Inch Cape Offshore Wind Farm

New Energy for Scotland

Offshore Environmental Statement:

VOLUME 2H

Appendix 21A: Unexploded Ordnance Assessment

Unexploded Ordnance (UXO) Assessment

***Project*: Inch Cape Offshore Wind Farm**

***Client*: Inch Cape Offshore Limited**

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Acronyms and Abbreviations

AAA	Anti-Aircraft Artillery
AHT	Anchor Handling Tugboat
ALARP	As Low As Reasonably Practicable
CIRIA	Construction Industry Research and Information Association
BD	Bomb Disposal
BDO	Bomb Disposal Officer
BMAPA	British Marine and Aggregate Producers Association
dGPS	Differential Global Positioning Systems
EO	Explosive Ordnance
EOD	Explosive Ordnance Disposal
ERW	Explosive Remnants of War
GIS	Geographical Information System
HDD	Horizontal Directional Drilling
HE	High Explosive
HV	High Voltage
HMX	High Molecular (mass) RDX
HSE	Health and Safety Executive
HSF	Hull Shock Factor
IB	Incendiary Bomb
ICOL	Inch Cape Offshore Limited
JSEODOC	Joint Service Explosive Ordnance Disposal Operations Centre
KHz	Kilohertz
Kg	Kilogram
KSF	Keel Shock Factor
Kv	Kilovolt
Km	Kilometre
lb	Pound (weight)
LSA	Land Service Ammunition
M	Metres
MCM	Mine Countermeasures

MDA	Mine Danger Area
MCA	Maritime and Coastguard Agency
MoD	Ministry of Defence
mm	Millimetres
MSL	Mean Sea Level
NEQ	Net Explosive Quantity
NGR	National Grid Reference
Nm	Nautical Mile
OSPT	Offshore Superintendent
PLGR	Pre Lay Grapnel Run
POW	Prisoners of War
RAF	Royal Air Force
RDX	Research Department (composition) ‘X’
RN	Royal Navy
ROV	Remotely Operated Vehicle
RPL	Route Position List
QA/QC	Quality Assurance/Quality Control
SAA	Small Arms Ammunition
SI	Site Investigation
SOE	Special Operations Executive
SOP	Standard Operating Procedure
SSS	Side Scan Sonar
SQRA	Semi Quantitative Risk Assessment
TA	Territorial Army
TNT	Trinitrotoluene
UK	United Kingdom
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
WTG	Wind Turbine Generator
WWI	World War One
WWII	World War Two

Executive Summary

Study Area

This desk study provides a Detailed Unexploded Ordnance (UXO) Threat and Risk Assessment for the proposed Inch Cape Offshore Wind Farm and related Offshore Transmission Works within the outer Firth of Tay, Scotland.

- The Wind Farm infrastructure will be installed within the Development Area (henceforth the "Study Area") and is found approximately 15 km to the east of the Angus coastline and covers an area of approximately 150 km^2.
- Up to six export cables are located into the Offshore Export Cable Corridor which is approximately 83 km long. The Offshore Export Cable Corridor divides into two as it nears the shore as there are two alternative cable landfall options at either Seton Sands or Cockenzie.
- The Project Area includes the Development Area and the Offshore Export Cable Corridor.

The Study Area is shown at Annex 21A.1 and encompasses both the Development Area and Offshore Export Cable Corridor.

For the avoidance of doubt the Study Area for the purpose of this assessment excludes any onshore elements and only relates offshore works up to mean high water springs (MHWS).

Key Findings

This threat and risk assessment identifies significant variations in the risk to construction and operations due to among other things, the location of potential UXO threat sources as well as the level of prospective kinetic energy associated with each investigative or installation operations and the seabed.

UXO threat sources have been identified at the Project Area, some of which poses a relatively high threat. It is also possible that UXO may have migrated from additional threat sources in the vicinity of the Project Area from the wider Study Area although the types, quantities and locations of such UXO are difficult to accurately forecast.

The region surrounding the Site was considered to be strategically important during both World Wars. The Firth of Forth is Scotland's largest river with a number of important ports and cities such as Leith, Edinburgh, Methil and Rosyth located on its banks. The Firth of Tay and Forth were highly important rivers for trade and were strategically important during both World Wars because they are located on the North Sea coast providing a link to mainland European ports.

The Germans heavily targeted the cities, ports and shipping routes into the Firths of Tay and Forth during both World Wars. U-Boat attacks on shipping were carried out in WWI whilst aerial bombardment of terrestrial sites such as ports and cities and attacks on shipping took place in WWII. Mine laying activities by German U-Boats took place in both World Wars although in WWII aerial mine deployment became the preferred emplacement method.

The Firth of Forth was used as a convoy marshalling point during both Wars, with convoy routes assembling along the east coast of Britain for dispersal in supply routes to the USSR. German forces specifically targeted convoy routes during both World Wars in order to disrupt trade and supplies and there are a number of munitions related shipwrecks located within the vicinity of the Study Area which may be attributed to both World Wars. Former convoy routes are located across both the Offshore Export Cable Corridor and the Development Area.

British sea mine laying activities were undertaken to defend against the German threat to shipping during both World Wars, with extensive East Coast defensive mine laying occurring during WWII especially. Terrestrial defences against enemy ships and aerial bombardment included a number of Royal Air Force bases and anti-aircraft batteries were also located along the coast.

The Firth of Forth and Firth of Tay area has been highly militarised with naval bases located at Rosyth, Port Edgar and a submarine base at Dundee. The Forth River continues to be militarily important and there is a significant naval presence within the Forth due to the naval base at Rosyth and various military training areas are located along the coast and offshore. These historic and current training sites include live firing, exercises, torpedo, submarine and mine counter measure training sites. Some of these live firing training areas are located across the Offshore Export Cable Corridor and Development Area part of the Study Area. In addition there are disused munitions disposal sites located into the west of the Study Area, which date to the post-war period.

Both World Wars together with more modern military activities have left a significant UXO legacy within the vicinity of the Study Area. The main threat items identified include shipwreck related munitions, torpedoes as well as Axis and Allied sea mines. In addition it is possible that there are artillery projectiles and UXO items relating to the various military training areas that surround the Site.

The Development Area has a "medium" level of UXO risk posed by intrusive surveys, foundation, substructure and cable installations. All other activities in the Development Area are considered to be "low" risk.

The Offshore Export Cable Corridor is considered to have a higher UXO risk level than posed in the Development Area, largely due to the proximity of terrestrial bombing targets and the historic and military training areas located across the route. Excluding non-intrusive survey, all later installation activities are considered to be a "medium" risk within the Export Cable Corridor.

Potential Threat Items

Potential threat items in the Study Area include shipwreck related munitions, *Allied* and *Axis* Sea Mines, Torpedoes, Dumped Munitions, Artillery Projectiles and High Explosive (HE) Bombs.

Risk Mitigation Recommendations:

Risk mitigation recommendations, focus upon investigative and installation activities taking place within the Development Area and the Off Shore Export Cable Corridor. The following proactive and reactive risk mitigation actions are recommended in order to reduce the risk of encountering and initiating UXO to As Low As Reasonably Practicable (ALARP):

- **Proactive Risk Mitigation**

Recommended proactive risk mitigation measures vary, depending on the activities to be undertaken in the Development Area and Offshore Export Cable Corridor. The main activities which incur significant risk on Site and the proactive measures to mitigate against UXO encounter are outlined in the table below:

Proposed Operation	Proactive Risk Mitigation Procedure
Intrusive Surveys including Boreholing, Vibrocoring & CPT Site investigation from a Jack-up / Dynamically Positioned (DP) barge.	1. Ensure Side Scan Sonar (SSS) and close line spaced magnetometer coverage of investigation area; 2. Avoid anomalies that model as UXO; 3. Relocate positions (micro-site) onto survey lines if required; 4. Obtain sign-off certification from a UXO consultant to provide evidence of the risk management procedure and reducing risks to ALARP.
Substructure Foundation and Inter-Array Cable Installation Construction operations	1. Ensure Side Scan Sonar (SSS) and close line spaced magnetometer coverage of investigation area; 2. Avoid anomalies that model as UXO; 3. Relocate positions (micro-site) onto survey lines if required; 4. Obtain sign-off certification from a UXO consultant to

Proposed Operation	Proactive Risk Mitigation Procedure
to be carried out on the Development Area Site.	provide evidence of the risk management procedure and reducing risks to ALARP.
Export Cable Installation	1. Ensure Side Scan Sonar (SSS) and close line spaced magnetometer coverage of investigation area; 2. Avoid anomalies that model as UXO; 3. Relocate positions (micro-site) onto survey lines if required; 4. Obtain sign-off certification from a UXO consultant to provide evidence of the risk management procedure and reducing risks to ALARP. **Additionally at the landfall locations:** Undertake land based threat and risk assessment (following a similar risk management methodology) and either avoid or investigate anomalies to provide evidence that UXO risks have been reduced to ALARP.

- **Reactive Risk Mitigation**

Whilst the risk of UXO encounter is expected to have been significantly reduced following the execution of the proactive risk mitigation measures, the threat posed by UXO can be reduced to ALARP, but it cannot be reduced to zero. Therefore, the following additional reactive measures are recommended not only to mitigate risk incurred by any subsequent intrusive activities on the Project, but also to provide evidence that ICOL and the principal contractor have reduced UXO risk to ALARP:

- UXO Coordinators; the vessel Master/OSPT level UXO action plan for each vessel with UXO coordinators assigned to undertake pre-determined drills to ensure safety in the event of a UXO discovery; and
- Tool Box Briefs; crew level UXO safety and awareness (“tool box”) briefings for each vessel.

Once both the proactive and reactive risk mitigation measures have been successfully implemented, 6 Alpha would consider that the risk will have been reduced to ALARP, and the geotechnical investigation and subsequent installation activities may then take place safely on the Site.

21A.1 Introduction

21A.1.1 Overview

Inch Cape Offshore Limited (ICOL) has commissioned 6 Alpha Associates Limited (6 Alpha) to conduct a detailed desk based Unexploded Ordnance (UXO) Threat and Risk Assessment study for the Inch Cape Offshore Wind Farm and related Offshore Transmission Works within the outer Firth of Tay, Scotland.

- The Wind Farm infrastructure will be installed within the Development Area Study Area and is found approximately 15 km to the east of the Angus coastline and covers an area of approximately 150 km^2.
- Up to six export cables are located in the Offshore Export Cable Corridor which is approximately 83 km long. The Offshore Export Cable Corridor divides into two as it nears the shore as there are two alternative cable landfall options at either Seton Sands or Cockenzie.
- The Project Area includes the Development Area and the Offshore Export Cable Corridor.

The Study Area is shown in Annex 21A.1 and encompasses both the Development Area and Offshore Export Cable Corridor and the surrounding area. The Study Area has been selected as being appropriate to provide a wider context for UXO risk in the vicinity of the Project.

For the avoidance of doubt the Study Area for the purpose of this assessment excludes any onshore elements and only relates offshore works up to mean high water springs (MHWS).

