DESK STUDY FOR POTENTIAL UXO CONTAMINATION ENERGY ISLAND - NORTH SEA OWF SITE

Risk Assessment and Mitigation Strategy

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Desk Study for Potential UXO Contamination – Energy Island - North Sea OWF Site

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ABBREVIATIONS

Abbreviation	Definition
AAA	Anti-Aircraft Artillery
ALARP	As Low As Reasonably Practicable
AOI	Area of Interest
CPT	Cone Penetration Test
EOD	Explosive Ordnance Disposal
GU	German EMA mine
GY	German EMC/EMG mine
HE	High Explosive
HIRA	Hazard Identification and Risk Assessment
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
mm	Millimetres
MoD	Ministry of Defence
OSPAR	Convention for the Protection of the Marine Environment of the North East Atlantic
OWF	Offshore Wind Farm
PLGR	Pre-Lay Grapnel Run
pUXO	Potential UXO
RAF	Royal Air Force
RN	Royal Navy
ROV	Remotely Operated Vehicle
RPL	Route Position List
QA	Quality Assurance
QC	Quality Control
SAA	Small Arms Ammunition
SBP	Sub Bottom Profiler
SIT	Surrogate Item Trial
SSS	Side Scan Sonar
TNT	Trinitrotoluene
UK	United Kingdom
UKHO	United Kingdom Hydrographic Office
USBL	Ultra-Short Base Line
UXO	Unexploded Ordnance
WWI	World War One
WWII	World War Two

EXECUTIVE SUMMARY

Background

RPS Explosives Engineering Services (RPS), part of RPS Energy Ltd, has been commissioned by **Energinet** to conduct a desktop study and risk assessment for potential Unexploded Ordnance (UXO) contamination at the **Energy Island – North Sea Offshore Energy Infrastructure**. This Offshore Energy Infrastructure comprises an Offshore Wind Farm of 3 GW and an artificial island to host substation functionality and potentially PtX and maintenance facilities.

This document (**EES1228 R-01-00 UXO DS Energy Island – North Sea OWF Site**) will provide an overview of UXO risk handling for all potential upcoming construction/installation work at the **Energy Island – North Sea OWF Site**.

The Area of Interest (AOI) of this report is the **Energy Island - North Sea OWF Site**. The Offshore Wind Farm (OWF) site, located in the Danish North Sea, covers an area of 1052 km^2 and is expected to be of 3 GW power generating potential. The AOI is as defined by the client provided shapefile: "project_area_northsea_owf_3GW.shp". Importantly, this report does not cover the Artificial Island area, which is included in a separate report: **EES1228 R-02-00 UXO DS Energy Island – North Sea Artificial Island.**

The principal aim of RPS, for this report, is to provide Energinet with an appropriate and pragmatic assessment of the risks posed by UXO to the **Energy Island - North Sea OWF Site**, 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 **Moderate** risk from encountering UXO on site. The risk is primarily due to the presence of Allied Contact Mines, Allied Ground Mines, Danish Contact Mines and Axis Contact Mines.

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.

Table 0.1 - Overall Risk Level

Overall Risk Level			
UXO		Risk Zones	
		A	B
Small Arms Ammunition		Low	Low
Land Service Ammunition		Low	Low
≤155 mm Projectiles		Low	Low
>155 mm Projectiles		Low	Low
HE Bombs	Allied Origin	Low	Low
	Axis Origin ≤25 kg	Low	Low
	Axis Origin >25 kg	Low	Low
Sea Mines	Allied Origin (Contact Mine)	Mod	Mod
	Allied Origin (Ground Mine)	Mod	Mod
	Danish Origin (Contact Mine)	Mod	Mod
	Axis Origin (Contact Mine)	Mod	Mod
	Axis Origin (Non-Ferrous)	Low	Low
Torpedoes		Low	Low
Depth Charges		Low	Low

Overall Risk Level		
UXO	Risk Zones	
	A	B
Conventional Dumped Munitions	Low	Low
Dumped Chemical Munitions	Low	Low
Missiles/Rockets	Low	Low

UXO Burial

The water depths within the AOI are large enough to reduce any burial via initial penetration. Any burial would therefore be caused by natural processes, such as scour and mobile sediments. Based on the MMT report which suggests the presence of sandwaves and megaripples in the AOI, RPS expect there will be burial on site but without more detailed information, the extent of this burial cannot be determined.

Opensource Vibrocore data suggests the base of the Holocene layer is within 0.85 m and 4 m below seabed. RPS understand the client is planning a campaign of Geotechnical Investigations which may help constrain the depth of this layer. As ordnance is only expected within the Holocene layer and not the Pleistocene, this knowledge may be used to help constrain the maximum depth of burial in some areas of the AOI.

Recommendations

Based on the identified risk levels, it is recommended that appropriate mitigation is implemented to reduce the risk, prior to and/or during any works.

As the exact nature of any intrusive works taking place at this stage are not fully known, the methods of mitigation outlined for the site, which consist of both Proactive and Reactive methodologies, should allow the project team to design an appropriate strategy to mitigate the risks.

The proposed mitigation for each zone can be found in **Table 8.1.**

1 INTRODUCTION

1.1 Instruction

RPS Explosives Engineering Services (RPS), part of RPS Energy Ltd, has been commissioned by **Energinet** to conduct a desktop study and risk assessment for potential Unexploded Ordnance (UXO) contamination at the **Energy Island – North Sea Offshore Energy Infrastructure**. This Offshore Energy Infrastructure comprises an Offshore Wind Farm of 3 GW and an artificial island to host substation functionality and potentially PtX and maintenance facilities.

RPS has been requested for delivery of this UXO desk study in two reports:

- **EES1228 R-01-01 UXO DS Energy Island – North Sea OWF Site (This report)** – Review of historical information, UXO risk assessment and risk mitigation strategy for the Energy Island – North Sea Offshore Wind Farm Site.
- **EES1228 R-02-01 UXO DS Energy Island – North Sea Artificial Island** – Review of historical information, UXO risk assessment and risk mitigation strategy for the Energy Island – North Sea Artificial Island.

This document (**EES1228 R-01-01 UXO DS Energy Island – North Sea OWF Site**) will provide an overview of UXO risk handling for all potential upcoming construction/installation work at the **Energy Island – North Sea OWF Site**.

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, appropriate mitigation measures that have been recommended to allow works to proceed safely and with minimal disruption. The recommendations will be designed to reduce the risk on site to As Low As Reasonably Practicable ('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 and any associated risk with the proposed scheme of work.

1.3 Definitions

The term 'Site' refers to the area within the extent of the works associated with the **Energy Island - North Sea OWF Site**, illustrated in **Appendix 1.**

The term '**Area of Interest (AOI)**' refers to the area within the extent of the works associated with the site**.** This is defined by the client-provided ArcGIS shapefile: "project_area_northsea_owf_3GW.shp".

The term "**Area of Interest Buffer"** is a 10 km buffer surrounding the AOI. Due to the degree of inaccuracy when plotting historical munitions and the possibility for munitions to migrate in the marine environment this buffer is used to aid in determining the probability of encountering UXO within the site.

The term "**Wider Area of Interest**" is an undefined area outside of the AOI in which some of the information detailed in this report may relate to, to outline the overall military history of the area

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 Energinet with an appropriate and pragmatic assessment of the risks posed by UXO to the **Energy Island - North Sea OWF Site**, 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 site. 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 is only able to identify 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 which have been deemed suitable following review. RPS will however 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; and
- Internet Research.

RPS has also consulted a series of research documents to compile this report. These are listed in **Section 10**.

1.6.1 Specific Documents

RPS has consulted a number of research documents and existing reports in researching this report. These are listed below:

[1] Menzel, P., Wranik, H. & Paschen, M. (2017). 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. Lehrstuhl für Meerestechnik.

[2] MMT. (2021). North Sea OWF and Energy Islands – Geophysical Survey for Offshore Wind Farms and Energy Island.

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 (AOI) of this report is the **Energy Island - North Sea OWF Site**. The OWF site, located in the Danish North Sea, covers an area of 1052 km^2 and is expected to be of 3 GW power generating potential. The AOI is as defined by the client provided shapefile: "project_area_northsea_owf_3GW.shp". Importantly, this report does not cover the Artificial Island area, which is included in a separate report: **EES1228 R-02-00 UXO DS Energy Island – North Sea Artificial Island.**

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

2.2 Proposed Scheme of Work

The exact nature of installation activities is at this time unknown. However it is expected to include:

- Pre-Lay Grapnel Run (PLGR);
- Cable Lay;
- Cable Installation:
  - Ploughing;
  - Vessel Mounted Jetting;
  - Tracked Vehicle Jetting;
  - Trenching (including Chain Cutter);
- Dredging;
- Turbine Installation:
  - Anchoring;
  - Jack-Up Operations;
  - Piled Foundation Installation;
  - Suction Pile Foundations;
- Protection Activities:
  - Rock Placement;
  - Mattress Installation;
- Geotechnical Investigation:
  - Borehole / Vibrocore;
  - Cone Penetration Test (CPT); and
  - Grab Sampling.

2.3 Geology and Bathymetry

RPS has been supplied with geophysical survey reporting from the eastern half of the OWF site. In this reporting, MBES, SSS and grab sampling data has been supplied which is used in the subsequent sections to provide an overview of the geological and bathymetric conditions within the OWF site.

2.3.1 Geology

SSS survey and grab sampling has been used to determine seabed sediment conditions across the site. Seabed sediments across the survey area are expected to comprise gravelly sand to sandy gravel, mud and muddy sand, and sands.

Gravelly sand and sandy gravels are predominantly found in the central eastern and western sections of the survey area, with areas of these sediments also seen in the north-east of the survey area. Muds and muddy sands are seen almost as a belt running north-south in the centre of the survey area. Sands are seen predominantly in the north-eastern and western sections of the survey area.

Open-source Vibrocore data obtained from GEUS (Geological Survey of Denmark and Greenland) shows that underlying the Holocene sediments across the OWF site is senglacial sands, gravels and clays as well as glacial moraine tills. The Holocene – Pleistocene boundary varies throughout the site, with the Holocene sediment layer varying in thickness from 0.85 m to almost 4 m. In some locations, particularly in the north-east of the OWF site, Holocene sediments are absent and so senglacial clays are found as the seabed sediment.

2.3.2 Bathymetry

MBES data shows that the water depths in the area of the OWF site for which survey has been conducted and reported (at time of this report's issue) vary from a minimum of 25.75 m at the site of the Artificial Island to a maximum of 48.17 m in the western section of the survey area.

Mobile sediment bedforms are seen throughout the site at all scales, from ripples through to sand waves and sand bars. Ripples are seen in the east and west of the survey site, typically with wavelengths of <2 m and heights of 0.1 – 0.2 m. Large ripples are seen in the west of the survey site with wavelengths of approximately 5 – 7 m. Megaripples can also be see in the west of the survey site with wavelengths of approximately 30 m. Sand waves are frequently seen, especially in the north-west of the survey area. These have wavelengths of approximately 50 – 200 m. The sandwaves are expected to have a height of 3-5 m. Large-scale sandbars, on which the more mobile, smaller-scale bedforms are often seen, are observed in the north-east, east, south and west of the survey area.

A sediment mound can be seen in the north-eastern section of the survey area which is significantly higher than the surrounding seafloor (~32.5 m compared to ~41.5 m).

2.3.3 Boulders

Survey data shows that, although boulders are present throughout the survey site, boulder fields are predominantly found in the north-eastern section of the survey site, with smaller boulder fields seen in the north-west, south and east of the survey area.

3 UNEXPLODED ORDNANCE RISK ANALYSIS

3.1 Naval Warfare

The North Sea and the Skagerrak areas have been prominent theatres of conflict / operations for a significant period. Within the region during World War I (WWI) (1914-1918) and World War II (WWII) (1939-1945) this conflict was elevated to levels never seen historically before or since. The nature and proximity of these confrontations may have a potential to cause a UXO-related impact upon parts of the OWF site. The potential sources of this contamination are discussed within the subsequent sections and for clarity are broken down by period or nationality.

3.1.1 World War One (WWI) (1914-1918)

During WWI Denmark maintained a stance of neutrality, this position was agreed and recognised by all sides. However, despite this neutrality Denmark acceded to pressure from Germany to lay naval mines in the Great Belt area and in Danish waters in general. RPS have identified a number of sites of historic naval confrontation that impact upon the boundaries of the route. These are discussed in more detail below.

Denmark's neutrality was violated several times, in fact, 164 violations were reported, the most important taking place on August 19, 1915, when British submarine *E.13* which was grounded off Saltholm was attacked by a German torpedo boat in Danish territorial waters, despite the presence of Danish ships.

3.1.1.1 Action off Horns Reef

A naval night action fought on 17th August 1915. British forces were en route to the Heligoland Bight to lay a large minefield in an attempt to destroy, damage and blockade German vessels coming in and out of their home ports. The Minelayer, *Princess Margaret*, was escorted by seven 'M' class destroyers of the 10th Flotilla. The sun had recently set, and the British taskforce were using the Danish Horns Reef Light Vessel as a navigational marker to gain a position fix before beginning the mine laying operation. Five German destroyers of the 2nd *Torpedoboots-Flottille* returning from a search mission to the north were heading back to their homeport and also using the Horns Reef light vessel to get a navigational fix to enable their final run into port.

At approximately 2000hrs the German Fleet spotted the British Fleet, silhouetted against the setting sun and altered course to intercept. The British Destroyer escort spotted the approaching German Fleet and opened fire with naval gunnery from a range of approximately 5,000 yards and launched torpedoes, all of which missed. The British fleet turned away and under cover of darkness contact was broken between the two fleets. The British minelayers then attempted to resume minelaying operations, however at approximately 2040hrs the German fleet reacquired the British Fleet and began attacking with torpedoes and naval gunnery at a range of approximately 600 yards. *HMS Minos* and the German Destroyer *B109* were both sunk by naval gunfire, however all of the German launched torpedoes missed. The British Fleet once again broke contact and headed west.

3.1.1.2 The Battle of Jutland

On the afternoon of 31st May 1916, a British Naval force commanded by Vice Admiral David Beatty intercepts a squadron of German warships commanded by Admiral Franz von Hipper approximately 75 miles off the Danish Coast, both fleets open fire with naval gunnery at approximately the same time. This was the opening phase of the battle, lasting just 55 minutes during which time the Royal Navy lost 2 battlecruisers, sunk by naval gunnery, *HMS Indefatigable* and *HMS Queen Mary*.

The Battle of Jutland, or the Battle of the Skagerrak as it was known to the Germans, involved over 100,000 men aboard 250 ships and lasted 72 hours during which time the British sunk 11 German ships and heavily damaged another 10, whilst the German fleet sunk 14 British Ships and damaged 23. Whilst the German High Seas Fleet claimed this as a victory, after carrying out a planned withdrawal under the cover of darkness to their home port of Wilhelmshaven the fleet never left port again, with Admiral Scheer reporting to the German high command that further fleet action was not an option, and that submarine warfare was Germany's best hope for victory at sea.

In addition to the above detailed incidents multiple small-scale skirmishes between Allied mine sweeping vessels and German mine laying vessels took place within the North Sea and the Skagerrak. The calibre of weapons utilised by these vessels varied greatly and have the potential to impact upon the AOI, particularly within the nearshore environment.

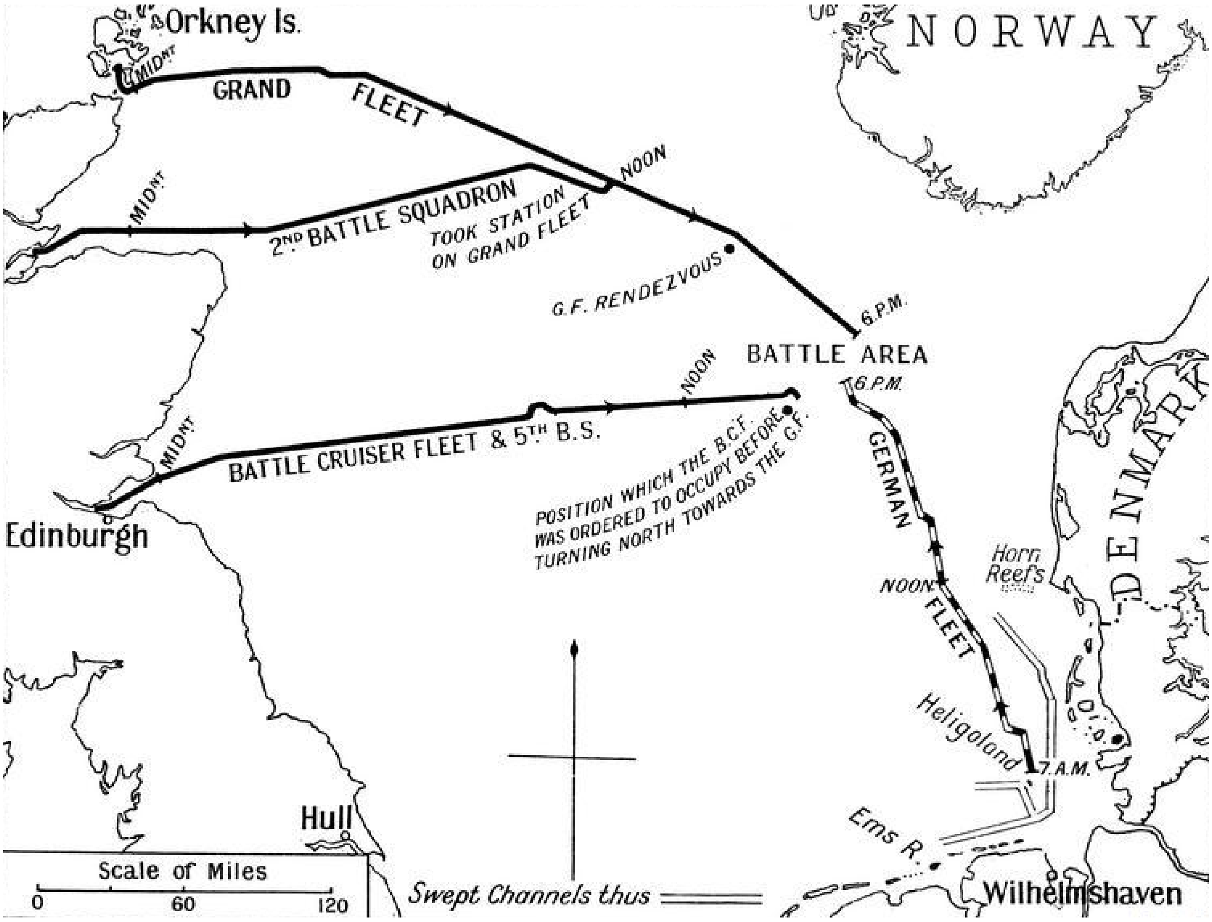


Figure 3.1 - Battle of Jutland Overview (AOI approx. Location in Plum)

3.1.2 World War Two (WWII) (1939-1945)

The warfare experienced in the North Sea throughout WWII contributed to the greater 'Battle for the Atlantic'. This was the most prolonged campaign of the war. The strategic aim for both Allied and Axis Naval forces was to restrict naval access. For the Allies this meant restricting North Atlantic access to the *Kriegsmarine*, whilst Germany's aim was to restrict access to the UK from allied convoys bringing vital supplies. The aim for both sides was to bring about surrender by restricting access to vital war material and food supplies. The German Navy (*Kriegsmarine*) suffer significant losses to their large ocean going fleet early after the outbreak of war, as such much of their larger ships were sheltered and later blockaded in captured ports, in Norwegian fjords and in home ports in the Baltic Sea, to circumnavigate this the *Kriegsmarine* utilised submarines to evade the blockades and for much of the conflict in the North Sea the *Kriegsmarine* utilised small vessels, including minesweepers, torpedo boats, and fast attack craft or *Kleinkampfverbande.*

RPS has seen records of several attacks on British submarines operating in the Wider Area of Interest, the first on 24th September 1939; HMS Spearfish was operating in the German Bight area and was heavily damaged by German warships off Horns Reef, by depth charges.

