore Activities

If an Explosive Engineer on Vessel is not deemed necessary, RPS would recommend an on-call service is set up which can be used by the contractors in the event of a potential UXO encounter. This would provide 24/7 on-call availability to a UXO Expert who could assist the vessel in dealing with a potential UXO encounter. A procedure would be implemented in the event that potential UXO is encountered during installation so that the item can be identified and dealt with as quickly as possible.

Appendix 1 - AOI Map



Legend	
	Area of Interest (AOI)
	5km AOI Buffer
	Proposed Survey Area
	Proposed Cable Route

Overview

0 5 10 20 30 40 50 Kilometers

0 2.5 5 10 15 20 25 Nautical Miles

Geodetic Information:
CRS: ETRS 1989 UTM Zone 32N, Datum: ETRS 1989
EPSG Code: 25832

Data Sources: Client
Service Layer Credits: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS
World Topographic Map: Danish Geodata Agency, Esri, HERE, Garmin, FAO, METI/NASA, USGS

Ver	Description	By	Check	Date
00	INITIAL ISSUE	NG/LM	RM	02/12/20

Figure Number	Rev	Page
EES1129-F-001	00	1 of 1

rps MAKING COMPLEX EASY

rpsgroup.com

Client: Energinet

Project: Hesselo OWF - Cable Route

Title: Site Location

Project Number: EES1129

Scale @ A3: 1:500,000

Drawn By: NG/LM

Checked By: RM

Status: INITIAL ISSUE

Date Created: 02/12/20

Notes:
1. This drawing has been prepared in accordance with the scope of RPS's appointment with its client and is subject to the terms and conditions of that appointment. RPS accepts no liability for any use of this document other than by its client and only for the purposes for which it was prepared and provided.
2. If received electronically it is the recipients responsibility to print to correct scale.
3. Only written dimensions should be used .
4. Not to be used for Navigation.
5. The locations shown are based on the information identified /provided, and should be used for general guidance only.

Appendix 2 - Terminology

Terminology

Explosive Ordnance Disposal (EOD) - The detection, identification, evaluation, rendering safe, recovery and disposal of UXO.

Fuze- A designed and manufactured mechanism to activate munitions. It can be designed for use by electrical, chemical or mechanical systems, by push, pull, pressure, release and time activation, singly or in combination. Usually consists of an igniter and detonator.

High Explosive (HE) - An explosive that normally detonates rather than burns; that is, the rate of detonation exceeds the velocity of sound.

Initiation - A physical process that sets in motion a cascade of chemical reactions of ever increasing energy (the explosive chain) that will eventually generate sufficient energy (the velocity of detonation) to allow the main charge to detonate in a violent, explosive chemical reaction, releasing energy in the form of heat and blast.

Snag on Vessel - UXO is snagged on submarine equipment and subsequently brought onto the vessel.

Unexploded Bomb (UXB) -The term UXB refers to any WWII aerial-delivered unexploded bomb, torpedo, projectile or mine consisting of a complete ferrous casing (without tailfins) weighing 50kg or greater.

Unexploded Ordnance (UXO) - Explosive Ordnance that has been primed, fuzed, armed or otherwise prepared for action, and which has been fired, dropped, launched, projected or placed in such a manner as to constitute a threat to the safety and/or security of people, animals, property or material and remains unexploded either by malfunction or design or for any other reason.

UXO Contamination - UXO that is present, within any given physical context that is considered to be an impediment to the safe on-going or intended use of a facility, including geological features. Safety in this instance is measured against an acceptable level of exposure to the potential risks that UXO present.

MAKING COMPLEX EASY

Explosives Engineering Services

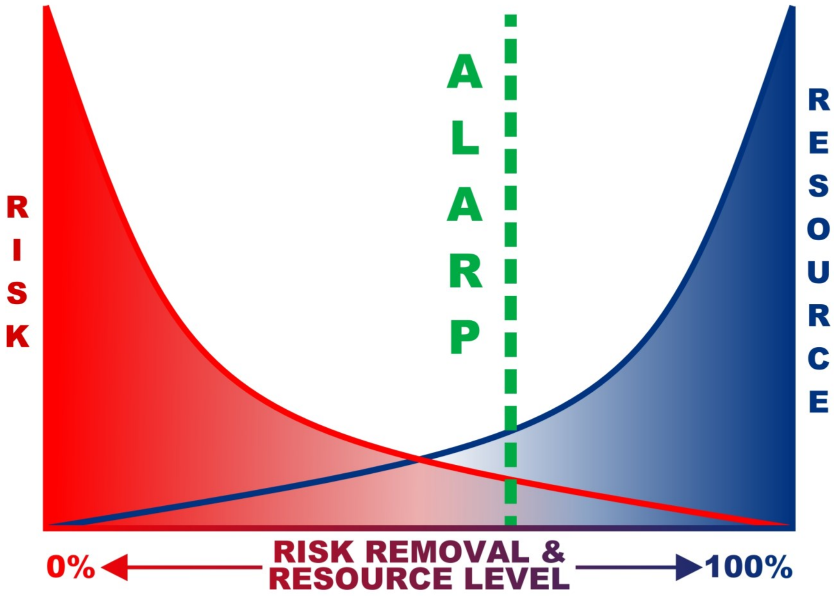
☎ +44 (0) 845 638 4760

www.rpsuxo.com

Appendix 3 - ALARP Principle

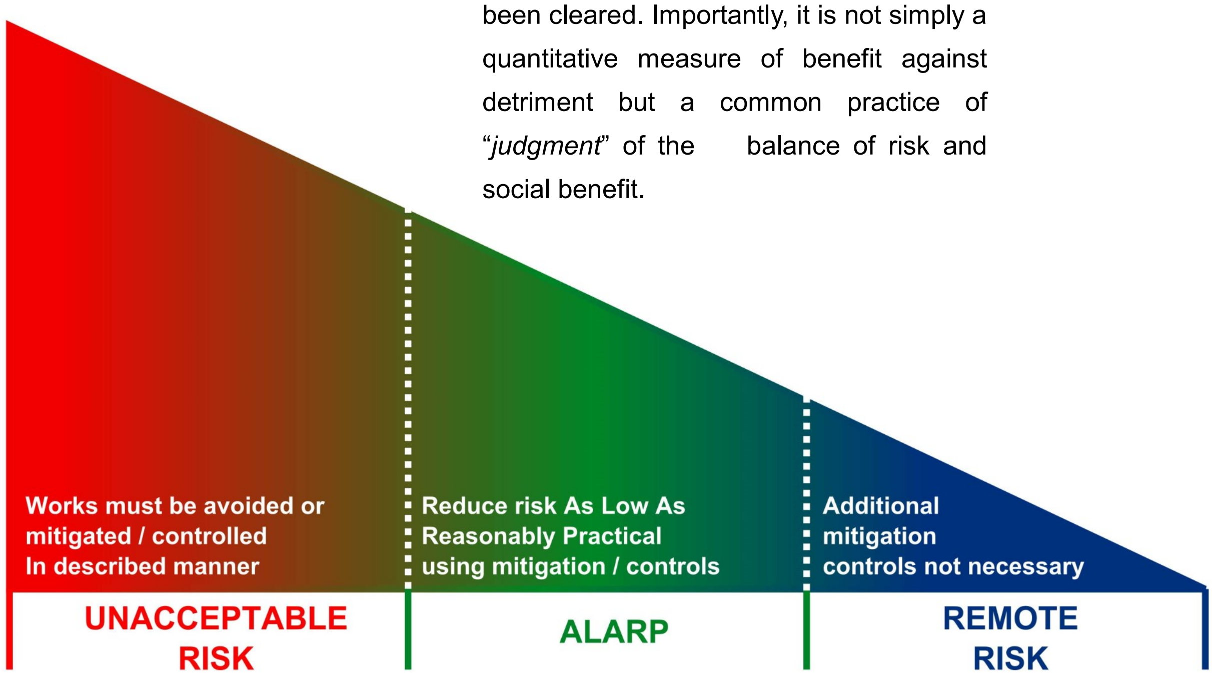
'ALARP PRINCIPLE'

ALARP has particular connotations in UK Health and Safety law and the core concept of what is "*reasonably practicable*". This involves weighing a risk against the effort, time and costs needed to control it, which will vary greatly dependent upon the level of UXO Hazard and the environment within which it is associated.



ALARP Resource Graph

For a risk to be reduced in line with ALARP it must be possible to demonstrate that the cost involved in reducing the risk further would be "*grossly disproportionate*" to the benefit gained. The ALARP principle arises from the fact that it would be possible to spend infinite time, effort and money attempting to reduce a risk to zero, which may never be achievable. This is particularly true of UXO risk, where there will always remain a residual (albeit low) risk, for example from smaller UXO that is not easily detectable, or due to the limitations of survey equipment, and particularly in the marine environment where UXO can migrate after the area has been cleared. Importantly, it is not simply a quantitative measure of benefit against detriment but a common practice of "*judgment*" of the balance of risk and social benefit.



ALARP Diagram Approach

rps MAKING COMPLEX EASY

Explosives Engineering Services

☎ +44 (0) 845 638 4760

www.rpsuxo.com

Appendix 4 - Legislation

RPS believe that it would be prudent to refer to EU guidance and legislation with regards to Health and Safety.

The minimum standard requirements for all countries residing in the EU and businesses therein were illustrated in the Council Directive 89/391/EEC established on the 12th June 1989. This directive outlined measures to promote improvements for the Health and Safety of workers. The EEC Directive 383/91/EEC further outlines the guidelines for the correct practice of business in regards Health and Safety within the EU.

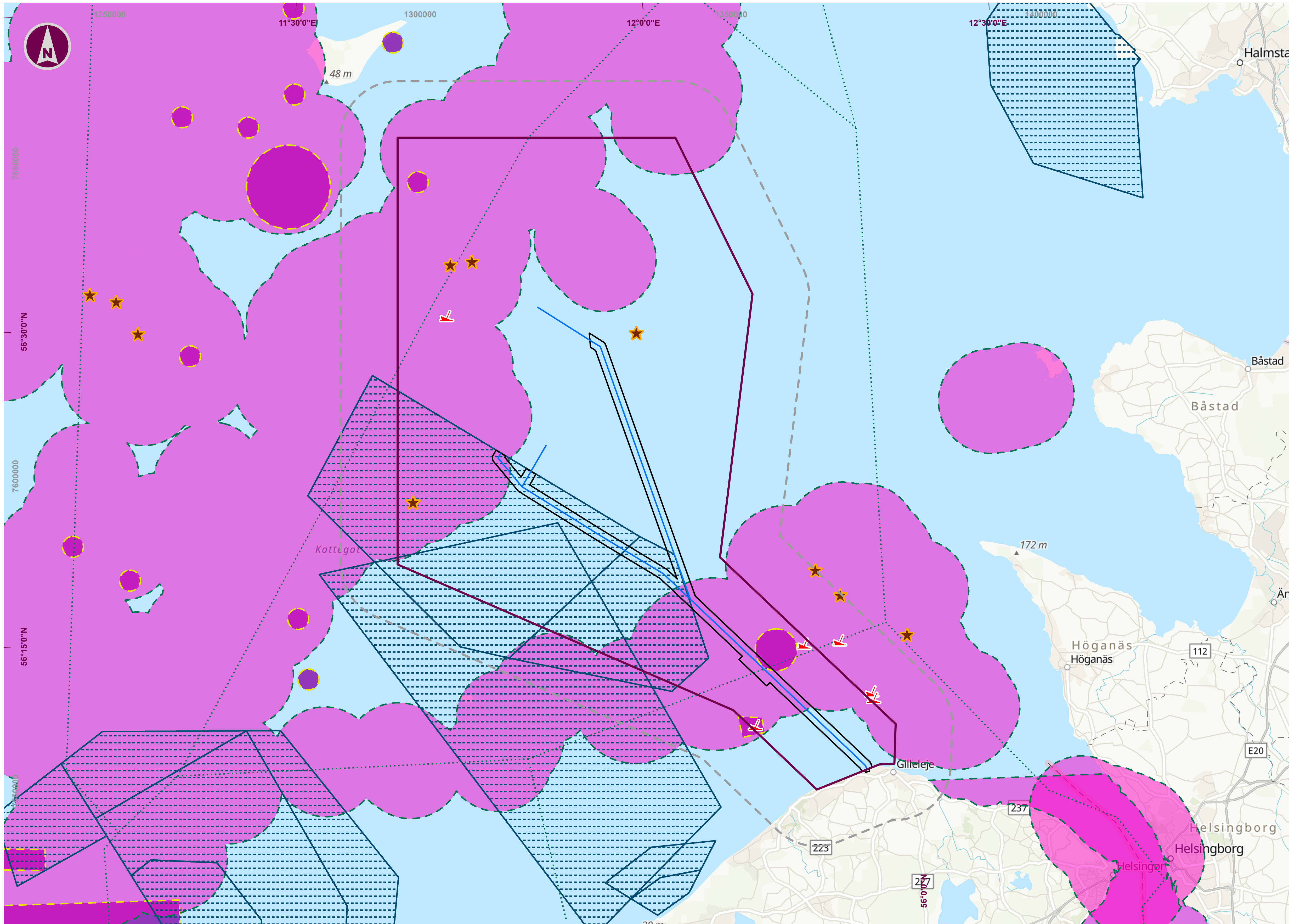
Whilst UXO is not specifically mentioned in the above directives, RPS works to these guidelines in an effort to illustrate a conformance to the ALARP principle. This has not been subjected to legal scrutiny/testing; however, RPS believe that the rationale behind this practice is sound given its track record in dealing with UXO in the workplace.

Whilst the services completed by UXO companies can be used to illustrate an effort to work to the ALARP principle, the ultimate decision as to whether a Client has conformed to ALARP would rest with courts of law.

Given that the Client is scheduled to be working in the construction/civil engineering arena, Health and Safety at Work legislation will likely be required to be observed.

The Client should be aware that if the risks posed by UXO have not been considered to have been reduced to ALARP or equivalent applicable standard, they may face a common law liability.

Appendix 5 - UXO Features Map



Legend

- Area of Interest (AOI)
- 5km AOI Buffer
- Proposed Cable Route
- Proposed Survey Area
- Wreck Record (HO/emapsite) - Within 5km - UXO Related (HO/emapsite)
- OSPAR Munition Encounters (up to 2017)
- Wartime Convoy/Vessel Route
- Firing Exercise Area
- Historic Offshore Minefield - British (WWII)
- Historic Offshore Minefield - Unspecified Origin (Unspecified Conflict)

Overview

0 2.5 5 10 15 20 25 30 Kilometers

0 2.5 5 10 15 Nautical Miles

Geodetic Information:
CRS: ETRS 1989 UTM Zone 32N, Datum: ETRS 1989
EPSG Code: 25832

Ver	Description	By	Check	Date
00	INITIAL ISSUE	LM	RM	02/12/20

Figure Number: EES1129-F-003
Rev: 00
Page: 1 of 1

rps MAKING COMPLEX EASY
rpsgroup.com

Client: Energinet
Project: Hesselo OWF - Cable Route
Title: UXO Related Features

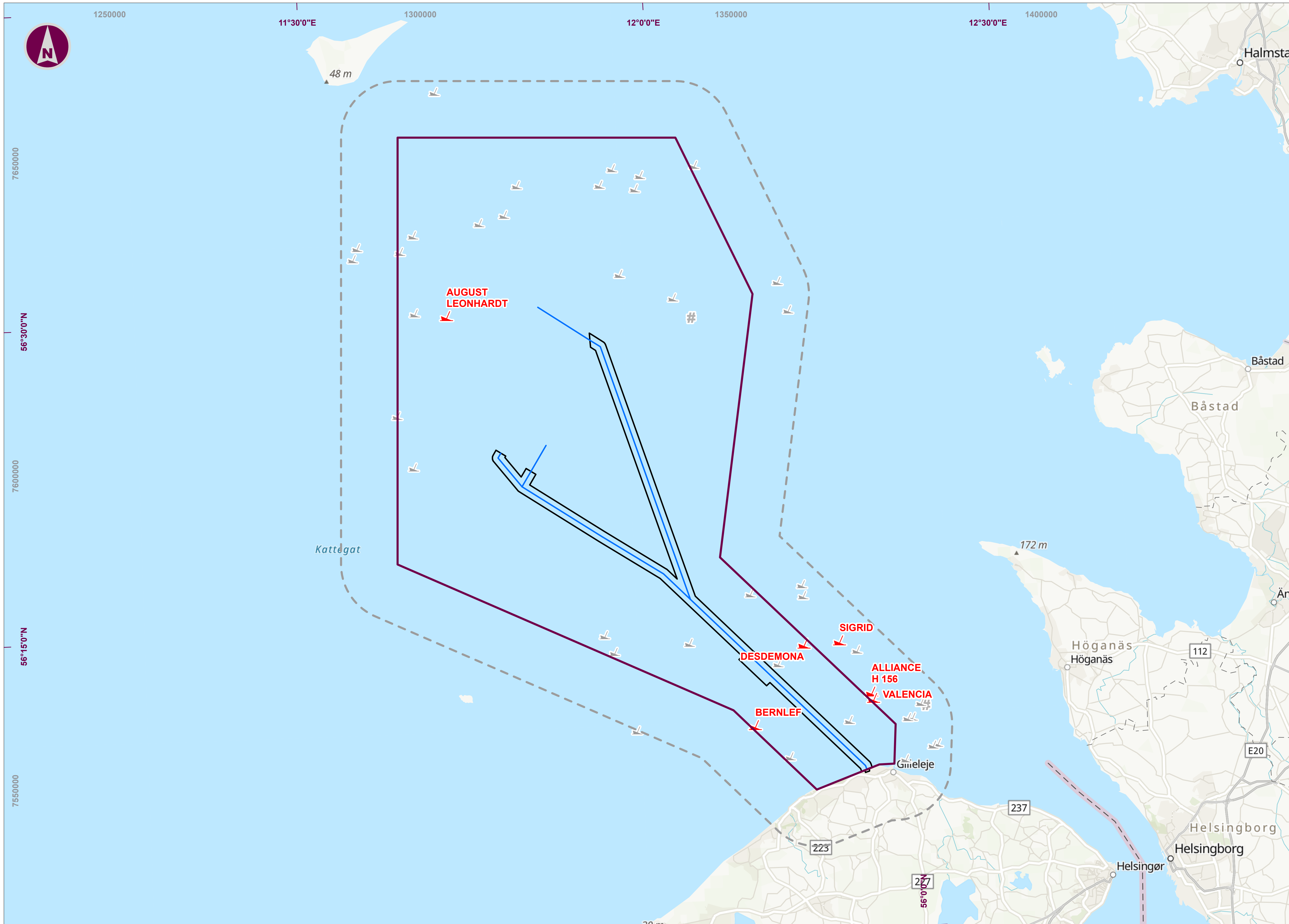
Project Number: EES1129
Scale @ A3: 1:350,000

Drawn By: LM
Checked By: RM

Status: INITIAL ISSUE
Date Created: 02/12/2020

Notes:
1. This drawing has been prepared in accordance with the scope of RPS's appointment with its client and is subject to the terms and conditions of that appointment. RPS accepts no liability for any use of this document other than by its client and only for the purposes for which it was prepared and provided.
2. If received electronically it is the recipients responsibility to print to correct scale.
3. Only written dimensions should be used .
4. Not to be used for Navigation.
5. The locations shown are based on the information identified /provided, and should be used for general guidance only.