The scope of this study will include survey and construction operations involved with the installation of wind turbine generators (WTG), offshore substation platforms (OSPs), met masts, inter-array cables and associated work in the Development Area. It also includes the installation of the Export Cable located in the Offshore Export Cable Corridor in order to holistically determine the potential UXO threat.

21A.1.2 UXO and Munitions Threat in the North Sea

Items of UXO are regularly encountered in the *North Sea*, as has been confirmed by a variety of *Royal Navy* (RN) clearance tasks. Specifically, there have been ten incidents where UXO items have been found washed ashore or caught by fishermen since July

2005 within the *Firth of Forth* region. UXO rarely becomes inert or loses its effectiveness with age. Over time, trigger mechanisms (such as fuses and gaines) can become more sensitive and therefore more prone to detonation. This applies equally to items that have been submersed in water and/or lodged within the seabed. It is possible that the generation of significant kinetic energy over a short duration, which might be created by marine engineering (such as site investigation boreholes, foundation installation or cable trenching) could cause an inadvertent detonation of sensitive UXO.

21A.1.3 Marine Risk Management Framework

In order to mitigate the UXO risk in the marine environment *6 Alpha* has developed a UXO Marine Risk Management Framework. The Marine Risk Management Framework is divided into five phases, namely:

1. Preliminary UXO Threat Assessment;
2. Detailed UXO Threat & Risk Assessment;
3. Strategic Risk Management Options;
4. Risk Mitigation Design & Specification; and
5. Implementation of Risk Mitigation Measures.

The purpose of this report is to address Stages 2 and 3 of the overarching UXO Marine Risk Management process by providing a holistic overview of the UXO threats and risks for the entire marine component of the operation, together with a strategy for the mitigation of those risks presented. (The delivery of Stage 1 is superseded by the work in Stage 2).

Therefore, 6 Alpha aim to proactively employ the Risk Management Framework to guide this study and to inform ICOL not only about the risks associated with UXO on this project, but also about how those risks can be managed at best value. This work will include the employment of background research and factual data which has been provided, in part, by third parties, and upon which we have relied.

21A.1.4 ICOL's Intention

In commissioning this study, it is assumed that ICOL intends to:

- Discharge their legal duty of care to those involved in the development of the project site;

- Ensure that they take appropriate "best practice" measures to manage all of the risks posed by the UXO threat;
- Protect the development itself from the risks of UXO and in doing so, protect its investors, investment and reputation;
- Procure the most time efficient and cost effective means of managing and mitigating the UXO risk.

21A.2 Report Methodology and Best Practice

21A.2.1 Structure

This study consists of a desk-based collation and review of readily available documentation and records relating to the possibility of encountering UXO and/or dangerous Explosive Ordnance (EO) related paraphernalia, within the study area. This study methodology is based on best practice for UXO risk assessment.

Certain information obtained to inform this report may be either classified or restricted under protective marking schemes, or may otherwise be considered confidential to *6 Alpha* therefore, summaries of such information have been provided. Please note that this appraisal relies significantly upon the accuracy of the information contained in these and other third party documents and that 6 Alpha cannot be held responsible for the inaccuracy of such third party information.

In agreement with ICOL, the following facets have been considered within this report:

- The entire scope of the proposed Development Area and the Offshore Export Cable Corridor for the project have been considered;
- A review of the site specific data has been undertaken;
- The history of the region has been considered;
- Relevant historic and modern military records have been researched and presented;
- Wartime activities have been researched and presented;
- The holistic UXO threat has been considered, including the types that could be encountered, the probabilities of encountering them as well as exposing their potential mechanisms and risks of detonation;
- An outline assessment of how UXO interacts with the natural environment and conditions has been made;
- The risks regarding UXO have been assessed;
- A semi-quantitative risk assessment (SQRA) has been undertaken employing *6 Alpha's* "Azimuth ©" proprietary risk model;
- The consequences of an inadvertent High Explosive (HE) detonation has been considered;

- Conclusions have been drawn;
- A risk mitigation strategy has been presented;
- Recommendations have been made.

21A.2.2 Sources of Information

The sources of information consulted for this report include:

- Royal Navy (Diving Units);
- The National Archives, Kew;
- Naval Historical Centre, Portsmouth;
- UK Hydrographic Office, Taunton;
- 6 Alpha's "Agility Database ©" which contains historic maps, aerial photographs and records.
- SeaEnergy's "Non-Technical Summary of the Environmental Impact Assessment Scoping Report" August 2010. <Available at: http://www.inchcapewind.com/assets /docs/inch_cape_ scoping_nts_web.pdf>

21A.2.3 Standards, Guidance and Best Practice

We have assumed that *British* naval forces will not proactively search or survey for UXO, nor will they lend support to commercial developments (as is case in UK). If UXO is unexpectedly discovered and presents a life-threatening situation, then the relevant *British* emergency authorities may lend assistance. It is assumed however, as is the experience of development within and beyond UK Territorial Waters, that the identification of UXO risks and their amelioration is the primary responsibility of the renewable energy developer i.e. ICOL and its Principal Contractor.

6 Alpha's view of the law, in terms of compliance with UXO matters, is presented in Annex A.

In producing this document, the study has consulted the most relevant published guidance and best practice. Although some of those sources may not appear to be especially relevant to this project/study, in the absence of specific guidance concerning the management of UXO in the offshore environment in general and in renewable industry in particular, the following sources of guidance are considered most pertinent:

- Construction Industry Research & Information Association (CIRIA) – UXO A Guide for the Construction Industry (reference number C681) 2009;
- Unexploded Ordnance Risk. Considering Unexploded Ordnance Risk on and around the British Isles (PMSS/6 Alpha Associates – April 2011);
- British Marine Aggregate Producers Association (BMAPA) guidance for dealing with UXO March 2010;
- Maritime and Coastguard Agency (MCA) specific guidance concerning the discovery of UXO, and prospective requirements in concern with its disposal i.e. Admiralty Notice to Mariners (NIMs) and Notice to Airmen (NOTAM);
- Health & Safety Executive (HSE) guidance concerning UXO, as covered in the CIRIA guidance (C681);
- Construction Design and Management (CDM) Regulations 2007.

21A.3 Proposed Operations

21A.3.1 Marine Site Investigation

21A.3.1.1 Non-Intrusive Survey

Non-intrusive survey includes any methodology which doesn't require direct physical contact of survey equipment with the seabed. This includes geophysical survey and some methods of environmental surveys. Geophysical survey methodology generally employs remote and direct sensing (e.g. swathe bathymetry, sub-bottom profiling (aka "pinger"), SSS and magnetometry as well as single or multi-channel seismic techniques), most of which use the reflection or refraction of energy sources to generate data that can be interpreted to provide a "picture" of the make-up of seabed. Whilst it may be theoretically possible that some of these energy sources could initiate very sensitive marine explosive ordnance, it is considered practically impossible to do so. Furthermore, there is no evidence of historic UXO in the marine environment (or elsewhere), being initiated by conventional methods of marine (or land based), geophysical survey.

21A.3.1.2 Intrusive Survey

Intrusive survey includes any methodology which does require direct physical contact of survey equipment with the seabed. This includes geotechnical survey and some methods of environmental surveys. Marine geotechnical investigation methods (e.g. Grab Sampling, Boreholing and Cone Penetrometer Testing (CPT) techniques) employ kinetic energy to invasively penetrate the seabed. Such techniques are capable of initiating UXO, especially if the leading edge of the tools employed, come into direct contact with UXO.

Similarly, some of the platforms that are generally employed to undertake this sort of work (e.g. jack-up barges) may deploy legs and/or anchors which also deliver significant, short-duration, kinetic energy and which themselves might also initiate high Net Explosive Quantity (NEQ) items of UXO, which may lie upon the seabed surface.

By contrast, sophisticated dynamically positioned vessels, which will hold their position without the requirement for spud legs or anchors interacting with the seabed, clearly present a significantly reduced risk in terms of seabed/UXO interaction.

21A.3.2 Marine Cable Installation

It is expected that inter-array cables will be employed within the Development Area. Given empirical evidence and typical construction sequences gathered from similar projects, it is conceivable that potential interaction with UXO may occur during the following installation operations:

21A.3.2.1 Pre-Lay Grapnel Run (PLGR)

PLGRs are used to prove that the route is clear of obstructions such as disused cables or scrap. It involves towing a plough and/or heavy grapnel iron(s) along the Route Position List (RPL) and such an operation might, unless the risk is mitigated, encounter and initiate UXO that is either very shallow buried or on the surface of the seabed. Conventional PLGR cannot be considered a safe method of partially ameliorating UXO risk in advance of subsequent intrusive engineering works (especially cable trenching and, to a more limited extent, foundation installation) because it may expose an unprotected vessel and its crew to a significant high explosive event.

21A.3.2.2 Cable Laying and Burial

Electricity power cables are expected be laid on the seabed and (concurrently or sequentially), shallow buried to protect them. A number of generic cable burial systems might be employed and the choice of system is dependent upon among other things the seabed conditions/geology.

An overview of generic systems is described briefly below, in order to inform subsequently the risks that UXO might pose to such techniques:

- **Cable Plough**; in circumstances where burial is acceptable (e.g. up to 2 meters (m) to 3 m deep), and where seabed conditions allow, it is anticipated that a cable plough might be employed to lay and concurrently bury cables. A skid mounted underwater cable plough is fed with cable (from the cable lay vessel) and the plough lays and buries the cable. The energy to drive the plough forward is provided through a towing catenary, via the cable-laying vessel (or via a moored cable lay-barge). Plough depths can be set by articulating the plough itself and/or via its hydraulic skids. Ploughs are relatively heavy (typically 10-30 tonnes for this sort of application) and they generate considerable forces when they are initially deployed to the seabed and whilst operating. Those forces may be considered sufficient to initiate surface or buried UXO.

- **Deployment of Barge Anchors**; in areas where the water depth is less than 10 m, a cable plough may be deployed from a moored cable lay barge. Anchors are required to stabilise the vessel and to give it sufficient counter-force to plough-in the cable. The anchor spread will facilitate this and the anchors will generally be positioned using one or more Anchor Handling Tugboats (AHT). There is a risk that anchors could initiate UXO if they were to come into direct contact as they are dropped. However the deployment and post-tensioning of anchor catenaries are considered much less likely to inadvertently initiate UXO. In the latter case, this is due to a number of factors, namely: the cable forces are comparatively longer in duration and of lower magnitude; the risk is generally confined to surface UXO only (as the cables will generally sweep the surface of the seabed); cable contact with UXO is likely to be linear (i.e. along the cable/UXO length rather than as a "point" force) which is considered less aggressive.
- **Trenching Tools**; trenching tools such as heavy-duty chain saws (or rock saws) might be employed where a very hard seabed needs to be cut to form a cable trench. In such circumstances the cable might be laid concurrently with the cut. Those forces may be considered sufficient to initiate surface or shallow buried UXO.
- **Water Jetting**; where much softer seabed conditions are encountered, post cable lay water jetting is often employed to bury surface laid cables, especially where there is a mobile seabed or relatively soft sediment (which would not require a plough or other trenching tool to bury them). Water jetting is considered a more benign and less aggressive installation methodology (as compared with cable ploughing or trenching) and therefore is less likely to inadvertently initiate UXO.
- **Horizontal Directional Drilling (HDD)**; is a trenchless methodology that provides a cable installation alternative to traditional "open-cut" methodologies. It is often used on shore, to drill though sea defenses (e.g. bunds, dykes or sea walls). HDD involves drilling a small pilot hole, using technology that allows the drill to be steered and tracked from the surface. The pilot bore is launched from the surface, typically at an angle between 8 and 20 degrees to the horizontal, and transitions to horizontal as the required depth is reached. A bore path of very gradual curvature is normally followed to minimize friction and so decreases the chance of getting a cable "hung up"

in the soil. The section of the cable route near to where it makes landfall might be installed using HDD. Much of the HDD route might be at such a depth that UXO encounter would be extremely unlikely (subject to maximum bomb penetration depth). The risks that might be presented on "land" (defined as above the high water mark) are beyond the scope of this report.