Of particular note is the attack on and sinking of *HMS Tarpon* within the AOI. Records seen by RPS indicate that on 10th April 1940 *HMS Tarpon* encountered the German 'Q-Ship' *Schiff 40* and fired two torpedoes at the vessel, both of which missed. *Schiff 40* located *HMS Tarpon* with Sonar and counter attacked with depth charges. Records indicate that this counterattack continued all morning until a pattern of depth charges brought wreckage to the surface.

During the invasion of Denmark, the *Kriegsmarine* used *Schnellbootes* of *Gruppe 10* at Esbjerg and the town Nordby on the island of Fanø to the south of the AOI and Thyborön to the north. Thyborön was subsequently occupied by the minesweepers of *Gruppe 11*. Throughout WWII *Schnellbootes* operated from Heligoland and Keil utilising fortified harbours along the Danish coast as required, to attack shipping and lay mines.

Records seen by RPS also indicate that the Horns Reef Lightboat, mentioned previously, was used by *Kriegsmarine* U-boats as a navigational marker for entering / exiting the Baltic Sea.

The diversity and quantity of vessels active within the North Sea (either during conflict, convoy or returning to ports) results in significant potential for attacks to have occurred within the boundaries of the route. Therefore, there is a risk, albeit Low, of UXO contamination from Naval Warfare which affects the whole AOI.

3.2 Mine Laying Campaigns

The North Sea and the Danish Coastline was subject to extensive mine-laying operations throughout WWI and WWII; as such, an elevated likelihood of an encounter with unexploded mines on the seabed can be expected.

It is important to consider the navigational difficulties of mine-laying vessels in the early twentieth century, especially for smaller craft. Often, a compass, sextant, distance log and lead lines were the only tools to aid vessels in poor weather conditions and at night. Therefore, the accuracy of plotted minefields may contain significant discrepancies.

3.2.1 World War One (WWI) (1914-1918)

At the outbreak of WWI, despite declared neutrality, the Royal Danish Navy laid minefields in Danish waters following pressure from Germany. If the Danes had refused, the German *Kaiserliche Marine,* far better prepared to conduct mine warfare operations than their counterparts the Royal Navy (RN), had indicated to the Danish Government they would lay defensive minefields.

3.2.1.1 Danish Offshore Mine Laying

Following pressure from the German government the Danes began a programme of mine laying in Danish waters, initially these mine laying operations laid able mines across the Great Belt, Øresund and the Little Belt, this mining was later expanded to Danish coastal waters in the North Sea area. However, the mines initially laid, fitted with mercury shutters proved to be obsolete and many exploded. These mines were gradually replaced by Horned mines. Denmark laid in excess of 1,000 mines in its coastal waters during WWI.

3.2.1.2 German Offshore Mine Laying

The Imperial Germany Navy (*Kaiserliche Marine)* utilised Hertz-horned contact mines, which used wet guncotton as an explosive charge; although, cast TNT was also utilised. It is conceivable that TNT-hexanitrodiphenylamine mixtures were also used, which were similar to torpedo explosives at the time. By the close of WWI, the *Kaiserliche Marine* had laid in excess of 43,000 sea mines.

However, mapping seen by RPS indicate that no recorded German WWI minefields are present within the AOI or Wider Area of Interest.

3.2.1.3 British Offshore Mine Laying

During WWI the Royal Navy initially focused on defensive mining operations. However, in January 1915 they began offensive minelaying operations in the Heligoland Bight. The idea being to restrict and blockade the *Kaiserliche Marine* preventing the fleet fromm leaving Wilhelmshaven. By the end of 1915 the British had laid in excess of 4,000 mines within the Heligoland Bight area and a further 1,782 during 1916.

Review of the available data indicates this obstacle is approximately 80 km south-east of the AOI and as such not deemed to a likely source of UXO contamination.

Post-WWI large-scale clearance operations were conducted, however this clearance usually entailed trawlers sweeping the areas with a submerged cable between them the cut mooring lines, then as the mines rose to the surface, they were shot at to sink them, rather than detonate them. Therefore, there is potential for mines to remain on the seabed.

3.2.2 World War II (WWII) (1939-1945)

The tactics of WWII altered very little from those of WWI; in so much that the Royal Navy laid large defence mine barriers along the east coast, with only limited cleared channels for access by shipping under escort. Whilst the German *Kriegsmarine* laid nuisance minefields around key navigational routes and harbour entrances, predominately by submarine and aircraft due to the allied blockade of European ports.

3.2.2.1 German Offshore Mine Laying

Evidence seen by RPS indicates that Axis forces laid minefields in several places within the Heligoland Bight, Horns Reef and along the Danish Coast within the North Sea. However, review of these records show the nearest minefield (437X) to be located 26 km south-west of the AOI. As such RPS does not believe this to be a likely source of UXO contamination within the AOI.

3.2.2.2 British Offshore Mine Laying

At the outbreak of WWII, the Royal Navy once again initially concentrated on large defensive minefields to restrict and control the coastal waters around the UK and to restrict access to the European mainland to vessels bring war material to the German forces.

On 3rd March 1940, as part of Operation IE1, British Destroyers *HMS Esk*, *HMS Express*, *HMS Impulsive* and *HMS Icarus* laid a minefield near Horns Reef. Each Vessel Laid 60 (No) Mk XIV and Mk XV Moored Contact Mines.

Evidence seen at The National Archive shows a minefield Chart (ADM 239/304) dated 25th July 1941. This chart has mine laying operation 669X detailed in pencil. This directly transects the AOI. At the time of publication, no details of this mine laying operation have been seen by RPS.

3.3 Aerial Conflict and Bombing Campaigns

Aerial conflict and bombing campaigns formed a key part of strategic planning for all sides involved in both WWI and WWII. Certain planners on both Axis and Allied sides believed that aerial warfare was key to winning the entire campaign. The subsequent sections outline the impact of aerial warfare on the AOI within time periods.

3.3.1 World War One (WWI) (1914-1918)

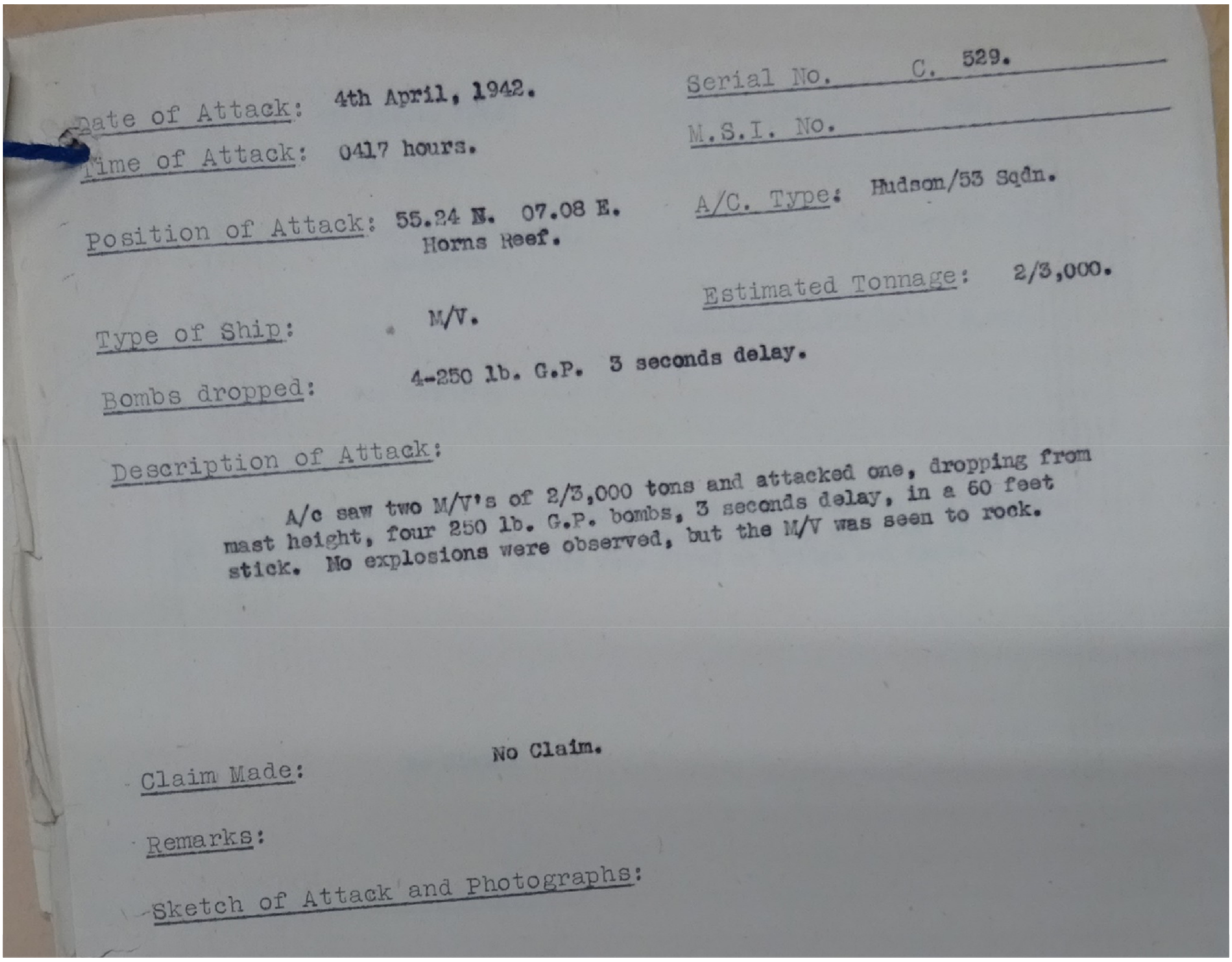
During WWI the range and capability of aircraft was limited. As detailed earlier Denmark was neutral and so aerial operations within their territory was limited. That said RPS has seen records of British Flying Boat operations within the Heligoland Bight area, although these operations appear to have been conducted to the south and at such a distance to have not affected on the AOI.

3.3.2 World War Two (WWII) (1939-1945)

Advances in technologies meant that aerial bombardment became a much more effective weapon during WWII and various military commanders of all nations advocated strategic bombing as key to winning WWII.

Whilst the AOI is at such a distance from the Danish coast to have not been directly targeted for aerial bombardment, the AOI does sit directly under the Allied northern air route used by bombers attacking strategic targets in the Baltic, such as Kiel, Peenemunde as well as northern German Cities Like Berlin and Hamburg. As such there is potential that damaged allied bombers have jettisoned their bomb loads at sea in the area to ensure a safe return, albeit low.

Further the AOI is also directly under a designated RAF Breakout Patrol route; codenamed ‘Hornli’. RAF Coastal Command and later Fighter Command flew this route in an attempt to intercept German shipping and U-Boats breaking out of the Baltic Sea. Records of contact with shipping for these patrols have been seen by RPS and indicate that there is a potential for aircraft to have attacked shipping in the area.



Date of Attack: 4th April, 1942.

Serial No. C. 529.

Time of Attack: 0417 hours.

M.S.I. No.

Position of Attack: 55.24 N. 07.08 E.
Horns Reef.

A/C. Type: Hudson/53 Sqdn.

Estimated Tonnage: 2/3,000.

Type of Ship: M/V.

Bombs dropped: 4-250 lb. G.P. 3 seconds delay.

Description of Attack:

A/c saw two M/V's of 2/3,000 tons and attacked one, dropping from mast height, four 250 lb. G.P. bombs, 3 seconds delay, in a 60 feet stick. No explosions were observed, but the M/V was seen to rock.

Claim Made: No Claim.

Remarks:

Sketch of Attack and Photographs:

Figure 3.2 - RAF Claim Form

Records seen indicate air dropped weapons used in the Wider Area of Interest. This highlights the potential for air dropped weapons to be within the AOI.

The *Luftwaffe* utilised airfields within occupied Denmark, namely Aalborg, Kopenhagen and Skagen, to conduct Anti-shipping and anti-submarine operations in the North Sea. Records indicate *Luftwaffe* HE115 and AR 196 float planes operating from Aalborg patrolling the Danish coast. These aircraft were both capable of carrying HE bombs, Torpedoes and in the case of the HE115 Sea mines.

3.4 Shipwrecks and Downed Aircraft

RPS has noted a number of wrecks within the vicinity of the AOI. The locations of known wreck sites recorded with the UKHO have been reviewed, along with other sources of information. The subsequent sections detail the known wrecks in the AOI and Wider Area of Interest with the potential for the elevation of UXO hazard, either due to the nature of their sinking, vessel type or its cargo.

3.4.1 World War One (WWI) (1914-1918)

The table below outlines a selection of known WWI-era wreck sites within the AOI and the Wider Area of Interest. Wreck sites, both ship and aircraft, can be a potential source of UXO. Within this section RPS has reviewed all recorded wreck sites and determined the potential for ordnance to be present. This is detailed within **Table 3.1** below. A plan highlighting these wrecks is presented at **Appendix 6**.

Table 3.1 - Select WWI Wreck Data

Vessel Name	Easting	Northing	Circumstance of Sinking
HMS Sparrowhawk	323969.79	6248851.76	Sunk during the Battle of Jutland
German Torpedo Boat (V27)	319011.61	6290860.76	Sunk during the Battle of Jutland
German Torpedo Boat (V29)	316007.17	6291589.57	Sunk during the Battle of Jutland
HMS Nomad	310944.31	6290067.58	Sunk during the Battle of Jutland
HMS Black Prince	322815.71	6215916.84	Sunk during the Battle of Jutland
HMS Turbulent	333336.47	6208600.54	Sunk during the Battle of Jutland
SMS Rostock	329178.03	6179887.29	Sunk during the Battle of Jutland
HMS E50	325974.69	6188868.74	WWI Wreck

3.4.2 World War Two (WWII) (1939-1945)

The table below outlines known WWII era wreck sites within the AOI and Wider Area of Interest. Wreck sites, both ship and aircraft, can be a potential source of UXO. Within this section RPS has reviewed all recorded wreck sites and determined the potential for ordnance to be present. This is detailed within **Table 3.2** below. A plan highlighting these wrecks is presented at **Appendix 6**.

Table 3.2 - Select WWII Wreck Data

Vessel Name	Easting	Northing	Circumstance of Sinking
HMS Tarpon	348872.315	6284050.785	British Submarine sunk by depth charges from German Q ship.
Unknown German Torpedo Boat	331421.27	6238088.04	Unknown

In addition to the above detailed Wrecks there is conflicting evidence to suggest that the wreck of German *U-Boat 702* may be situated at position 56.34N, 06.16E after striking a British mine. However, at the time of publication RPS has been unable to confirm this.

The AOI has recorded wrecks within its bounds as a result of WWI and WWII. As such the client is advised to be aware that the UXO risk may be elevated in proximity of any wrecks noted.

3.5 Anti-Aircraft Artillery / Coastal Batteries

The AOI sits in excess of 90 km offshore of the nearest landfall in Denmark. As such there is no potential for UXO from this source to be present within the AOI given it is beyond the range of Coastal artillery, unless the ordnance has been dumped.

3.6 Military Practice Areas

From the review of available information RPS understand that there are no Military Practice areas within the AOI or its vicinity. Therefore, the likelihood of encountering UXO from this source is considered reduced.

3.7 Offshore UXO Dumpsites

For decades after the end of both World Wars, the disposal of both conventional and chemical weapons at sea was considered to be best practice. This practice was prohibited in 1972 with the signing of the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention). However, these dumped munitions remain a real and significant hazard.

Having reviewed data detailing recorded North Sea dumpsites RPS has determined the nearest reported munitions dumpsite is approximately 100 km to the north of the AOI. As such RPS does not believe there is an elevated likelihood of encountering UXO from this source.

3.8 OSPAR Munition Encounters

The Convention for the Protection of the Marine Environment of the North-East Atlantic (The Oslo and Paris Conventions (OSPAR)) regulates international co-operation on environmental protection within the north-east Atlantic. As part of this regulation the commission holds a database of known encounters with ordnance within the North-East Atlantic. RPS has reviewed the latest available data on known encounters and the following table outline those within close proximity to the AOI.

Table 3.3 - OSPAR Finds

OSPAR Reference	Latitude	Longitude	Date	Nature of Encounter
247	56.704	6.0925	03/04/2016	Conventional munition encountered during cable / pipe laying operation. Destroyed in situ

3.9 Post-War Clearance Operations

At the cessation of conflict clearance efforts were made to make the waters safe once more for vessels, utilising the best available technology for that period. After the end of WWI, the Royal Navy lead a joint operation, by all participants, to sweep the minefields within the North Sea Area. This involved a cable submerged between two vessels, sweeping the clearance area. The cable sweeping was designed to cut the mooring chain and allow the mine to rise to the surface, it was then destroyed by gunfire. It’s estimated the operation found only 25% - 30% of the mines laid; It was assumed the others had either broken free, sunk to the bottom, or been destroyed already.

Post-WWII a series of historical maps were produced which illustrate the progress of mine clearance operations in European waters. Records indicate that the post war mine clearance within the AOI was the responsibility of Germany.

4 BASELINE THREAT ASSESSMENT

The results of the historical review have been used to conduct a threat assessment to determine the baseline pre-construction and pre-mitigation risk posed by UXO contamination on site. The assessment outlines the types of UXO that have been identified during the research and assesses the probability of encountering them on site (without considering that any construction activities have already taken place).