Appendix 6 - Shipwrecks and Obstruction Map



Legend

- Area of Interest (AOI)
- 5km AOI Buffer
- Proposed Cable Route
- Proposed Survey Area
- Wreck Record (HO/emapsite) - Within 5km - UXO Related (HO/emapsite)
- Wreck Record (HO/emapsite) - Within 5km - Not UXO Related (HO/emapsite)
- Foul / Obstruction / Other Record (HO/emapsite)

Overview

0 2.5 5 10 15 20 25 30 Kilometers

0 1 2 4 6 8 10 12 14 16 Nautical Miles

Geodetic Information:

CRS: ETRS 1989 UTM Zone 32N, Datum: ETRS 1989

EPSG Code: 25832

Ver	Description	By	Check	Date
00	INITIAL ISSUE	NG/LM	RM	02/12/20

Figure Number: EES1129-F-002 | Rev: 00 | Page: 1 of 1

rpsgroup.com

Client: Energinet

Project: Hesselo OWF - Cable Route

Title: Wrecks Within 5km

Project Number: EES1129

Scale @ A3: 1:350,000

Drawn By: NG/LM

Checked By: RM

Status: INITIAL ISSUE

Date Created: 02/12/20

Notes:
1. This drawing has been prepared in accordance with the scope of RPS's appointment with its client and is subject to the terms and conditions of that appointment. RPS accepts no liability for any use of this document other than by its client and only for the purposes for which it was prepared and provided.
2. If received electronically it is the recipients responsibility to print to correct scale.
3. Only written dimensions should be used.
4. Not to be used for Navigation.
5. The locations shown are based on the information identified /provided, and should be used for general guidance only.

Appendix 7 - Risk Assessment

Hazard Evaluation Matrix

Regular Munitions		Cable Lay	Ploughing	Vessel Mounted Jetting	Tracked Vehicle Jetting	Tracked Mechanical Trencher	Snag on Vessel	Dredging	Anchoring	Jack-Up Operations	Rock Placement	Mattress Installation	PLGR	Borehole/Vibrocore	CPT	Grab Sampling
		Activity / Pathway														
		Probability of Detonation														
Small Arms Ammunition		F	E	E	E	E	E	E	E	F	E	F	E	F	F	F
Land Service Ammunition		E	D	E	E	D	D	D	D	E	D	E	D	E	E	E
≤155mm Projectiles		E	D	E	E	D	D	D	D	E	D	E	D	E	E	E
≥155mm Projectiles		E	D	E	E	D	D	D	D	E	D	E	D	E	E	E
HE Bombs	Allied Origin	E	C	D	D	C	C	C	C	D	C	E	D	D	D	E
HE Bombs	Axis Origin	E	C	D	D	C	C	C	C	D	C	E	D	D	D	E
Sea Mines	Allied Origin	D	C	D	D	C	C	C	C	D	C	D	D	D	D	D
Sea Mines	Axis Origin	D	C	D	D	C	C	C	C	D	C	D	D	D	D	D
Sea Mines	Axis Origin (non-ferrous)	D	C	D	D	C	C	C	C	D	C	D	D	D	D	D
Torpedoes		E	C	D	D	C	C	C	C	D	C	E	D	D	D	E
Depth Charges		E	C	D	D	C	C	C	C	D	C	E	D	D	D	E
Conventional Dumped Munitions		E	D	E	E	D	D	D	D	E	D	E	D	E	E	E
Dumped Chemical Munitions		E	D	E	E	D	D	D	D	E	D	E	D	E	E	E
Missiles/Rockets		E	D	E	E	D	D	D	D	E	D	E	D	E	E	E

Regular Munitions		Cable Lay		Ploughing		Vessel Mounted Jetting		Tracked Vehicle Jetting		Tracked Mechanical Trencher		Snag on Vessel	Dredging		Anchoring		Jack-Up Operation		Rock Placement		Mattress Installation		PLGR		Borehole/Vibrocore		CPT		Grab Sampling	
Water Depth		0m-10m	>10m	0m-10m	>10m	0m-10m	>10m	0m-10m	>10m	0m-10m	>10m	Surface	0m-10m	10m-20m	0m-10m	>10m	0m-10m	>10m	0m-10m	>10m	0m-10m	>10m	0m-10m	>10m	0m-10m	>10m	0m-10m	>10m	0m-10m	>10m
		Consequence of Detonation																												
Small Arms Ammunition		5	5	5	5	5	5	5	5	5	5	3	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Land Service Ammunition		5	5	5	5	5	5	5	5	5	5	2	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
≤155mm Projectiles		5	5	5	5	5	5	5	5	5	5	2	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
≥155mm Projectiles		4	5	4	5	4	5	4	5	4	5	2	4	5	4	5	4	5	4	5	4	5	4	5	4	5	4	5	4	5
HE Bombs	Allied Origin	3	4	3	4	2	4	3	4	3	4	2	2	4	3	4	2	4	2	4	2	4	3	4	2	4	2	4	2	4
HE Bombs	Axis Origin	3	4	3	4	2	4	3	4	3	4	2	2	4	3	4	2	4	2	4	2	4	3	4	2	4	2	4	2	4
Sea Mines	Allied Origin	2	3	2	3	2	3	2	3	2	3	2	2	3	2	3	2	3	2	3	2	3	3	3	2	3	2	3	2	3
Sea Mines	Axis Origin	2	3	2	3	2	3	2	3	2	3	2	2	3	2	3	2	3	2	3	2	3	3	3	2	3	2	3	2	3
Sea Mines	Axis Origin (non-ferrous)	2	3	2	3	2	3	2	3	2	3	2	2	3	2	3	2	3	2	3	2	3	3	3	2	3	2	3	2	3
Torpedoes		2	3	2	3	2	3	2	3	2	3	2	2	3	2	3	2	3	2	3	2	3	3	3	2	3	2	3	2	3
Depth Charges		2	3	2	3	2	3	2	3	2	3	2	2	3	2	3	2	3	2	3	2	3	3	3	2	3	2	3	2	3
Conventional Dumped Munitions		2	3	2	3	2	3	2	3	2	3	2	2	3	2	3	2	3	2	3	2	3	3	3	2	3	2	3	2	3
Dumped Chemical Munitions		4	4	4	4	4	4	4	4	4	4	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Missiles/Rockets		3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	4	4	3	3	3	3	3	3

Source: UXO
Potential Pathway: Cable Lay Operations
Potential Receptor: People, Equipment, Ifrastructure, Vessels, Environment

Probability: A = high probability to F = Low probability
Consequence: 1 = High to 5 = Low

Assumptions: Probability of detonation is based on a encountering a single item
Consequence/Impact levels are based on the worst case consequence/impact for each tier level

Area	Approx. Depth Range (m LAT)
Zone A	<10m

UXO		Probability of Encounter on Seabed	Probability of Encounter on Vessel*	Cable Lay	Risk Rating	Ploughing	Risk Rating	Vessel Mounted Jetting	Risk Rating	Tracked Vehicle Jetting	Risk Rating	Tracked Mechanical Trencher	Risk Rating	Snag on Vessel*	Risk Rating	Dredging	Risk Rating	Anchoring	Risk Rating
				Activity / Pathway															
Regular Munitions				Final Hazard Level															
Small Arms Ammunition		E	F	EF5	Negligible	EE5	Negligible	EE5	Negligible	EE5	Negligible	EE5	Negligible	FE3	Low	EE5	Negligible	EE5	Negligible
Land Service Ammunition		E	F	EE5	Negligible	ED5	Low	EE5	Negligible	EE5	Negligible	ED5	Low	FD2	Low	ED5	Low	ED5	Low
≤155mm Projectiles		E	F	EE5	Negligible	ED5	Low	EE5	Negligible	EE5	Negligible	ED5	Low	FD2	Low	ED5	Low	ED5	Low
≥155mm Projectiles		E	F	EE4	Low	ED5	Low	EE4	Low	EE4	Low	ED4	Low	FD2	Low	ED4	Low	ED4	Low
HE Bombs	Allied Origin	E	F	EE3	Low	EC4	Low	ED2	Low	ED3	Low	EC3	Low	FC2	Low	EC2	Low	EC3	Low
HE Bombs	Axis Origin	E	F	EE3	Low	EC4	Low	ED2	Low	ED3	Low	EC3	Low	FC2	Low	EC2	Low	EC3	Low
Sea Mines	Allied Origin	E	F	ED2	Low	EC3	Low	ED2	Low	ED2	Low	EC2	Low	FC2	Low	EC2	Low	EC2	Low
Sea Mines	Axis Origin	E	F	ED2	Low	EC3	Low	ED2	Low	ED2	Low	EC2	Low	FC2	Low	EC2	Low	EC2	Low
Sea Mines	Axis Origin (Non-Ferrous)	E	F	ED2	Low	EC3	Low	ED2	Low	ED2	Low	EC2	Low	FC2	Low	EC2	Low	EC2	Low
Torpedoes		E	F	EE2	Low	EC3	Low	ED2	Low	ED2	Low	EC2	Low	FC2	Low	EC2	Low	EC2	Low
Depth Charges		E	F	EE2	Low	EC3	Low	ED2	Low	ED2	Low	EC2	Low	FC2	Low	EC2	Low	EC2	Low
Conventional Dumped Munitions		E	F	EE2	Low	ED3	Low	EE2	Low	EE2	Low	ED2	Low	FD2	Low	ED2	Low	ED2	Low
Dumped Chemical Munitions		E	F	EE4	Low	ED4	Low	EE4	Low	EE4	Low	ED4	Low	FD2	Low	ED4	Low	ED4	Low
Missiles/Rockets		E	F	EE3	Low	ED3	Low	EE3	Low	EE3	Low	ED3	Low	FD2	Low	ED3	Low	ED3	Low

UXO		Probability of Encounter on Seabed	Probability of Encounter on Vessel*	Jack-Up Operation	Risk Rating	Rock Placement	Risk Rating	Mattress Installation	Risk Rating	PLGR	Risk Rating	Borehole/ Vibrocore	Risk Rating	CPT	Risk Rating	Grab Sampling	Risk Rating
				Activity / Pathway													
Regular Munitions				Final Hazard Level													
Small Arms Ammunition		E	F	EF5	Negligible	EE5	Negligible	EF5	Negligible	EE5	Negligible	EF5	Negligible	EF5	Negligible	EF5	Negligible
Land Service Ammunition		E	F	EE5	Negligible	ED5	Low	EE5	Negligible	ED5	Low	EE5	Negligible	EE5	Negligible	EE5	Negligible
≤155mm Projectiles		E	F	EE5	Negligible	ED5	Low	EE5	Negligible	ED5	Low	EE5	Negligible	EE5	Negligible	EE5	Negligible
≥155mm Projectiles		E	F	EE4	Low	ED4	Low	EE4	Low	ED4	Low	EE4	Low	EE4	Low	EE4	Low
HE Bombs	Allied Origin	E	F	ED2	Low	EC2	Low	EE2	Low	ED3	Low	ED2	Low	ED2	Low	EE2	Low
HE Bombs	Axis Origin	E	F	ED2	Low	EC2	Low	EE2	Low	ED3	Low	ED2	Low	ED2	Low	EE2	Low
Sea Mines	Allied Origin	E	F	ED2	Low	EC2	Low	ED2	Low	ED3	Low	ED2	Low	ED2	Low	ED2	Low
Sea Mines	Axis Origin	E	F	ED2	Low	EC2	Low	ED2	Low	ED3	Low	ED2	Low	ED2	Low	ED2	Low
Sea Mines	Axis Origin (Non-Ferrous)	E	F	ED2	Low	EC2	Low	ED2	Low	ED3	Low	ED2	Low	ED2	Low	ED2	Low
Torpedoes		E	F	ED2	Low	EC2	Low	EE2	Low	ED3	Low	ED2	Low	ED2	Low	EE2	Low
Depth Charges		E	F	ED2	Low	EC2	Low	EE2	Low	ED3	Low	ED2	Low	ED2	Low	EE2	Low
Conventional Dumped Munitions		E	F	EE2	Low	ED2	Low	EE2	Low	ED3	Low	EE2	Low	EE2	Low	EE2	Low
Dumped Chemical Munitions		E	F	EE4	Low	ED4	Low	EE4	Low	ED4	Low	EE4	Low	EE4	Low	EE4	Low
Missiles/Rockets		E	F	EE3	Low	ED3	Low	EE3	Low	ED4	Low	EE3	Low	EE3	Low	EE3	Low

Probability: A = high probability to F = Low probability
Consequence: 1 = High to 5 = Low

Final Hazard Level: Encounter (Detonation - Consequence)

Risk Levels:

Risk Levels
High
Moderate
Low
Negligible

Notes:

For 'Hazard Levels on Seabed' the depth is stated in Column B
For 'Hazard Levels on Vessel' the depth is Surface (0 m)
All Hazard Levels given are prior to any mitigation
(Detonation - Consequence) Levels are taken from worksheet Hazard_Eval-1
Consequence level definitions are found in *Appendix 014*
Snag on Vessel refers to any possibility of snagging UXO and transferring to vessel
The final risk rating is based on the highest score for each activity
* For encounter of Chemical Munitions on vessel, the likelihood of snag on vessel resulting from retrieval of cable is considered to be minimal but this does not include residues contaminating equipment

Area	Approx. Depth Range (m LAT)
Zone B	>10m

UXO		Probability of Encounter on Seabed	Probability of Encounter on Vessel*	Cable Lay	Risk Rating	Ploughing	Risk Rating	Vessel Mounted Jetting	Risk Rating	Tracked Vehicle Jetting	Risk Rating	Tracked Mechanical Trencher	Risk Rating	Snag on Vessel*	Risk Rating	Dredging	Risk Rating	Anchoring	Risk Rating
				Activity / Pathway															
Regular Munitions				Final Hazard Level															
Small Arms Ammunition		E	F	EF5	Negligible	EE5	Negligible	EE5	Negligible	EE5	Negligible	EE5	Negligible	FE3	Low	EE5	Negligible	EE5	Negligible
Land Service Ammunition		E	F	EE5	Negligible	ED5	Low	EE5	Negligible	EE5	Negligible	ED5	Low	FD2	Low	ED5	Low	ED5	Low
≤155mm Projectiles		E	F	EE5	Negligible	ED5	Low	EE5	Negligible	EE5	Negligible	ED5	Low	FD2	Low	ED5	Low	ED5	Low
≥155mm Projectiles		E	F	EE5	Negligible	ED5	Low	EE5	Negligible	EE5	Negligible	ED5	Low	FD2	Low	ED5	Low	ED5	Low
HE Bombs	Allied Origin	E	F	EE4	Low	EC4	Low	ED4	Low	ED4	Low	EC4	Low	FC2	Low	EC4	Low	EC4	Low
	Axis Origin	E	F	EE4	Low	EC4	Low	ED4	Low	ED4	Low	EC4	Low	FC2	Low	EC4	Low	EC4	Low
Sea Mines	Allied Origin	D	E	DD3	Low	DC3	Low	DD3	Low	DD3	Low	DC3	Low	EC2	Low	DC3	Low	DC3	Low
	Axis Origin	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	EC3	Low	FC2	Low	EC3	Low	EC3	Low
	Axis Origin (Non-Ferrous)	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	EC3	Low	FC2	Low	EC3	Low	EC3	Low
Torpedoes		E	F	EE3	Low	EC3	Low	ED3	Low	ED3	Low	EC3	Low	FC2	Low	EC3	Low	EC3	Low
Depth Charges		E	F	EE3	Low	EC3	Low	ED3	Low	ED3	Low	EC3	Low	FC2	Low	EC3	Low	EC3	Low
Conventional Dumped Munitions		E	F	EE3	Low	ED3	Low	EE3	Low	EE3	Low	ED3	Low	FD2	Low	ED3	Low	ED3	Low
Dumped Chemical Munitions		E	F	EE4	Low	ED4	Low	EE4	Low	EE4	Low	ED4	Low	FD2	Low	ED4	Low	ED4	Low
Missiles/Rockets		E	F	EE3	Low	ED3	Low	EE3	Low	EE3	Low	ED3	Low	FD2	Low	ED3	Low	ED3	Low

UXO		Probability of Encounter on Seabed	Probability of Encounter on Vessel*	Jack-Up Operation	Risk Rating	Rock Placement	Risk Rating	Mattress Installation	Risk Rating	PLGR	Risk Rating	Borehole/ Vibrocore	Risk Rating	CPT	Risk Rating	Grab Sampling	Risk Rating
				Activity / Pathway													
Regular Munitions				Final Hazard Level													
Small Arms Ammunition		E	F	EF5	Negligible	EE5	Negligible	EF5	Negligible	EE5	Negligible	EF5	Negligible	EF5	Negligible	EF5	Negligible
Land Service Ammunition		E	F	EE5	Negligible	ED5	Low	EE5	Negligible	ED5	Low	EE5	Negligible	EE5	Negligible	EE5	Negligible
≤155mm Projectiles		E	F	EE5	Negligible	ED5	Low	EE5	Negligible	ED5	Low	EE5	Negligible	EE5	Negligible	EE5	Negligible
≥155mm Projectiles		E	F	EE5	Negligible	ED5	Low	EE5	Negligible	ED5	Low	EE5	Negligible	EE5	Negligible	EE5	Negligible
HE Bombs	Allied Origin	E	F	ED4	Low	EC4	Low	EE4	Low	ED4	Low	ED4	Low	ED4	Low	EE4	Low
	Axis Origin	E	F	ED4	Low	EC4	Low	EE4	Low	ED4	Low	ED4	Low	ED4	Low	EE4	Low
Sea Mines	Allied Origin	D	E	DD3	Low	DC3	Low	DD3	Low	DD3	Low	DD3	Low	DD3	Low	DD3	Low
	Axis Origin	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low
	Axis Origin (Non-Ferrous)	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low
Torpedoes		E	F	ED3	Low	EC3	Low	EE3	Low	ED3	Low	ED3	Low	ED3	Low	EE3	Low
Depth Charges		E	F	ED3	Low	EC3	Low	EE3	Low	ED3	Low	ED3	Low	ED3	Low	EE3	Low
Conventional Dumped Munitions		E	F	EE3	Low	ED3	Low	EE3	Low	ED3	Low	EE3	Low	EE3	Low	EE3	Low
Dumped Chemical Munitions		E	F	EE4	Low	ED4	Low	EE4	Low	ED4	Low	EE4	Low	EE4	Low	EE4	Low
Missiles/Rockets		E	F	EE3	Low	ED3	Low	EE3	Low	ED4	Low	EE3	Low	EE3	Low	EE3	Low