- **Concrete Mattress Emplacement**; where seabed conditions prevent cable burial, concrete mattress may be placed over the cables for protection. This is commonly undertaken by carefully lowering the mattress into the water from an on board crane with divers or ROVs guiding the final emplacement ensure their proper emplacement. Although concrete mattress burial is not considered an especially aggressive installation methodology (as compared with WTG and foundation and/or cable installation) it is possible that UXO might be initiated. The consequences of UXO detonation are exacerbated by the prospective presence of divers.
- **Rock Emplacement**; where seabed conditions prevent cable burial or deployment of concrete mattresses, cable can be buried under rock. Rock emplacement is considered an aggressive installation methodology and might inadvertently initiate UXO.

21A.3.3 Wind Turbine, Offshore Substation Platform (OSP) and Met Mast Installation

21A.3.3.1 Substructure and Foundations

Construction of wind turbines, OSPs and met masts involves the installation of substructure and foundations. These are usually piled jackets or gravity base substructures (GBS), however suction pile foundations can also be used. Piled jacket foundations are usually installed by a specialist vessel employing significant force (kinetic energy) to drive them into the seabed. Suction pile foundations use less kinetic energy than piled foundations however their interference with the seabed is still significant.

Whichever foundation installation method is used, the key factor concerning UXO risk is the resultant kinetic energy employed during the installation methodology, which might be considered sufficient to initiate a variety of different types of UXO.

Once the foundation technique has been selected and the design and installation method is complete, ICOL can reassess the specific installation risks and 6 Alpha can then consider UXO risks.

21A.3.3.2 Scour Protection Systems

It is expected that the wind turbine, OSP and met mast foundations may require some form of anti-scour protection system in the form of either static or dynamic rock armour (alternatively Frond Mats might also be employed to slow and trap sediment). Rock is usually emplaced after installation works and the inter array cabling work is complete. The type and extent of anti-scour protection depends upon the soil and sea conditions as well as the type of foundations employed.

If rock or scour protection systems are employed, the UXO risk is dependent upon the resultant kinetic energy generated which may be considered sufficient to initiate a variety of different types of UXO.

21A.4 Sources of UXO Contamination

21A.4.1 General

This assessment has included detailed archive research to support the project. And after analysing the datasets, it is envisaged that there are eight principal potential sources of UXO contamination that may influence the project; they are presented at Table 21A.1 (For colour coding key see Annex C and Section 21A.7):

Table 21A.1 – UXO Threats to the Study Area

POTENTIAL SOURCES OF UXO CONTAMINATION	THREAT ITEMS	PROSPECTIVE THREAT TO DEVELOPMENT AREA	PROSPECTIVE THREAT TO OFFHSRE EXPORT CABLE CORRIDOR
Naval Warfare (WWI and WWII)	Torpedoes and artillery projectiles	Possible; *German* U-Boats were active within the *North Sea* in both *World Wars*. *Allied* vessels (both merchant and warships) were armed in order to combat the U-Boats.	Possible to likely; German U-Boats were active within the *North Sea* in both *World Wars*. *Allied* vessels (both merchant and warships) were armed in order to combat the U-Boats.
Sea Minefields (*Axis*)	*German* sea mines	Possible to likely; the *Axis* forces used U-Boat deployed mines in WWI and aerial delivered mines in WWII in the vicinity of the Study Area.	Possible to likely; the *Axis* forces used U-Boat deployed mines in WWI and aerial delivered mines in WWII in the vicinity of the Study Area.
Sea Minefields (*Allied*)	*British* sea mines (Mk. XVII)	Possible; *Allied* minefields that formed parts of the east coast mine barrier were located within 20 km of the Development Area.	Possible to likely; An *Allied* declared mine area is located off *North Berwick* to the south of the Offshore Export Cable corridor.
Aerial Bombing	*German* 50kg-1,000kg High Explosive (HE) bombs	Possible to likely; convoys that passed through the site were often bombed by the *Luftwaffe.*	Possible to likely; convoys that passed through the site were often bombed by the *Luftwaffe* and the Offshore Export Cable Corridor is also within proximity to land based targets.
Munitions Related Shipwrecks	Unspecified general munitions	Almost Certain; naval warfare sank 1 wreck within the Development Area.	Almost certain; naval and Submarine warfare sunk 5 wrecks within the Export Cable corridor.
Armament and Training Areas (WWII)	Artillery projectiles and torpedoes	Highly likely; WWII Torpedo running from aircraft facility and firing practice located over the Site. *Royal Naval* training areas are located to the west and south of the Site and anti-aircraft batteries are located along the east coast of	Highly likely; WWII Torpedo running from aircraft facility and firing practice located over the Site. *Royal Naval* training areas are located to the west and south of the Site and anti-aircraft batteries are located along the east coast of *Scotland.*

POTENTIAL SOURCES OF UXO CONTAMINATION	THREAT ITEMS	PROSPECTIVE THREAT TO DEVELOPMENT AREA	PROSPECTIVE THREAT TO OFFHSRE EXPORT CABLE CORRIDOR
		Scotland.	
Armament and Training Areas (Modern)	Training mines and other unspecified munitions	Likely to highly likely; there are *Royal Naval* training areas located in the vicinity of the Development Area.	Highly likely; there are *Royal Naval* training areas located in the vicinity of the Offshore Export Cable Corridor. Live Mine Counter Measures and General Practices are located on Site.
Munitions Disposal Areas	Unspecified general munitions	Remote: there are munitions disposal areas located 30 km from the Development Area. However post WWII munitions dumping was often poorly monitored and thus illegal dumping in the vicinity of specified munitions dumps often occurred.	Likely: there are munitions disposal areas located 2.5 km from this part of the Offshore Export Cable Corridor. Post WWII munitions dumping was often poorly monitored and thus illegal dumping in the vicinity of specified munitions dumps often occurred.

The details of all UXO threats are described in detail subsequently and have been collectively summarised for convenience in one geo-referenced overlay in Annex 21A.8. The details of Table 21A.1 are expanded upon in the following pages, as are details of why certain potential sources of UXO contamination have been discounted at this Study Area.

21A.4.2 Naval Warfare

There was considerable German U-Boat activity recorded in the Study Area during WWI. These vessels were used to lay mines and carry out torpedo attacks on shipping. Additionally, U-Boats were active throughout the North Sea during WWII. These vessels attempted to sink and disrupt the Allied shipping carrying vital supplies along the east coast of Britain. In order to protect against submarine and naval attack in the Firth of Forth an anti-submarine boom net was constructed that stretched from the Isle of May (located at the entrance to the Forth to the west of the Study Area) to both banks of the River. An induction loop was also installed across the estuary, which gave off an electrical signal when ships passed over it. Any ship not declaring its presence prior to crossing the loop would cause an alert.

The Firth of Forth and Firth of Tay were key naval areas during both World Wars with convoy assembly points, naval bases and key ports in the region. HMS Lochinvar, located at Port Edgar, was a minesweeper base throughout both World Wars and the port at Dundee was home to the 9th Submarine Flotilla during WWII. Armed ships escorted merchant vessels along the convoy routes located near to and within the Study Area, these were regularly attacked. In the Development Area, convoy 322S would have travelled directly though the centre. In the area of the Export Cable Corridor, convoy routes 840S, 832S, 436S, and 332S passed through it. The waters in and around both rivers and along the East Coast, were highly militarised and vessels patrolled the coast to protect shipping against enemy vessels and mines. As a result there are likely to be UXO relating to skirmishes between British and German vessels within the Study Area.

Allied vessels, of both Royal Navy and Merchant varieties, were armed in both World Wars and a number of vessels were tasked specifically to deal with the U-Boat threat. One of the wrecks, the FV Erith, located within the Development Area was captured by a U-Boat and sunk by shelling and explosive charges during WWI. The location of this wreck is recorded subsequently in Table 21A.3. During WWII the U-Boat threat was reduced by the presence of Allied minefields along the East Coast. Although five U-Boats are known to have been sunk or lost within the region, none are known to be within the Study Area, therefore probability of encounter is considered low.

There was significant naval activity within the Study Area during both World Wars and the probability of encountering UXO in the vicinity of the wrecks on Site is elevated. There is an additional possibility of contamination of the area by naval ordnance that may have missed its intended target. This is considered a background UXO threat to the Study Area, as records of exact locations of naval battles and munitions deployed are difficult to obtain and/or poorly recorded.

21A.4.3 Sea Mine Laying

21A.4.3.1 *Axis* Sea Minefields

During WWI *German* mining of the *North Sea* was undertaken by U-Boats and surface vessels. U-Boat mines were more frequently deployed in this area because they met less resistance than surface vessels although just one wreck within the Study Area was sunk by a mine in WWI, there are examples of other vessels being mined within the Firth of Forth in general, and in the vicinity of the Project in particular during this period. The most common U-Boat mine employed at this time was the UC 200, a moored contact mine with a charge of 200 kg.

Axis sea mining of the North Sea in WWII was predominantly carried out by air, because Allied minefields made it more difficult for Axis vessels to access the East Coast. The east coast of Scotland was of strategic importance in WWII, due to the key trade and supply routes running from Scottish ports to Russia. Shipping along these routes was vulnerable to German mining. A British “declared mining area” is located within the eastern corner of the Development Area which is known to have been mined by Axis forces during WWII. The Offshore Export Cable Corridor is also located near a British “declared mining area”, located off Berwick. Records state that Axis forces carried out heavy offshore mine laying from St Abb’s Head (58 km south of the Site) to Kinnaird Head (123 km north of the Site) on the 22nd August, 1940. Secondary sources state “considerable, suspected and extensive,” mine laying occurred in the Firth of Forth estuary between August and November 1940.

The presence of a minesweeper base at HMS Lochinvar indicates this area was heavily mined and necessitated regular minesweeping activity. Aerially deployed parachute mines and magnetic (ground) mines were used by Axis forces during WWII and are likely to be the type of mines encountered within the Study Area and are therefore considered to be a key threat.