4.1 Probability Assessment

Each of the types of UXO that have been identified through the research have been assessed and given a probability of encounter Grade based on the following Level and Rationale.

Table 4.1 - Probability Levels

Probability Assessment Levels		
Grade	**Probability Level**	**Rationale**
A	Highly Probable	Clear evidence that this type of munition would be encountered.
B	Probable	Significant evidence to indicate that this type of munition would be encountered.
C	Possible	Evidence suggests that this type of munition could be encountered.
D	Remote	Evidence suggest that these munitions have been found in the Wider Area of Interest but not specifically within the AOI.
E	Improbable	Not considered likely to encounter this type of munition within the AOI, but not possible to discount completely.
F	Highly Improbable	No evidence that this type of munition would be encountered within the AOI or the immediate vicinity.

4.1.1 Risk Zoning

The probability assessment results may vary across the site leading to differing risk level based on the affected areas identified in the research presented above. These are highlighted in **Appendix 5** and detailed in **Table 4.2**. RPS Risk Zoning is shown in **Appendix 9**.

4.1.2 Probability Assessment Results

The research from the above sections has been used to determine the Probability of Encounter for each ordnance variety. The results are shown in the table below:

Table 4.2 - Shows the probability of encounter for each assessed ordnance variety, based on the research provided in the prior sections

Probability of Encounter			
UXO		**Risk Zones**	
		A	**B**
Small Arms Ammunition		E	E
Land Service Ammunition		E	E
≤155 mm Projectiles		E	E
≥155 mm Projectiles		D	D
HE Bombs	Allied Origin	D	D
	Axis Origin < 25 kg	D	D
	Axis Origin > 25 kg	D	D
Sea Mines	Allied Origin (Contact Mine)	C	D
	Allied Origin (Ground Mine)	C	D

Probability of Encounter			
UXO		Risk Zones	
		A	B
	Danish Origin (Contact Mine)	C	D
	Axis Origin (Contact Mine)	D	D
	Axis Origin (Non-Ferrous)	E	E
Torpedoes		D	D
Depth Charges		D	D
Conventional Dumped Munitions		E	E
Dumped Chemical Munitions		E	E
Missiles/Rockets		E	E

5 MARINE UXO MIGRATION / DRIFT AND BURIAL

5.1 Migration / Drift

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 tidal current or current velocity, 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. Interaction with the seabed from fishing activities are therefore a possible vector 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 250lb 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:

Table 5.1 - Critical Velocities

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

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 the larger an item is and the greater its mass, the larger the tidal current or current velocity must be to move it.

Open source data suggests that ocean surface currents are < 1.0 m/s and this is expected to be lower nearer the seabed. The most appropriate surrogate for the ordnance expected within the site would be the GU Mine, which mobilises at 1.8 m/s when 5% buried. The maximum current velocity on site is lower than the critical velocity noted in **Table 5.1**. Therefore, it is concluded that seabed currents are not sufficient to cause the migration of UXO.

5.2 Depth of Burial

5.2.1 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 throughout the site (entirely >10 m w.d.), 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.

5.2.2 Burial Via Natural Processes

Across the site the seabed sediments are expected to be gravelly sands through to muddy sand and mud. In these softer sediments, it is possible for munitions to be covered by shifting sediments on the seabed 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 maximum burial depth due to scour is approximately equal to the diameter of the munition. Burial is not possible in areas where bedrock is exposed. Additionally, in areas where the seabed substrate is till, it is unlikely that burial due to scour will occur.

Given the water depths throughout the site, it is considered likely that burial via natural processes (i.e. mobile seabed) will be the main form of burial rather than burial as a direct result of penetration upon impact.

5.2.2.1 Sediment Mobility

RPS have reviewed reports provided by the client, including a geophysical survey report created by MMT. As detailed in **Section 2.3.2**, mobile sediment bedforms are expected throughout the site, though predominantly in areas of sands, sandy gravels and gravelly sands. The smaller bedforms found across the site (ripples and megaripples) are expected to be more mobile than the larger sand waves and sandbars. The sandwaves are expected to have a height of 3-5 m. The mobility of these bedforms is not well constrained but could be up to 50 m per year (Danish Coast Agency). Nevertheless, large mobile bedforms moving over ordnance contribute significantly to the expected burial depth. Therefore, based on the reports presented, there is a risk of UXO burial throughout the AOI.

5.2.3 Depth of Burial Analysis

The water depths within the AOI are large enough to reduce any burial via initial penetration. Any burial would therefore be caused by natural processes, such as scour and mobile sediments. Based on the MMT report which suggests the presence of sandwaves and megaripples in the AOI, RPS expect there will be burial on site but without more detailed information, the extent of this burial cannot be determined.

Opensource Vibrocore data suggests the base of the Holocene layer is within 0.85 m and 4 m below seabed. RPS understand the client is planning a campaign of Geotechnical Investigations which may help constrain the depth of this layer. As ordnance is only expected within the Holocene layer and not the Pleistocene, this knowledge may be used to help constrain the maximum depth of burial in some areas of the AOI.

6 RPS UXO ANALYSIS & ASSESSMENT

6.1 General

A 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.

6.2 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 proposed site:

- Projectiles;
- HE Bombs;
- Sea Mines;
- Torpedoes; and
- Depth Charges.

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 will be found on or below the sea floor that are still hermetically sealed; with no water ingress. Other devices may however be cracked, with the outer casings of some mines for example, worn away over time. Therefore, it is not possible to state with any certainty that historic munitions pose less of a risk based on their degradation over time.

6.3 Pathway

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

- Pre-Lay Grapnel Run (PLGR);
- Cable Lay;
- Cable Installation:
  - Ploughing;
  - Vessel Mounted Jetting;
  - Tracked Vehicle Jetting;
  - Trenching (including Chain Cutter);
- Dredging;
- Turbine Installation:
  - Anchoring;
  - Jack-Up Operations;
  - Piled Foundation Installation;
  - Suction Pile Foundations;
- Protection Activities:
  - Rock Placement;
  - Mattress Installation;

- Geotechnical Investigation:
  - Borehole / Vibrocore;
  - Cone Penetration Test (CPT); and
  - Grab Sampling.

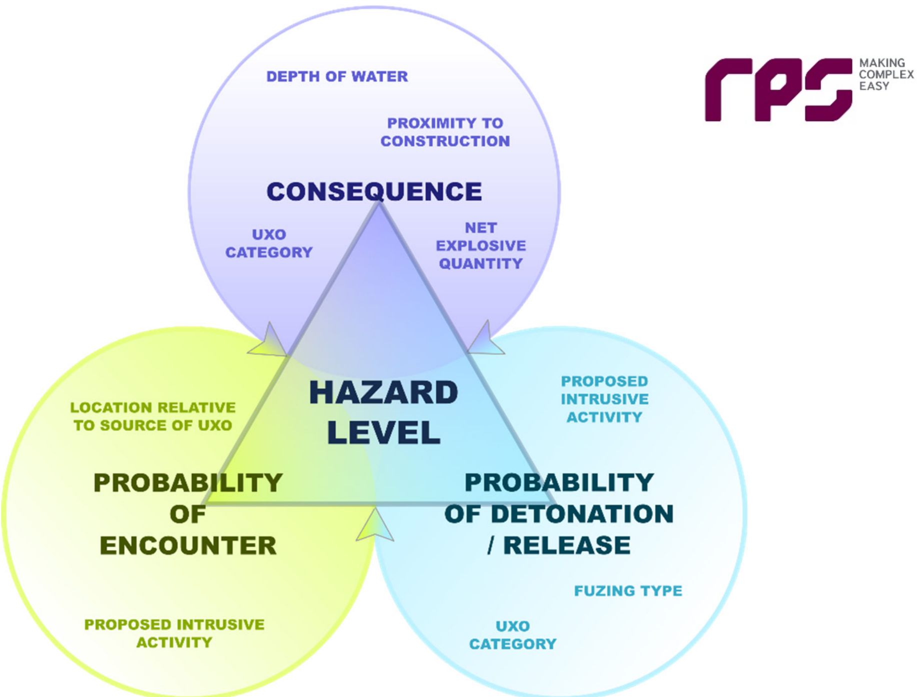
6.4 Receptors

Sensitive receptors applicable to this proposed route would be:

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

6.5 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 6.1 - Hazard Level Considerations

If a significant risk is identified, 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.

6.6 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 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 detailed below.

6.6.1 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.

- A – Highly Probable
- B – Probable
- C – Possible
- D – Remote
- E – Improbable
- F – Highly Improbable

6.6.2 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:

- A – Highly Probable
- B – Probable
- C – Possible
- D – Remote
- E – Improbable
- F – 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*).

6.6.3 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.

6.6.4 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*)

- **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.

Table 6.1 - Probability & Consequence Levels

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 6.2 - Example Risk Score and Associated Risk Rating (Full details in Appendix 8)

		Probability of Encounter, P_E					
C = 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 6.3 - Definition of Risk Levels

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.

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

7 UXO RISK LEVELS

7.1 UXO Risk

Based on the conclusions of the research and the risk assessment undertaken, RPS has found there to be a **Moderate** risk from encountering UXO on site. The risk is primarily due to the presence of Allied Contact Mines, Allied Ground Mines, Danish Contact and Axis Contact Mines.

As per **Figure 6.1** 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 OWF site has been split into two zones (A & B), dependent on the risk presented and the planned installation activities. **Table 7.1** shows the maximum risk for each zone. Descriptions of the zones are given in **Section 7.1.2**. RPS Risk Zoning is shown graphically in **Appendix 9**.

7.1.1 Risk Levels

Table 7.1 - Overall Risk Level

Overall Risk Level			
UXO		Risk Zones	
		A	B
Small Arms Ammunition		Low	Low
Land Service Ammunition		Low	Low
≤155 mm Projectiles		Low	Low
>155 mm Projectiles		Low	Low
HE Bombs	Allied Origin	Low	Low
	Axis Origin ≤25 kg	Low	Low
	Axis Origin >25 kg	Low	Low
Sea Mines	Allied Origin (Contact Mine)	Mod	Mod
	Allied Origin (Ground Mine)	Mod	Mod
	Danish Origin (Contact Mine)	Mod	Mod
	Axis Origin (Contact Mine)	Mod	Mod
	Axis Origin (Non-Ferrous)	Low	Low
Torpedoes		Low	Low
Depth Charges		Low	Low
Conventional Dumped Munitions		Low	Low
Dumped Chemical Munitions		Low	Low
Missiles/Rockets		Low	Low

7.1.2 Risk Zones

7.1.2.1 Zone A – Moderate Risk

669X Minefield buffer

This zone represents the area of the OWF site covered by the 669X Minefield. In this zone there is an increased probability of encountering Allied Mines as it lies within a British WWII minefield.

There is also potential for encountering projectiles and torpedoes associated with actions related to the Battle of Jutland, although this risk is considered Low. Wrecks in the Wider Area of Interest show that there is potential for these ordnance types to impact this zone. There is also the potential for encountering HE Bombs (Allied and Axis) associated with Allied and Axis jettisons as well as Allied Anti-submarine bombing campaigns (considered Low Risk). Depth charges may also be present in this area, as seen by the presence of the wreck of HMS Tarpon in the vicinity (sunk by depth charges). This zone also lies within a Danish WWI Minefield and so there is the potential for Contact Mines from this source to be present resulting in a Moderate Risk.

7.1.2.2 Zone B – Moderate Risk

This zone represents the area of the OWF site lying outside of the 669X Minefield. This zone also lies within a Danish WWI Minefield and so there is the potential for Contact Mines from this source to be present resulting in a Moderate Risk.

There is potential for encountering projectiles and torpedoes associated with actions related to the Battle of Jutland, although this risk is considered Low. Wrecks in the Wider Area of Interest show that there is potential for these ordnance types to impact this zone. There is also the potential for encountering HE Bombs (Allied and Axis) associated with Allied and Axis jettisons as well as Allied Anti-submarine bombing campaigns (considered Low Risk). Depth charges may also be present in this area, as seen by the presence of the wreck of HMS Tarpon in the vicinity (sunk by depth charges).

7.1.3 Risk Level by Activity

Table 7.2 - Risk Level by Activity and Risk Zone

Risk Level by Activity																			
Risk Zone	Activity / Pathway																		
	Cable Lay	Open Cut Trenching	Ploughing	Vessel Mounted Jetting	Tracked Vehicle Jetting	Chain Cutter	Snag on Vessel	Dredging	Anchoring	Jack-Up Operations	Piled Foundations	Suction Pile Foundations	Rock Placement	Mattress Installation	Peel Grab Operations	PLGR	Borehole / Vibrocore	CPT	Grab Sampling
A	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Low	Low	Mod	Mod	Mod	Low
B	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Mod	Low	Mod	Low	Low	Mod	Mod	Mod	Low

Table 7.3 - Risk Level by Activity and Munition

Risk Level by Activity																	
Activity / Pathway	Risk Item																
					HE Bombs			Sea Mines									
	Small Arms Ammunition	Land Service Ammunition	≤155mm Projectiles	≥155mm Projectiles	Allied Origin	Axis Origin (<25 kg)	Axis Origin (>25 kg)	Allied Origin – Contact	Allied Origin – Ground	Danish Origin - Contact	Axis Origin - Contact	Axis Origin – Non-Ferrous	Torpedoes	Depth Charges	Conventional Dumped Munitions	Dumped Chemical Munitions	Missiles/Rockets
Cable Lay	Neg	Neg	Neg	Neg	Low	Low	Low	Mod	Low	Mod	Mod	Low	Low	Low	Low	Low	Low
Open Cut Trenching	Neg	Low	Low	Low	Low	Low	Low	Mod	Low	Mod	Mod	Low	Low	Low	Low	Low	Low
Ploughing	Neg	Low	Low	Low	Low	Low	Low	Mod	Low	Mod	Mod	Low	Low	Low	Low	Low	Low
Vessel Mounted Jetting	Neg	Neg	Low	Low	Low	Low	Low	Mod	Mod	Mod	Mod	Low	Low	Low	Low	Low	Low
Tracked Vehicle Jetting	Neg	Low	Neg	Neg	Low	Low	Low	Mod	Low	Mod	Mod	Low	Low	Low	Low	Low	Low
Chain Cutter	Neg	Low	Low	Low	Low	Low	Low	Mod	Mod	Mod	Mod	Low	Low	Low	Low	Low	Low
Snag on Vessel	Low	Low	Low	Low	Low	Low	Low	Mod	Low	Mod	Mod	Low	Low	Low	Low	Low	Low
Dredging	Neg	Low	Low	Low	Low	Low	Low	Mod	Low	Mod	Mod	Low	Low	Low	Low	Low	Low
Anchoring	Neg	Neg	Low	Low	Low	Low	Low	Mod	Low	Mod	Mod	Low	Low	Low	Low	Low	Low
Jack-Up Operations	Low	Low	Low	Low	Low	Low	Low	Mod	Low	Mod	Mod	Low	Low	Low	Low	Low	Low
Piled Foundations	Low	Low	Low	Low	Low	Low	Low	Mod	Low	Mod	Mod	Low	Low	Low	Low	Low	Low
Suction Pile Foundations	Neg	Low	Low	Low	Low	Low	Low	Mod	Low	Low	Low	Low	Low	Low	Low	Low	Low
Rock Placement	Neg	Low	Neg	Low	Low	Low	Low	Mod	Low	Mod	Mod	Low	Low	Low	Low	Low	Low
Mattress Installation	Neg	Neg	Neg	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Peel Grab Operations	Neg	Neg	Neg	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
PLGR	Neg	Low	Low	Low	Low	Low	Low	Mod	Low	Mod	Mod	Low	Low	Low	Low	Low	Low
Borehole / Vibrocore	Neg	Neg	Neg	Low	Low	Low	Low	Mod	Low	Mod	Mod	Low	Low	Low	Low	Low	Low
CPT	Neg	Neg	Neg	Low	Low	Low	Low	Mod	Low	Mod	Mod	Low	Low	Low	Low	Low	Low
Grab Sampling	Neg	Neg	Neg	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low

7.1.4 Threat Item Characterisation

A list of UXO types that are expected to present a risk to the project is provided in **Appendix 10**, along with diagrams and photos of some examples.

8 RISK MITIGATION STRATEGY

8.1 Mitigation Strategy Rationale

RPS' Risk Assessment for Potential UXO contamination has identified a risk from UXO on site. 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.

8.2 Recommendations

Based on the identified risk levels, it is recommended that appropriate mitigation is implemented to reduce the risk, prior to and/or during any works.

As the exact nature of any intrusive works taking place at this stage are not fully known, the methods of mitigation outlined for the site, which consist of both Proactive and Reactive methodologies, should allow the project team to design an appropriate strategy to mitigate the risks.

The proposed mitigation for each zone can be found in **Table 8.1.**

Table 8.1 - Risk Mitigation Strategy Overview

Zone	Risk Level	Risk Items	Risk Activities	Risk Mitigation Strategy
A	Low	N/A	• Mattress Installation • Peel Grab Operations • Grab Sampling	• Explosives Safety and Awareness Briefing (See **Section 12.1**)
A	Moderate	• Allied Contact Mine • Allied Ground Mine • Danish Contact Mine • Axis Contact Mine	• Cable Lay • Open Cut Trenching • Ploughing • Vessel Mounted Jetting • Tracked Vehicle Jetting • Chain Cutter • Snag on Vessel • Dredging • Anchoring* • Jack-Up Operations • Piled Foundations • Suction Pile Foundations • Rock Placement • PLGR • Borehole/Vibrocore • CPT	• Explosives Safety and Awareness Briefing (See **Section 12.1**) • UXO Survey (See **Section 9.1**) • ID&C or Avoidance (See **Section 10**) • * Risk resulting from Anchoring mitigated by appropriate Anchor Management (See **Section 12.4**)
B	Low	N/A	• Suction Pile Foundations • Mattress Installation • Peel Grab Operations • Grab Sampling	• Explosives Safety and Awareness Briefing (See **Section 12.1**)
B	Moderate	• Allied Contact Mine • Allied Ground Mine • Danish Contact Mine • Axis Contact Mine	• Cable Lay • Open Cut Trenching • Ploughing • Vessel Mounted Jetting • Tracked Vehicle Jetting • Chain Cutter • Snag on Vessel • Dredging • Anchoring* • Jack-Up Operations • Piled Foundations • Rock Placement • PLGR • Borehole/Vibrocore • CPT	• Explosives Safety and Awareness Briefing (See **Section 12.1**) • UXO Survey (See **Section 9.1**) • ID&C or Avoidance (See **Section 10**) • * Risk resulting from Anchoring mitigated by appropriate Anchor Management (See **Section 12.4**)

9 PROACTIVE MITIGATION

9.1 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.