Probability: A = high probability to F = Low probability
Consequence: 1 = High to 5 = Low

Final Hazard Level: Encounter (Detonation - Consequence)

Risk Levels:

High
Moderate
Low
Negligible

Notes:
For 'Hazard Levels on Seabed' the depth is stated in Column B
For 'Hazard Levels on Vessel' the depth is Surface (0 m)
All Hazard Levels given are prior to any mitigation
(Detonation - Consequence) Levels are taken from worksheet Hazard_Eval-1
Consequence level definitions are found in *Appendix 014*
Snag on Vessel refers to any possibility of snagging UXO and transferring to vessel
The final risk rating is based on the highest score for each activity
* For encounter of Chemical Munitions on vessel, the likelihood of snag on vessel resulting from retrieval of cable is considered to be minimal but this does not include residues contaminating equipment

Area	Approx. Depth Range (m LAT)
Zone C	>10m

	UXO	Probability of Encounter on Seabed	Probability of Encounter on Vessel*	Cable Lay	Risk Rating	Ploughing	Risk Rating	Vessel Mounted Jetting	Risk Rating	Tracked Vehicle Jetting	Risk Rating	Tracked Mechanical Trencher	Risk Rating	Snag on Vessel*	Risk Rating	Dredging	Risk Rating	Anchoring	Risk Rating
				#REF!															
Regular Munitions				Final Hazard Level															
	Small Arms Ammunition	E	F	EF5	Negligible	EE5	Negligible	EE5	Negligible	EE5	Negligible	EE5	Negligible	FE3	Low	EE5	Negligible	EE5	Negligible
	Land Service Ammunition	E	F	EE5	Negligible	ED5	Low	EE5	Negligible	EE5	Negligible	ED5	Low	FD2	Low	ED5	Low	ED5	Low
	≤155mm Projectiles	D	E	DE5	Low	DD5	Low	DE5	Low	DE5	Low	DD5	Low	ED2	Low	DD5	Low	DD5	Low
	≥155mm Projectiles	D	E	DE5	Low	DD5	Low	DE5	Low	DE5	Low	DD5	Low	ED2	Low	DD5	Low	DD5	Low
HE Bombs	Allied Origin	E	F	EE4	Low	EC4	Low	ED4	Low	ED4	Low	EC4	Low	FC2	Low	EC4	Low	EC4	Low
HE Bombs	Axis Origin	E	F	EE4	Low	EC4	Low	ED4	Low	ED4	Low	EC4	Low	FC2	Low	EC4	Low	EC4	Low
Sea Mines	Allied Origin	C	D	CD3	Low	CC3	Mod	CD3	Low	CD3	Low	CC3	Mod	DC2	Mod	CC3	Mod	CC3	Mod
Sea Mines	Axis Origin	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	EC3	Low	FC2	Low	EC3	Low	EC3	Low
Sea Mines	Axis Origin (Non-Ferrous)	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	EC3	Low	FC2	Low	EC3	Low	EC3	Low
	Torpedoes	E	F	EE3	Low	EC3	Low	ED3	Low	ED3	Low	EC3	Low	FC2	Low	EC3	Low	EC3	Low
	Depth Charges	E	F	EE3	Low	EC3	Low	ED3	Low	ED3	Low	EC3	Low	FC2	Low	EC3	Low	EC3	Low
	Conventional Dumped Munitions	D	E	DE3	Low	DD3	Low	DE3	Low	DE3	Low	DD3	Low	ED2	Low	DD3	Low	DD3	Low
	Dumped Chemical Munitions	E	F	EE4	Low	ED4	Low	EE4	Low	EE4	Low	ED4	Low	FD2	Low	ED4	Low	ED4	Low
	Missiles/Rockets	E	F	EE3	Low	ED3	Low	EE3	Low	EE3	Low	ED3	Low	FD2	Low	ED3	Low	ED3	Low

	UXO	Probability of Encounter on Seabed	Probability of Encounter on Vessel*	Jack-Up Operation	Risk Rating	Rock Placement	Risk Rating	Mattress Installation	Risk Rating	PLGR	Risk Rating	Borehole/ Vibrocore	Risk Rating	CPT	Risk Rating	Grab Sampling	Risk Rating
				Activity / Pathway													
Regular Munitions				Final Hazard Level													
	Small Arms Ammunition	E	F	EF5	Negligible	EE5	Negligible	EF5	Negligible	EE5	Negligible	EF5	Negligible	EF5	Negligible	EF5	Negligible
	Land Service Ammunition	E	F	EE5	Negligible	ED5	Low	EE5	Negligible	ED5	Low	EE5	Negligible	EE5	Negligible	EE5	Negligible
	≤155mm Projectiles	D	E	DE5	Low	DD5	Low	DE5	Low	DD5	Low	DE5	Low	DE5	Low	DE5	Low
	≥155mm Projectiles	D	E	DE5	Low	DD5	Low	DE5	Low	DD5	Low	DE5	Low	DE5	Low	DE5	Low
HE Bombs	Allied Origin	E	F	ED4	Low	EC4	Low	EE4	Low	ED4	Low	ED4	Low	ED4	Low	EE4	Low
HE Bombs	Axis Origin	E	F	ED4	Low	EC4	Low	EE4	Low	ED4	Low	ED4	Low	ED4	Low	EE4	Low
Sea Mines	Allied Origin	C	D	CD3	Low	CC3	Mod	CD3	Low	CD3	Low	CD3	Low	CD3	Low	CD3	Low
Sea Mines	Axis Origin	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low
Sea Mines	Axis Origin (Non-Ferrous)	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low
	Torpedoes	E	F	ED3	Low	EC3	Low	EE3	Low	ED3	Low	ED3	Low	ED3	Low	EE3	Low
	Depth Charges	E	F	ED3	Low	EC3	Low	EE3	Low	ED3	Low	ED3	Low	ED3	Low	EE3	Low
	Conventional Dumped Munitions	D	E	DE3	Low	DD3	Low	DE3	Low	DD3	Low	DE3	Low	DE3	Low	DE3	Low
	Dumped Chemical Munitions	E	F	EE4	Low	ED4	Low	EE4	Low	ED4	Low	EE4	Low	EE4	Low	EE4	Low
	Missiles/Rockets	E	F	EE3	Low	ED3	Low	EE3	Low	ED4	Low	EE3	Low	EE3	Low	EE3	Low

Probability: A = high probability to F = Low probability
Consequence: 1 = High to 5 = Low

Final Hazard Level: Encounter (Detonation - Consequence)

Risk Levels:

Risk Levels
High
Moderate
Low
Negligible

Notes:

For 'Hazard Levels on Seabed' the depth is stated in Column B
For 'Hazard Levels on Vessel' the depth is Surface (0 m)
All Hazard Levels given are prior to any mitigation
(Detonation - Consequence) Levels are taken from worksheet Hazard_Eval-1
Consequence level definitions are found in *Appendix 014*
Snag on Vessel refers to any possibility of snagging UXO and transferring to vessel
The final risk rating is based on the highest score for each activity
* For encounter of Chemical Munitions on vessel, the likelihood of snag on vessel resulting from retrieval of cable is considered to be minimal but this does not include residues contaminating equipment

Area	Approx. Depth Range (m LAT)
Zone D	>10m

UXO		Probability of Encounter on Seabed	Probability of Encounter on Vessel*	Cable Lay	Risk Rating	Ploughing	Risk Rating	Vessel Mounted Jetting	Risk Rating	Tracked Vehicle Jetting	Risk Rating	Tracked Mechanical Trencher	Risk Rating	Snag on Vessel*	Risk Rating	Dredging	Risk Rating	Anchoring	Risk Rating
Regular Munitions				Final Hazard Level															
Small Arms Ammunition		E	F	EF5	Negligible	EE5	Negligible	EE5	Negligible	EE5	Negligible	EE5	Negligible	FE3	Low	EE5	Negligible	EE5	Negligible
Land Service Ammunition		E	F	EE5	Negligible	ED5	Low	EE5	Negligible	EE5	Negligible	ED5	Low	FD2	Low	ED5	Low	ED5	Low
≤155mm Projectiles		C	D	CE5	Low	CD5	Low	CE5	Low	CE5	Low	CD5	Low	DD2	Low	CD5	Low	CD5	Low
≥155mm Projectiles		C	D	CE5	Low	CD5	Low	CE5	Low	CE5	Low	CD5	Low	DD2	Low	CD5	Low	CD5	Low
HE Bombs	Allied Origin	E	F	EE4	Low	EC4	Low	ED4	Low	ED4	Low	EC4	Low	FC2	Low	EC4	Low	EC4	Low
	Axis Origin	E	F	EE4	Low	EC4	Low	ED4	Low	ED4	Low	EC4	Low	FC2	Low	EC4	Low	EC4	Low
Sea Mines	Allied Origin	C	D	CD3	Low	CC3	Mod	CD3	Low	CD3	Low	CC3	Mod	DC2	Mod	CC3	Mod	CC3	Mod
	Axis Origin	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	EC3	Low	FC2	Low	EC3	Low	EC3	Low
	Axis Origin (Non-Ferrous)	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	EC3	Low	FC2	Low	EC3	Low	EC3	Low
Torpedoes		E	F	EE3	Low	EC3	Low	ED3	Low	ED3	Low	EC3	Low	FC2	Low	EC3	Low	EC3	Low
Depth Charges		E	F	EE3	Low	EC3	Low	ED3	Low	ED3	Low	EC3	Low	FC2	Low	EC3	Low	EC3	Low
Conventional Dumped Munitions		E	F	EE3	Low	ED3	Low	EE3	Low	EE3	Low	ED3	Low	FD2	Low	ED3	Low	ED3	Low
Dumped Chemical Munitions		E	F	EE4	Low	ED4	Low	EE4	Low	EE4	Low	ED4	Low	FD2	Low	ED4	Low	ED4	Low
Missiles/Rockets		E	F	EE3	Low	ED3	Low	EE3	Low	EE3	Low	ED3	Low	FD2	Low	ED3	Low	ED3	Low

UXO		Probability of Encounter on Seabed	Probability of Encounter on Vessel*	Jack-Up Operation	Risk Rating	Rock Placement	Risk Rating	Mattress Installation	Risk Rating	PLGR	Risk Rating	Borehole/ Vibrocore	Risk Rating	CPT	Risk Rating	Grab Sampling	Risk Rating
Regular Munitions				Final Hazard Level													
Small Arms Ammunition		E	F	EF5	Negligible	EE5	Negligible	EF5	Negligible	EE5	Negligible	EF5	Negligible	EF5	Negligible	EF5	Negligible
Land Service Ammunition		E	F	EE5	Negligible	ED5	Low	EE5	Negligible	ED5	Low	EE5	Negligible	EE5	Negligible	EE5	Negligible
≤155mm Projectiles		C	D	CE5	Low	CD5	Low	CE5	Low	CD5	Low	CE5	Low	CE5	Low	CE5	Low
≥155mm Projectiles		C	D	CE5	Low	CD5	Low	CE5	Low	CD5	Low	CE5	Low	CE5	Low	CE5	Low
HE Bombs	Allied Origin	E	F	ED4	Low	EC4	Low	EE4	Low	ED4	Low	ED4	Low	ED4	Low	EE4	Low
	Axis Origin	E	F	ED4	Low	EC4	Low	EE4	Low	ED4	Low	ED4	Low	ED4	Low	EE4	Low
Sea Mines	Allied Origin	C	D	CD3	Low	CC3	Mod	CD3	Low	CD3	Low	CD3	Low	CD3	Low	CD3	Low
	Axis Origin	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low
	Axis Origin (Non-Ferrous)	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low
Torpedoes		E	F	ED3	Low	EC3	Low	EE3	Low	ED3	Low	ED3	Low	ED3	Low	EE3	Low
Depth Charges		E	F	ED3	Low	EC3	Low	EE3	Low	ED3	Low	ED3	Low	ED3	Low	EE3	Low
Conventional Dumped Munitions		E	F	EE3	Low	ED3	Low	EE3	Low	ED3	Low	EE3	Low	EE3	Low	EE3	Low
Dumped Chemical Munitions		E	F	EE4	Low	ED4	Low	EE4	Low	ED4	Low	EE4	Low	EE4	Low	EE4	Low
Missiles/Rockets		E	F	EE3	Low	ED3	Low	EE3	Low	ED4	Low	EE3	Low	EE3	Low	EE3	Low

Probability: A = high probability to F = Low probability
Consequence: 1 = High to 5 = Low

Final Hazard Level: Encounter (Detonation - Consequence)

Risk Levels:

High
Moderate
Low
Negligible

Notes:

For 'Hazard Levels on Seabed' the depth is stated in Column B
For 'Hazard Levels on Vessel' the depth is Surface (0 m)
All Hazard Levels given are prior to any mitigation
(Detonation - Consequence) Levels are taken from worksheet Hazard_Eval-1
Consequence level definitions are found in *Appendix 014*
Snag on Vessel refers to any possibility of snagging UXO and transferring to vessel
The final risk rating is based on the highest score for each activity
* For encounter of Chemical Munitions on vessel, the likelihood of snag on vessel resulting from retrieval of cable is considered to be minimal but this does not include residues contaminating equipment

Area	Approx. Depth Range (m LAT)
Zone E	>10m

UXO		Probability of Encounter on Seabed	Probability of Encounter on Vessel*	Cable Lay	Risk Rating	Ploughing	Risk Rating	Vessel Mounted Jetting	Risk Rating	Tracked Vehicle Jetting	Risk Rating	Tracked Mechanical Trencher	Risk Rating	Snag on Vessel*	Risk Rating	Dredging	Risk Rating	Anchoring	Risk Rating
				Activity / Pathway															
Regular Munitions				Final Hazard Level															
Small Arms Ammunition		E	F	EF5	Negligible	EE5	Negligible	EE5	Negligible	EE5	Negligible	EE5	Negligible	FE3	Low	EE5	Negligible	EE5	Negligible
Land Service Ammunition		E	F	EE5	Negligible	ED5	Low	EE5	Negligible	EE5	Negligible	ED5	Low	FD2	Low	ED5	Low	ED5	Low
≤155mm Projectiles		C	D	CE5	Low	CD5	Low	CE5	Low	CE5	Low	CD5	Low	DD2	Low	CD5	Low	CD5	Low
≥155mm Projectiles		C	D	CE5	Low	CD5	Low	CE5	Low	CE5	Low	CD5	Low	DD2	Low	CD5	Low	CD5	Low
HE Bombs	Allied Origin	E	F	EE4	Low	EC4	Low	ED4	Low	ED4	Low	EC4	Low	FC2	Low	EC4	Low	EC4	Low
HE Bombs	Axis Origin	E	F	EE4	Low	EC4	Low	ED4	Low	ED4	Low	EC4	Low	FC2	Low	EC4	Low	EC4	Low
Sea Mines	Allied Origin	D	E	DD3	Low	DC3	Low	DD3	Low	DD3	Low	DC3	Low	EC2	Low	DC3	Low	DC3	Low
Sea Mines	Axis Origin	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	EC3	Low	FC2	Low	EC3	Low	EC3	Low
Sea Mines	Axis Origin (Non-Ferrous)	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	EC3	Low	FC2	Low	EC3	Low	EC3	Low
Torpedoes		D	E	DE3	Low	DC3	Low	DD3	Low	DD3	Low	DC3	Low	EC2	Low	DC3	Low	DC3	Low
Depth Charges		E	F	EE3	Low	EC3	Low	ED3	Low	ED3	Low	EC3	Low	FC2	Low	EC3	Low	EC3	Low
Conventional Dumped Munitions		E	F	EE3	Low	ED3	Low	EE3	Low	EE3	Low	ED3	Low	FD2	Low	ED3	Low	ED3	Low
Dumped Chemical Munitions		E	F	EE4	Low	ED4	Low	EE4	Low	EE4	Low	ED4	Low	FD2	Low	ED4	Low	ED4	Low
Missiles/Rockets		E	F	EE3	Low	ED3	Low	EE3	Low	EE3	Low	ED3	Low	FD2	Low	ED3	Low	ED3	Low

UXO		Probability of Encounter on Seabed	Probability of Encounter on Vessel*	Jack-Up Operation	Risk Rating	Rock Placement	Risk Rating	Mattress Installation	Risk Rating	PLGR	Risk Rating	Borehole/ Vibrocore	Risk Rating	CPT	Risk Rating	Grab Sampling	Risk Rating
				Activity / Pathway													
Regular Munitions				Final Hazard Level													
Small Arms Ammunition		E	F	EF5	Negligible	EE5	Negligible	EF5	Negligible	EE5	Negligible	EF5	Negligible	EF5	Negligible	EF5	Negligible
Land Service Ammunition		E	F	EE5	Negligible	ED5	Low	EE5	Negligible	ED5	Low	EE5	Negligible	EE5	Negligible	EE5	Negligible
≤155mm Projectiles		C	D	CE5	Low	CD5	Low	CE5	Low	CD5	Low	CE5	Low	CE5	Low	CE5	Low
≥155mm Projectiles		C	D	CE5	Low	CD5	Low	CE5	Low	CD5	Low	CE5	Low	CE5	Low	CE5	Low
HE Bombs	Allied Origin	E	F	ED4	Low	EC4	Low	EE4	Low	ED4	Low	ED4	Low	ED4	Low	EE4	Low
HE Bombs	Axis Origin	E	F	ED4	Low	EC4	Low	EE4	Low	ED4	Low	ED4	Low	ED4	Low	EE4	Low
Sea Mines	Allied Origin	D	E	DD3	Low	DC3	Low	DD3	Low	DD3	Low	DD3	Low	DD3	Low	DD3	Low
Sea Mines	Axis Origin	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low
Sea Mines	Axis Origin (Non-Ferrous)	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low
Torpedoes		D	E	DD3	Low	DC3	Low	DE3	Low	DD3	Low	DD3	Low	DD3	Low	DE3	Low
Depth Charges		E	F	ED3	Low	EC3	Low	EE3	Low	ED3	Low	ED3	Low	ED3	Low	EE3	Low
Conventional Dumped Munitions		E	F	EE3	Low	ED3	Low	EE3	Low	ED3	Low	EE3	Low	EE3	Low	EE3	Low
Dumped Chemical Munitions		E	F	EE4	Low	ED4	Low	EE4	Low	ED4	Low	EE4	Low	EE4	Low	EE4	Low
Missiles/Rockets		E	F	EE3	Low	ED3	Low	EE3	Low	ED4	Low	EE3	Low	EE3	Low	EE3	Low