21A.4.3.2 Allied Sea Minefields

Records of Allied WWI mine laying are not substantial and show areas of mine laying rather than individual mine lays. There were minefields laid at the entrance of the Firth of Forth but there do not appear to have been any located within the Project Area.

Records of WWII mine laying are more accurate and informative. Records indicate that there were several Allied mine lays located within 50 km of the Site which formed part of the East Coast Mine Barrage. The minefields consist predominantly of British Mark XVII mines, placed at a depth of 8 to 12 feet (approximately 2.5 to 3.5 metres), in a linear formation. The threat from Allied mine fields is considered to pose a medium level of threat to the Site.

The details of these minefields are given in Table 21A.2. Although the Site is only partially covered by a minefield it is possible that Allied mines could have drifted over the Site from local minefield sources or during the clearing process (when they may have been dislodged and sunk within the Site). There is therefore, a pertinent threat to the Site from this source. In addition to the mines laid in the East Coast Mine Barrage there were also mines laid off the southern bank of the Firth of Forth itself. The location of these minefields changed throughout the war and various “Notices to Mariners” were issued identifying cleared passages through the minefields at different points during the war. It is possible that these mines could have drifted out into the larger estuarine area.

Table 21A.2 – Allied Mine Laying in the Vicinity of the Study Area During WWII

MINE LAY ID	DISTANCE FROM DEVELOPMENT AREA	DISTANCE FROM OFFSHORE EXPORT CABLE CORRIDOR
SN17A	20.7 km	22 km
SN17 (i)	34 km	34 km
SN17 (ii)	34 km	34 km
SN18A	31.8 km	35.5 km
BS 97	41.5 km	43 km
BS 48	44 km	42 km

21A.4.3.3 Mine Clearance by Vessels

Historical Admiralty mapping confirms that minefields that had been situated off the eastern British coast were cleared post-WWII, and there was a significant sea-mine clearance operation undertaken by both Allied and German Navies, who attempted to clear their respective minefields. Whether all mines that were recorded as being laid, were in fact recovered during clearance, could not be confirmed (but it should be noted that 100 per cent clearance of minefields, even with today’s technology, is not always achievable).

The clearance operations were usually undertaken by one of two methods:

- Using two minesweepers, a sweep-wire (with a serrated edge and an “otter” or “kite” to keep the sweep wire at the required depth), was laid into the water and both ends were attached to a winch at the stern of each ship. Both vessels towed the sweep-wire over a mined area and, when connected to the “mooring stay” of a moored mine, the ships momentum would then force the stay to the serrated edge of the sweep wire, which cut it. The mine would then (usually), float to the surface for disposal.
- An alternative method was to use one ship only with the sweep wire attached to an “oropesa” float (to keep the sweep wire away from the ships), and the wire would then cut the mooring stay of the mine (as described above). The untethered mine would then (usually) float to the surface for disposal.

For floating mines (that had been cut by sweeping), disposal was sometimes by rifle fire. However, on occasions, the rifle bullet only penetrated the outer casing of the mine, which allowed water to ingress and it would then sink and come to rest on the sea bed; an explosive hazard thus remained.

The towing of gear for snaring and cutting the cable by which conventional floating or “contact” mines were anchored to the seabed would not work for dealing with magnetic mines. This is because magnetic mines are “ground” mines, which rest on the seabed, rather than floating. As they naturally sat on the seabed, rather than being anchored by chains, they would remain unaffected by sweep wires.

The main method used to clear magnetic mines was an approach termed “LL”. This entailed towing two parallel pairs of electric cables on floats behind a ship. These cables gave out pulses every few seconds and thereby generated magnetic fields much greater than those of ordinary, non-pulsing, electromagnets. These magnetic fields could be used to detonate magnetic mines at a safe distance from friendly shipping.

21A.4.3.4 Mine Clearance Analysis

Whilst mine clearance was carried out extensively across the East Coast Mine Barrier and the surrounding waters after WWII it is probable that not all the mines laid were recovered. In some areas of the British Isles it is thought that up to 70 percent of previously laid mines were not recovered after WWII. (Reference: “Bernaerts, Arnd Climate Change and Naval War” pp.285-290 (2006) Trafford). It is not known how many of the mines laid in the Study Area were recovered after WWII.

In addition Axis mines would have been very difficult to clear, as their locations were unknown. Clearance of “surface” mines was generally more successful than clearance of “ground” mines, as “ground” mines such as magnetic mines could be set to initiate after multiple numbers of “detections” of enemy vessels. These types of mines were laid to provide a threat to areas where enemy minesweepers were active. Given the proximity to important Scottish ports, such as Leith, Rosyth and Dundee, magnetic mines primed to initiate on the third detection of an enemy ship, or even later than this, were used in the area. It is these “ground” mines therefore, that probably pose the main residual threat today.

Additionally, there is a RN mine counter measures training area located within the Forth estuary. The Forth and surrounding area is occasionally mine swept whilst training takes place. In July 2008 a RN training exercise found a mine located within one of the main shipping channels off Inchkeith Island. There are however, no records of modern minesweeping activities having taken place within the Site boundary.

Research carried out by 6 Alpha has indicated that there have been at least ten reported incidents of UXO (such as depth charges, mines, torpedoes and artillery projectiles), having been recovered from the seabed or washed ashore, since 2005, in the area between Montrose and the Firth of Forth. These figures do not include those mines that are encountered by the Royal Navy during their mine counter measures training exercises within the region. This would suggest that there is a significant residual threat from mines and other items of UXO within the Study Area.

21A.4.4 Aerial Bombing

The Study Area is situated at the entrance of the Firth of Tay; the river had strategic importance during both World Wars. Aerial bombing was concentrated in areas such as London and the Southeast during WWI, and the threat from WWI UXBs at this site is therefore considered to be low. The port of Dundee is located on this river and was of industrial and military importance in WWII. Dundee was home to the 9th Submarine Flotilla from April 1940. This site was a key target for Luftwaffe aerial bombing attacks. Fifteen Junkers Ju-88 aircraft left Westerland to target HMS Hood off the Scottish Coast. HMS Hood had reached the dock before they arrived in Scotland and they had been instructed to be mindful of civilians. The Ju-88's changed target and dropped their bombs on HMS Southampton, HMS Mohawk and HMS Edinburgh further out in the estuary. The Ju-88's were subsequently engaged in air battle by British Spitfires over the estuary and further offshore. One of the German aircraft ditched into the sea but its location is unknown.

Airfields at Leuchars, Turnhouse, Drem and Montrose would have also attracted Luftwaffe bombing. Aerial bombing was not accurate in WWII and there are records of errors of up to thirty miles in aerial bomb deployment. Typical failure to function rate was 10 percent, therefore these bombs may be encountered on the seabed within the vicinity of the Site, however quantities are expected to be relatively low. A decoy-bombing site was set up in proximity to the Offshore Export Cable Corridor in 1940, this site was successful in acting as a decoy aerodrome, and was bombed eleven times between 1940 and 1941. There is therefore a possibility that aerial deployed bombs may be located in the vicinity of the landfall area of the export cable. Aircraft returning to Europe may have also have offloaded munitions into the sea as they returned from bombing targets.

Shipping coming into and out of the Firth of Tay was of major importance to Britain in WWII. Merchant shipping was organised into convoys in order to protect ships from U-

Boat and aerial attack and numbered convoy routes were located within these larger overarching convoy classifications. This includes 322S in the Development Area, and 840S, 832S, 436S, and 332S in the area of the Export Cable Corridor. Convoy routes were specifically targeted by German bombers with HE bombs and aerially deployed sea mines; therefore such UXO threats associated with convoy routes have the potential to be present across the Site.

The first air attack to take place on Britain happened on 16 October 1939 at the Firth of Forth, the so-called "Queensferry Forth Rail Bridge Raid" where the Luftwaffe targeted the Rosyth Naval Base. While there is no record of UXO contamination from this attack affecting the area (where the Export Cable will make landfall), it is possible that UXO contamination may have landed unnoticed, as the landfall area is an unpopulated, open wooded space.

21A.4.5 Shipwrecks and Downed Aircraft

6 Alpha have identified 14 wrecks that have a munitions related history within the vicinity of the Study Area, of these six are within the Study Area itself. This includes wrecks that are considered to be 'dead' under the *UKHO* classification system. 'Dead' wrecks are those that can no longer be identified on the seabed. Even if a wreck has degraded to such an extent as to be effectively invisible on the seabed this does not mean that munitions that are associated with the wreck are not still *in situ* and a therefore they may still pose a threat.

German Submarines sank five of the wrecks with torpedoes in the vicinity, two of which are within the Study Area. A German Submarine also scuttled one ship within the Study Area. The Luftwaffe bombed two vessels in the vicinity, one of which is within the study site. Mines sunk four of the wrecks within the vicinity, one of which is recorded as a wreck within the Study Area. Collision sunk one ship within the Study Area, while another sank after becoming waterlogged, within the vicinity of the Site.

In general, the risk of munitions contamination is somewhat reduced in the vicinity of wrecks (as compared with munitions dump-sites), because the munitions, are more likely to remain enclosed and immobile within the body of the wrecks. However, it may be possible that some items may have been thrown clear of the vessel as it sank or they could become exposed as the wrecks gradually broke up.

Regardless of the type of weapons system employed to attack the ships, direct fire weapons systems lacked the first time strike accuracy of more modern weapons and it is unlikely that any vessel was sunk in the first exchange of fire. Therefore, many of the weapons systems employed are likely to have missed the target at first instance and it is entirely feasible that a number of exchanges of fire would have preceded a successful attack. As a result, there may also be UXO (projectiles more specifically) generated by this sort of exchange of fire, in the regions of those wrecks that may have been sunk by gunfire.

Fortunately, shipwrecks (and to some extent aircraft wrecks) are usually easy to distinguish via charts and/or geophysical survey and simple avoidance them can effectively mitigate the UXO risks associated with them. Where a wreck is in poor condition, however, there is an increased probability of UXO contamination in the vicinity. Unknown wrecks and wrecks without a munitions related history have not been assessed within assessment and, from a UXO threat perspective, all unknown wrecks should be avoided anyway. The shipwrecks that have a UXO-related history are summarised in *Table 21A.3* and shown in Annex 21A.4.