RPS is aware that geophysical survey (SSS, MBES, SBP) of the Eastern section of the AOI has already been completed. Although not removing the need for UXO specific survey, this information will contribute to the classification of targets and supplement the information collected during UXO survey operations.

9.1.1 Magnetic Survey

It has been determined that, given the potential UXO within the AOI, a magnetic UXO Survey will be required across the site. This should be designed to detect the smallest identified ferrous ordnance expected within the AOI.

The following table details the detection requirements that should be used for UXO Surveys on the **Energy Island - North Sea OWF Site**:

Table 9.1 - Detection requirements

Risk Zones	Minimum Threat Item	Ferrous Mass	Dimensions	Maximum Depth of Detection below Seabed (m)
A & B	Mine Explosives Encasement	50 kg	0.65 m x 0.57 m	TBC*

*Further analysis of the UXO depth of burial should be undertaken once the geotechnical data is available to determine the maximum depth of detection required.

9.1.1.1 Survey Specifications

Based on the conditions outlined above, it is recommended that the magnetometer survey is conducted with a line spacing of no greater than 5 m between magnetometers and an altitude of no greater than 4 m above the seabed.

However, the above is provided as a minimum specification and RPS would always recommend for increased data quality to reduce the spacing between magnetometers as much as is feasible. For example, 1.5 m spacing between magnetometers and an altitude of 2 m to 3 m. This additional data provides a better map of the seabed and greater probability of detection, which ultimately assists in the interpretation of anomalies as potential UXO. RPS has found that this greater data density will assist in reducing false anomalies and ultimately reducing the final number of targets that require further investigation/avoidance. In addition, starting with a greater data density often reduces the level of infill required, which can often take almost as long as the main survey

9.1.1.2 Dynamic Coverage

Magnetometer survey coverage should be assessed using the 'dynamic coverage' method. Dynamic coverage considers the required penetration depth, detection range of the sensors (determined by the Surrogate Item Trial) and the altitude of the sensors at each data point to give an accurate coverage width, ensuring no data gaps are left but also that no unnecessary infill is completed. This is described in **Figure 9.1** and is calculated using the following formula:

$$Dynamic\ Coverage = 2 \times \sqrt{((Detection\ Range)^2 - (Altitude + Detection\ Depth)^2)}$$

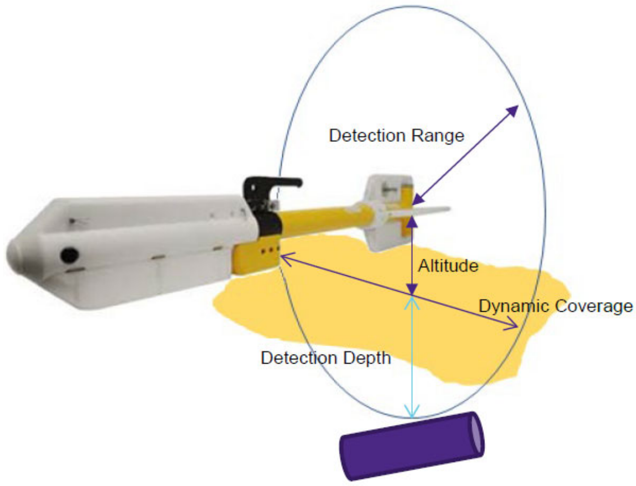


Figure 9.1: Variables involved in calculating dynamic coverage

9.1.1.3 Alternative Survey Methods

The above sections describe a towed array of magnetometers to complete the UXO survey, which is the recommended method due to the size of the area. However, other survey methods such as ROV arrays would use slightly different sensor set up and therefore would have differing altitude and sensors spacing requirements. As such the parameters for these systems if they are considered would need to be reviewed by RPS to confirm the requirements. Importantly, any system would require the completion of a Surrogate Item Trial, as detailed in **Section 9.2.**

9.1.2 Additional Sensors

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 should be used to detect UXO; however, if the risk of burial can be discounted then this may not be required. Furthermore (as detailed in **Table 8.1**) activities that do not significantly penetrate the seabed, such as Rock Dumping and Scour Protection can be mitigated through surface detection methods alone such as MBES and SSS.

9.2 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.

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 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.

The item(s) should then be surveyed with the equipment configuration which will be employed during the main survey. This would involve running survey lines at various heights to show the differing responses and detection limitations.

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

Table 9.2 - Surrogate Item Specification

Risk Zones	Ordnance Simulant	Dimensions		Ferrous Mass (*kg*)	Construction Material	Maximum Depth of Detection Below Seabed (*m*)
		Length (*m*)	Diameter (*m*)			
A & B	Mine Explosives Encasement	0.65	0.57	50	Steel	TBC

9.3 Survey Corridor Requirements

The aim is to provide a sufficiently wide corridor for the installation activities, which has been surveyed for UXO and subsequent investigation undertaken on any potential UXO (pUXO) assessed as posing a risk to installation.

To do this an appropriate corridor width is defined around the RPL, within which all pUXO identified by the survey will be investigated and cleared. The corridor width will vary based on the survey accuracy and the installation techniques to be used during installation, including the area of potential impact of each installation methodology. Each anomaly that has been assigned UXO potential must therefore be avoided by the distance calculated during installation activities.

The examples given below represent a minimum survey corridor, it is recommended that a larger corridor is used to allow for rerouting/repositioning of assets to take place to reduce the cost and time associated with target investigation.

The calculation for the minimum avoidance distance is given below:

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

The above variables are defined in the following:

- **Installation Positional Accuracy** – The accuracy with which the installation activity can take place. e.g., the error in the positioning of the plough.
- **Half the Tool Footprint** – Half the width of the tool (that interacts with the seafloor). E.g., Half the width of a tracked trencher.
- **UXO Survey Positional Accuracy** – The positioning error in the data collected during the UXO Survey.
- **UXO Extent** – Half the length of the maximum size of UXO, combined with the target positioning error (where the UXO Consultant / Geophysicist has picked the target within the data). Typically, equal to the length of the largest threat item.

9.3.1 Avoidance Examples

The following shows typical examples of avoidance distances used for each activity; however these would need to be refine once the installation activity specifications are known. They are calculated in **Table 9.3** and displayed in **Figure 9.2.**

Table 9.3 - A calculation of example avoidance distances

Examples	**Installation Accuracy**		**Half Tool Footprint**		**Survey Accuracy**		**UXO Extent**		
Trencher / Plough	2	+	5	+	2	+	5	=	**14***
Jack Up Operations	2	+	2	+	2	+	5	=	**11***
Anchoring	2	+	1	+	2	+	5	=	**10***
Rock Placement	2	+	3	+	2	+	5	=	**12***

**These are examples only and will be subject to change*

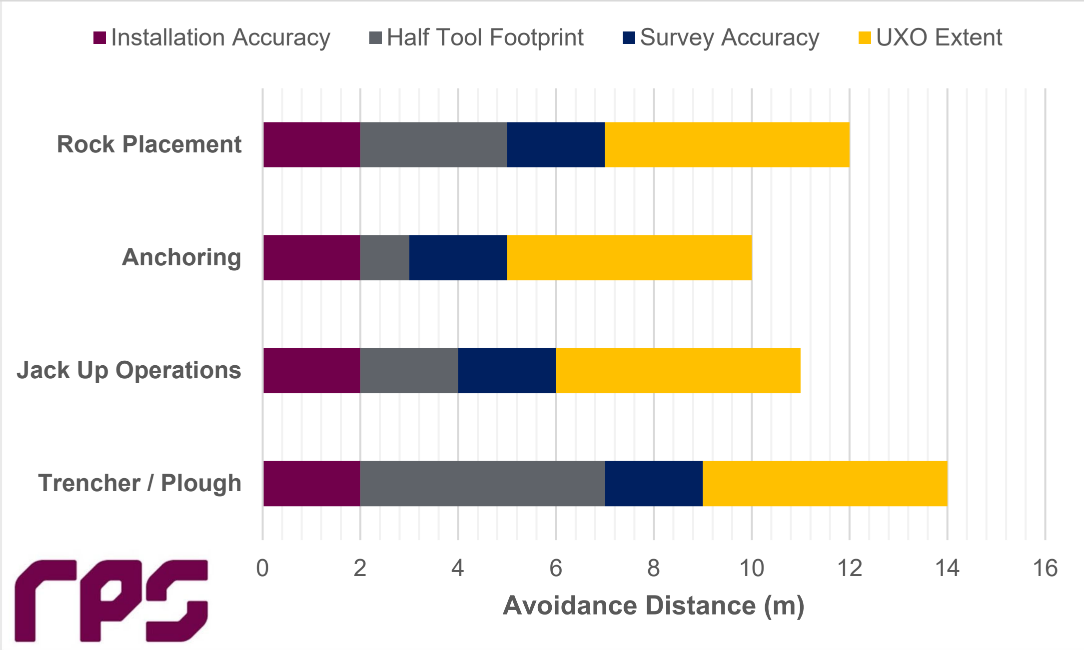


Figure 9.2 - A plot of example avoidance distances

9.3.2 Avoidance Schematics

The following sections visualise the examples covered above; it is important to note that not all installation activities are covered. A further example can be found in **Appendix 11.**

9.3.2.1 Cable Installation

The following schematic visualises the avoidance distances required for cable installation.

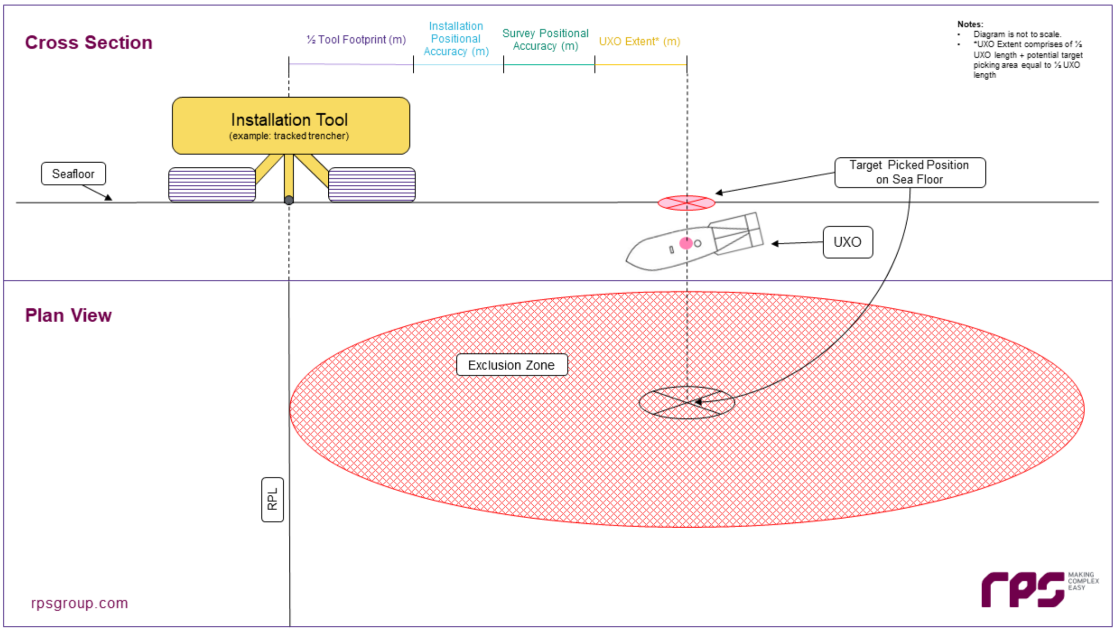


Figure 9.3 - A visualisation of the avoidance distance calculation for cable installation.

9.3.2.2 Anchoring / Jack-Up Operations

The following schematic visualises the avoidance distances required for Anchoring and Jack – Up Operations. The exact distances for these activities will not be the same.

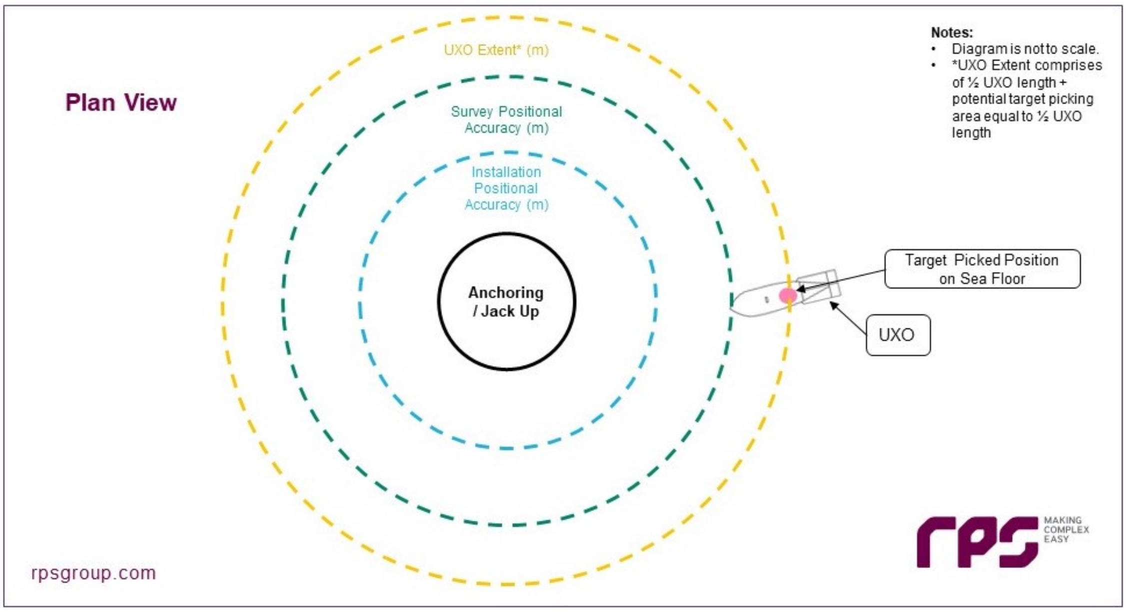


Figure 9.4 - A visualisation of the avoidance distance calculation for Anchoring / Jack-Up Operations

For anchoring, in addition to the radii the contractor would need to include an additional safety buffer to allow for the positioning of their anchor and to cover any anchor drag along the seabed, as the anchor is pulled taught into the seabed.

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.

9.3.2.3 Rock Placement

The following schematic visualises the avoidance distances required for rock placement.

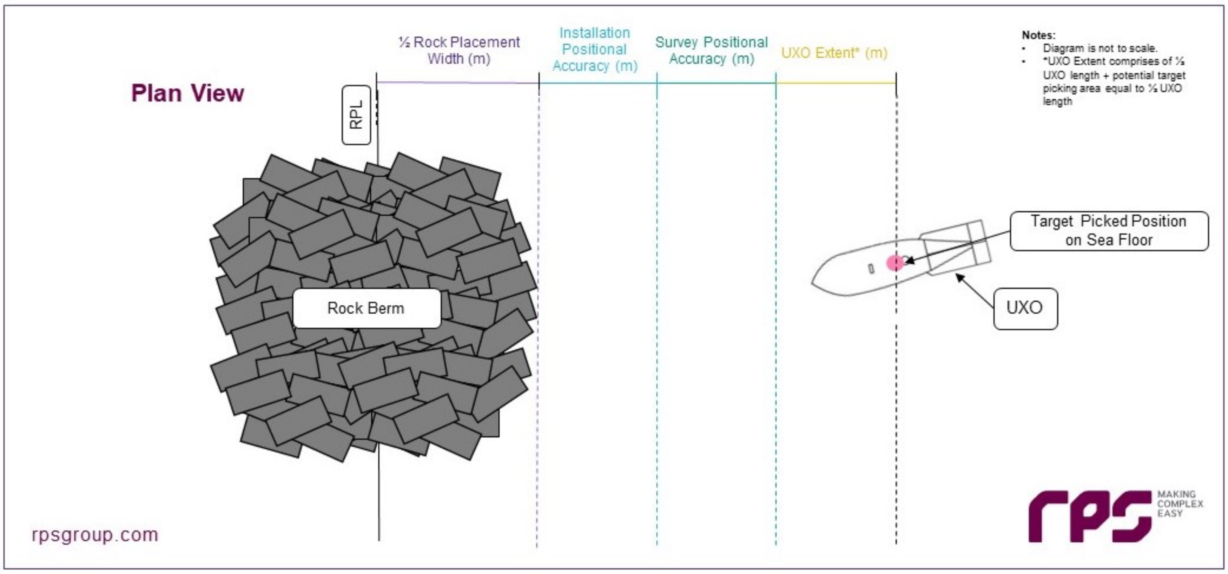


Figure 9.5 - A visualisation of the avoidance distance calculation for Rock Placement.

9.4 Potential UXO Targets

The UXO survey will produce numerous data sets and maps along with lists of targets that will require review in order to identify those that are potential UXO and those that are considered 'safe'.

Magnetic targets need be correlated to SSS and MBES targets (if available) and the information used to determine the likelihood of the anomaly being UXO or discounted as potential UXO. This would be based on the perceived threat items along the various sections of the route 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, especially SSS targets, should be reviewed by UXO Consultants to determine their likelihood of being UXO. This will possibly reduce the number of 'potential UXO' anomalies that require further mitigation whilst also confirming that nothing is missed.

9.5 Target Avoidance

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. However, generally avoidance is the only necessary mitigation method for maintenance operations.

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 9.3**) and would apply to most maintenance 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 2.5 m to 5 m.

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 in order to determine a safe avoidance distance (see **Section 9.5.1**).

9.5.1 Piling

With regards to piling activities, **Section 7.1.3** shows that multiple munitions pose a moderate risk. Studies have shown that sympathetic detonation of a UXO can occur some distance from the piling activities and is dependent on pile size, installation mechanism and soil conditions. Calculations can be conducted to determine this distance based on specific site conditions however in lieu of these calculations a conservative estimate would be approximately 150 m.

10 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.

Within Danish waters it is important to plan that the Danish Navy will need to provide a representative on board the investigation spread to confirm the identification of UXO.

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.

10.1 Investigation by ROV

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 site 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.

10.2 Investigation by Diver

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.

10.3 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 Navy. As such consideration needs to be given with regards to the timing of these works and availability of the Navy along with confirmation that they can use the contractor's vessel to conduct these operations.

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 survey corridor is +/-11 m from the RPL then your avoidance distance will also be +/-11 m from the UXO position, as a minimum).

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 sediment deposition.

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 5.1**).

In terms of wave action moving UXO in deeper waters (>10m LAT) it is considered unlikely and would require extraordinary conditions for the UXO to moved such as significant storm events.