Probability: A = high probability to F = Low probability
Consequence: 1 = High to 5 = Low

Final Hazard Level: Encounter (Detonation - Consequence)

Risk Levels:

- High
- Moderate
- Low
- Negligible

Notes:

For 'Hazard Levels on Seabed' the depth is stated in Column B
For 'Hazard Levels on Vessel' the depth is Surface (0 m)
All Hazard Levels given are prior to any mitigation
(Detonation - Consequence) Levels are taken from worksheet Hazard_Eval-1
Consequence level definitions are found in *Appendix 014*
Snag on Vessel refers to any possibility of snagging UXO and transferring to vessel
The final risk rating is based on the highest score for each activity
* For encounter of Chemical Munitions on vessel, the likelihood of snag on vessel resulting from retrieval of cable is considered to be minimal but this does not include residues contaminating equipment

Area	Approx. Depth Range (m LAT)
Zone F	>10m

UXO		Probability of Encounter on Seabed	Probability of Encounter on Vessel*	Cable Lay	Risk Rating	Ploughing	Risk Rating	Vessel Mounted Jetting	Risk Rating	Tracked Vehicle Jetting	Risk Rating	Tracked Mechanical Trencher	Risk Rating	Snag on Vessel*	Risk Rating	Dredging	Risk Rating	Anchoring	Risk Rating
Regular Munitions				Final Hazard Level															
Small Arms Ammunition		E	F	EF5	Negligible	EE5	Negligible	EE5	Negligible	EE5	Negligible	EE5	Negligible	FE3	Low	EE5	Negligible	EE5	Negligible
Land Service Ammunition		E	F	EE5	Negligible	ED5	Low	EE5	Negligible	EE5	Negligible	ED5	Low	FD2	Low	ED5	Low	ED5	Low
≤155mm Projectiles		C	D	CE5	Low	CD5	Low	CE5	Low	CE5	Low	CD5	Low	DD2	Low	CD5	Low	CD5	Low
≥155mm Projectiles		C	D	CE5	Low	CD5	Low	CE5	Low	CE5	Low	CD5	Low	DD2	Low	CD5	Low	CD5	Low
HE Bombs	Allied Origin	E	F	EE4	Low	EC4	Low	ED4	Low	ED4	Low	EC4	Low	FC2	Low	EC4	Low	EC4	Low
HE Bombs	Axis Origin	E	F	EE4	Low	EC4	Low	ED4	Low	ED4	Low	EC4	Low	FC2	Low	EC4	Low	EC4	Low
Sea Mines	Allied Origin	C	D	CD3	Low	CC3	Mod	CD3	Low	CD3	Low	CC3	Mod	DC2	Mod	CC3	Mod	CC3	Mod
Sea Mines	Axis Origin	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	EC3	Low	FC2	Low	EC3	Low	EC3	Low
Sea Mines	Axis Origin (Non-Ferrous)	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	EC3	Low	FC2	Low	EC3	Low	EC3	Low
Torpedoes		D	E	DE3	Low	DC3	Low	DD3	Low	DD3	Low	DC3	Low	EC2	Low	DC3	Low	DC3	Low
Depth Charges		E	F	EE3	Low	EC3	Low	ED3	Low	ED3	Low	EC3	Low	FC2	Low	EC3	Low	EC3	Low
Conventional Dumped Munitions		E	F	EE3	Low	ED3	Low	EE3	Low	EE3	Low	ED3	Low	FD2	Low	ED3	Low	ED3	Low
Dumped Chemical Munitions		E	F	EE4	Low	ED4	Low	EE4	Low	EE4	Low	ED4	Low	FD2	Low	ED4	Low	ED4	Low
Missiles/Rockets		D	E	DE3	Low	DD3	Low	DE3	Low	DE3	Low	DD3	Low	ED2	Low	DD3	Low	DD3	Low

UXO		Probability of Encounter on Seabed	Probability of Encounter on Vessel*	Jack-Up Operation	Risk Rating	Rock Placement	Risk Rating	Mattress Installation	Risk Rating	PLGR	Risk Rating	Borehole/ Vibrocore	Risk Rating	CPT	Risk Rating	Grab Sampling	Risk Rating
Regular Munitions				Final Hazard Level													
Small Arms Ammunition		E	F	EF5	Negligible	EE5	Negligible	EF5	Negligible	EE5	Negligible	EF5	Negligible	EF5	Negligible	EF5	Negligible
Land Service Ammunition		E	F	EE5	Negligible	ED5	Low	EE5	Negligible	ED5	Low	EE5	Negligible	EE5	Negligible	EE5	Negligible
≤155mm Projectiles		C	D	CE5	Low	CD5	Low	CE5	Low	CD5	Low	CE5	Low	CE5	Low	CE5	Low
≥155mm Projectiles		C	D	CE5	Low	CD5	Low	CE5	Low	CD5	Low	CE5	Low	CE5	Low	CE5	Low
HE Bombs	Allied Origin	E	F	ED4	Low	EC4	Low	EE4	Low	ED4	Low	ED4	Low	ED4	Low	EE4	Low
HE Bombs	Axis Origin	E	F	ED4	Low	EC4	Low	EE4	Low	ED4	Low	ED4	Low	ED4	Low	EE4	Low
Sea Mines	Allied Origin	C	D	CD3	Low	CC3	Mod	CD3	Low	CD3	Low	CD3	Low	CD3	Low	CD3	Low
Sea Mines	Axis Origin	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low
Sea Mines	Axis Origin (Non-Ferrous)	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low
Torpedoes		D	E	DD3	Low	DC3	Low	DE3	Low	DD3	Low	DD3	Low	DD3	Low	DE3	Low
Depth Charges		E	F	ED3	Low	EC3	Low	EE3	Low	ED3	Low	ED3	Low	ED3	Low	EE3	Low
Conventional Dumped Munitions		E	F	EE3	Low	ED3	Low	EE3	Low	ED3	Low	EE3	Low	EE3	Low	EE3	Low
Dumped Chemical Munitions		E	F	EE4	Low	ED4	Low	EE4	Low	ED4	Low	EE4	Low	EE4	Low	EE4	Low
Missiles/Rockets		D	E	DE3	Low	DD3	Low	DE3	Low	DD4	Low	DE3	Low	DE3	Low	DE3	Low

Probability: A = high probability to F = Low probability
Consequence: 1 = High to 5 = Low

Final Hazard Level: Encounter (Detonation - Consequence)

Risk Levels:

Risk Levels
High
Moderate
Low
Negligible

Notes:

For 'Hazard Levels on Seabed' the depth is stated in Column B
For 'Hazard Levels on Vessel' the depth is Surface (0 m)
All Hazard Levels given are prior to any mitigation
(Detonation - Consequence) Levels are taken from worksheet Hazard_Eval-1
Consequence level definitions are found in *Appendix 014*
Snag on Vessel refers to any possibility of snagging UXO and transferring to vessel
The final risk rating is based on the highest score for each activity
* For encounter of Chemical Munitions on vessel, the likelihood of snag on vessel resulting from retrieval of cable is considered to be minimal but this does not include residues contaminating equipment

Area	Approx. Depth Range (m LAT)
Zone G	>10m

UXO		Probability of Encounter on Seabed	Probability of Encounter on Vessel*	Cable Lay	Risk Rating	Ploughing	Risk Rating	Vessel Mounted Jetting	Risk Rating	Tracked Vehicle Jetting	Risk Rating	Tracked Mechanical Trencher	Risk Rating	Snag on Vessel*	Risk Rating	Dredging	Risk Rating	Anchoring	Risk Rating
				Activity / Pathway															
Regular Munitions				Final Hazard Level															
Small Arms Ammunition		E	F	EF5	Negligible	EE5	Negligible	EE5	Negligible	EE5	Negligible	EE5	Negligible	FE3	Low	EE5	Negligible	EE5	Negligible
Land Service Ammunition		E	F	EE5	Negligible	ED5	Low	EE5	Negligible	EE5	Negligible	ED5	Low	FD2	Low	ED5	Low	ED5	Low
≤155mm Projectiles		C	D	CE5	Low	CD5	Low	CE5	Low	CE5	Low	CD5	Low	DD2	Low	CD5	Low	CD5	Low
≥155mm Projectiles		C	D	CE5	Low	CD5	Low	CE5	Low	CE5	Low	CD5	Low	DD2	Low	CD5	Low	CD5	Low
HE Bombs	Allied Origin	E	F	EE4	Low	EC4	Low	ED4	Low	ED4	Low	EC4	Low	FC2	Low	EC4	Low	EC4	Low
HE Bombs	Axis Origin	E	F	EE4	Low	EC4	Low	ED4	Low	ED4	Low	EC4	Low	FC2	Low	EC4	Low	EC4	Low
Sea Mines	Allied Origin	D	E	DD3	Low	DC3	Low	DD3	Low	DD3	Low	DC3	Low	EC2	Low	DC3	Low	DC3	Low
Sea Mines	Axis Origin	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	EC3	Low	FC2	Low	EC3	Low	EC3	Low
Sea Mines	Axis Origin (Non-Ferrous)	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	EC3	Low	FC2	Low	EC3	Low	EC3	Low
Torpedoes		E	F	EE3	Low	EC3	Low	ED3	Low	ED3	Low	EC3	Low	FC2	Low	EC3	Low	EC3	Low
Depth Charges		E	F	EE3	Low	EC3	Low	ED3	Low	ED3	Low	EC3	Low	FC2	Low	EC3	Low	EC3	Low
Conventional Dumped Munitions		E	F	EE3	Low	ED3	Low	EE3	Low	EE3	Low	ED3	Low	FD2	Low	ED3	Low	ED3	Low
Dumped Chemical Munitions		E	F	EE4	Low	ED4	Low	EE4	Low	EE4	Low	ED4	Low	FD2	Low	ED4	Low	ED4	Low
Missiles/Rockets		E	F	EE3	Low	ED3	Low	EE3	Low	EE3	Low	ED3	Low	FD2	Low	ED3	Low	ED3	Low

UXO		Probability of Encounter on Seabed	Probability of Encounter on Vessel*	Jack-Up Operation	Risk Rating	Rock Placement	Risk Rating	Mattress Installation	Risk Rating	PLGR	Risk Rating	Borehole/ Vibrocore	Risk Rating	CPT	Risk Rating	Grab Sampling	Risk Rating
				Activity / Pathway													
Regular Munitions				Final Hazard Level													
Small Arms Ammunition		E	F	EF5	Negligible	EE5	Negligible	EF5	Negligible	EE5	Negligible	EF5	Negligible	EF5	Negligible	EF5	Negligible
Land Service Ammunition		E	F	EE5	Negligible	ED5	Low	EE5	Negligible	ED5	Low	EE5	Negligible	EE5	Negligible	EE5	Negligible
≤155mm Projectiles		C	D	CE5	Low	CD5	Low	CE5	Low	CD5	Low	CE5	Low	CE5	Low	CE5	Low
≥155mm Projectiles		C	D	CE5	Low	CD5	Low	CE5	Low	CD5	Low	CE5	Low	CE5	Low	CE5	Low
HE Bombs	Allied Origin	E	F	ED4	Low	EC4	Low	EE4	Low	ED4	Low	ED4	Low	ED4	Low	EE4	Low
HE Bombs	Axis Origin	E	F	ED4	Low	EC4	Low	EE4	Low	ED4	Low	ED4	Low	ED4	Low	EE4	Low
Sea Mines	Allied Origin	D	E	DD3	Low	DC3	Low	DD3	Low	DD3	Low	DD3	Low	DD3	Low	DD3	Low
Sea Mines	Axis Origin	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low
Sea Mines	Axis Origin (Non-Ferrous)	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low
Torpedoes		E	F	ED3	Low	EC3	Low	EE3	Low	ED3	Low	ED3	Low	ED3	Low	EE3	Low
Depth Charges		E	F	ED3	Low	EC3	Low	EE3	Low	ED3	Low	ED3	Low	ED3	Low	EE3	Low
Conventional Dumped Munitions		E	F	EE3	Low	ED3	Low	EE3	Low	ED3	Low	EE3	Low	EE3	Low	EE3	Low
Dumped Chemical Munitions		E	F	EE4	Low	ED4	Low	EE4	Low	ED4	Low	EE4	Low	EE4	Low	EE4	Low
Missiles/Rockets		E	F	EE3	Low	ED3	Low	EE3	Low	ED4	Low	EE3	Low	EE3	Low	EE3	Low

Probability: A = high probability to F = Low probability
Consequence: 1 = High to 5 = Low

Final Hazard Level: Encounter (Detonation - Consequence)

Risk Levels:

High
Moderate
Low
Negligible

Notes:

For 'Hazard Levels on Seabed' the depth is stated in Column B
For 'Hazard Levels on Vessel' the depth is Surface (0 m)
All Hazard Levels given are prior to any mitigation
(Detonation - Consequence) Levels are taken from worksheet Hazard_Eval-1
Consequence level definitions are found in *Appendix 014*
Snag on Vessel refers to any possibility of snagging UXO and transferring to vessel
The final risk rating is based on the highest score for each activity
* For encounter of Chemical Munitions on vessel, the likelihood of snag on vessel resulting from retrieval of cable is considered to be minimal but this does not include residues contaminating equipment

Area	Approx. Depth Range (m LAT)
Zone H	>10m

UXO		Probability of Encounter on Seabed	Probability of Encounter on Vessel*	Cable Lay	Risk Rating	Ploughing	Risk Rating	Vessel Mounted Jetting	Risk Rating	Tracked Vehicle Jetting	Risk Rating	Tracked Mechanical Trencher	Risk Rating	Snag on Vessel*	Risk Rating	Dredging	Risk Rating	Anchoring	Risk Rating
				Activity / Pathway															
Regular Munitions				Final Hazard Level															
Small Arms Ammunition		E	F	EF5	Negligible	EE5	Negligible	EE5	Negligible	EE5	Negligible	EE5	Negligible	FE3	Low	EE5	Negligible	EE5	Negligible
Land Service Ammunition		E	F	EE5	Negligible	ED5	Low	EE5	Negligible	EE5	Negligible	ED5	Low	FD2	Low	ED5	Low	ED5	Low
≤155mm Projectiles		D	E	DE5	Low	DD5	Low	DE5	Low	DE5	Low	DD5	Low	ED2	Low	DD5	Low	DD5	Low
≥155mm Projectiles		D	E	DE5	Low	DD5	Low	DE5	Low	DE5	Low	DD5	Low	ED2	Low	DD5	Low	DD5	Low
HE Bombs	Allied Origin	E	F	EE4	Low	EC4	Low	ED4	Low	ED4	Low	EC4	Low	FC2	Low	EC4	Low	EC4	Low
	Axis Origin	E	F	EE4	Low	EC4	Low	ED4	Low	ED4	Low	EC4	Low	FC2	Low	EC4	Low	EC4	Low
Sea Mines	Allied Origin	D	E	DD3	Low	DC3	Low	DD3	Low	DD3	Low	DC3	Low	EC2	Low	DC3	Low	DC3	Low
	Axis Origin	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	EC3	Low	FC2	Low	EC3	Low	EC3	Low
	Axis Origin (Non-Ferrous)	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	EC3	Low	FC2	Low	EC3	Low	EC3	Low
Torpedoes		E	F	EE3	Low	EC3	Low	ED3	Low	ED3	Low	EC3	Low	FC2	Low	EC3	Low	EC3	Low
Depth Charges		E	F	EE3	Low	EC3	Low	ED3	Low	ED3	Low	EC3	Low	FC2	Low	EC3	Low	EC3	Low
Conventional Dumped Munitions		E	F	EE3	Low	ED3	Low	EE3	Low	EE3	Low	ED3	Low	FD2	Low	ED3	Low	ED3	Low
Dumped Chemical Munitions		E	F	EE4	Low	ED4	Low	EE4	Low	EE4	Low	ED4	Low	FD2	Low	ED4	Low	ED4	Low
Missiles/Rockets		E	F	EE3	Low	ED3	Low	EE3	Low	EE3	Low	ED3	Low	FD2	Low	ED3	Low	ED3	Low

UXO		Probability of Encounter on Seabed	Probability of Encounter on Vessel*	Jack-Up Operation	Risk Rating	Rock Placement	Risk Rating	Mattress Installation	Risk Rating	PLGR	Risk Rating	Borehole/ Vibrocore	Risk Rating	CPT	Risk Rating	Grab Sampling	Risk Rating
				Activity / Pathway													
Regular Munitions				Final Hazard Level													
Small Arms Ammunition		E	F	EF5	Negligible	EE5	Negligible	EF5	Negligible	EE5	Negligible	EF5	Negligible	EF5	Negligible	EF5	Negligible
Land Service Ammunition		E	F	EE5	Negligible	ED5	Low	EE5	Negligible	ED5	Low	EE5	Negligible	EE5	Negligible	EE5	Negligible
≤155mm Projectiles		D	E	DE5	Low	DD5	Low	DE5	Low	DD5	Low	DE5	Low	DE5	Low	DE5	Low
≥155mm Projectiles		D	E	DE5	Low	DD5	Low	DE5	Low	DD5	Low	DE5	Low	DE5	Low	DE5	Low
HE Bombs	Allied Origin	E	F	ED4	Low	EC4	Low	EE4	Low	ED4	Low	ED4	Low	ED4	Low	EE4	Low
	Axis Origin	E	F	ED4	Low	EC4	Low	EE4	Low	ED4	Low	ED4	Low	ED4	Low	EE4	Low
Sea Mines	Allied Origin	D	E	DD3	Low	DC3	Low	DD3	Low	DD3	Low	DD3	Low	DD3	Low	DD3	Low
	Axis Origin	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low
	Axis Origin (Non-Ferrous)	E	F	ED3	Low	EC3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low
Torpedoes		E	F	ED3	Low	EC3	Low	EE3	Low	ED3	Low	ED3	Low	ED3	Low	EE3	Low
Depth Charges		E	F	ED3	Low	EC3	Low	EE3	Low	ED3	Low	ED3	Low	ED3	Low	EE3	Low
Conventional Dumped Munitions		E	F	EE3	Low	ED3	Low	EE3	Low	ED3	Low	EE3	Low	EE3	Low	EE3	Low
Dumped Chemical Munitions		E	F	EE4	Low	ED4	Low	EE4	Low	ED4	Low	EE4	Low	EE4	Low	EE4	Low
Missiles/Rockets		E	F	EE3	Low	ED3	Low	EE3	Low	ED4	Low	EE3	Low	EE3	Low	EE3	Low