Table 21A.3 - Ship Wreck Data

NAME	UKHO WRECK NO.	UTM (30N)	TYPE	REASON	DEPTH
SS Jonkoping II [+1918]	N/A	56.4342 -2.28413	*Swedish*	UC-49, torpedo	N/A
SS Bay Fisher [+1941]	3023	56.46945 -2.3216	*British* Transport	Bombed by aircraft	41 m
FV Erith [+1917]	N/A	56.47557 -2.16788	*British* Trawler	Scuttled by sub	N/A
Fylgia SS [+1918]	2997	56.38277 -2.27938	*Swedish* Cargo	Torpedoed by UC-49	43 m
Einar Jarl SS ? [+1941]	2989	56.31588 -2.28828	*Norwegian* Cargo	Mined	44 m
Thrive FV [+1946]	2947	56.17307 -2.335	*British* Trawler	Mined	N/A
Avondale Park SS	2934	56.15465 -2.50358	*Canadian* Cargo	Torpedoed by U2336	41 m
Royal Fusilier SS [+1941]	2913	56.10693 -2.58833	*British* Cargo	Bombed by Aircraft	37 m
Ben Attow [+1940]	2955	56.19167 -2.34167	*British* Trawler	Mined	N/A
Sneland SS [+1945]	2939	56.16097 -2.51362	*Norwegian* Cargo	Torpedoed by U2336	40 m
Columba HMT [+1918]	2933	56.15875 -2.55847	*British* Trawler	Mined	46 m
Munchen [+1921]	2919	56.12167 -2.77292	Ex-*German* Light Cruiser	Torpedo experiments	40 m
LCA 845 [+1944]	2908	56.09083 -2.88667	Landing Assault Craft	Waterlogged & sank	N/A
Chester HMT [+1916]	2902	56.07112 -2.87083	*British* Armed Trawler	Collision	15.8 m

21A.4.6 Armament and Training Areas.

21A.4.6.1 WWII Armament and Training Areas

The historic armament and training areas have been geo-referenced from current data sets; they are presented at Annex 21A.5 and summarised in Table 21A.4. (For colour coding key see Annex C and Section 21A.7):

Table 21A.4 – WWII Military Training Areas and Armament Areas

RANGE	NAME	USER	FACILITY	DISTANCE FROM DEVELOPMENT AREA	DISTANCE FROM OFFSHORE EXPORT CABLE CORRIDOR
N267	*Firth of Forth (Outer)*	*Navy*	Torpedoes deployed from aircraft, gun practice from ships	Located in the South Area of the Site	Located over the Site
N136	*Crail Area 5*	*Navy*	Torpedo running from aircraft	21 km to the southwest of the Site	4.9 km to the west of the Site
N249	*Megs Craig*	*Navy*	AA (Light artillery)	9 km to the west of the Site	11.5 km to the northwest of the Site
N251	*Arbroath North*	*Navy*	AA (Light artillery)	12 km to the west of the Site	12 km to the northwest of the Site
N255	*Crail (Fifeness) Area 2*	*Navy*	Torpedo running from aircraft	15.6 km to the southwest of the Site	5.4 km to the west of the Site
N259	*Crail (Firth of Forth) Area 1*	*Navy*	Torpedo running from aircraft	9 km to the west of the Site	11.5 km to the northwest of the Site
N262	*Firth of Forth (Middle)*	*Navy*	AA (Heavy & light artillery)	41 km to the southwest of the Site	Located over the Site
N261	*Firth of Forth (Inner)*	*Navy*	Coastal Defence Battery	60 km to the southwest of the Site	Located over the Site
M256	*Kingsbarns*	*Navy*	Anti-aircraft Machine Gun	25.5 km to the south of the Site	19 km west of the Site
N252	*Arbroath South*	*Navy*	AA (Light artillery)	12 km to the west of the Site	12 km to the northwest of the Site
A324	*Barry Buddon*	*Navy*	Firing Range	25 km to the west of the Site	29 km to the west of the Site

6 Alpha have identified three areas of potential threat within the Study Area. They are Royal Navy training areas N267, N261, and N262 where torpedo training, gun practice, Anti-Aircraft Artillery (AAA), and a Coastal Defence Battery were located. A series of Royal Navy (RN) training areas were located within the vicinity of the Site during WWII, including: N136, N249, N251, N255, N259, M256, N252, and A324. They are likely to pose a significant UXO threat to the Site because items of UXO such as torpedoes and artillery projectiles are likely to be found within the Site from these sources.

In addition, a series of WWII anti-tank landing blocks are located 12.7 km northwest along the coast, stretching 14.9 km from Dunbar to Scoughall. The presence of this terrestrial military activity is unlikely to affect the Site, and therefore represents a low level of threat. However there is a possibility that UXO items from these sources closer to the Study Area might have migrated across the seabed and onto the Site, and this likelihood is enhanced due to their small size.

21A.4.6.2 Current Armament and Training Areas

6 Alpha have identified significant modern military activity within the region and the affected areas are presented in *Table 21A.5* and Annex 21A.6.

Table 21A.5 – Current Armament and Training Areas

RANGE NUMBER	NAME	USER	FACILITY	DISTANCE FROM DEVELOPMENT AREA	DISTANCE FROM OFFSHORE EXPORT CABLE CORRIDOR
X5642	*Firth of Forth (Outer)*	*Navy*	General Practice	12 km to the southeast of the Site	7.2 km to the east of the Site.
X5641	*Firth of Forth (Middle)*	*Navy*	General Practice	10.4 km to the south of the Site	Located over the Site
X5615	*Forth Deep*	*Navy*	Mine Counter Measures	21.9 km to the southwest of the Site	Located over the Site
X5637	*Firth of Forth*	*Navy*	Mine Counter Measures	35.9 km to the southwest of the Site	Located over the Site
X5638	*Firth of Forth*	*Navy*	Mine Counter Measures	27 km to the southwest of the Site	3.2 km to the west of the Site
X5614	*May Island*	*Navy*	Anti-submarine warfare, submarine exercises.	20.6 km to the southwest of the Site	Located over the Site
X5625	*Anstruther*	*Navy*	Mine Counter Measures	30.5 km to the southwest of the Site	8.1 km to the west of the site

RANGE NUMBER	NAME	USER	FACILITY	DISTANCE FROM DEVELOPMENT AREA	DISTANCE FROM OFFSHORE EXPORT CABLE CORRIDOR
X5612	*Aberlady Bay*	*Navy*	Mine Counter Measures	69.5 km to the southwest of the Site	Located over the Site
X5613S	*Firth of Forth*	*Navy*	General Practices and Mine Counter Measures	55.5 km to the southwest of the Site	Located over the Site
X5613N	*Firth of Forth*	*Navy*	General Practices and Mine Counter Measures	48.2 km to the southwest of the Site	5.5 km to the north of the Site
X5611	*Kirkcaldy Bay (F)*	*Navy*	Mine Counter Measures and Mine Disposal	54.2 km to the southwest of the Site	7.6 km to the north of the Site
X5610	*Burntisland*	*Navy*	Degaussing	75 km to the west of the Site	16.2 km to the west of the Site
D604	*Barry Buddon*	*Army*	Demolition of UXO, Firing, and Parachute Dropping	22.5 km to the east of the site	22.3 km to the east of the site
D613B	*Central MDA*	*Air Force*	Air Combat Training and High Energy Manoeuvres	29.5 km to the east of the site	32.9 km to the east of the site
D609	*St. Andrews*	*Air Force*	Firing, HM Ships (non firing exercises, practices, and trials), Missile Firing, and Sonobuoy Dropping	27.6 km to the east of the site	30.2 km to the east of the site
D613C	*Central MDA*	*Air Force*	Air Combat Training and High Energy Manoeuvres	34.2 km to the east of the site	36.8 km to the east of the site

Royal Navy training areas X5642 and X5641 are identified on navigational charts for the area as being submarine exercise areas used for “general practice”, and area X5641 is located directly on the Study Area. Although these training areas are not used for live firing however, the threat of UXO from this source cannot be completely discounted (because training items resemble live UXO it can often be confused with it). Area X5614 used for anti-submarine warfare exercises may involve the use of live munitions and it is also located on the Site.

The mine counter measures training areas X5615, X5612, X5613S and X5637 are located within the Site, and areas X5613N and X5638 are located only 5.5 km to the north and 3.2 km to the west of the Study Area respectively. Because these areas are located within the Site, there is a distinct possibility that a UXO threat might be generated from them. These sites are expressly identified in the United Kingdom Hydrographic Office’s (UKHO) “Notice to Mariners No. 10 - Mine-laying and mine countermeasures exercises” as being in regular use for mine-laying and clearing exercises. Training would usually involve use of non-explosive devices that will not pose a threat to the proposed Site but which may resemble live items. The quantity and types of mines and counter mine (high explosive) charges employed are not known nor is their failure rate. Whilst, training mines are not filled with high explosives, they are often the same size and shape as those that are, and the two types are very difficult to differentiate.

The Army Base D604 was located 22.3 km from the Site. It is estimated to represent a low to risk to operations on the Study Area; due to its distance from the Site. Three Air Force (RAF) Bases D613B, D609, and D613C are all within 40 km of the Study Area. However, these are all considered to be too great a distance from the Site to pose a UXO threat on the Site.

21A.4.7 Munitions Disposal Areas

There are two disused conventional munitions disposal areas located to the west of the Site off the Isle of May. These are 30.5 km and 32.5 km from the Development Area and 2.8km and 2.5 km from the Offshore Export Cable Corridor respectively and, due to their distance from the Export Cable Corridor, they are considered to pose a potential UXO threat to the Site. Smaller items of UXO especially are capable of migrating significant distances, although it is unlikely that larger items such as mines or depth charges will have migrated from this source onto the Site. In addition, not all munitions dumping actually occurred at designated disposal sites and, as empirical evidence from other sites in UK waters shows, there may have been unrecorded munitions dumping within other areas of the seabed and potentially within the Study Area. This is an unquantifiable threat and should be considered as a background threat to the Site.

21A.5 UXO - Seabed Penetration, Migration and Burial

21A.5.1 Generally

In the marine environment it is possible that those items that enter the sea with significant kinetic energy (e.g. aerially delivered bombs or artillery projectiles), might have the capacity to bury themselves into the seabed. However, the velocity of the items, their shape index, the depth of water and shear strength of the seabed, significantly influences their potential for penetration. In regions of deep water, munitions might enter the water and come to rest upon the seabed, rather than penetrating it. Such items may then migrate across the seabed subject to, among other things their shape as well as seabed geology and current/tidal action.

Therefore, this section explores, in outline, the factors that are to be considered whilst assessing munitions penetration, migration or burial. When establishing the options for UXO risk mitigation, it is important to ascertain the level of potential sediment cover and seabed mobility in areas of the proposed works.

21A.5.2 The Physical Environment

21A.5.2.1 Bathymetry and Hydrodynamics

Water depths within the Study Area range from 35.5 m LAT to approximately 63.3 m LAT. Water depths within the Offshore Export Cable Corridor range from 0 m LAT to 45 m LAT. The shallowest waters are encountered closest to the shore. The seabed undulates across the Study Site but extreme topography has not been identified. Sand waves have been reported to both the southeast and northeast zones of the Site. The sand waves are approximately 8m in crest height with wavelengths of between 160 and 270 m. The mobility of these bedforms is unknown.

The regional tidal regime is a general flow pattern of a southerly flood tide along the eastern coast of Scotland into the Firth of Forth and Firth of Tay region. Tidal currents within the region have a maximum tidal velocity of approximately 1.2 knots (0.6 m/s) and a range of approximately 5.5 m. In addition to the tidal regime the River Tay is a source of freshwater flow into the estuary.