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 2 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 2-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.

12 REACTIVE MITIGATION

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. **Table 7.2** details the activities where reactive mitigation is recommended in place of proactive mitigation.

However, even where a Low Risk has been assessed or after proactive mitigation measures are implemented there will always remain a residual possibility that UXO could be encountered or potentially brought on board the vessels working in the area. Due to the residual risk it is therefore recommended that as a minimum Explosives Safety Awareness be implemented to manage any inadvertent UXO encounters during operations and maintenance.

12.1 Explosives Safety Awareness

Explosives Safety and Awareness Briefings should be provided to personnel carrying out operations and maintenance works. The Briefing would allow the project team to plan the proposed works and potentially deal with the event of a suspicious item / UXO discovery incident. It would address the risk to all of the specific proposed works and will inform personnel how to undertake the works safely and will refer to the specific risk items/hazards that have been identified for the site and where applicable the mitigation that has been completed to reduce the risk.

If deemed beneficial a set of ***Explosives Site Safety Guidelines (ESSGs)*** could be produced, which would be provided to the Client along with training. The guidelines would allow the project team to manage the safety and awareness briefings and provide them in-house and also allow the project team to manage an inadvertent UXO encounter. The guidelines would typically be provided to the Client in the form of a '*Guidelines Document'* along with a supporting PowerPoint Slideshow. Safety and Awareness Training would be provided to key personnel, offshore teams, survey and trenching teams.

RPS would specifically recommend that these be delivered to personnel involved in intrusive works on the seabed. Training on how to recognise UXO for these personnel would be considered most prudent given the risks in the area.

12.2 Explosives Engineer on Vessel

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 Engineers*** (*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.

12.3 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.

12.4 Anchor Management

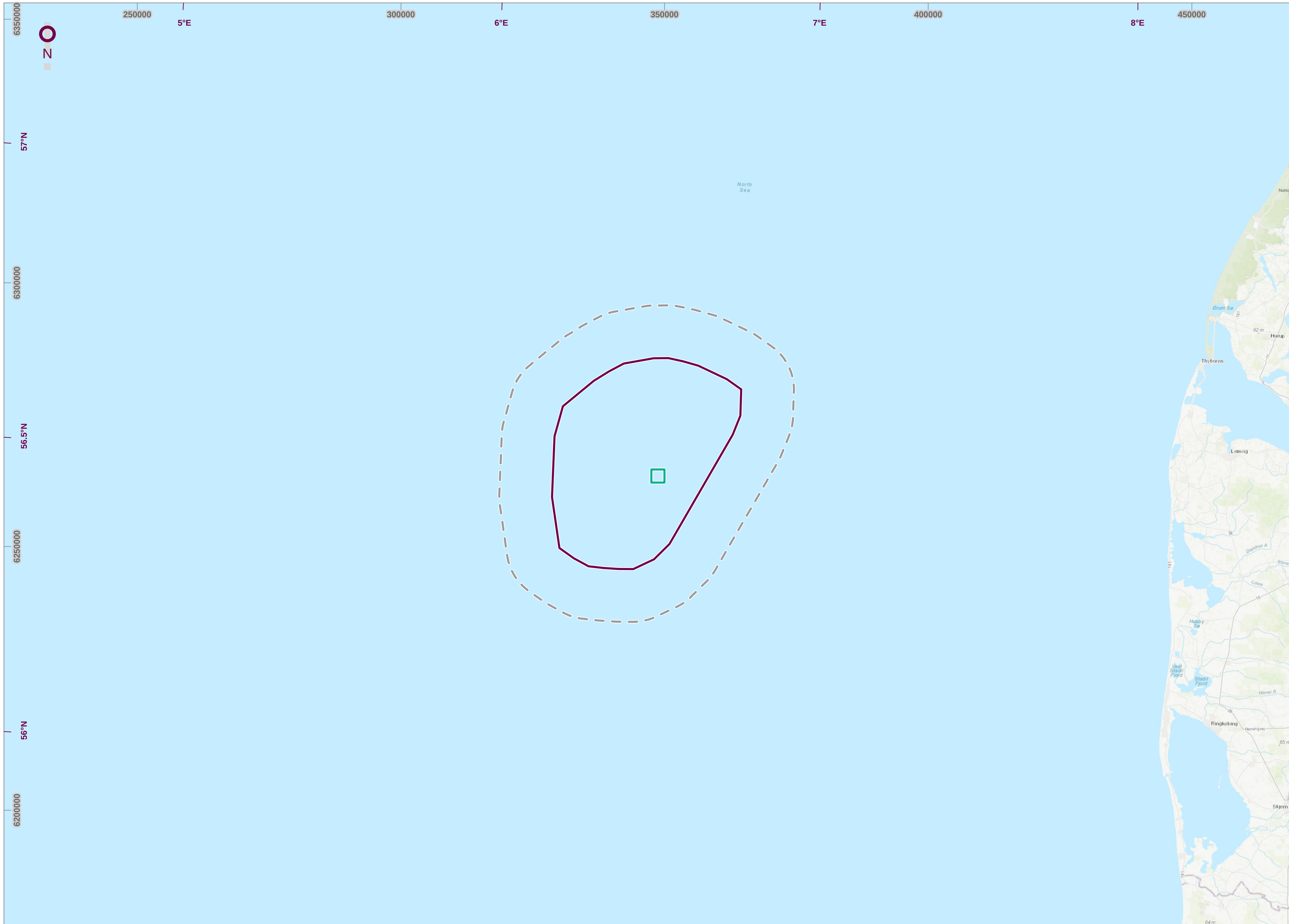
Typically anchor deployment is carried out by dynamically positioned vessels. In offshore construction, typical anchors include delta flipper types which are employed for lateral positioning. A delta flipper type anchor will only embed if it arrives on the seabed in the correct orientation, therefore a second line must be used to ensure correct orientation. The process is as follows:

- The anchor is lowered from the vessel.
- A second vessel is used to ensure the anchor deploys at a shallow angle; this cable is kept taught to maintain the angle of lowering.
- The anchor contacts the seabed, no further pulling is required.

Additionally, anchors connected to a steel wire rope mooring line will penetrate deeper that an anchor connected to a chain mooring line. It should be noted that the line/chain attached to any anchor is not considered a significant risk. The highest risk involved with anchoring and encountering UXO is associated with the anchor directly striking a UXO with sufficient force to cause a detonation. Any tensioning once the anchor is placed is expected to have insufficient energy to cause a detonation.

As such, in order to mitigate the risk from UXO during anchoring activities it is recommended that a controlled anchor lowering takes place to reduce the potential force exerted on any items of UXO.

Appendix 1 – Site Map



Legend

- OWF Project Area
- Artificial Island Project Area
- OWF Project Area 10km Buffer

Overview

0 2.5 5 10 15 20 25 30 35 40 45 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: Esri, HERE, Garmin, USGS, NGA

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00	INITIAL ISSUE	LM	RM	16/12/21

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Client	Energinet Eltransimission A/S	Project Number: EES1228	Drawn By: LM	Status: INITIAL ISSUE
Project	North Sea Offshore Wind Farm (OWF) Project	Scale @ A3: 1:750,000	Checked By: RM	Date Created: 16/12/2021
Title	Project Location			

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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.

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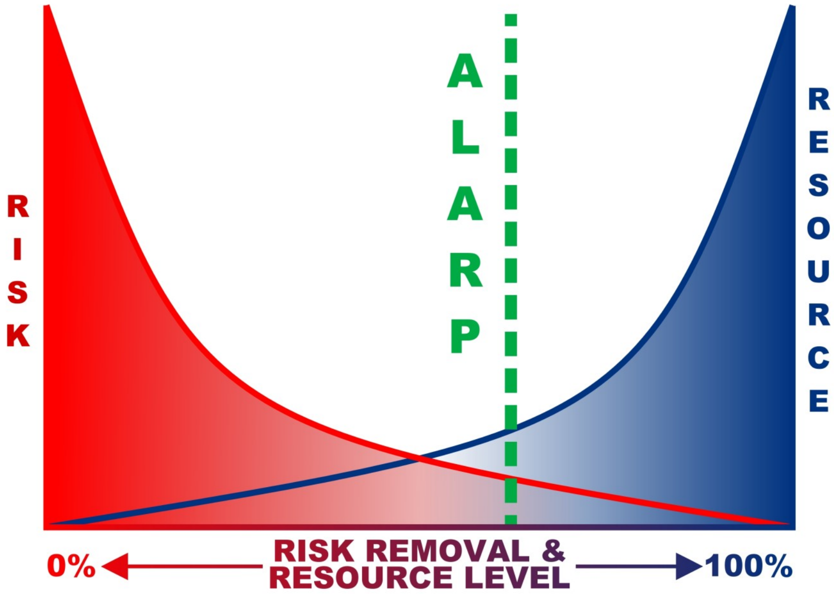
Appendix 3 – ALARP Principle

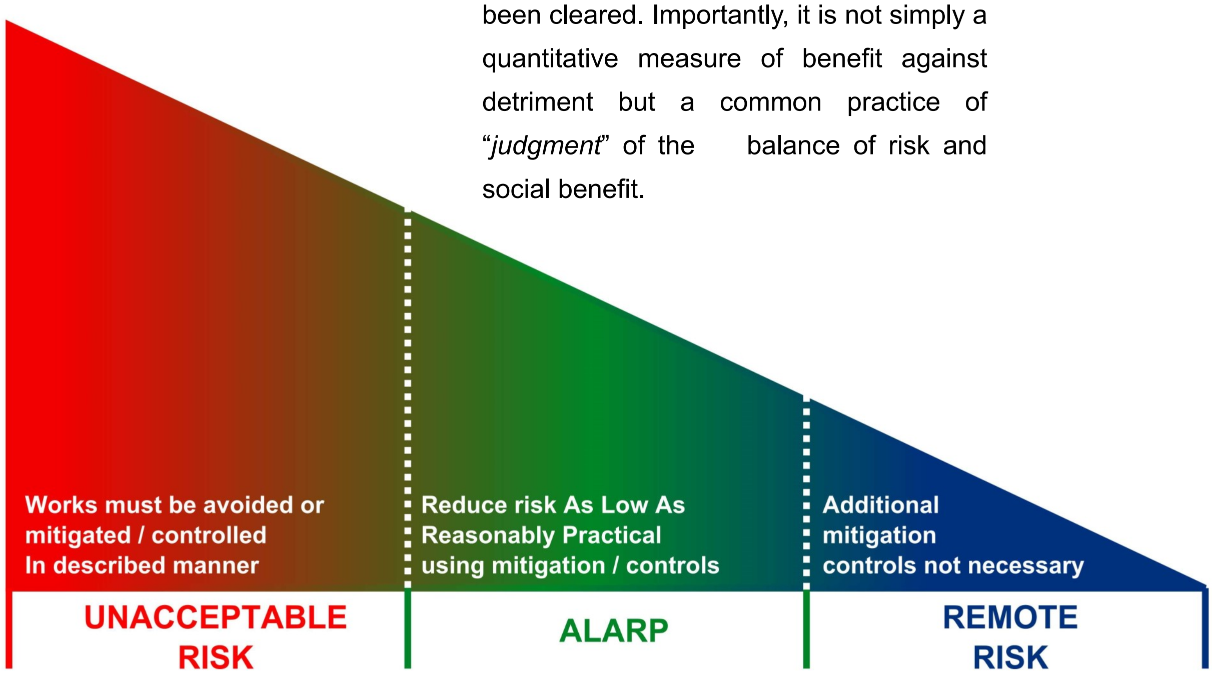
'ALARP PRINCIPLE'

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.

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 Resource Graph



ALARP Diagram Approach

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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.

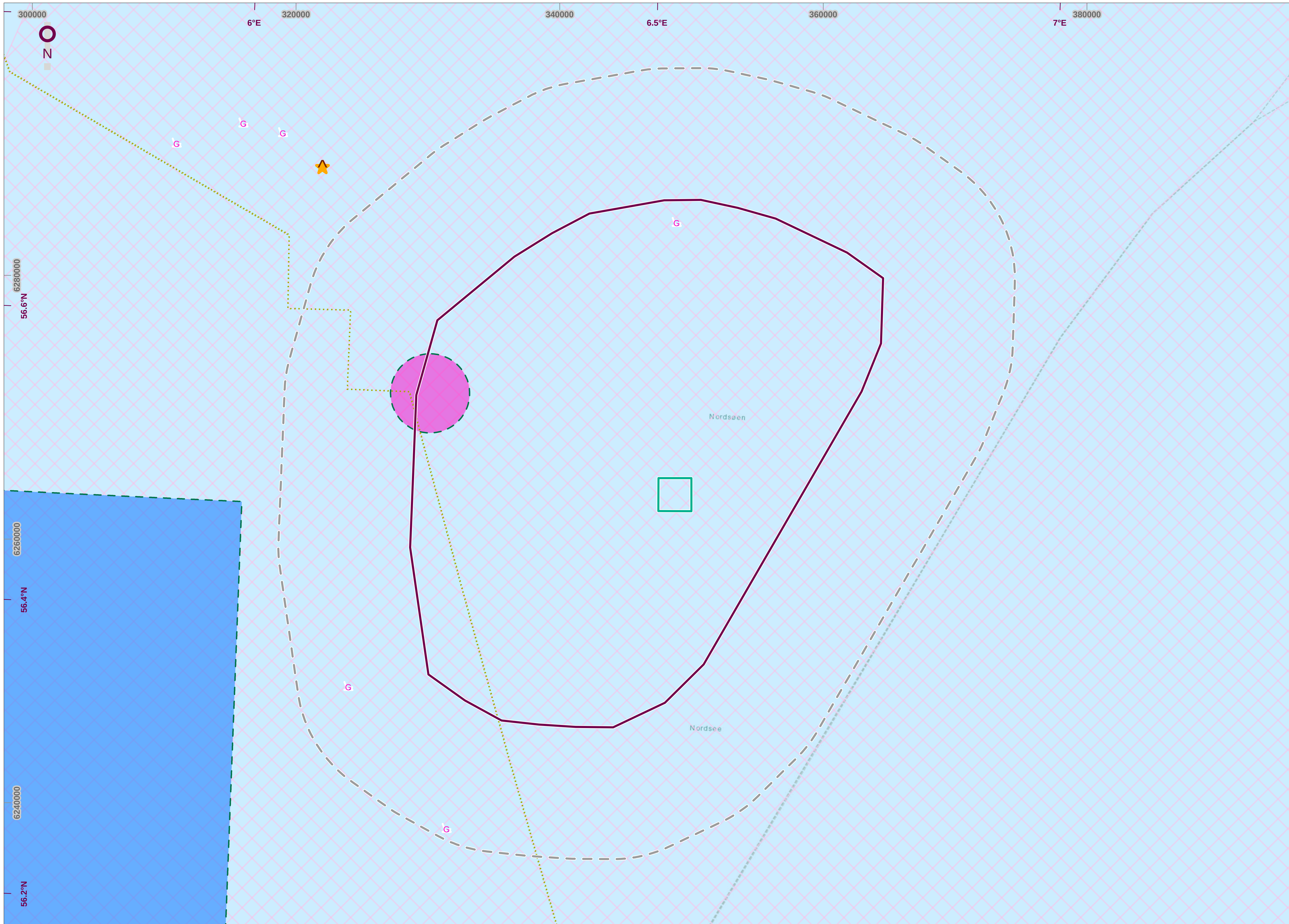
Whilst UXO is not specifically mentioned in the above directives, RPS works to these guidelines in an effort to illustrate a conformance to the ALARP principle. This has not been subjected to legal scrutiny/testing; however, RPS believe that the rationale behind this practice is sound given its track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

- OWF Project Area
- Artificial Island Project Area
- OWF Project Area 10km Buffer
- Wreck Record (Client/Survey): High UXO Risk
- OSPAR Munition Encounters (up to 2017)
- Military Vessel Movement - German - WWI
- Historic Offshore Minefield - British (WWII)
- Historic Offshore Minefield - German (WWII)
- Heligoland Bight Minefield Area (WWI)

Overview

0 2.5 5 10 15 20 25 Kilometers

0 1 2 4 6 8 10 Nautical Miles

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

Data Sources: Client, OSPAR, Various Reference Material - see associated report.
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Service Layer Credits: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS
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Figure Number: EES1228-F-003
Rev: 00
Page: 1 of 1

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Client: Energinet Eltransimission A/S
Project: North Sea Offshore Wind Farm (OWF) Project
Title: UXO Related Features

Project Number: EES1228
Scale @ A3: 1:300,000

Drawn By: LM
Checked By: RM

Status: INITIAL ISSUE
Date Created: 16/12/2021

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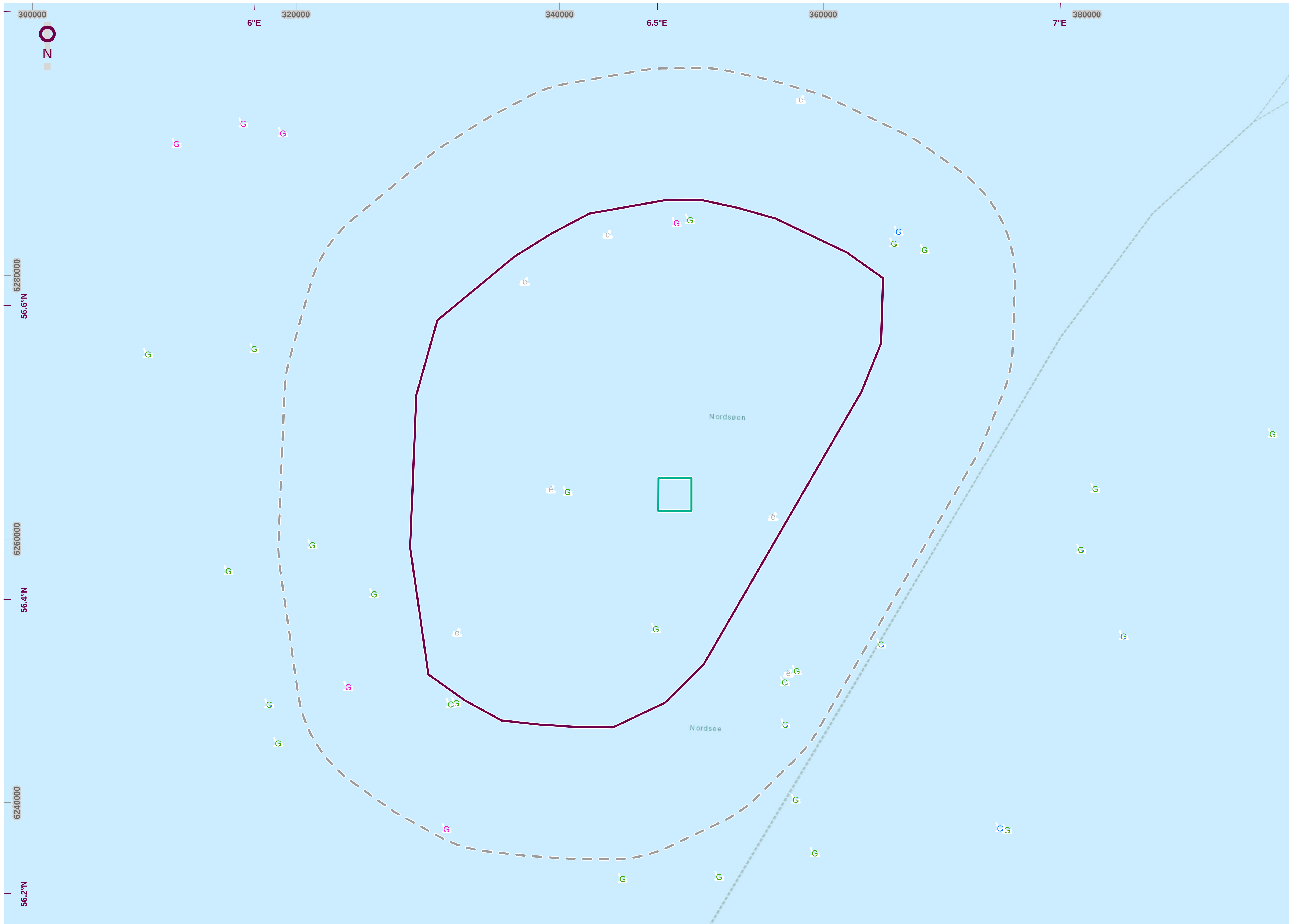
Appendix 6 – Shipwreck Map