Probability: A = high probability to F = Low probability
Consequence: 1 = High to 5 = Low

Final Hazard Level: Encounter (Detonation - Consequence)

Risk Levels:

High
Moderate
Low
Negligible

Notes:

For 'Hazard Levels on Seabed' the depth is stated in Column B
For 'Hazard Levels on Vessel' the depth is Surface (0 m)
All Hazard Levels given are prior to any mitigation
(Detonation - Consequence) Levels are taken from worksheet Hazard_Eval-1
Consequence level definitions are found in *Appendix 014*
Snag on Vessel refers to any possibility of snagging UXO and transferring to vessel
The final risk rating is based on the highest score for each activity
* For encounter of Chemical Munitions on vessel, the likelihood of snag on vessel resulting from retrieval of cable is considered to be minimal but this does not include residues contaminating equipment

Appendix 8 - Consequence Levels

		EXPECTED CONSEQUENCES / IMPACTS			
		Human Health/ Safety	Environment	Financial Impact	
				Plant and Equipment	Structures
CONSEQUENCE LEVEL	1	Fatalities Over Extended Area	Major – Full Scale Response Required	Multiple Unit Destruction	Widespread Structural Collapse
	2	Localised Fatalities	Major – Full Scale Response Required	Unit Destruction	Localised Structural Collapse
	3	Serious Injury	Serious Resource Required	Component Replacement / Repairs Required	Structural Damage
	4	Injury Requiring Medical Treatment	Moderate/Limited Response Required	Superficial Damage	Non-Structural / Superficial Damage
	5	Minor Impact/First Aid	Minor Response Required	Minor/ No notable effect	Minor/ No notable effect

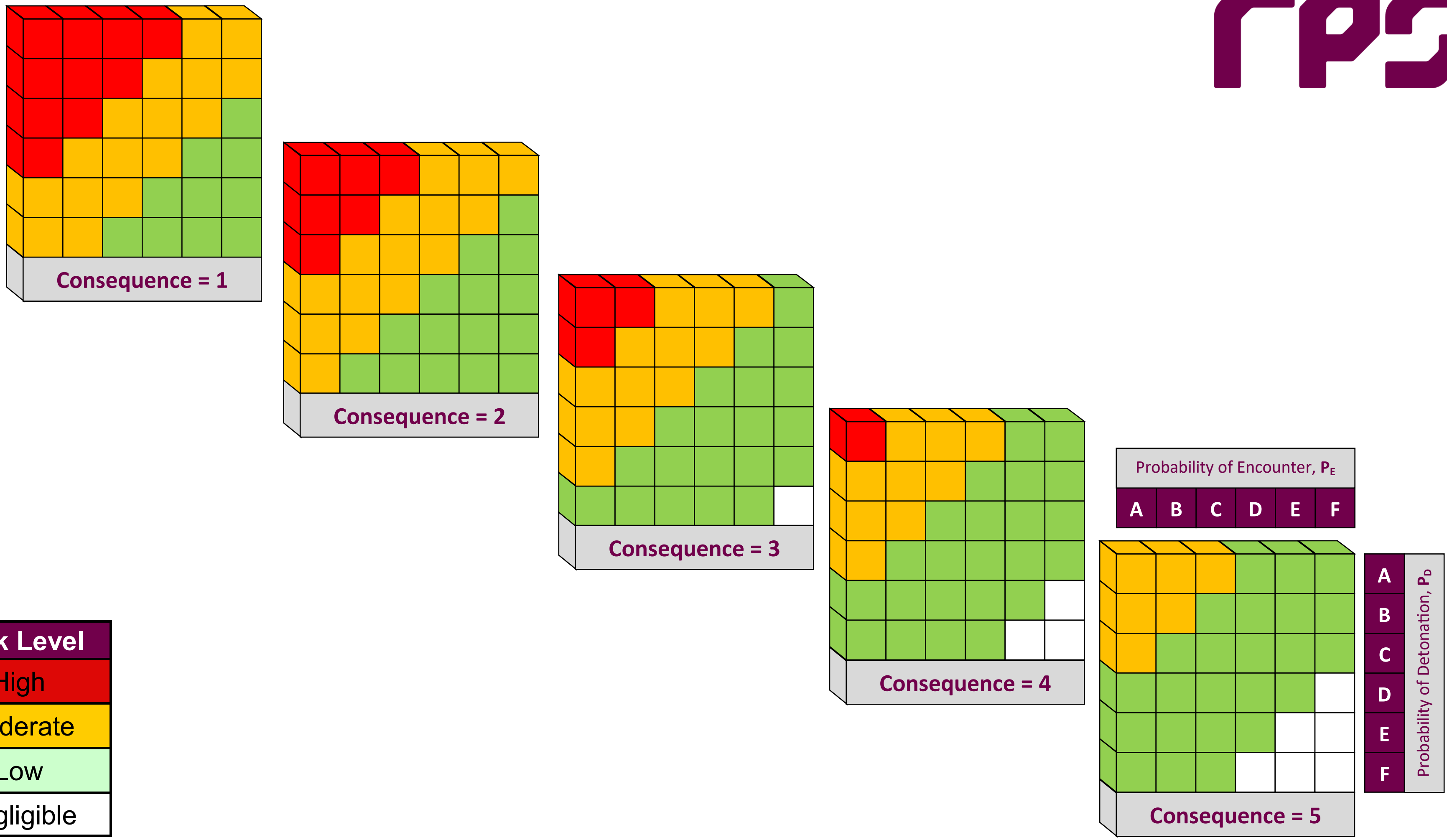
Probability Level	
A	Highly Probable
B	Probable
C	Possible
D	Remote
E	Improbable
F	Highly Improbable

rps MAKING COMPLEX EASY

Explosives Engineering Services

+44 (0) 845 638 4760

www.rpsuxo.com



Risk Level
High
Moderate
Low
Negligible

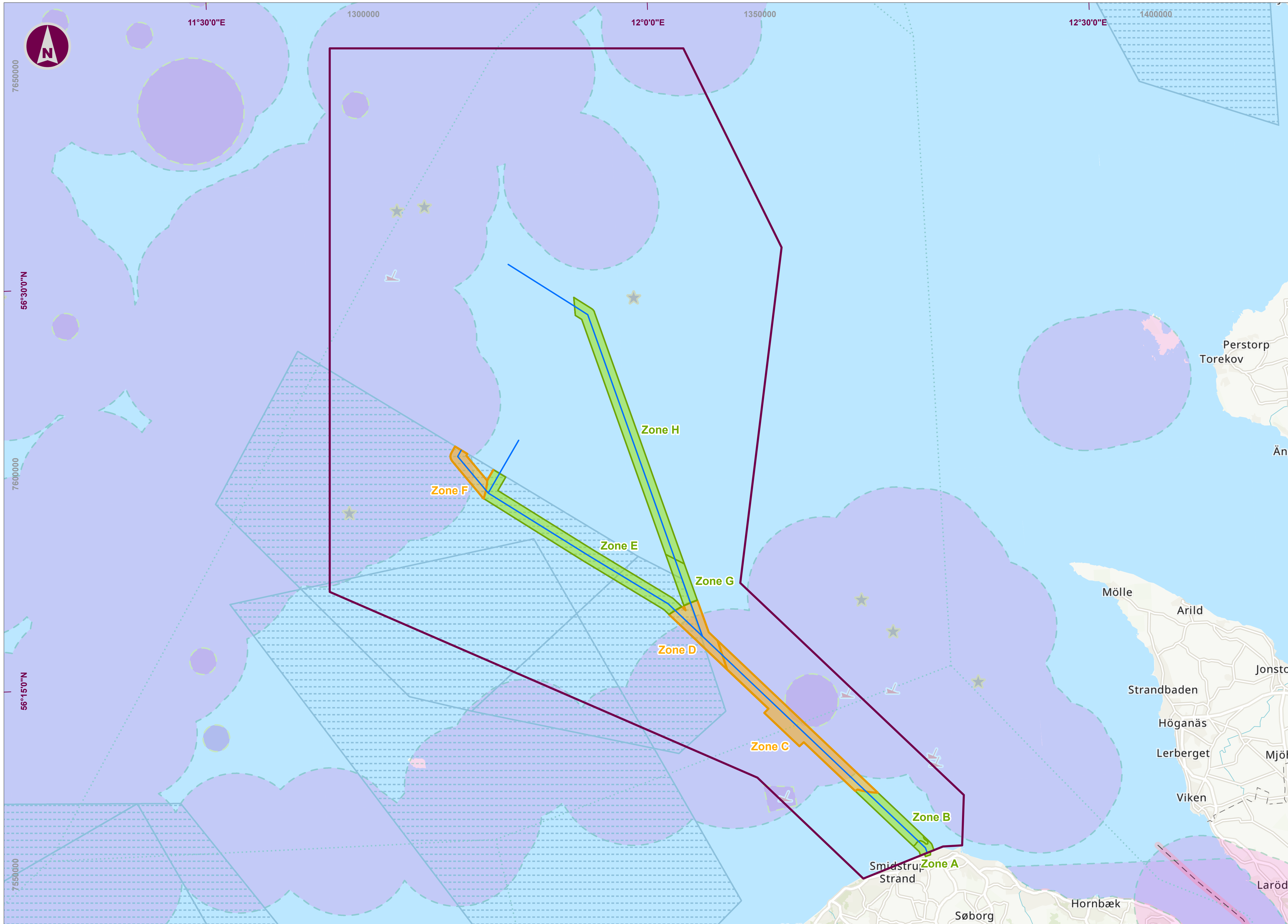
Project: Hesselø, Energinet

Project Ref: EES1129

Appendix 008: Consequence Levels 2 of 2

Explosives Engineering Services
+44 (0) 845 638 4760
www.rpsuxo.com

Appendix 9 - Risk Zone Map



Legend

- Area of Interest (AOI)
- Proposed Cable Route
- Low UXO Risk
- Moderate UXO Risk
- Proposed Survey Area
- Wreck Record (HO/emapsite) - Within 5km - UXO Related (HO/emapsite)
- OSPAR Munition Encounters (up to 2017)
- Wartime Convoy/Vessel Route
- Firing Exercise Area
- Historic Offshore Minefield - British (WWII)
- Historic Offshore Minefield - Unspecified Origin (Unspecified Conflict)

Overview

0 2.5 5 10 15 20 25 30 Kilometers

0 2.5 5 10 15 Nautical Miles

Geodetic Information:

CRS: ETRS 1989 UTM Zone 32N, Datum: ETRS 1989

EPSG Code: 25832

Data Sources: Client, Various Reference Material - see associated report.WreckData: © British Crown and OceanWise, 2020. All rights reserved. License No. EK001-EMS-626577. Not to be used for Navigation.
Service Layer Credits: World Topographic Map: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Ver	Description	By	Check	Date
00	INITIAL ISSUE	LM	RM	08/12/20

Figure Number: EES1129-F-004

Rev: 00

Page: 1 of 1

MAKING COMPLEX EASY

rpsgroup.com

Client: Energinet

Project: Hesselo OWF - Cable Route

Title: UXO Risk Zoning

Project Number: EES1129

Scale @ A3: 1:275,000

Drawn By: LM

Checked By: RM

Status: INITIAL ISSUE

Date Created: 08/12/2020

Notes:
1. This drawing has been prepared in accordance with the scope of RPS's appointment with its client and is subject to the terms and conditions of that appointment. RPS accepts no liability for any use of this document other than by its client and only for the purposes for which it was prepared and provided.
2. If received electronically it is the recipients responsibility to print to correct scale.
3. Only written dimensions should be used .
4. Not to be used for Navigation.
5. The locations shown are based on the information identified /provided, and should be used for general guidance only.

Appendix 10 - Met Ocean Study

TIDAL CURRENTS

The effects of tides were generated using RPS's advanced ocean/coastal model, HYDROMAP. The HYDROMAP model has been thoroughly tested and verified through field measurements throughout the world over more than 20 years (Isaji and Spaulding, 1984; Isaji et al., 2001; Zigic et al., 2003). In fact, HYDROMAP tidal current data has been used as input for the OILMAP hydrocarbon spill modelling system, which forms part of the Incident Management System (IMS) operated by Maritime New Zealand (MNZ), Australian Maritime Safety Authority (AMSA) and the United Kingdom Maritime and Coastguard Agency, as well as several major oil and gas companies.

HYDROMAP employs a sophisticated sub-gridding strategy, which supports up to six levels of spatial resolution, halving the grid cell size as each level of resolution is employed. The sub-gridding allows for higher resolution of currents within areas of greater bathymetric and coastline complexity, and/or of particular interest to a study.

The numerical solution methodology follows that of Davies (1977a and 1977b) with further developments for model efficiency by Owen (1980) and Gordon (1982). A more detailed presentation of the model can be found in Isaji and Spaulding (1984) and Isaji et al. (2001).

Grid Setup

RPS has a seamless global tidal model. The tidal domains are sub-gridded to a resolution of 500 m for shallow and coastal regions, starting from an offshore (or deep water) resolution of 8 km. The finer grid cells are allocated in a step-wise fashion to more accurately resolve flows along the coastline, around islands and over regions with more complex bathymetry. Figure 1 shows a zoomed in image of the North Sea.

A combination of datasets was used to describe the shape of the seabed within the high-resolution grid. Depths for the region were extracted from digital nautical charts and the European Marine Observation and Data Network (EMODnet) digital terrain model, which provides 115 m resolution.

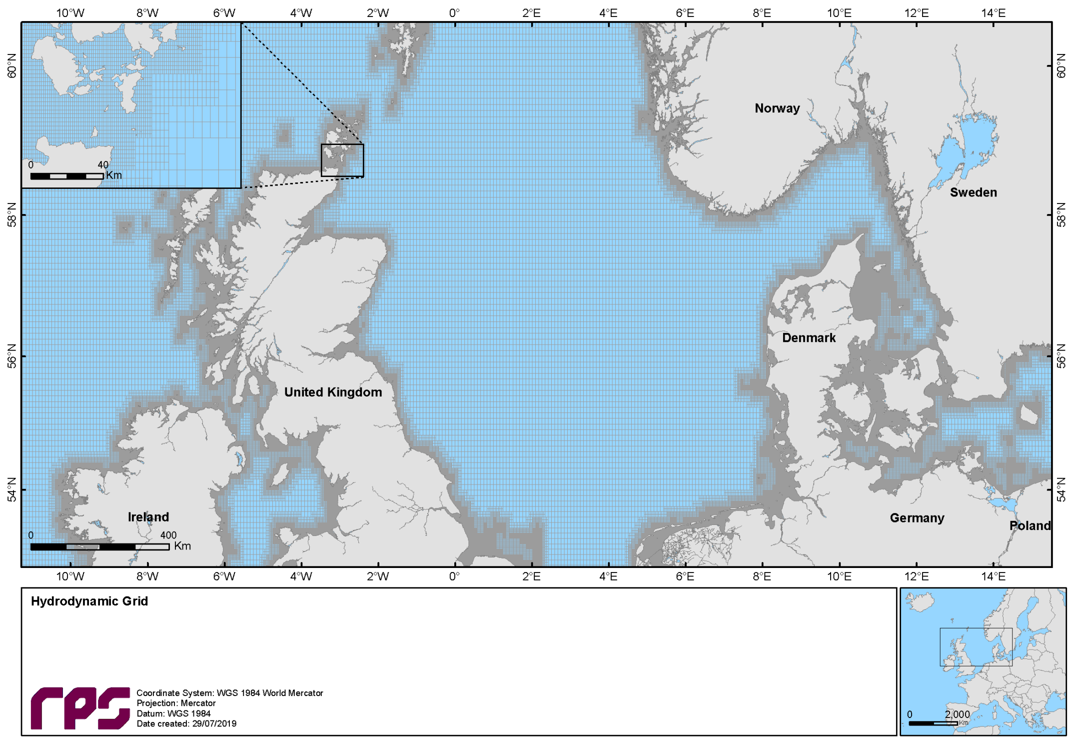


Figure 1 Map showing an example of the regions of sub-gridding for the study area

Tidal Conditions

The ocean boundary data for the regional model was obtained from satellite measured altimetry data (TOPEX/Poseidon 7.2) which provided estimates of the eight dominant tidal constituents at a horizontal scale of approximately 0.25 degrees. The eight major tidal constituents used were K_2, S_2, M_2, N_2, K_1, P_1, O_1 and Q_1. Using the tidal data, surface heights were firstly calculated along the open boundaries, at each time step in the model.

The Topex-Poseidon satellite data is produced, and quality controlled by National Aeronautics and Space Administration (NASA). The satellites, equipped with two highly accurate altimeters, capable of taking sea level measurements accurate to less than ± 5 cm, measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005). In total these satellites carried out 62,000 orbits of the planet. The Topex-Poseidon tidal data has been widely used amongst the oceanographic community, being the subject of more than 2,100 research publications (e.g. Andersen, 1995; Ludicone et al., 1998; Matsumoto et al., 2000; Kostianoy et al., 2003; Yaremchuk and Tangdong, 2004; Qiu and Chen 2010). As such the Topex/Poseidon tidal data is considered suitably accurate for this study.

Surface Elevation Validation

To ensure that tidal predictions were accurate, predicted surface elevations were compared to data observed at twelve (12) locations situated across the study region (Figure 2).

Figure 3 to Figure 6 illustrate a comparison of the predicted and observed surface elevations for each location for January 2014. As shown on the graph, the model accurately reproduced the phase and amplitudes throughout the spring and neap tidal cycles well.

To provide a statistical measure of the model's performance, the Index of Agreement (IOA – Willmott, 1981) and the Mean Absolute Error (MAE – Willmott, 1982; Willmott and Matsuura, 2005) were used.