21A.5.2.2 Sediment and Coastal Processes

According to the *British Geological Survey* the geology of the Site is composed of the following strata:

- Holocene, sand or gravely sand from 0 m to 5 m;
- Quaternary (Fourth Formation), sand with clay and silt in layers from 0 m to 5 m;
- Quaternary (Wee Bankie Formation), stiff to hard clay with interbeds of sand and silty clay from 5 m to 10 m;
- Triassic and/or Permian, bed rock from 10 m and greater.

Sedimentary transport within the region is dependent on several factors including the type of sediment populations within the Site and their responses to the hydrodynamics of the region. There are no large scale mobile bedforms within the Site; however there are sand waves present in the surrounding area. The direction of sediment transport is likely to follow the tidal regime for the region.

21A.5.3 UXO Penetration

A significant mass of water always reduces the velocity of munitions entering it. Even bombs deployed from high altitude have their potential for seabed penetration reduced as they enter a significant column of water.

The deeper waters experienced within the Study Area ensure that significant UXO penetration of the seabed in these locations is highly unlikely.

Limited UXO penetration of the seabed may be possible in the shallower waters of the Study Area. Significant UXO penetration is highly likely where the water is much shallower, especially in the region where the cable(s) approach and reach landfall.

21A.5.4 UXO Migration

Munitions can migrate across the seafloor and the main factors concerning the degree of movement concern among other things; the strength and direction of currents; the overall shape of the item (influencing the degree to which UXO are free to move without obstruction); ordnance protrusions such as fins and lugs (the latter being employed for suspension from the aircraft in flight); and the UXO position on the seabed (e.g. in either sediment, gradient or a seabed recess), all of which could significantly enhance or impede movement.

The coastal waters around the Firth of Tay can experience a spring tidal stream of 1.2 knots and smaller items of UXO (e.g. AAA shells) could, conceivably, migrate onto the Site from surrounding threat sources. However, the larger bombs and “ground” mines, which were generally used against shipping, weighed hundreds of kilograms and are unlikely to migrate as far in the relatively shallow water found on the Site.

21A.5.5 UXO Burial

It is possible that UXO or mines that have come to rest upon the surface of the seabed might be buried (and potentially, re-exposed) subsequently. In such circumstances, even partial UXO burial may be sufficient to obstruct the item sufficiently, to prevent its identification.

The prevailing seabed conditions for the Site are expected to be a mixture of sand, silt, and clay for at least 10 m. These conditions make it possible for UXO to have become buried in the sand and silt especially after which there is clay and bedrock.

Given the expected investigative and intrusive engineering methodologies that are expected to be employed on this project, UXO burial must be taken into consideration when considering UXO risks on this site.

Geotechnical investigation, Wind Turbine Generator (WTG) foundation installation, ploughing, cutting or jetting cables into the seabed, and burying cables under concrete mattresses or rocks will incur significant disturbance. If items of UXO that have become partly or wholly buried are encountered with significant mechanical and kinetic energy, they might be inadvertently initiated.

21A.5.6 Blast and Fragmentation

Significant blast and fragmentation amelioration can be delivered where there are sufficient water depths between an item of UXO and sensitive receptors (e.g. people, vessels and equipment). However, there is expected to be a great variation in water depth and therefore in the level of blast and fragmentation amelioration provided by the shallower water in particular, especially in the zone where the export cable(s) make landfall.

Although the direct consequences of UXO initiation on the seabed can only be partly mitigated, it is also possible in such deep-water circumstances, that other effects (such as shock waves and large volume gas bubbles) might affect other forms of indirect vessel damage (and see *Section 6*).

21A.6 UXO Detonations

21A.6.1 UXO – Generic Design and Detonation Sensitivity

In simple terms, large NEQ items of UXO tend to have the following basic components:

- **Case**; i.e. the bomb (or mine, or torpedo) body, which is usually (but not always) manufactured from ferrous metal (N.B. *German* WWII G Mines cases are manufactured from non-ferrous metal). The case shatters when the high explosive charge is initiated and generates primarily fragmentation;
- **Main Charge**; a secondary high explosive "main charge" is usually manufactured from an insensitive explosive compound;
- **Booster**; a secondary high explosive "booster charge" is usually manufactured from slightly more sensitive explosive compound. The booster charge is usually relatively small, as compared with the main charge;
- **Fuze**; a primarily high explosive "fuze" is usually manufactured from explosives which are sufficiently sensitive to be initiated by a "trigger" device (e.g. by chemical or mechanical means (e.g. shock or friction). The fuze is usually relatively small as compared with the booster, and is often housed in a "fuze pocket" and in extremely close proximity to the booster (in order to initiate it).
- **Trigger**; a mechanical, electrical or chemical trigger mechanism is employed to initiate the fuze, at the appropriate time. During the 1980s, *British* Royal Navy clearance divers were informed, by technical experts from *North Atlantic Treaty Organisation* (NATO), that WWII-era munitions, which relied on an electrical capacitor in the firing system (e.g. aerially delivered bombs and sea mines), would not retain enough electrical charge to function as designed. But, very old items, which rely on magnetic or acoustic fuzing to initiate them via an electrical charge may be detonated by direct or indirect impacts that generate enough kinetic energy to precipitate a detonation. Therefore they may still pose a risk to installation operations on the Site.

An explosive chain reaction is triggered when sufficient energy (mechanical, electrical or chemical) is generated to initiate the fuze, which will initiate (practically instantaneously), the booster and the main charge itself. The fuze component is always relatively small and is always located in a specific part of the UXO (in a bomb, for example, it might be “nose” and/or “tail” and/or “transverse” fused). In a mine, the “triggers” might be located on the surface (in the form of contact “horns” for example) but the fuze is often located centrally, within the body of the mine.

Explosives in old munitions (especially primary high explosives) deteriorate over time and can leach onto the surface of munitions, often near the fuse pocket (or gather within the pocket itself). When this happens, this residue is often especially sensitive to friction and shock, which can easily initiate the fuze.

21A.6.2 Initiation Scenarios in the Offshore Construction Environment

In terms of offshore wind farm development, the aim is to ensure, wherever possible, to avoid contact with UXO, but if contact is made then it should be with insufficient energy to initiate an explosives chain reaction. Unfortunately this is not always possible because conventional site investigation and installation activities might initiate (either directly or indirectly) the most sensitive (fuze) components, which could lead to a “high-order” explosion.

Therefore, in the event of an inadvertent UXO discovery within the offshore construction environment, there are a number of potential initiation activities, namely:

- **Geotechnical Activities**; e.g. bore-holing, cone penetration testing (CPT) or vibro-core soil investigations. Whilst the kinetic energy associated with such activities are considered comparatively benign (when compared with installation activities), they may be nonetheless sufficient to initiate sensitive components within UXO. More importantly perhaps, their work platforms (e.g. jack-up barges and/or seabed emplaced “rigs” and platforms) often deliver significantly more force than the geotechnical activities themselves, which is often theoretically sufficient to initiate UXO;
- **Installation Activities**; e.g. WTG and Foundation installations (especially mono-piling) as well as PLGR and cable installation/burial activities. The forces employed are generally an order of magnitude greater than those associated with geotechnical activities. In addition, the (larger) jack-up platforms, which are often employed, and/or Anchor Handling Tugboats (AHTs) and anchor handling activities are also considered sufficient to initiate UXO.

In either circumstance, a variety of initiation scenarios are possible, namely:

- **Direct Impact;** onto the main body of the munition or its fuze pocket;
- **Indirect Impact**; e.g. by over-pressure (precipitated, for example by piling) that may initiate a hydrostatic fuzed munition (where present and in proximity); or indirect shock (transmitted through the body of the UXO, to or through, the fuze pocket); or a light friction impact (e.g. “grazing”) the fuze pocket, or the fuze itself (where it is exposed).

21A.6.3 Extraordinary Initiation Scenarios

In conventional conditions at sea, UXO does not usually spontaneously explode. Ordinarily, high explosive within UXO requires the input of a significant amount of energy (usually kinetic energy) to create the conditions for detonation to occur. Although the British Geological Society seismological records (Reference: Quality Status Report 2010–*OSPAR Commission*) suggest that there were 47 “spontaneous” detonations of dumped munitions in the Beauforts Dyke dumping grounds in the UK, between 1992 and 2004, it is possible that they were the result of munitions deteriorating in the salt-water environment (which is in itself unlikely) and/or becoming more sensitive to shock with age (which is more likely). In the latter circumstances, it is considered highly probable that an external mechanical impact (e.g. the movement of dumped munitions in close proximity) triggered the detonations.

Whilst such a scenario is included in this report for purposes of completeness, because OWF are subject to vendor and developer due diligence, it is considered practically impossible for an offshore wind farm development to be inadvertently located upon or within such a known UXO dumping ground, and therefore, such a scenario is not considered relevant to this type of project.

21A.6.4 Detonation Variables

The consequences of munitions detonation have been the subject of a number of studies. It is generally accepted that these consequences depend upon:

- Age and condition of the UXO (including the estimated “figure of insensitivity” concerning all of the components that make up the explosives “chain reaction”);
- The type of explosive and/or fill (e.g. high explosive, incendiary, or specialist).
- Where a high explosives fill is present, the estimated power of the high explosive “main charge” element;

- Mass and explosives composition of the “main charge” element (known as the Net Explosive Quantity (NEQ));
- Location of the item which might be:
  - Floating on the body of water (buoyant mines only and therefore considered unlikely in these circumstances);
  - On the seabed and:
    1. Partially buried or;
    2. Totally buried.
- The proximity of sensitive receptors (e.g. people, vessels and equipment), at the time of the detonation event;
- The construction and structural strength of any vessel, equipment or structures near the site of an explosion;
- The robustness of those sensitive receptors and any direct or indirect protection they might be afforded at the time of an event, as well as their juxtaposition;
- The column of water (generally the depth) and the lateral separation that is between the UXO and the sensitive receptor, which might ameliorate the blast and other effects.

21A.6.5 Underwater HE Detonations

21A.6.5.1 Underwater Detonation Hazards

When an item of UXO detonates underwater, there are four main hazards:

- Blast;
- Fragmentation;
- A pulsing and rising gas bubble;
- A shockwave.

21A.6.5.2 Direct Effects of UXO Detonation

If a significantly large high explosive item of UXO detonates underwater (e.g. after close contact with pile, jack up barge leg or cable plough/trenching equipment), then the effect is very similar to that experienced at the surface. A high order detonation causing blast and fragmentation would certainly destroy mechanical equipment or significantly damage (shatter or buckle) part of a cable plough, for example.

21A.6.5.3 Effect of Explosive Shockwave and Gas Bubble on Supporting Vessels

If a mine or a bomb detonated underwater at some distance from the underside of a floating vessel, fragmentation is not a primary consequence. Upon the detonation of a high explosive charge, the explosive gases rapidly form a rising spherical bubble. The momentum imparted to the water in the early stages, enables the water to expand until the pressure in the bubble is far less than the hydrostatic pressure of the surrounding water. A violent contraction therefore takes place, followed by a second expansion (almost as rapid as the first) that may be followed by further expansions and contractions.