Legend

- OWF Project Area
- Artificial Island Project Area
- OWF Project Area 10km Buffer
- Wreck Record (UKHO) Within 10km - Not/Unknown if UXO Related
- Wreck Record (Client/Survey): High UXO Risk
- Wreck Record (Client/Survey): Low UXO Risk
- Wreck Record (Client/Survey): Unknown UXO Risk

Overview

0 2.5 5 10 15 20 25 Kilometers

0 1 2 4 6 8 10 Nautical Miles

Geodetic Information:

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

Data Sources: Client
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Service Layer Credits: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS
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Ver	Description	By	Check	Date
00	INITIAL ISSUE	LM	RM	16/12/21

Figure Number: EES1228-F-002 | Rev: 00 | Page: 1 of 1

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Client	Energinet Eltransimission A/S	Project Number	EES1228	Drawn By	LM
Project	North Sea Offshore Wind Farm (OWF) Project	Scale @ A3	1:300,000	Checked By	RM
Title	Recorded Wrecks				

Status: INITIAL ISSUE

Date Created: 16/12/2021

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Appendix 7 – Risk Assessment

Regular Munitions		Cable Lay	Ploughing	Vessel Mounted Jetting	Tracked Vehicle Jetting	Chain Cutter	Snag on Vessel	Dredging	Anchoring	Jack-Up Operations	Piled Foundation	Suction Pile Foundation	Rock Placement	Mattress Installation	Peel Grab Operations	PLGR	Borehole/Vibrocore	CPT	Grab Sampling
		Activity / Pathway																	
		Probability of Detonation																	
Small Arms Ammunition		F	E	E	E	E	E	E	F	D	D	E	E	F	F	E	F	F	F
Land Service Ammunition		E	D	E	D	D	D	D	E	C	C	D	D	E	E	D	E	E	E
≤155mm Projectiles		F	D	D	F	D	D	D	D	C	C	D	E	E	E	D	E	E	E
≥155mm Projectiles		F	D	D	F	D	D	D	D	C	C	D	E	E	E	D	E	E	E
HE Bombs	Allied Origin	D	D	D	C	C	C	C	D	C	C	C	D	E	E	D	D	D	E
HE Bombs	Axis Origin < 25 kg	F	D	C	F	B	C	C	E	C	C	C	F	E	E	D	F	F	E
HE Bombs	Axis Origin > 25 kg	F	D	C	F	B	C	C	E	C	C	C	F	E	E	D	F	F	E
Sea Mines	Allied Origin - Contact Mines	C	B	B	B	B	B	B	B	B	B	C	B	D	D	B	B	B	D
Sea Mines	Allied Origin - Ground Mines	F	D	C	E	B	D	D	E	D	D	D	E	E	E	D	E	E	E
Sea Mines	Danish Origin - Contact Mines	B	B	B	B	B	B	B	B	B	B	C	B	D	D	B	B	B	D
Sea Mines	Axis Origin - Contact Mines	B	B	B	B	B	B	B	B	B	B	C	B	D	D	B	B	B	D
Sea Mines	Axis Origin (non-ferrous)	F	D	C	E	B	C	C	D	C	C	C	F	D	D	D	D	D	D
Torpedoes		D	C	C	D	C	C	C	C	C	C	C	D	E	E	C	D	D	E
Depth Charges		D	C	C	C	C	C	C	C	C	C	C	D	E	E	C	D	D	E
Conventional Dumped Munitions		E	D	E	D	C	D	D	E	C	C	D	D	E	E	D	E	E	E
Dumped Chemical Munitions		E	D	E	D	C	D	D	E	C	C	D	D	E	E	D	E	E	E
Missiles/Rockets		E	D	E	D	C	D	D	E	C	C	D	D	E	E	D	E	E	E

Regular Munitions		Cable Lay	Ploughing	Vessel Mounted Jetting	Tracked Vehicle Jetting	Chain Cutter	Snag on Vessel	Dredging	Anchoring	Jack-Up Operations	Piled Foundations	Suction Pile Foundations	Rock Placement	Mattress Installation	Peel Grab Operations	PLGR	Borehole / Vibrocore	CPT	Grab Sampling
		Activity / Pathway																	
Water Depth		>10m	>10m	>10m	>10m	>10m	Surface	>10m	>10m	>10m	>10m	>10m	>10m	>10m	>10m	>10m	>10m	>10m	>10m
		Consequence of Detonation																	
Small Arms Ammunition		5	5	5	5	5	3	5	5	5	5	5	5	5	5	5	5	5	5
Land Service Ammunition		5	5	5	5	5	2	5	5	5	5	5	5	5	5	5	5	5	5
≤155mm Projectiles		5	5	5	5	5	2	5	5	5	5	5	5	5	5	5	5	5	5
≥155mm Projectiles		5	5	5	5	5	2	5	5	5	5	5	5	5	5	5	5	5	5
HE Bombs	Allied Origin	4	4	4	4	4	2	4	4	4	4	4	4	4	4	4	4	4	4
HE Bombs	Axis Origin < 25 kg	4	4	4	4	4	2	4	4	4	4	4	4	4	4	4	4	4	4
HE Bombs	Axis Origin > 25 kg	4	4	4	4	4	2	4	4	4	4	4	4	4	4	4	4	4	4
Sea Mines	Allied Origin - Contact Mines	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3
Sea Mines	Allied Origin - Ground Mines	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3
Sea Mines	Danish Origin - Contact Mines	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3
Sea Mines	Axis Origin - Contact Mines	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3
Sea Mines	Axis Origin (non-ferrous)	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3
Torpedoes		3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3
Depth Charges		3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3
Conventional Dumped Munitions		3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3
Dumped Chemical Munitions		4	4	4	4	4	2	4	4	4	4	4	4	4	4	4	4	4	4
Missiles/Rockets		3	3	3	3	3	2	3	3	3	3	3	3	3	3	4	3	3	3

Source: UXO
Potential Pathway: Construction / Installation Activities
Potential Receptor: People, Equipment, Infrastructure, 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	Chain Cutter	Risk Rating	Snag on Vessel*	Risk Rating	Dredging	Risk Rating	Anchoring	Risk Rating	Jack-Up Operation	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	EF5	Negligible	ED5	Low
Land Service Ammunition		E	F	EE5	Negligible	ED5	Low	EE5	Negligible	ED5	Low	ED5	Low	FD2	Low	ED5	Low	EE5	Negligible	EC5	Low
≤155mm Projectiles		E	F	EF5	Negligible	ED5	Low	ED5	Low	EF5	Negligible	ED5	Low	FD2	Low	ED5	Low	ED5	Low	EC5	Low
≥155mm Projectiles		D	E	DF5	Negligible	DD5	Low	DD5	Low	DF5	Negligible	DD5	Low	ED2	Low	DD5	Low	DD5	Low	DC5	Low
HE Bombs	Allied Origin	D	E	DD4	Low	DD4	Low	DD4	Low	DC4	Low	DC4	Low	EC2	Low	DC4	Low	DD4	Low	DC4	Low
	Axis Origin < 25 kg	D	E	DF4	Low	DD4	Low	DC4	Low	DF4	Low	DB4	Low	EC2	Low	DC4	Low	DE4	Low	DC4	Low
	Axis Origin > 25 kg	D	E	DF4	Low	DD4	Low	DC4	Low	DF4	Low	DB4	Low	EC2	Low	DC4	Low	DE4	Low	DC4	Low
Sea Mines	Allied Origin - Contact Mines	C	D	CC3	Mod	CB3	Mod	CB3	Mod	CB3	Mod	CB3	Mod	DB2	Mod	CB3	Mod	CB3	Mod	CB3	Mod
	Allied Origin - Ground Mines	C	D	CF3	Low	CD3	Low	CC3	Mod	CE3	Low	CB3	Mod	DD2	Low	CD3	Low	CE3	Low	CD3	Low
	Danish Origin - Contact Mines	C	D	CB3	Mod	CB3	Mod	CB3	Mod	CB3	Mod	CB3	Mod	DB2	Mod	CB3	Mod	CB3	Mod	CB3	Mod
	Axis Origin - Contact Mines	D	E	DB3	Mod	DB3	Mod	DB3	Mod	DB3	Mod	DB3	Mod	EB2	Mod	DB3	Mod	DB3	Mod	DB3	Mod
	Axis Origin (non-ferrous)	E	F	EF3	Low	ED3	Low	EC3	Low	EE3	Low	EB3	Low	FC2	Low	EC3	Low	ED3	Low	EC3	Low
Torpedoes		D	E	DD3	Low	DC3	Low	DC3	Low	DD3	Low	DC3	Low	EC2	Low	DC3	Low	DC3	Low	DC3	Low
Depth Charges		D	E	DD3	Low	DC3	Low	DC3	Low	DC3	Low	DC3	Low	EC2	Low	DC3	Low	DC3	Low	DC3	Low
Conventional Dumped Munitions		E	F	EE3	Low	ED3	Low	EE3	Low	ED3	Low	EC3	Low	FD2	Low	ED3	Low	EE3	Low	EC3	Low
Dumped Chemical Munitions		E	F	EE4	Low	ED4	Low	EE4	Low	ED4	Low	EC4	Low	FD2	Low	ED4	Low	EE4	Low	EC4	Low
Missiles/Rockets		E	F	EE3	Low	ED3	Low	EE3	Low	ED3	Low	EC3	Low	FD2	Low	ED3	Low	EE3	Low	EC3	Low

UXO		Probability of Encounter on Seabed	Probability of Encounter on Vessel*	Piled Foundations	Risk Rating	Suction Pile Foundations	Risk Rating	Rock Placement	Risk Rating	Mattress Installation	Risk Rating	Peel Grab Operations	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	ED5	Low	EE5	Negligible	EE5	Negligible	EF5	Negligible	EF5	Negligible	EE5	Negligible	EF5	Negligible	EF5	Negligible	EF5	Negligible
Land Service Ammunition		E	F	EC5	Low	ED5	Low	ED5	Low	EE5	Negligible	EE5	Negligible	ED5	Low	EE5	Negligible	EE5	Negligible	EE5	Negligible
≤155mm Projectiles		E	F	EC5	Low	ED5	Low	EE5	Negligible	EE5	Negligible	EE5	Negligible	ED5	Low	EE5	Negligible	EE5	Negligible	EE5	Negligible
≥155mm Projectiles		D	E	DC5	Low	DD5	Low	DE5	Low	DE5	Low	DE5	Low	DD5	Low	DE5	Low	DE5	Low	DE5	Low
HE Bombs	Allied Origin	D	E	DC4	Low	DC4	Low	DD4	Low	DE4	Low	DE4	Low	DD4	Low	DD4	Low	DD4	Low	DE4	Low
	Axis Origin < 25 kg	D	E	DC4	Low	DC4	Low	DF4	Low	DE4	Low	DE4	Low	DD4	Low	DF4	Low	DF4	Low	DE4	Low
	Axis Origin > 25 kg	D	E	DC4	Low	DC4	Low	DF4	Low	DE4	Low	DE4	Low	DD4	Low	DF4	Low	DF4	Low	DE4	Low
Sea Mines	Allied Origin - Contact Mines	C	D	CB3	Mod	CC3	Mod	CB3	Mod	CD3	Low	CD3	Low	CB3	Mod	CB3	Mod	CB3	Mod	CD3	Low
	Allied Origin - Ground Mines	C	D	CD3	Low	CD3	Low	CE3	Low	CE3	Low	CE3	Low	CD3	Low	CE3	Low	CE3	Low	CE3	Low
	Danish Origin - Contact Mines	C	D	CB3	Mod	CC3	Mod	CB3	Mod	CD3	Low	CD3	Low	CB3	Mod	CB3	Mod	CB3	Mod	CD3	Low
	Axis Origin - Contact Mines	D	E	DB3	Mod	DC3	Low	DB3	Mod	DD3	Low	DD3	Low	DB3	Mod	DB3	Mod	DB3	Mod	DD3	Low
	Axis Origin (non-ferrous)	E	F	EC3	Low	EC3	Low	EF3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low
Torpedoes		D	E	DC3	Low	DC3	Low	DD3	Low	DE3	Low	DE3	Low	DC3	Low	DD3	Low	DD3	Low	DE3	Low
Depth Charges		D	E	DC3	Low	DC3	Low	DD3	Low	DE3	Low	DE3	Low	DC3	Low	DD3	Low	DD3	Low	DE3	Low
Conventional Dumped Munitions		E	F	EC3	Low	ED3	Low	ED3	Low	EE3	Low	EE3	Low	ED3	Low	EE3	Low	EE3	Low	EE3	Low
Dumped Chemical Munitions		E	F	EC4	Low	ED4	Low	ED4	Low	EE4	Low	EE4	Low	ED4	Low	EE4	Low	EE4	Low	EE4	Low
Missiles/Rockets		E	F	EC3	Low	ED3	Low	ED3	Low	EE3	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 010*
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	Chain Cutter	Risk Rating	Snag on Vessel*	Risk Rating	Dredging	Risk Rating	Anchoring	Risk Rating	Jack-Up Operation	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	EF5	Negligible	ED5	Low
Land Service Ammunition		E	F	EE5	Negligible	ED5	Low	EE5	Negligible	ED5	Low	ED5	Low	FD2	Low	ED5	Low	EE5	Negligible	EC5	Low
≤155mm Projectiles		E	F	EF5	Negligible	ED5	Low	ED5	Low	EF5	Negligible	ED5	Low	FD2	Low	ED5	Low	ED5	Low	EC5	Low
≥155mm Projectiles		D	E	DF5	Negligible	DD5	Low	DD5	Low	DF5	Negligible	DD5	Low	ED2	Low	DD5	Low	DD5	Low	DC5	Low
HE Bombs	Allied Origin	D	E	DD4	Low	DD4	Low	DD4	Low	DC4	Low	DC4	Low	EC2	Low	DC4	Low	DD4	Low	DC4	Low
HE Bombs	Axis Origin < 25 kg	D	E	DF4	Low	DD4	Low	DC4	Low	DF4	Low	DB4	Low	EC2	Low	DC4	Low	DE4	Low	DC4	Low
HE Bombs	Axis Origin > 25 kg	D	E	DF4	Low	DD4	Low	DC4	Low	DF4	Low	DB4	Low	EC2	Low	DC4	Low	DE4	Low	DC4	Low
Sea Mines	Allied Origin - Contact Mines	D	E	DC3	Low	DB3	Mod	DB3	Mod	DB3	Mod	DB3	Mod	EB2	Mod	DB3	Mod	DB3	Mod	DB3	Mod
Sea Mines	Allied Origin - Ground Mines	D	E	DF3	Low	DD3	Low	DC3	Low	DE3	Low	DB3	Mod	ED2	Low	DD3	Low	DE3	Low	DD3	Low
Sea Mines	Danish Origin - Contact Mines	D	E	DB3	Mod	DB3	Mod	DB3	Mod	DB3	Mod	DB3	Mod	EB2	Mod	DB3	Mod	DB3	Mod	DB3	Mod
Sea Mines	Axis Origin - Contact Mines	D	E	DB3	Mod	DB3	Mod	DB3	Mod	DB3	Mod	DB3	Mod	EB2	Mod	DB3	Mod	DB3	Mod	DB3	Mod
Sea Mines	Axis Origin (non-ferrous)	E	F	EF3	Low	ED3	Low	EC3	Low	EE3	Low	EB3	Low	FC2	Low	EC3	Low	ED3	Low	EC3	Low
Torpedoes		D	E	DD3	Low	DC3	Low	DC3	Low	DD3	Low	DC3	Low	EC2	Low	DC3	Low	DC3	Low	DC3	Low
Depth Charges		D	E	DD3	Low	DC3	Low	DC3	Low	DC3	Low	DC3	Low	EC2	Low	DC3	Low	DC3	Low	DC3	Low
Conventional Dumped Munitions		E	F	EE3	Low	ED3	Low	EE3	Low	ED3	Low	EC3	Low	FD2	Low	ED3	Low	EE3	Low	EC3	Low
Dumped Chemical Munitions		E	F	EE4	Low	ED4	Low	EE4	Low	ED4	Low	EC4	Low	FD2	Low	ED4	Low	EE4	Low	EC4	Low
Missiles/Rockets		E	F	EE3	Low	ED3	Low	EE3	Low	ED3	Low	EC3	Low	FD2	Low	ED3	Low	EE3	Low	EC3	Low