The MAE is the average of the absolute values of the difference between the model-predicted (P) and observed (O) variables. It is a more natural measure of the average error and more readily understood (Willmott and Matsuura, 2005).

$$MAE = N^{-1} \sum_{i=1}^{N} |P_i - O_i|$$

The Index of Agreement (IOA) is determined by:

$$IOA = 1 - \frac{\sum |X_{model} - X_{obs}|^2}{\sum (|X_{model} - \overline{X_{obs}}| + |X_{obs} - \overline{X_{obs}}|)^2}$$

Where: *X* represents the variable being compared and the time mean of that variable. A perfect agreement exists between the model and field observations if the index gives an agreement value of 1 and complete disagreement will produce an index measure of - (Wilmott, 1981). Willmott et al., (1985) also suggests that values meaningfully larger than -0.5 represent good model performance. Clearly, a greater IOA and lower MAE represent a better model performance.

Table 1 shows the IOA and MAE values for the selected locations.

Figure 2 Location of the tide stations around used to demonstrate the accuracy of the tidal model.

Table 1 Statistical comparison between the observed and HYDROMAP predicted surface elevations data from the 1st to 31st January 2014.

Tide Station	IOA	MAE (m)
Aberdeen	0.99	0.13
Arendal	0.92	0.03
Belfast	0.99	0.15
Concarneau	1.00	0.09
Dover	0.95	0.50
Galway	0.99	0.14
Hvalba	0.99	0.32
Immingham	0.91	0.66
Kristiansund	0.96	0.91
Lerwick, Shetland Islands	0.99	0.06
Milford Haven	0.98	0.32
Wierumergronden	0.92	0.28
Average	**0.97**	**0.30**

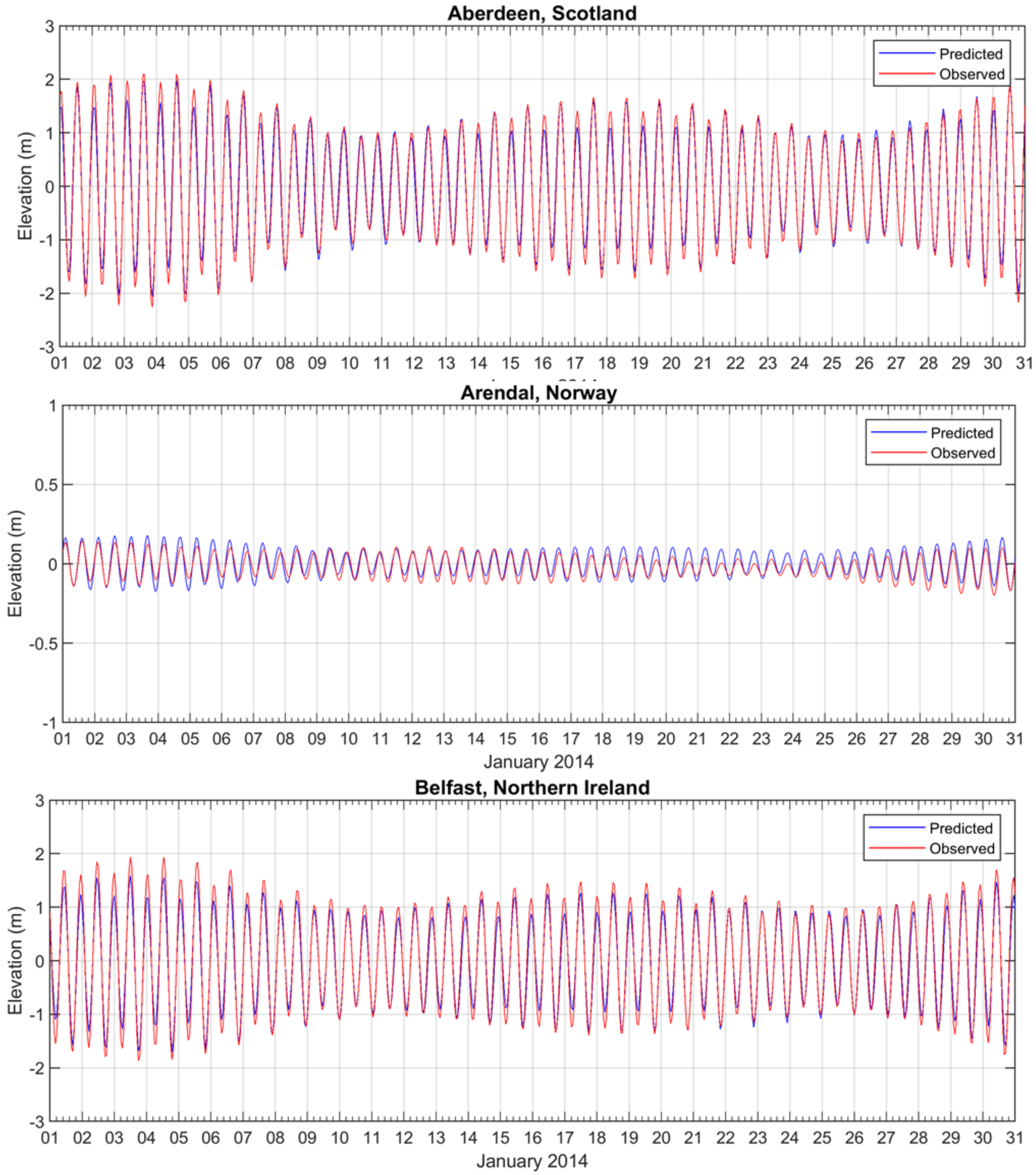


Figure 3 Comparison between predicted (blue line) and observed (red line) surface elevation variation at Aberdeen (top), Arendal (middle) and Belfast (bottom), between the 1st and the 31st of July 2014.

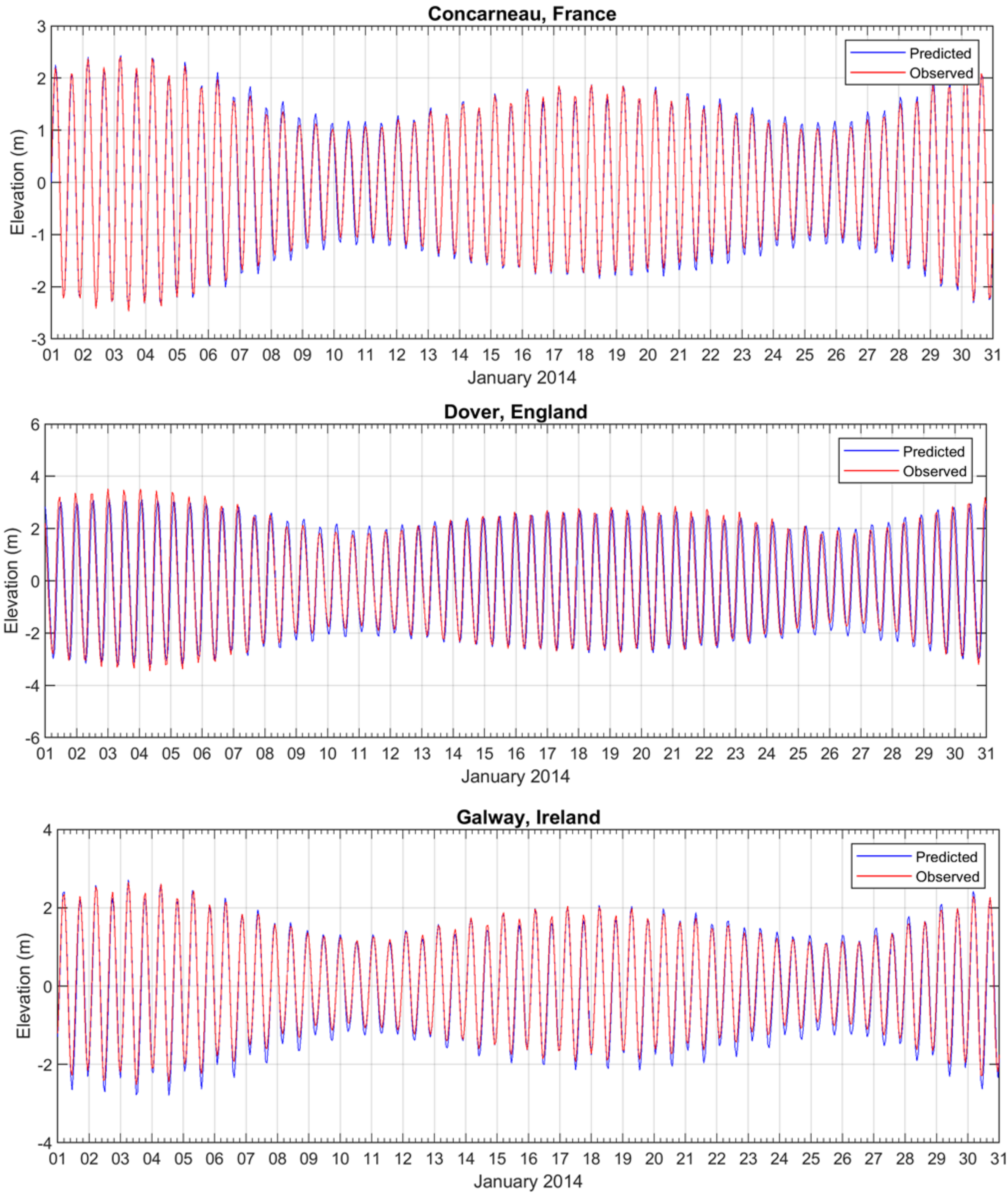


Figure 4 Comparison between predicted (blue line) and observed (red line) surface elevation variation at Concarneau (top), Dover (middle) and Galway (bottom), between the 1st and the 31st of July 2014.

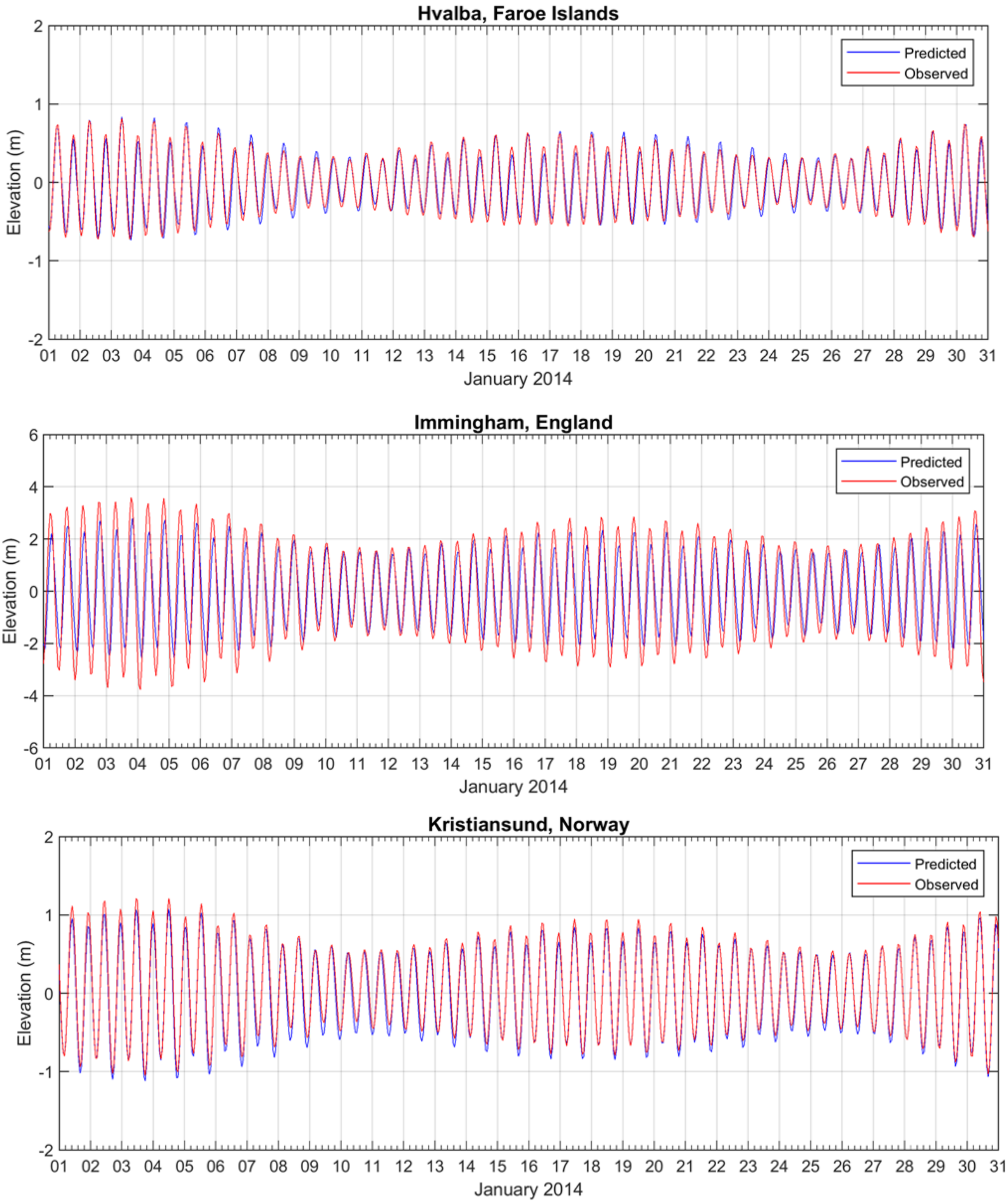


Figure 5 Comparison between predicted (blue line) and observed (red line) surface elevation variation at Hvalba (top), Immingham (middle) and Kristiansund (bottom), between the 1st and the 31st of July 2014.

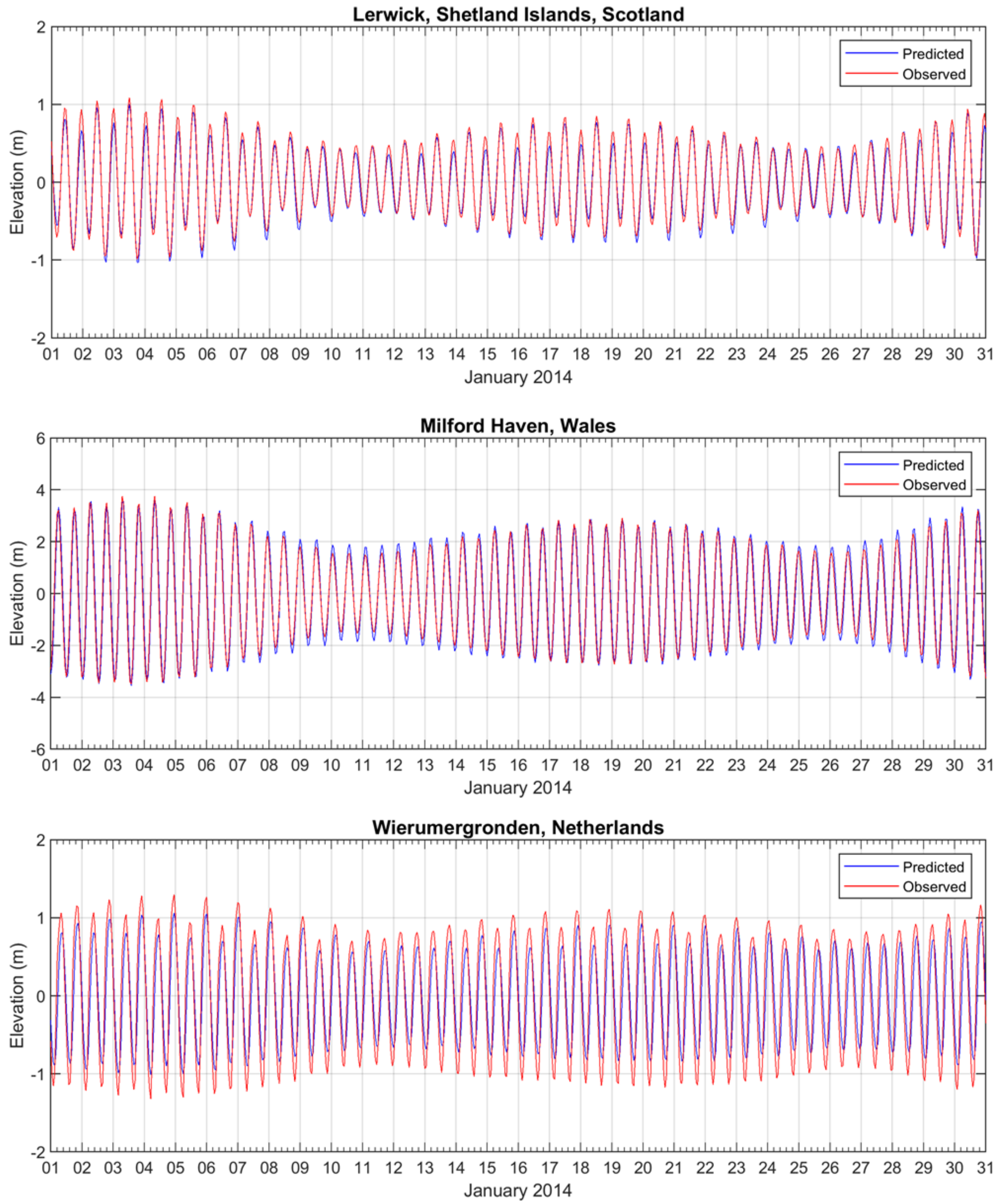


Figure 6 **Comparison between predicted (blue line) and observed (red line) surface elevation variation at Lerwick (top), Milford Haven (middle) and Wierumergronden (bottom), between the 1st and the 31st of July 2014.**

OCEAN CURRENT DATA

Data describing the flow of ocean currents was obtained from HYCOM (Hybrid Coordinate Ocean Model, (Chassignet et al., 2007), which is operated by the HYCOM Consortium, sponsored by the Global Ocean Data Assimilation Experiment (GODAE). HYCOM is a data-assimilative, three-dimensional ocean model that is run as a hindcast (for a past period), assimilating time-varying observations of sea-surface height, sea-surface temperature and in-situ temperature and salinity measurements (Chassignet et al., 2009).

The HYCOM predictions for drift currents are produced at a horizontal spatial resolution of approximately 8.25 km ($1/12^{th}$ of a degree) over the region, at a frequency of 3 hourly.

HYCOM uses isopycnal layers in the open, stratified ocean, but uses the layered continuity equation to make a dynamically smooth transition to a terrain-following coordinate in shallow coastal regions, and to z-level coordinates in the mixed layer and/or unstratified seas.

For this study, the 3-dimensional HYCOM hindcast currents were obtained for the year 2011-2015. Figure 7 shows an example of the modelled surface ocean currents (HYCOM) for the region.