Each expansion precipitates a pressure wave that is propagated outwards throughout the water in all directions. Because water is highly incompressible, the maximum pressure in the initial shockwave is very much higher than would occur in either the ground or in air (but the peak pressure is of much shorter duration). Although these shockwaves become gradually weaker as the bubble rises, the origin of those shockwaves (i.e. the centre point of the rising gas bubble) often closes with the intended target (i.e. the underside of a floating ship), and therefore still has sufficient energy to precipitate considerable shock wave damage at significant distance from the point of initiation. It is possible that the energy could be sufficient to damage and sink a vessel.

21A.6.5.4 Mine Damage

The damage that may be initiated by a mine depends upon two factors; the initial energy generated by the explosion and the distance between the target and the detonation. When taken in reference to ship hull plating, the term Hull Shock Factor (HSF) is used, while keel damage is termed Keel Shock Factor (KSF). If the explosion is directly underneath the keel, then HSF is equal to KSF, but explosions that are not directly underneath the ship will have a lower KSF value.

21A.6.5.5 Direct Damage – Blast and Fragmentation Effect

Direct damage is usually only created by contact mines and ordinarily results in a hole being blown through the hull of the ship. In such circumstances and, depending upon crew positioning, they might be killed outright (if they are close to the seat of the explosion), or they might otherwise suffer from associated blast and/or fragmentation/shrapnel wounds. Flooding typically occurs in one or more main watertight compartments, which can sink smaller ships or disable larger ones. Contact mine damage often occurs at, or close to, the waterline near the bow, but depending on circumstances a ship could be hit amidships (or anywhere) on its outer hull surface.

21A.6.5.6 Indirect Damage - Bubble Jet Effect

The bubble jet effect occurs when a mine detonates in the water a short distance away from the ship. The explosion creates a bubble in the water, and due to the difference in pressure, the bubble will collapse from the bottom. The bubble is buoyant and so rises towards the surface. If the bubble reaches the surface as it collapses, it can create a pillar of water that can shoot over a hundred metres into the air (known as a "columnar plume"). If conditions are right and the bubble collapses onto the ship's hull, the damage to the ship can be extremely serious. The collapsing bubble forms a high-energy jet that can break a significant hole (possibly up to 1 m diameter) straight through the hull of the ship, flooding one or more compartments. The forces are capable of breaking smaller ships apart. The crew in the area, if hit by the water pillar, are likely to be killed instantly. Associated damage is usually limited.

21A.6.5.7 Indirect Damage - Shock Effect

If the mine detonates at some distance from the ship, the change in water pressure can provoke the ship to resonate. This is frequently the most damaging type of explosion if it is strong enough. In such circumstances, the whole ship is dangerously shaken and loose objects on board may be dislodged with considerable force, sufficient to precipitate disabling injuries (for example to knees/hips and other joints in the body, particularly if the affected person stands on surfaces connected directly to the hull (such as a steel deck)). Similarly, ships engines can be torn from their mountings, power cables from their fastenings etc., which may also precipitate secondary injuries to ships' crews. A badly affected ship usually sinks quickly, as a result of hundreds, or even thousands of small leaks all over the ship; bilge pumps often fail to cope as a result of the pace of water ingress and/or localised power supply fails as a result of the shock effect. Any divers in the water in the vicinity are likely to be killed or incapacitated from the shock effect.

21A.6.6 Water Depth and Blast Suppression

The project has water depths varying from approximately 0 m to 63.3 m LAT. Should an item of high NEQ UXO (e.g. mine or iron bomb) be initiated on the seabed, subject among other things to its NEQ, the maximum depth water might well provide some blast and fragmentation amelioration, but is likely to be insufficient to significantly ameliorate either a shock wave travelling through it, nor to prevent the bubble-jet effect. Large NEQ items are likely to need significant depths of water to ameliorate their high explosive effects, and therefore blast effects of these items may not be completely mitigated by the water depth present on this project. Clearly though, the deeper the water the greater its ameliorative effect upon blast and fragmentation (although not perhaps shock and bubble jet effects) but the relationship between the two (i.e. depth and amelioration) is unlikely to be linear.

The ameliorative effect of water upon UXO blast and fragmentation effects from small NEQ items of UXO (e.g. AAA or small projectiles) are likely to be less significant and in some circumstances they may well be completely ameliorated.

Thus, in very shallow areas, shallow buried UXO might pose a more significant risk (if it is inadvertently initiated), because the high explosives pathway to sensitive receptors would be both short and incapable (in very shallow water/air) of significant blast amelioration.

21A.7 UXO Risk Assessment Factors

21A.7.1 Source – Pathway – Receptor

The threat must be considered in light of the proposed operations, the intrusive related activities, as well as the impact on key receptors such as personnel, key installations, high-value equipment and the environment.

21A.7.1.1 Sources

6 Alpha has considered that the threat is primarily the result of munitions and weaponry used during WWII, generated through mine laying, air battles and sea battles. This includes:

- HE Bombs;
- *Allied* sea mines;
- *Axis* sea mines;
- Artillery projectiles;
- Torpedoes.

21A.7.1.2 Pathways

The pathway is described as the route by which the hazard reaches the sensitive receptor. Given the nature of the site, pathways could be generated during:

- Geotechnical investigations;
- PLGR;
- Marine cable trenching (jetting or ploughing);
- Turbine installation;
- Laying barge anchors*.

*Post tensioning anchor catenaries are not expected to form a significant risk pathway because: first, if the cables make contact with UXO they are perhaps more likely to present a uniformly distributed load along the cable length in contact with the bomb/mine body (rather than a "point force", which is, arguably, more likely to precipitate an initiation); second, the forces generated in cable tensioning (in terms of kinetic energy) are expected to be an order of magnitude lower than those that might be associated with e.g. the deployment of the anchors themselves (even if the cables "snag" and then release under tension); third, those forces are expected to be more slowly applied over a relatively long duration (as the cables are tensioned post anchor deployment). NB: If a cable, whilst being tensioned, snags and dislodges a large item of UXO, it could conceivably, detonate that item.

21A.7.1.3 Receptors

Sensitive receptors on this site might include:

- Site Investigation Crews;
- Construction Workers/Engineers;
- High-value Equipment;
- Ships/vessels;
- Third party shipping/vessels in the immediate vicinity – Note: extended safety distances for detonations underwater apply (for reasons 6 Alpha has articulated above);
- Marine life (especially marine mammals, fish and birds);
- Infrastructure and people located along the coastline (close enough to be harmed if UXO was inadvertently detonated). Such a risk (when unmitigated) is only expected to be present when intrusive cable installation works are approaching the shore and are within close proximity (e.g. within 1,000 m) and/or when people are also in the vicinity (e.g. pleasure boaters in the vicinity and/or or pedestrians on shore).

Clearly, where such risks present themselves, they might be either avoided or ameliorated.

21A.7.2 Semi-Quantitative Risk Assessment

This chapter seeks to analyse the UXO risks to operations on the Study Area, by examining the risks associated with specific threat items when conducting specific activities. In undertaking a series of Semi-Quantitative Risk Assessments (SQRA) for this project, we have employed the technical data associated with the threat items presented within this report and the proposed scale and nature of the operation. For this Study Area, the UXO threat items identified are aerial delivered bombs, *Axis* aerial delivered sea mines, *Allied* sea mines, torpedoes and artillery projectiles. The proposed operations within the Study Area include site investigation (including a geotechnical investigation campaign), WTG and Foundation installation, inter-array and export cable installation.

The tables below outline and display the numeric scored assessment for the Area of Interest. This transparent methodology and the calculations used in conducting the SQRA for this Area are presented in Annex C (this includes an explanation behind the "Risk Levels"). The SQRA tables are followed by an analysis of the risks to the Area of Interest and will serve to inform the risk mitigation strategy, which 6 Alpha recommends for undertaking intrusive investigative and engineering activities at this Site.

It is important to note that throughout the following tables, the risk assessment for cable installation is conducted sequentially (i.e. based on the project related activities to be conducted beforehand). Therefore areas with multiple activities will have subsequent activities partially mitigated by works carried out beforehand.

21A.7.2.1 Development Area

7.2.1.1 Site Investigation

Activity	Ordnance Variant	Probability of Encounter and Initiation	Consequences of Initiation	Risk Level
Geophysical Survey	HE Bombs	1	2	2
	Allied Sea Mines	1	2	2
	Axis Sea Mines	1	2	2
	Artillery Projectiles	1	1	1
	Torpedoes	1	2	2
	Dumped Munitions	1	2	2
Geotechnical Investigation	HE Bombs	1	3	3
	Allied Sea Mines	2	3	6
	Axis Sea Mines	2	3	6
	Artillery Projectiles	1	1	1
	Torpedoes	2	2	4
	Dumped Munitions	1	2	2

7.2.1.2 Turbine Installation

Activity	Ordnance Variant	Probability of Encounter and Initiation	Consequences of Initiation	Risk Level
Foundation	HE Bombs	1	3	3
	Allied Sea Mines	2	4	8
	Axis Sea Mines	2	4	8
	Artillery Projectiles	2	1	2
	Torpedoes	2	3	6
	Dumped Munitions	1	2	2
Working Space	HE Bombs	1	2	2
	Allied Sea Mines	2	3	6

	Axis Sea Mines	2	3	6
	Artillery Projectiles	1	1	1
	Torpedoes	2	3	6
	Dumped Munitions	1	2	2

7.2.1.3 Inter-Array Cable Installation

Activity	Ordnance Variant	Probability of Encounter and Initiation	Consequences of Initiation	Risk Level
PLGR Seabed Operations	HE Bombs	1	2	2
	Allied Sea Mines	2	3	6
	Axis Sea Mines	2	3	6
	Artillery Projectiles	1	1	1
	Torpedoes	2	3	6
	Dumped Munitions	1	2	2
PLGR Equipment Recovery to Vessel	HE Bombs	1	2	2
	Allied Sea Mines	2	3	6
	Axis Sea Mines	2	3	6
	Artillery Projectiles	1	1	1
	Torpedoes	2	2	4
	Dumped Munitions	1	2	2
Cable Installation (Jetting or Ploughing)	HE Bombs	1	2	2
	Allied Sea Mines	2	3	6
	Axis Sea Mines	2	3	6
	Artillery Projectiles	1	1	1
	Torpedoes	2	2	4
	Dumped Munitions	1	2	2
Cable Installation (Concrete Mattress Protection)	HE Bombs	1	5	5
	Allied Sea Mines	2	5	10
	Axis Sea Mines	2	5	10
	Artillery Projectiles	1	5	5
	Torpedoes	2	5	10
	Dumped Munitions	1	5	5
Cable Installation (Rock Protection)	HE Bombs	1	3	3
	Allied Sea Mines	2	4	8
	Axis Sea Mines	2	4	8
	Artillery Projectiles	1	2	2
	Torpedoes	2	3	6
	Dumped Munitions	1	3	3