UXO		Probability of Encounter on Seabed	Probability of Encounter on Vessel*	Piled Foundations	Risk Rating	Suction Pile Foundations	Risk Rating	Rock Placement	Risk Rating	Mattress Installation	Risk Rating	Peel Grab Operations	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	ED5	Low	EE5	Negligible	EE5	Negligible	EF5	Negligible	EF5	Negligible	EE5	Negligible	EF5	Negligible	EF5	Negligible	EF5	Negligible
Land Service Ammunition		E	F	EC5	Low	ED5	Low	ED5	Low	EE5	Negligible	EE5	Negligible	ED5	Low	EE5	Negligible	EE5	Negligible	EE5	Negligible
≤155mm Projectiles		E	F	EC5	Low	ED5	Low	EE5	Negligible	EE5	Negligible	EE5	Negligible	ED5	Low	EE5	Negligible	EE5	Negligible	EE5	Negligible
≥155mm Projectiles		D	E	DC5	Low	DD5	Low	DE5	Low	DE5	Low	DE5	Low	DD5	Low	DE5	Low	DE5	Low	DE5	Low
HE Bombs	Allied Origin	D	E	DC4	Low	DC4	Low	DD4	Low	DE4	Low	DE4	Low	DD4	Low	DD4	Low	DD4	Low	DE4	Low
HE Bombs	Axis Origin < 25 kg	D	E	DC4	Low	DC4	Low	DF4	Low	DE4	Low	DE4	Low	DD4	Low	DF4	Low	DF4	Low	DE4	Low
HE Bombs	Axis Origin > 25 kg	D	E	DC4	Low	DC4	Low	DF4	Low	DE4	Low	DE4	Low	DD4	Low	DF4	Low	DF4	Low	DE4	Low
Sea Mines	Allied Origin - Contact Mines	D	E	DB3	Mod	DC3	Low	DB3	Mod	DD3	Low	DD3	Low	DB3	Mod	DB3	Mod	DB3	Mod	DD3	Low
Sea Mines	Allied Origin - Ground Mines	D	E	DD3	Low	DD3	Low	DE3	Low	DE3	Low	DE3	Low	DD3	Low	DE3	Low	DE3	Low	DE3	Low
Sea Mines	Danish Origin - Contact Mines	D	E	DB3	Mod	DC3	Low	DB3	Mod	DD3	Low	DD3	Low	DB3	Mod	DB3	Mod	DB3	Mod	DD3	Low
Sea Mines	Axis Origin - Contact Mines	D	E	DB3	Mod	DC3	Low	DB3	Mod	DD3	Low	DD3	Low	DB3	Mod	DB3	Mod	DB3	Mod	DD3	Low
Sea Mines	Axis Origin (non-ferrous)	E	F	EC3	Low	EC3	Low	EF3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low	ED3	Low
Torpedoes		D	E	DC3	Low	DC3	Low	DD3	Low	DE3	Low	DE3	Low	DC3	Low	DD3	Low	DD3	Low	DE3	Low
Depth Charges		D	E	DC3	Low	DC3	Low	DD3	Low	DE3	Low	DE3	Low	DC3	Low	DD3	Low	DD3	Low	DE3	Low
Conventional Dumped Munitions		E	F	EC3	Low	ED3	Low	ED3	Low	EE3	Low	EE3	Low	ED3	Low	EE3	Low	EE3	Low	EE3	Low
Dumped Chemical Munitions		E	F	EC4	Low	ED4	Low	ED4	Low	EE4	Low	EE4	Low	ED4	Low	EE4	Low	EE4	Low	EE4	Low
Missiles/Rockets		E	F	EC3	Low	ED3	Low	ED3	Low	EE3	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

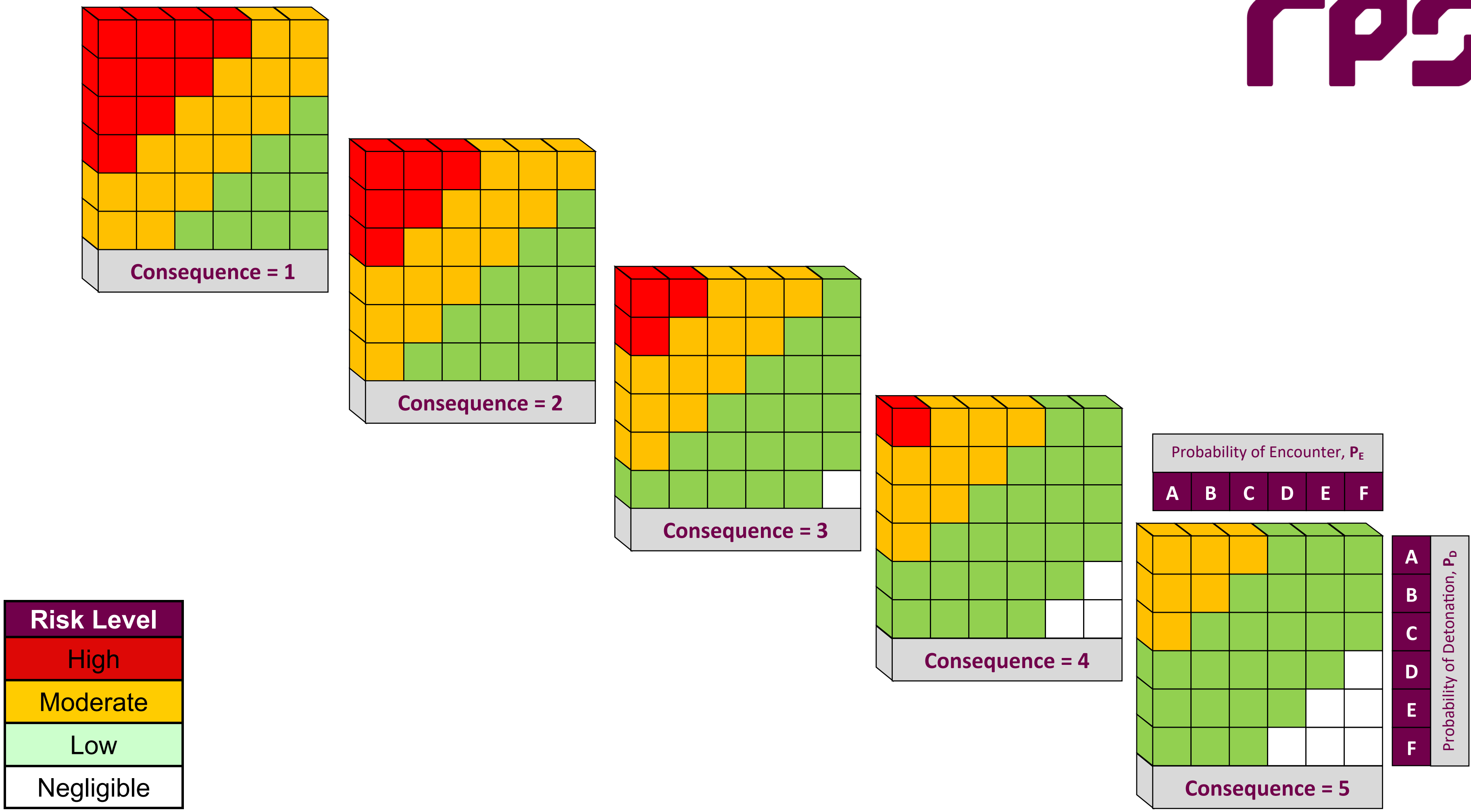
Notes:

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 010*
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



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Appendix 008: Consequence Levels 2 of 2

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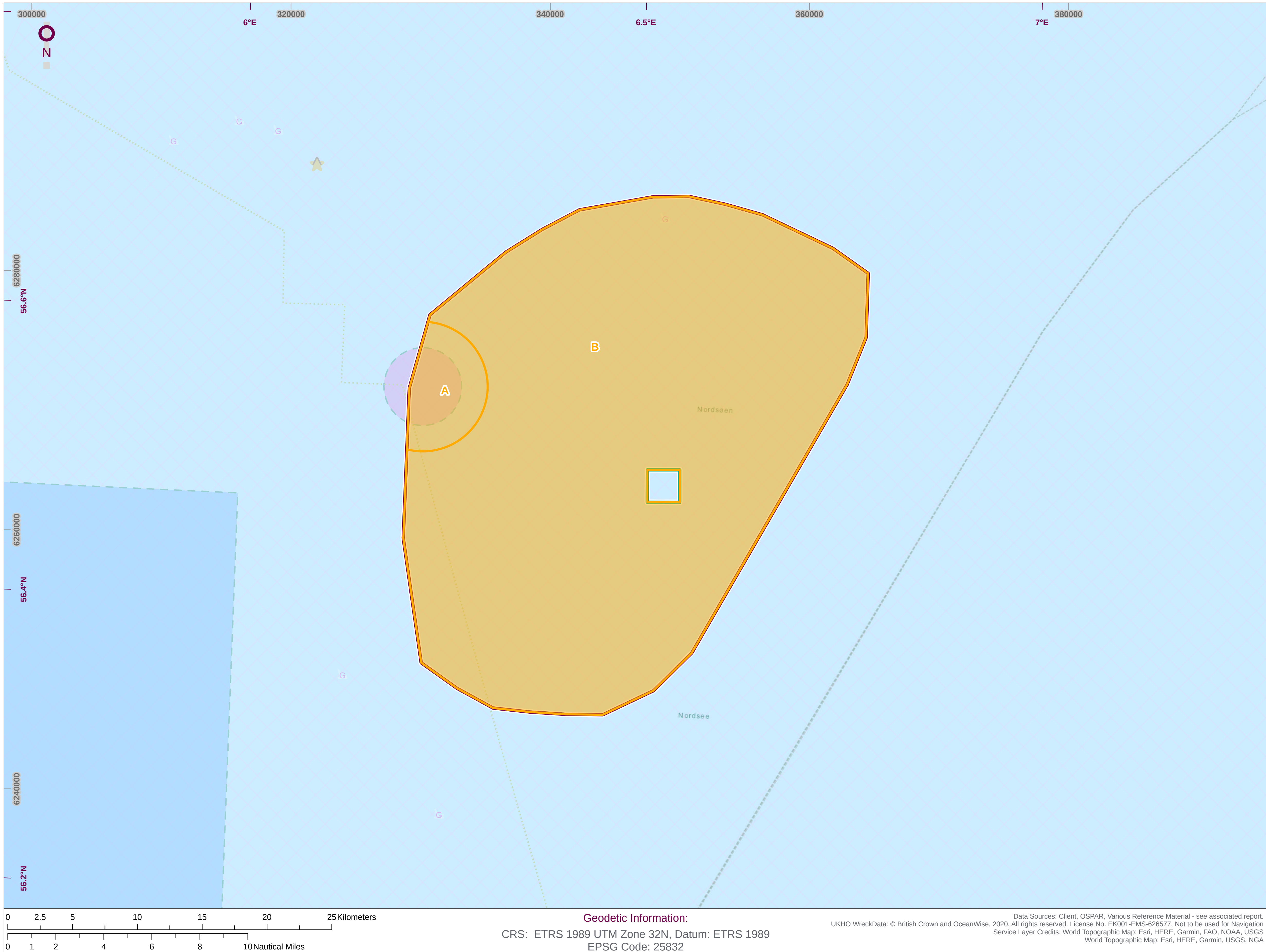
Appendix 9 – Risk Zone Map



Legend

- OWF Project Area
- Artificial Island Project Area
- Moderate UXO Risk
- Wreck Record (Client/Survey): High UXO Risk
- OSPAR Munition Encounters (up to 2017)
- Military Vessel Movement - German - WWI
- Historic Offshore Minefield - British (WWII)
- Historic Offshore Minefield - German (WWII)
- Heligoland Bight Minefield Area (WWI)

Overview

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

Data Sources: Client, OSPAR, Various Reference Material - see associated report.
UKHO 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: Esri, HERE, Garmin, FAO, NOAA, USGS
World Topographic Map: Esri, HERE, Garmin, USGS, NGA

Ver	Description	By	Check	Date
00	INITIAL ISSUE	LM	RM	16/12/21

Figure Number: EES1228-F-004 | Rev: 00 | Page: 1 of 1

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Client	Energinet Eltransimission A/S	Project Number	EES1228
Project	North Sea Offshore Wind Farm (OWF) Project	Scale @ A3	1:300,000
Title	UXO Risk Zoning		

Drawn By	LM
Checked By	RM
Status	INITIAL ISSUE
Date Created	16/12/2021

Notes:
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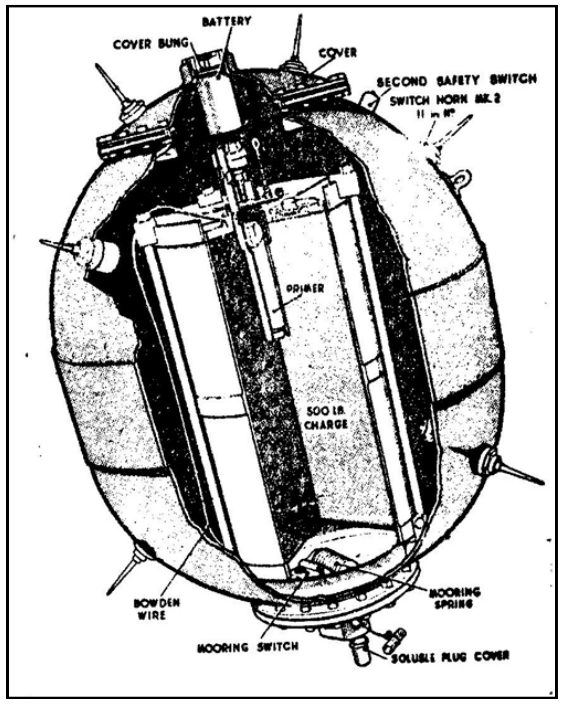
2. If received electronically it is the recipients responsibility to print to correct scale.
3. Only written dimensions should be used .
4. Not to be used for Navigation.
5. The locations shown are based on the information identified /provided, and should be used for general guidance only.

Appendix 10 – Expected UXO Types

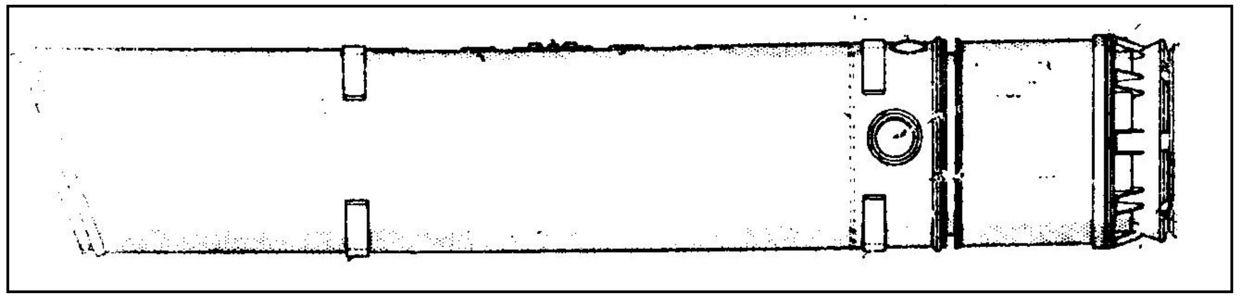
Description	Diameter	Weight	Charge filling & NEQ	Period	Notes
British Sea Mines					
Vickers Elia mine	0.836m	139kg to 203kg	TNT 54kg to 100kg	WWI	
S Mk 5 mine	0.79m	Unknown	Amatol 113kg	1919-1940	Submarine laid mine
Type H Mk II mine	0.965m	295kg	Amatol 145kg	1917-1941	Spherical mine
Mk I (M) mine	Unknown	Unknown	TNT 554kg	1918-1941	First magnetic mine
Mk XV mine	1.02m	381kg	Unknown 145kg or 295kg	WWII-1950s	Moored contact mone, frequently used in tidal currents
Mk XVII	Unknown	Unknown	Unknown 145kg, 204kg or 207kg	WWII to 1950s	Standard British contact mine of WWII
Mk XVII moored contact mine	Unknown	Unknown	Unknown 145kg 0r 227kg	WWII to 1950s	Used against S-boot and R-boot. Laid in 13m-37m depth
M Mk I magnetic mine	Unknown	Unknown	Unknown 227kg	WWII to 1950s	Emplaced in 146m to 1,430m depth
M Mk V magnetic mine	Unknown	853kg	Minol 499kg	1942-1950s	Submarine laid
A Mk I air dropped	Unknown	680kg	Unknown 340kg	WWII	Air laid
A Mk V air dropped	Unknown	490kg	Minol 318kg	1941-1945	Air laid parachute mine
A Mk VI and VII air dropped	0.47m (2.1m-2.3m length)	499kg	Minol 252kg or 277kg	1944-1950s	Air laid or MTB laid. Minimum of 12m depth for laying
A Mk IX air dropped	0.47m (2.6m length)	805kg to 837kg	Minol 474kg	1944-1950s	Air laid. Minimum of 12m for laying
Danish Sea Mines					
Type 1907 Contact Mine				WWI	Horned contact mine
Type 1918 Contact Mine	900mm		60-70kg Gun Cotton NEQ	WWI / WWII	Horned contact mine
German Sea Mines					
E-Mine *(Elektrische Minen A/B)*			150kg Gun Cotton NEQ (*EM A*), 220kg Gun Cotton NEQ (*EMB*)	WWI / WWII *(EM B)*	Produced in two versions, one for surface ships and the other for specially fitted submarines. Production discontinued at the end of the war but substantial stocks remained and they were used in the early part of World War II (*EM B*)
U-Mine			20kg Gun Cotton NEQ	WWI	This was specifically developed as an anti-submarine mine and was introduced in 1915
"Type I" (British designation)	800mm	254kg	81.6kg Wet Gun Cotton NEQ	WWI - Inter war	Moored Hertz Horn Contact Mine
"Type II" (British designation)	800mm	322kg	131kg Wet Gun Cotton NEQ	WWI - Inter war	Moored Hertz Horn Contact Mine
"Type III" (British designation)	860mm	281kg	100kg CastTNT NEQ	WWI - Inter war	Moored Hertz Horn Contact Mine
"Type IV" (British designation)	860mm	281kg	81.6kg Wet Gun Cotton NEQ	WWI - Inter war	Moored Hertz Horn Contact Mine
EMA (GU British Designation)			150kg Gun Cotton NEQ. Later changed to TNT	WWII	Modified WWI E-Mine (A). Moored Hertz Horn Contact Mine with 5 Horns
EMB			220kg Gun Cotton NEQ. Later Chanc=ged to TNT	WWII	Modified WWI E-Mine (B). Moored Hertz Horn Contact Mine with 5 Horns
EMC (GY British Designation)	1.12m		300kg NEQ	WWII	Moored Hertz Horn Contact Mine with seven Horns.
EMC m KA	1.12m		250kg - 285kg NEQ	WWII	Moored Hertz Horn Contact Mine with seven Horns. Fitted with anti-sweeping attachment.
EMC m KE	1.12m		250kg NEQ	WWII	Moored Hertz Horn Contact Mine
EMC m ANZ (antenna Firing) (GV British Designation)	1.12m		250kg - 285kg NEQ	WWII	Moored Hertz Horn Contact Mine.
EMC m Kette u Reissleine (snagline)	1.12m		250kg - 285kg NEQ	WWII	Moored Hertz Horn Contact Mine with five horns
EMD (GQ British Designation)	1m		150kg NRQ	WWII	Moored Hertz Horn Contact Mine with five horns
EMF (GO British Designation)			350kg NEQ	WWII	Moored Magnetic Influence Mine
LMF (GP British Designation)		1,050kg	290kg NEQ	WWII	Moored Influence mine used by aircraft and 'S' boats
UMA	800mm		30kg NEQ	WWII	Anti-Submarine Moored Contact mine with 5 Hertz and three switch horns
UMB	840mm		40kg NEW	WWII	Anti-Submarine Moored Contact mine with 5 Hertz and three switch horns