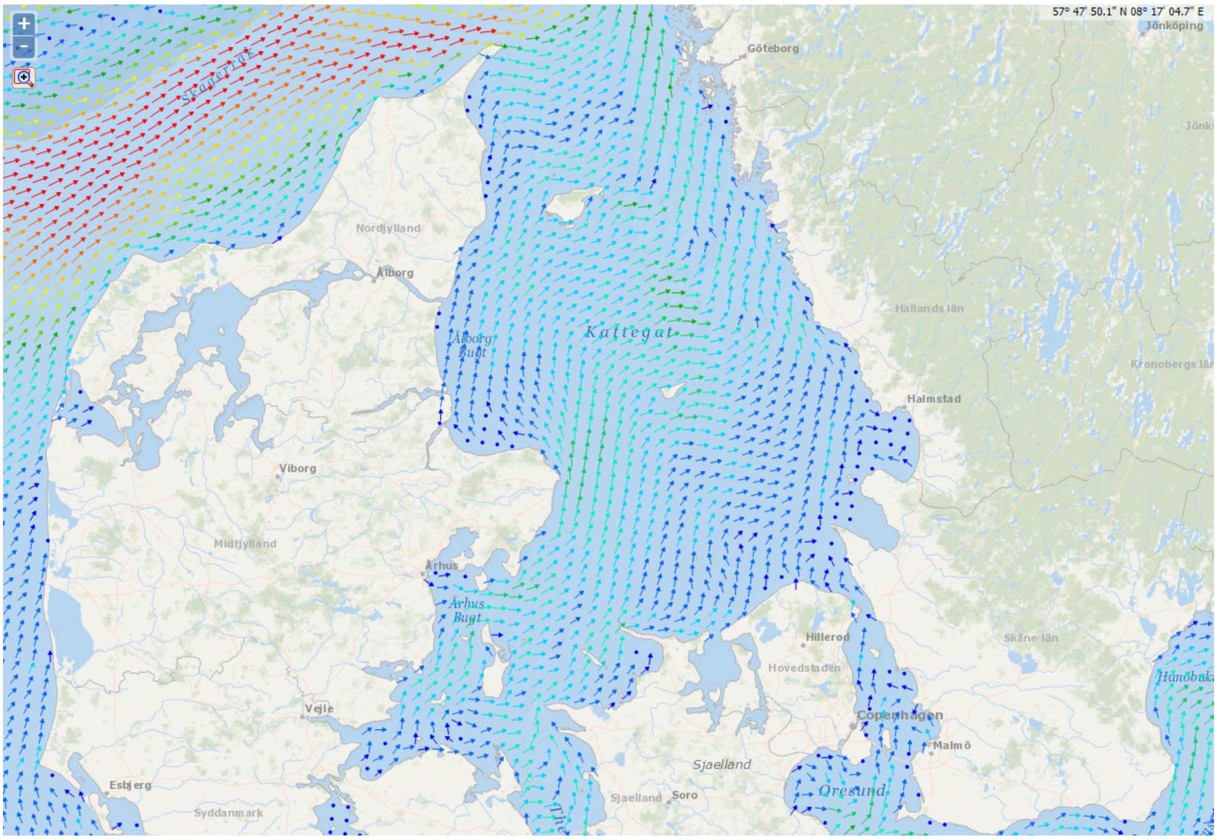


Figure 7 Snapshot example of the predicted HYCOM ocean surface currents in the region. Colour of individual arrows indicate current speed (m/s).

CURRENTS AT HESSELØ OWF

Table 2 displays the average and maximum combined near-surface current speeds (ocean currents plus tides) at the Hesselø Offshore Wind Farm.

Figure 8 provides an illustrative summary of the maximum velocity statistics through the water column. Note this is not a snapshot of an actual current profile at a given time.

Figure 9 to Figure 11 show the monthly, seasonal and annual near-surface current rose distributions, respectively.

Note the convention for defining current direction is the direction the current flows towards, which is used to reference current direction throughout this report. Each branch of the rose represents the currents flowing to that direction, with north to the top of the diagram. Sixteen directions are used. The branches are divided into segments of different colour, which represent the current speed ranges for each direction. Speed intervals of 0.1 m/s are typically used in these current roses. The length of each coloured segment is relative to the proportion of currents flowing within the corresponding speed and direction.

Table 2 Predicted average and maximum near-surface current speeds at the study site. The data was derived by combining the HYCOM ocean data and HYDROMAP tidal data for 2011-2015.

Month	Average current speed (m/s)	Maximum current speed (m/s)	General Direction
January	0.15	0.56	North through East and South
February	0.14	0.54	North through East and South
March	0.14	0.49	North through East and South
April	0.12	0.44	North through East and South
May	0.13	0.39	North through East and South
June	0.13	0.42	North through East and South
July	0.13	0.45	North through East and South
August	0.14	0.52	North through East and South
September	0.13	0.43	North through East and South
October	0.13	0.60	North through East and South
November	0.13	0.54	North through East and South
December	0.16	0.75	North through East and South
Minimum	**0.12**	**0.39**	
Maximum	**0.16**	**0.75**	

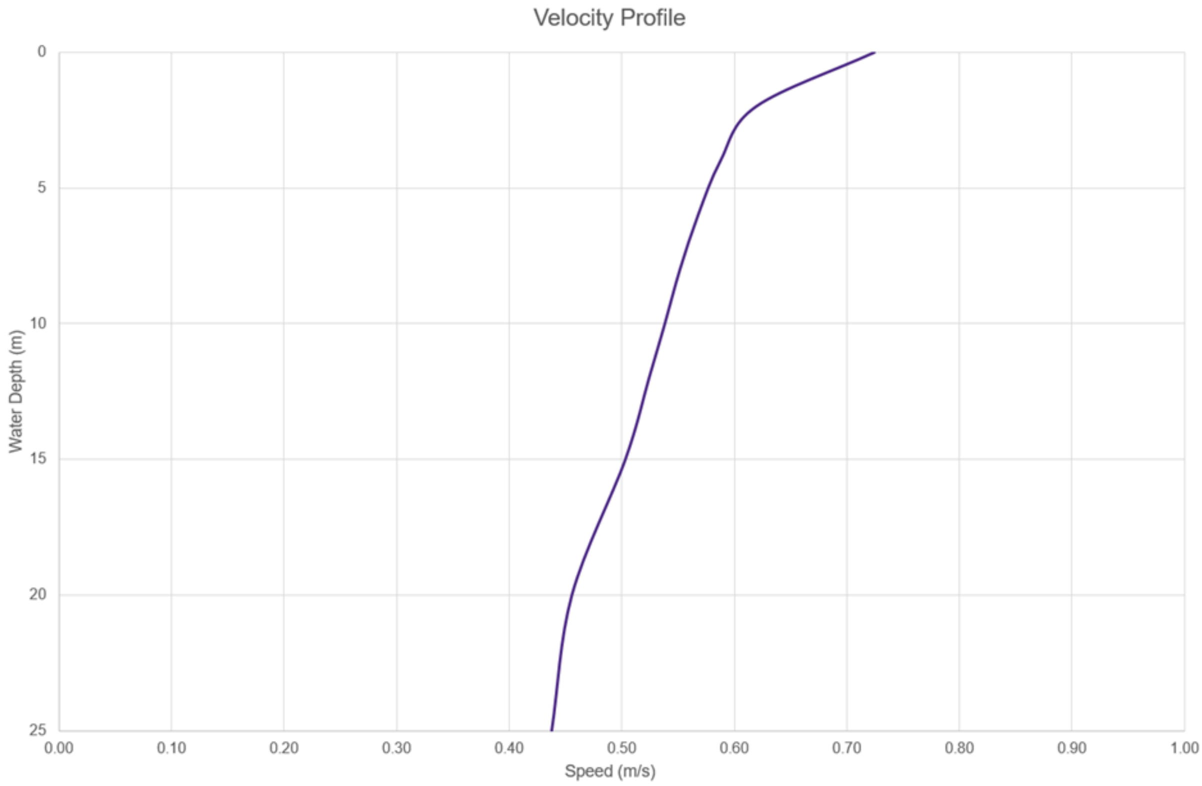


Figure 8 Vertical profile of the maximum current speeds. Note, this is summary representation of the statistics, not an actual snapshot of the current profile at a given time.

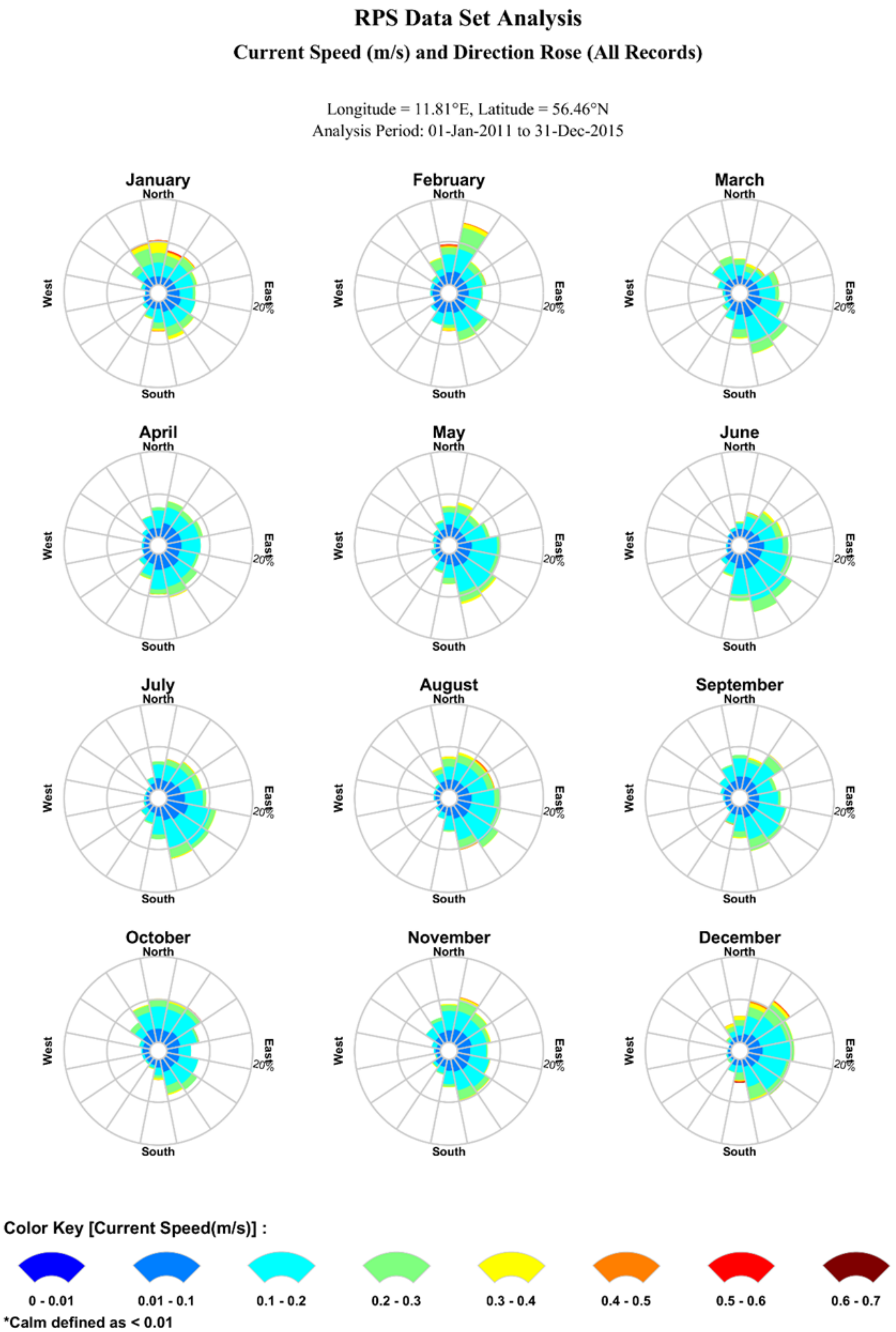


Figure 9 Monthly near-surface current rose plots at the study site. Data was derived by combining the HYDROMAP tidal currents and HYCOM ocean currents for 2011 – 2015. The colour key shows the current speed (m/s), the compass direction provides the current direction flowing TOWARDS and the length of the wedge gives the percentage of the record for a particular speed and direction combination.

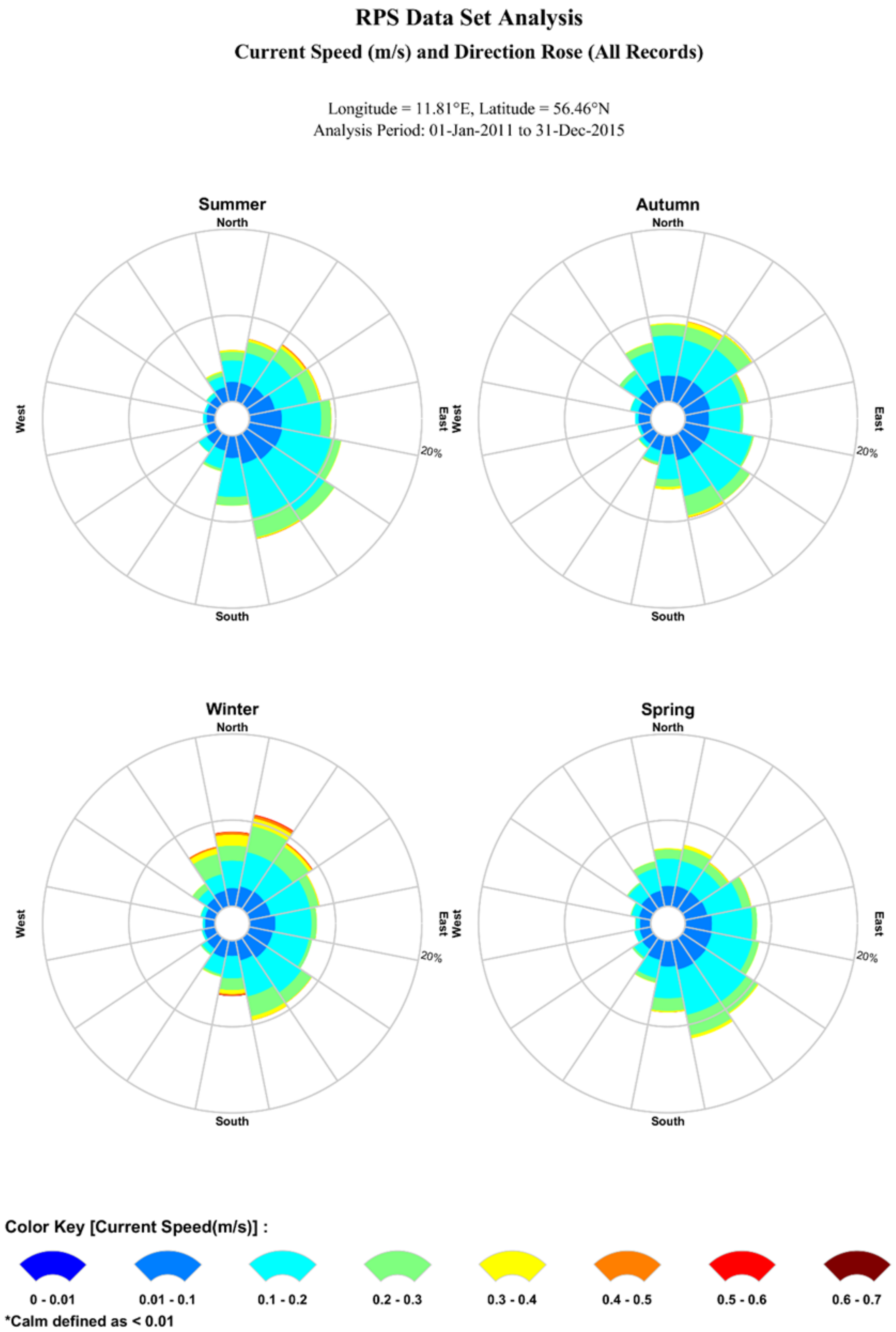


Figure **10** **Seasonal near- surface current rose plots at the study site. Data was derived by combining the HYDROMAP tidal currents and HYCOM ocean currents for 2011 – 2015. The colour key shows the current speed (m/s), the compass direction provides the current direction flowing TOWARDS and the length of the wedge gives the percentage of the record for a particular speed and direction combination.**

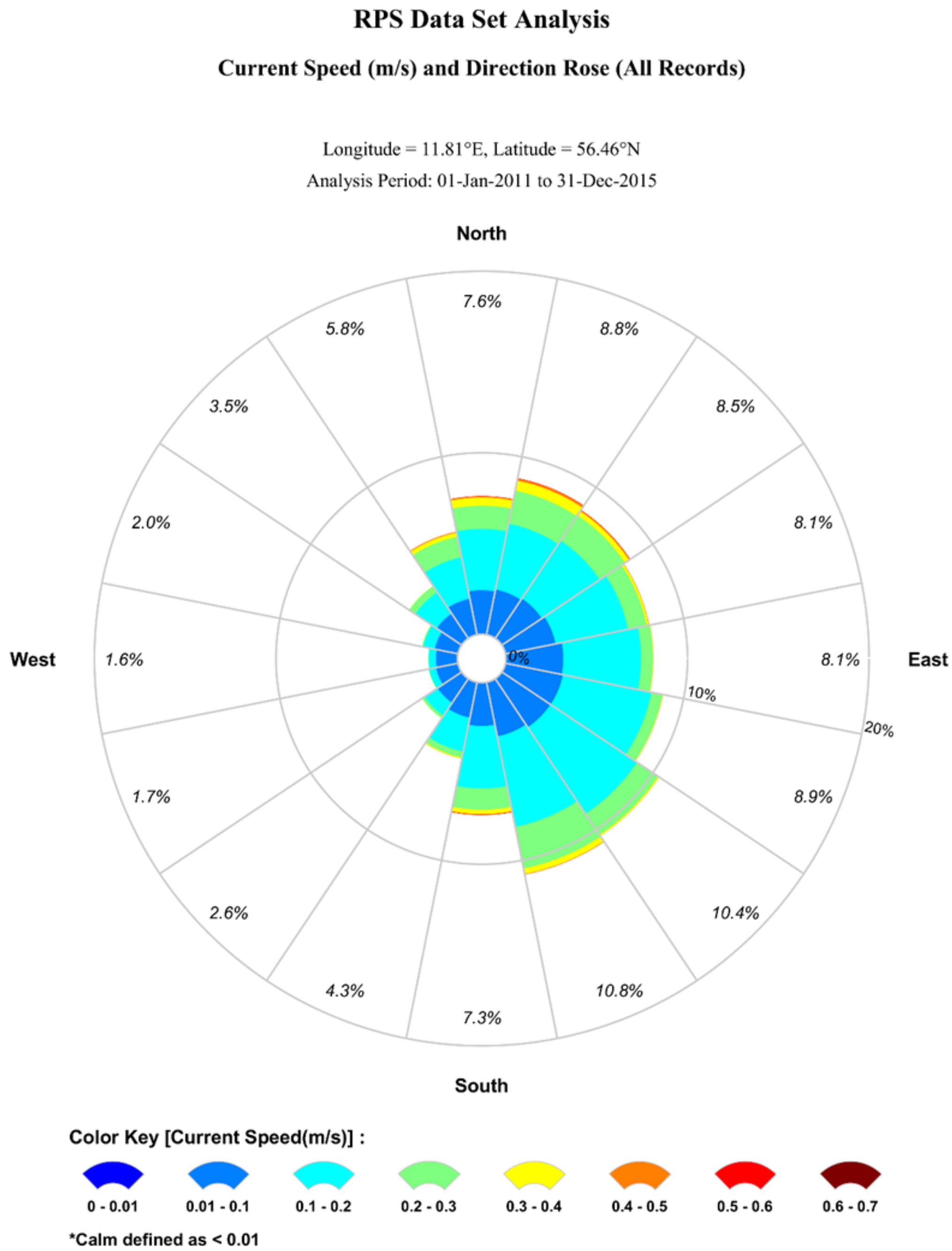


Figure 11 Annual near- surface current rose plots at the study site. Data was derived by combining the HYDROMAP tidal currents and HYCOM ocean currents for 2011 – 2015. The colour key shows the current speed (m/s), the compass direction provides the current direction flowing TOWARDS and the length of the wedge gives the percentage of the record for a particular speed and direction combination.

Currents at Hesselø ECR

Table 2 displays the average and maximum combined near-surface current speeds (ocean currents plus tides) at the Hesselø Export Cable Route.

Figure 8 provides an illustrative summary of the maximum velocity statistics through the water column. Note this is not a snapshot of an actual current profile at a given time.

Figure 9 to Figure 11 show the monthly, seasonal and annual near-surface current rose distributions, respectively.

Note the convention for defining current direction is the direction the current flows towards, which is used to reference current direction throughout this report. Each branch of the rose represents the currents flowing to that direction, with north to the top of the diagram. Sixteen directions are used. The branches are divided into segments of different colour, which represent the current speed ranges for each direction. Speed intervals of 0.1 m/s are typically used in these current roses. The length of each coloured segment is relative to the proportion of currents flowing within the corresponding speed and direction.

Table 2 Predicted average and maximum near-surface current speeds at the study site. The data was derived by combining the HYCOM ocean data and HYDROMAP tidal data for 2011-2015.

Month	Average current speed (m/s)	Maximum current speed (m/s)	General Direction
January	0.17	0.64	Northwest through East
February	0.14	0.52	Northwest through East
March	0.14	0.53	Northwest through East
April	0.13	0.43	Northwest through East
May	0.12	0.47	Northwest through East
June	0.13	0.44	Easterly
July	0.13	0.48	Easterly
August	0.14	0.54	Easterly
September	0.14	0.51	Easterly
October	0.14	0.56	Northwest through East
November	0.14	0.54	Northwest through East
December	0.15	0.67	Northwest through East
Minimum	**0.12**	**0.43**	
Maximum	**0.17**	**0.67**	

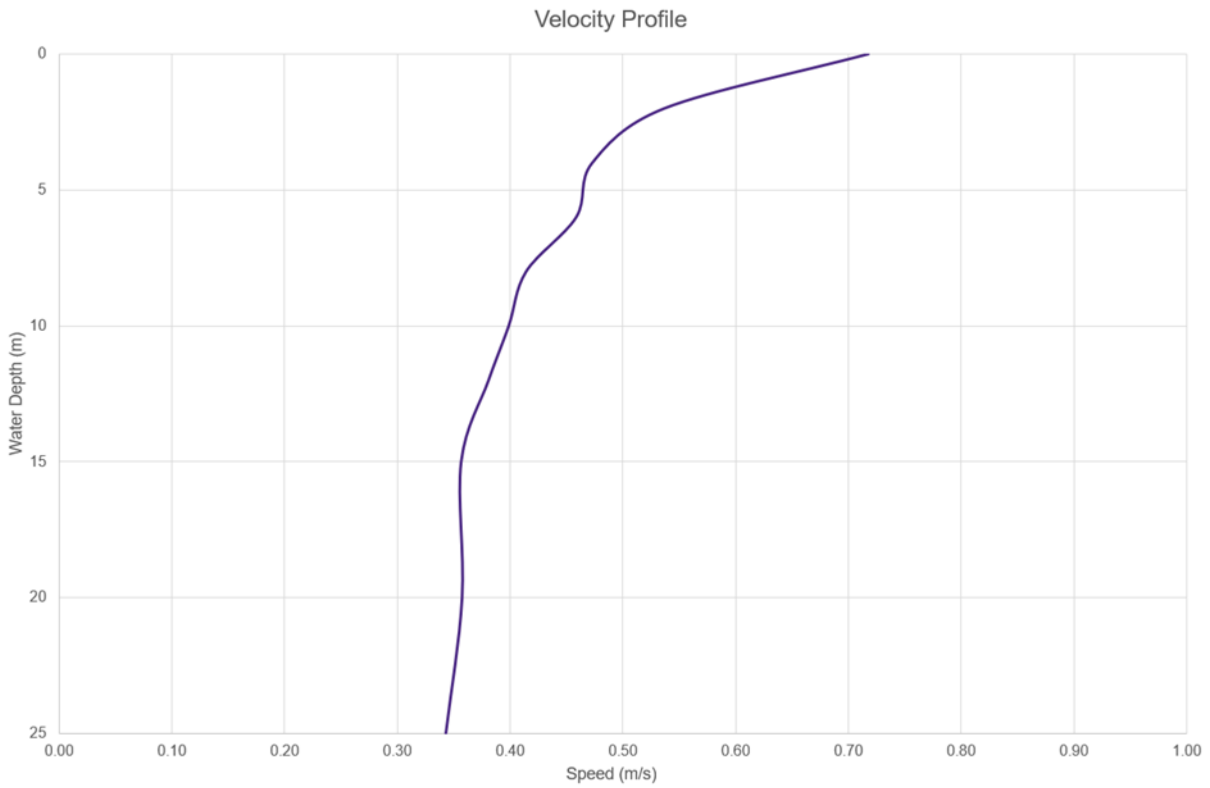


Figure 8 **Vertical profile of the maximum current speeds. Note, this is summary representation of the statistics, not an actual snapshot of the current profile at a given time.**

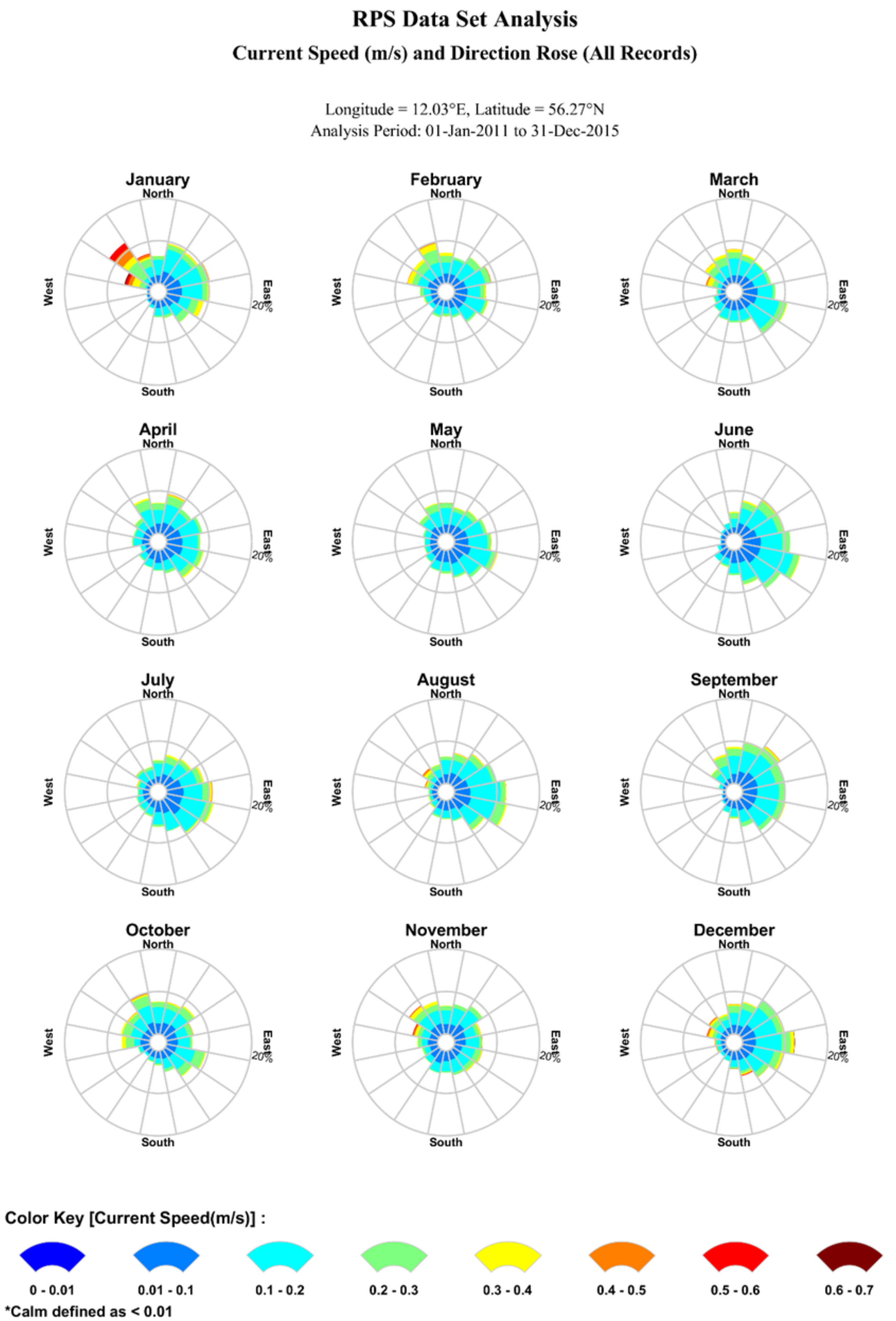


Figure 9 **Monthly near-surface current rose plots at the study site. Data was derived by combining the HYDROMAP tidal currents and HYCOM ocean currents for 2011 – 2015. The colour key shows the current speed (m/s), the compass direction provides the current direction flowing TOWARDS and the length of the wedge gives the percentage of the record for a particular speed and direction combination.**

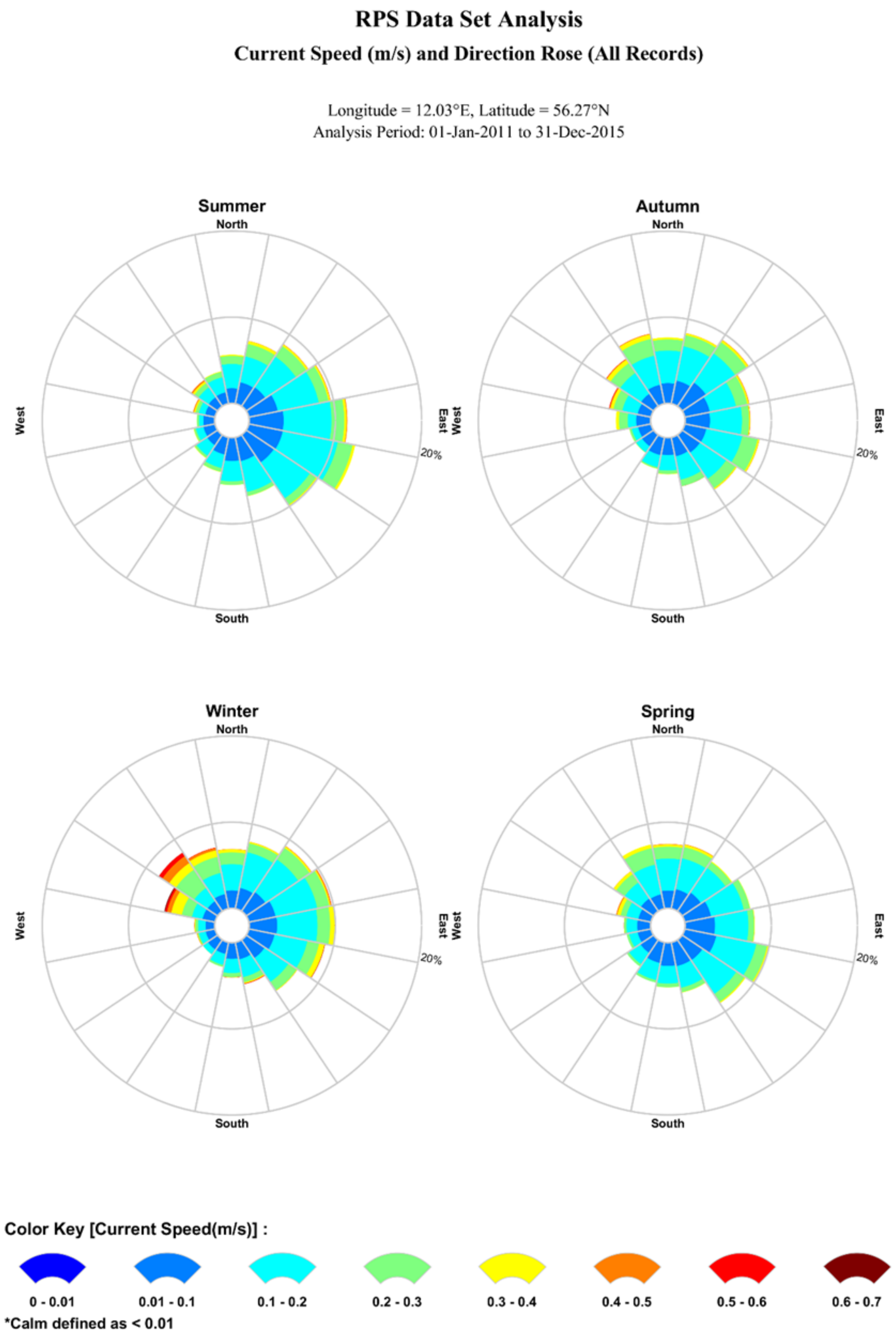


Figure 10 **Seasonal near- surface current rose plots at the study site. Data was derived by combining the HYDROMAP tidal currents and HYCOM ocean currents for 2011 – 2015. The colour key shows the current speed (m/s), the compass direction provides the current direction flowing TOWARDS and the length of the wedge gives the percentage of the record for a particular speed and direction combination.**

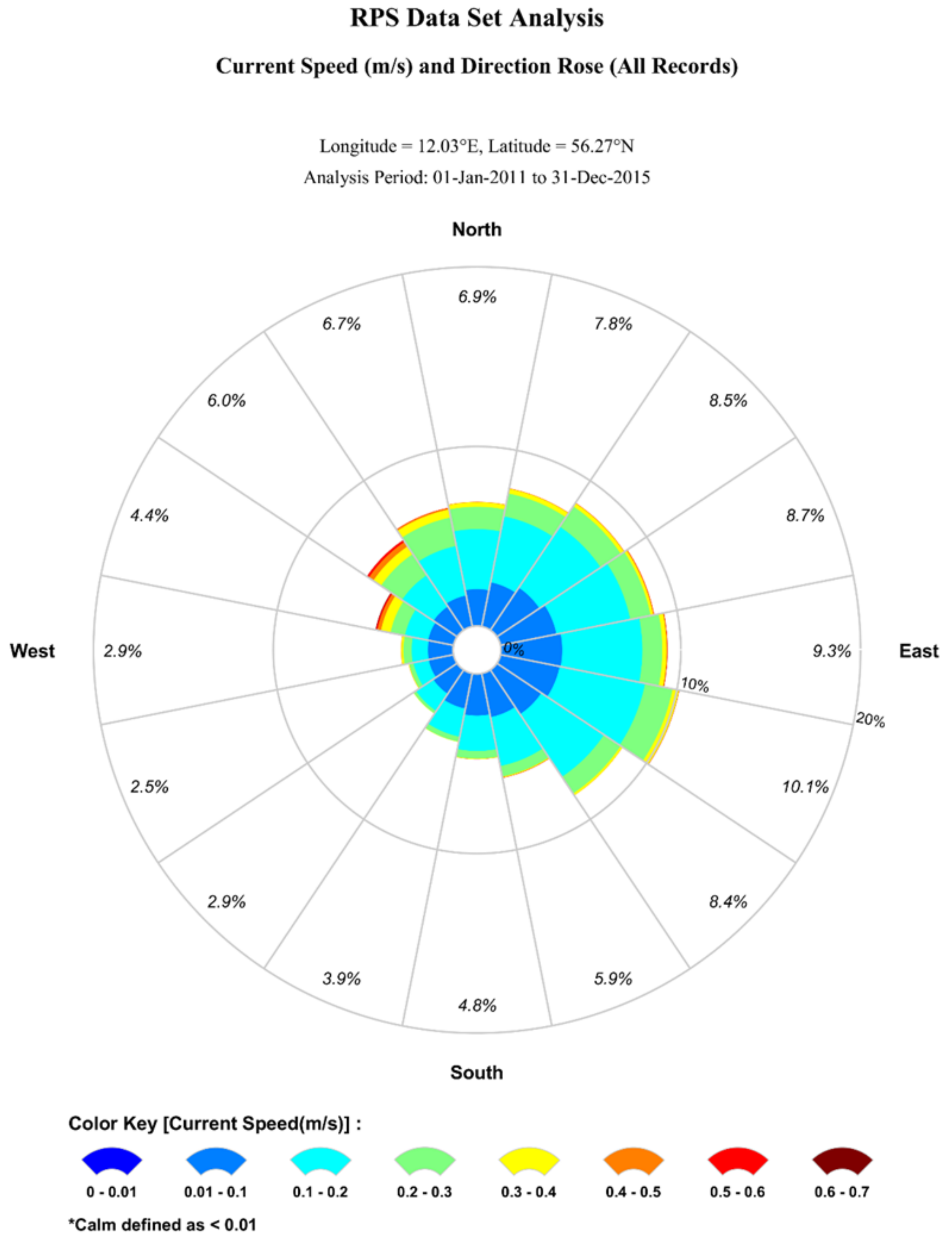


Figure 11 **Annual near- surface current rose plots at the study site. Data was derived by combining the HYDROMAP tidal currents and HYCOM ocean currents for 2011 – 2015. The colour key shows the current speed (m/s), the compass direction provides the current direction flowing TOWARDS and the length of the wedge gives the percentage of the record for a particular speed and direction combination.**