British Mark XVII Mine

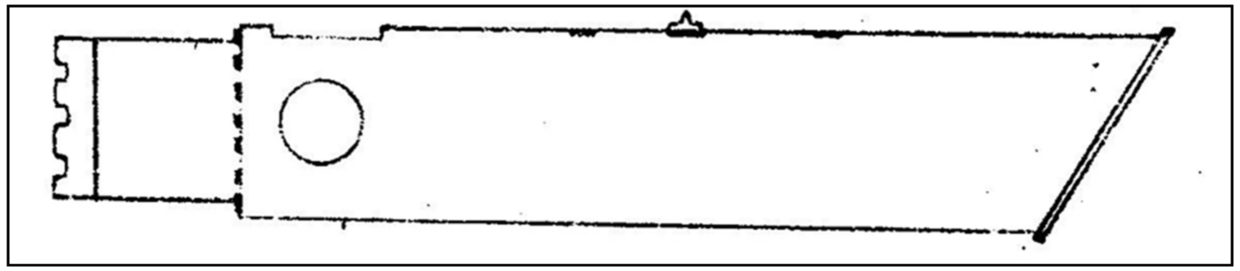


British M Mk I Mine

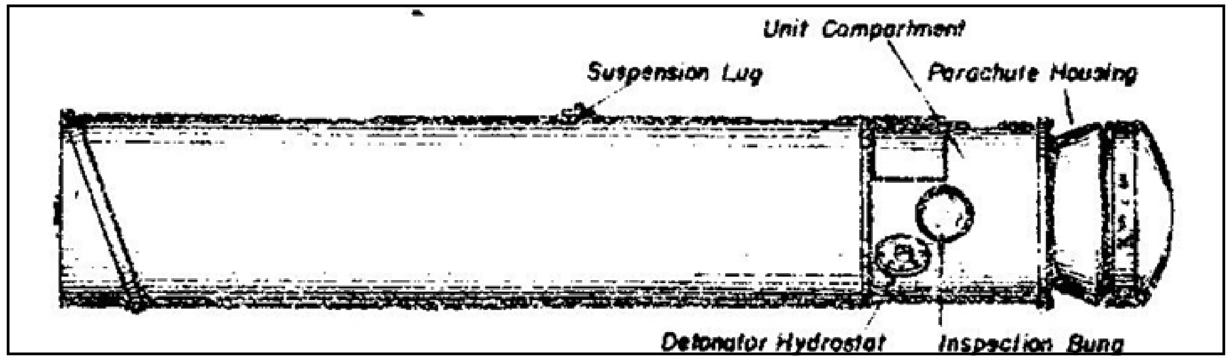
British Mk XII



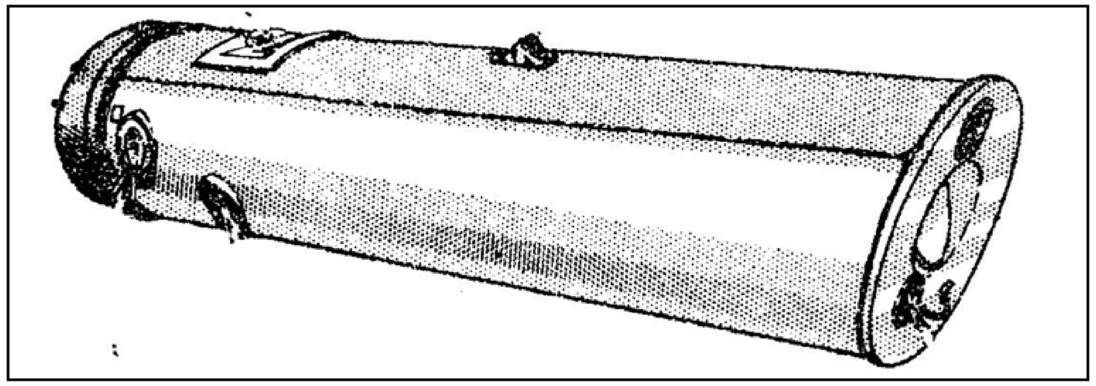
British Mk XII



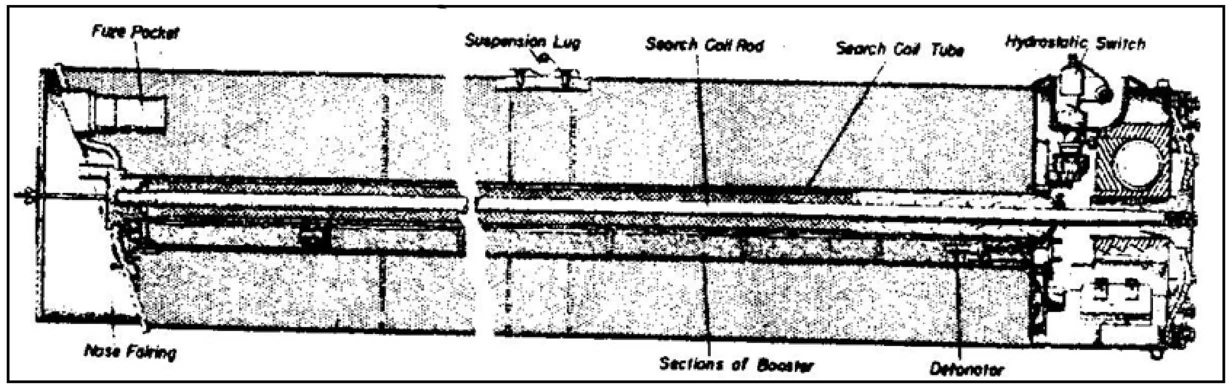
British "A" Mk VI



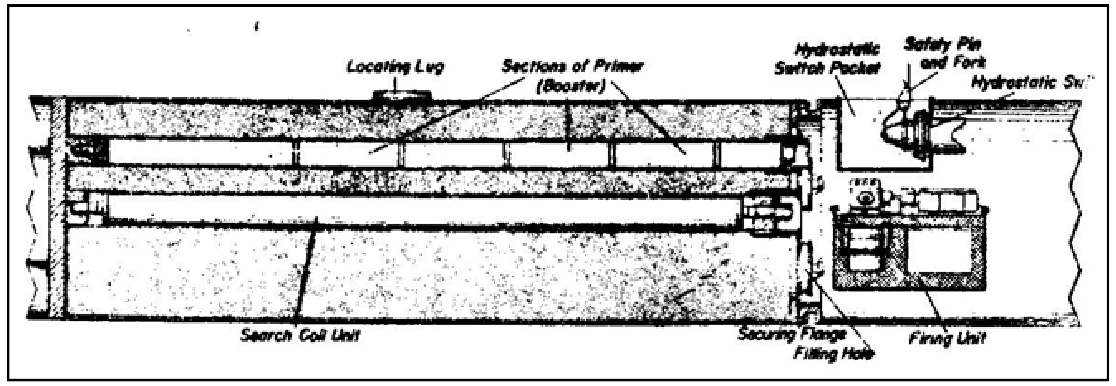
British Mk XII



British "A" Mk V



British "A" Mk I, II, III, IV



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Appendix 010: Examples of Sea Mines

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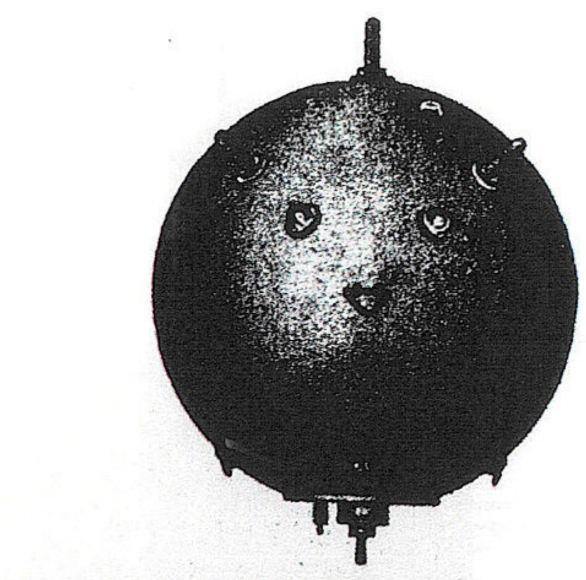
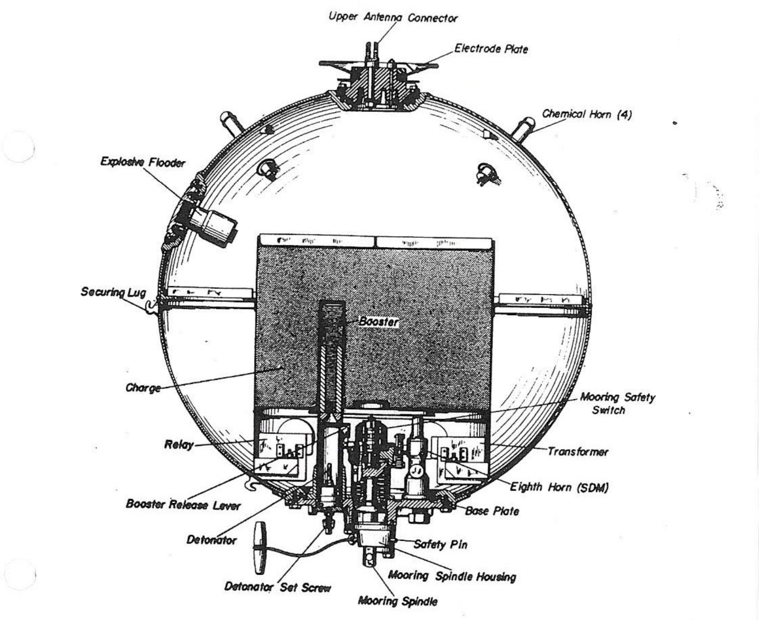
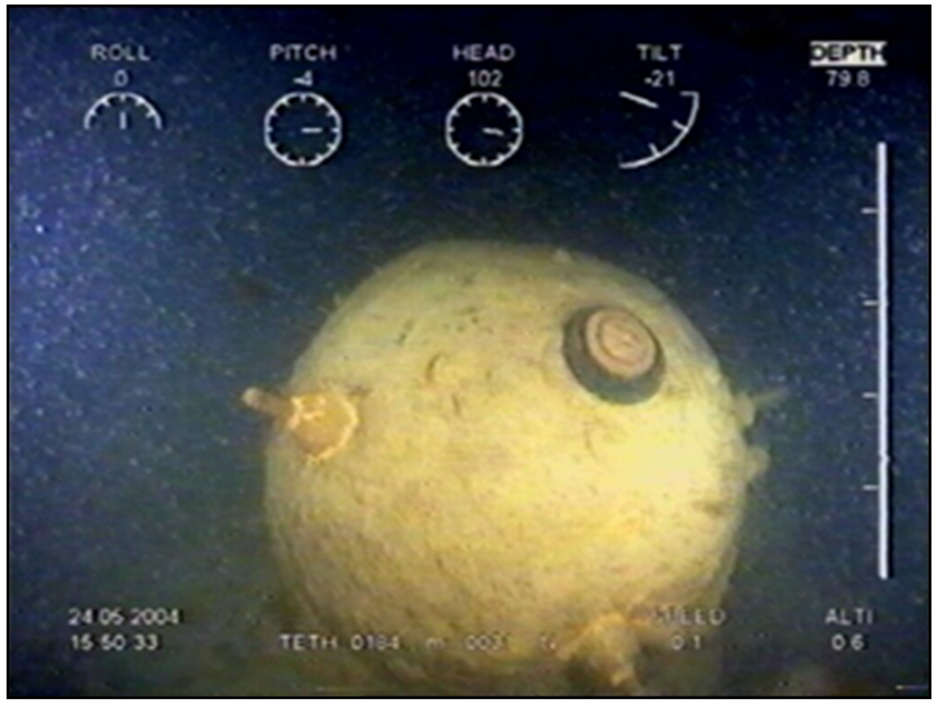
German EMD moored contact mine





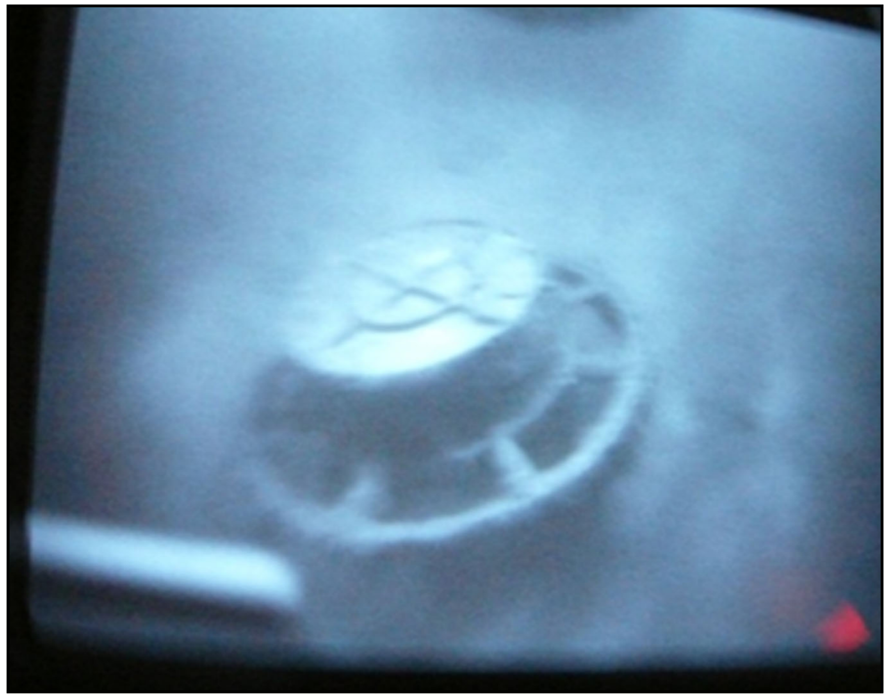
German WWI Type II Mine

German EMC Mine



EMC Mine showing no real degradation

EMC Mine showing corrosion of buoyant casing, revealing main charge



EMC main charge with significant degradation of buoyant casing

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Appendix 010: Examples of Sea Mines

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Appendix 11– Avoidance Schematics

Offshore UXO Project Indicative Standoff Distances

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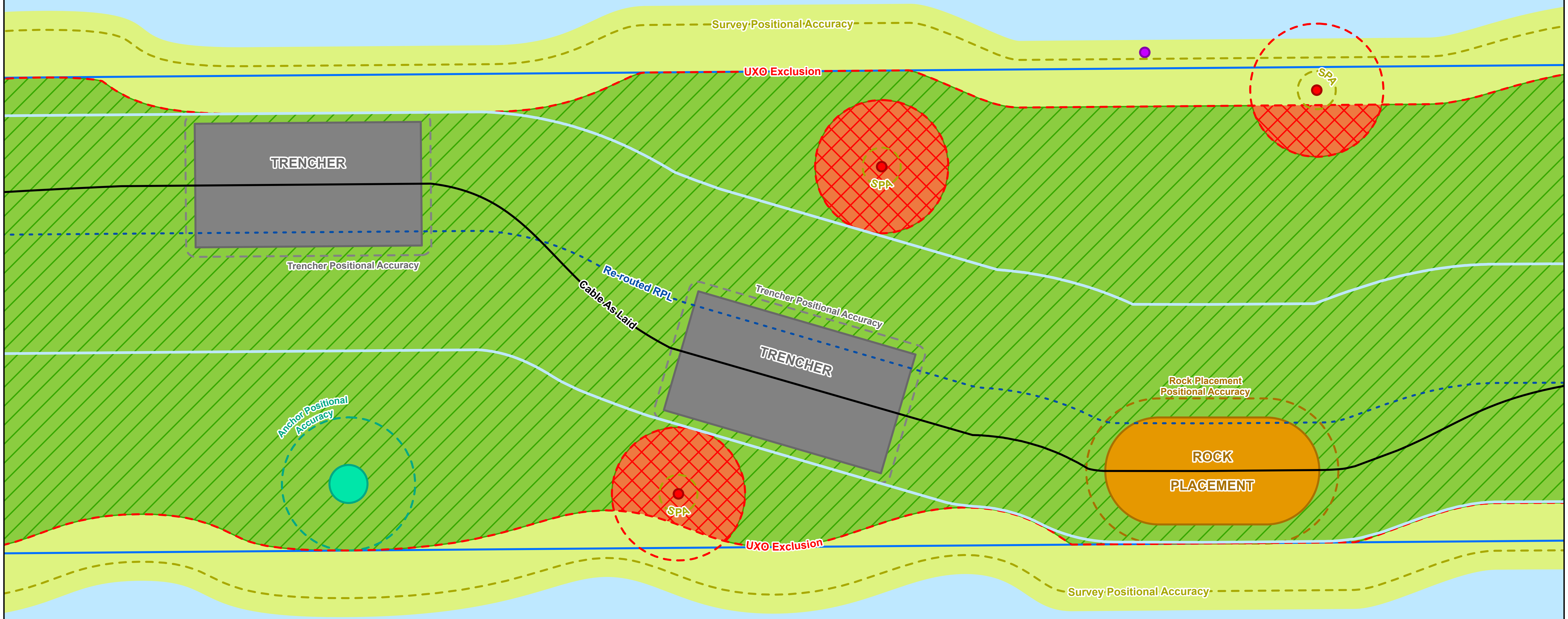

Re-routed RPL
Cable As Laid
Survey Positional Accuracy
Trencher Corridor
UXO Exclusion
Survey Corridor
Dynamic Data Coverage
Trencher
Trencher Positional Accuracy
Anchor / Clump Weight
Anchor Positional Accuracy
Rock Placement
Rock Placement Positional Accuracy
Potential UXO (pUXO)
UXO Exclusion Area
Undetected Potential UXO (pUXO)
ALARP Area