21A.7.2.2 Offshore Export Cable Corridor

7.2.2.1 Site Investigation

Activity	Ordnance Variant	Probability of Encounter and Initiation	Consequences of Initiation	Risk Level
Geophysical Survey	HE Bombs	1	2	2
	Allied Sea Mines	1	2	2
	Axis Sea Mines	1	2	2
	Artillery Projectiles	1	1	1
	Torpedoes	1	2	2
	Dumped Munitions	1	2	2
	Allied Terrestrial Mines	1	3	3
Geotechnical Investigation	HE Bombs	3	3	9
	Allied Sea Mines	2	4	8
	Axis Sea Mines	2	4	8
	Artillery Projectiles	4	1	4
	Torpedoes	3	3	9
	Dumped Munitions	3	2	6
	Allied Terrestrial Mines	1	2	2

7.2.2.2 Export Cable Installation

Activity	Ordnance Variant	Probability of Encounter and Initiation	Consequences of Initiation	Risk Level
PLGR Seabed Operations	HE Bombs	3	3	9
	Allied Sea Mines	3	4	12
	Axis Sea Mines	3	4	12
	Artillery Projectiles	2	2	4
	Torpedoes	3	3	9
	Dumped Munitions	4	2	8
	Axis Terrestrial Mines	1	2	2
PLGR Equipment Recovery to Vessel	HE Bombs	2	2	4
	Allied Sea Mines	2	3	6
	Axis Sea Mines	2	3	6
	Artillery Projectiles	2	1	2
	Torpedoes	2	3	6
	Dumped Munitions	2	2	4
	Axis Terrestrial Mines	1	2	2
Cable Installation (Jetting or Ploughing)	HE Bombs	3	2	6
	Allied Sea Mines	2	4	8
	Axis Sea Mines	2	4	8
	Artillery Projectiles	2	1	3
	Torpedoes	2	3	6
	Dumped Munitions	2	2	4
	Axis Terrestrial Mines	1	2	2

Activity	Ordnance Variant	Probability of Encounter and Initiation	Consequences of Initiation	Risk Level
Cable Installation (Concrete Mattress Protection)	HE Bombs	2	5	10
	Allied Sea Mines	2	5	10
	Axis Sea Mines	2	5	10
	Artillery Projectiles	2	5	10
	Torpedoes	2	5	10
	Dumped Munitions	2	5	10
	Axis Terrestrial Mines	1	5	5
Cable Installation (Rock Protection)	HE Bombs	3	4	12
	Allied Sea Mines	2	4	8
	Axis Sea Mines	2	5	10
	Artillery Projectiles	2	3	6
	Torpedoes	2	4	8
	Dumped Munitions	2	3	6
	Axis Terrestrial Mines	1	5	5

21A.7.3 Risk Assessment – Key Findings

21A.7.3.1 Geophysical Surevy

Geophysical surveying is assessed as being a low risk operation on all areas of the Study Area. No mitigation will be required for this activity.

21A.7.3.2 Geotechnical Investigation

Geotechnical investigation is assessed as "medium" risk activity in the Development Area, with contamination from both Allied and Axis mining operations, and torpedoes. The Offshore Export Cable Corridor, is also considered to have a "medium" risk level for this activity from both Allied and Axis mining operations, HE Bombs, Torpedoes and Dumped Munitions. The risk is generally elevated as the Offshore Export Cable Corridor closes with landfall.

21A.7.3.3 Installation Activities

- **WTG and Foundation Installation**; is a high kinetic energy activity and often requires significant working space for jack-up vessels. This activity assessed as having a "medium" level of risk. The main potential threat item to these operations is *Allied* and *Axis* sea mines, and torpedoes which have a significant NEQ and thus could precipitate high levels of damage to equipment, seriously injure personnel and severely delay the project. Whilst the probability of encountering these items is considered medium across the Site the potential consequences of initiating UXO during the WTG and Foundation installation significantly elevate the holistic risk level for this operation;

- **Inter-Array Cable Installation**; there are a number of activities to be conducted relating to the installation of cables between turbines and substations on the Development Area. It is expected that PLGR will be carried out before the installation of cables and, unmitigated, it is assessed to be a medium level risk. The threat items posing this risk are Allied and Axis Sea Mines, and Torpedoes. There is a lower level of risk assessed for recovery of PLGR equipment from the seabed to the vessel. The burial installation of cables (which is expected to be via jetting, or ploughing during Post Lay Inspection and Burial (PLIB)) is assessed as a "low" to risk operation. If cables are to be protected by mattresses or rock dumping, an elevated level of risk might be presented if divers are to be employed (with the former operation especially).
- **Export Cable Installation**; there are a number of activities to be conducted relating to the installation export cables between the Study Area and the Scottish coastline. It is expected that PLGR will be carried out before the installation of cables and, unmitigated, it is assessed to be a medium level risk. There is also a "medium" level of risk assessed for recovery of PLGR equipment from the seabed to the vessel. The burial installation of cables (which is expected to be via jetting, or ploughing during Post Lay Inspection and Burial (PLIB)) is also assessed as a "medium" risk operation. The risk is elevated as the Offshore Export Cable Corridor closes with the landfall. If cables are to be protected by mattresses or rock dumping, an elevated level of risk might be presented if divers are to be employed (with the former operation especially).

21A.8 Conclusions

21A.8.1 Key Findings

This threat and risk assessment identifies significant variations in the risk to operations due to among other things, the location of potential UXO threat sources as well as the level of prospective kinetic energy associated with each investigative or installation operations and the seabed.

Major UXO threat sources have been identified at the Study Area, some of which poses a relatively high threat. It is also possible that UXO may have migrated from additional threat sources in the vicinity of the Study Area although the types, quantities and locations of such UXO are impossible to accurately forecast.

The region surrounding the Site was considered to be strategically important during both World Wars. The Firth of Forth is Scotland's largest river with a number of important ports and cities such as Leith, Edinburgh, Methill and Rosyth located on its banks. The Firth of Tay and Forth were highly important rivers for trade and were strategically important during both World Wars because they are located on the North Sea coast providing a link to mainland European ports.

The Germans heavily targeted the cities, ports and shipping routes into the Firths of Tay and Forth during both World Wars. U-Boat attacks on shipping were carried out in WWI whilst aerial bombardment of terrestrial sites such as ports and cities and attacks on shipping took place in WWII. Mine laying activities by German U-Boats took place in both World Wars although in WWII aerial mine deployment became the preferred emplacement method.

The Firth of Forth was used as a convoy marshalling point during both Wars, with convoy routes assembling along the east coast of Britain dispersal in supply routes to the USSR. German forces specifically targeted convoy routes during both World Wars in order to disrupt trade and supplies and there are a number of munitions related shipwrecks located within the vicinity of the Study Area which may be attributed to both World Wars. Former convoy routes are located across both the Offshore Export Cable Corridor and the Development Area.

British sea mine laying activities were undertaken to defend against the German threat to shipping during both World Wars, with extensive East Coast defensive mine laying occurring during WWII especially. Terrestrial defences against enemy ships and aerial bombardment included a number of Royal Air Force bases and anti-aircraft batteries were also located along the coast.

The Firth of Forth and Firth of Tay area has been highly militarised with naval bases located at Rosyth, Port Edgar and a submarine base at Dundee. The Forth River continues to be militarily important and there is a significant naval presence within the Forth due to the naval base at Rosyth and various military training areas are located along the coast and offshore. These historic and current training sites include live firing, exercises, torpedo, submarine and mine counter measure training sites. Some of these live firing training areas are located across the Offshore Export Cable Corridor and Development Area part of the Site. In addition there are disused munitions disposal sites located to the west of the Study Site, which date to the post-war period.

Both World Wars together with more modern military activities have left a significant UXO legacy within the vicinity of the Study Area. The main threat items identified include shipwreck related munitions, torpedoes as well as Axis and Allied sea mines. In addition it is possible that there are artillery projectiles and UXO items relating to the various military training areas that surround the Site.

The Development Area has a “medium” level of UXO risk posed by geotechnical investigations, turbine installations and PLGR seabed operations. All other activities on the Development Area are considered to be “low” risk.

The Offshore Export Cable Corridor is considered to have a higher UXO risk level than posed in the Development Area, largely due to the proximity of terrestrial bombing targets and the historic and military training areas located across the route. Excluding geophysical survey, all later installation activities are considered to be a “medium” risk within the Offshore Export Cable Corridor.

21A.9 Recommendations – UXO Risk Mitigation

21A.9.1 Overview

In view of the UXO risk in this region in general and the specific nature of the proposed investigative and engineering works, the following risk mitigation strategy is recommended to reduce the risk to a level that conforms to the legal ALARP principle. This strategy has been developed in order to fully address the UXO risk across the entire development site.

The avoidance of potential risk items is the key to successful UXO risk management in this environment. By adhering to robust procedures and operational guidelines the impact to the ongoing development can be significantly reduced.

However, the risk from UXO could never be considered ‘”zero” in the offshore environment, as there is always the potential for UXO migration through natural sedimentation and transportation. Therefore *6 Alpha* recommend that the time between any proactive mitigation works and the proposed construction works, is minimised (within reasonable operational constraints).

21A.9.2 UXO Project Management and Quality Assurance/Quality Control

Given the significant cost and potential implications on site associated with undertaking UXO risk mitigation measures, the presence of specialist UXO Project Management and QA/QC representatives are considered essential to ensure that quick, and informative decisions are made concerning the UXO Risk Management tactics (and the potential strategy impact). Such findings may be reported directly to the client, the wider project management team and if required relevant authorities, in order to ensure that the highest quality of work is always being delivered at best client value.

21A.9.3 Strategic Risk Management

21A.9.3.1 Overview

At first sight, the general level of UXO contamination and potential for its encounter during wind farm construction activities may appear concerning. However, whilst UXO undoubtedly poses a risk across the development, it is not uncommon and it has been encountered and successfully ameliorated on a high proportion of wind farm developments in the *English Channel*, the *North Sea* and the *Baltic Sea*. Therefore, the presence of UXO should not present a barrier to OWF development, although there is a requirement to better quantify the risk by reviewing the possible types (including size, mass and density) of the potential UXO contamination, and reviewing the available information from previous and/or future geophysical, geotechnical or clearance surveys to determine the remaining/residual risk.

We recommend that UXO risks are reduced to conform with the ALARP principal. Typically, risk ameliorative measures are undertaken to tie in with key project milestones, for example:

- Small scale geophysical surveys to support geotechnical investigation;
- The selection of the preferred development area and the wind farm design;
- A detailed geophysical survey of the development area;
- WTG and Foundation micro-siting and cable route engineering.

21A.9.3.2 Geophysical Survey and Geotechnical Investigation Locations

Before any geotechnical investigation operations are undertaken, the probability of encounter chart at Annex 21A.9 should be consulted, and if there is an elevated threat of UXO encounter during such investigations, then risk ameliorative work should be undertaken in advance (in the form of geophysical survey and the delivery of supporting ALARP sign-off certificates for each "box").

21A.9.3.3 Selection of Development Area and Wind Farm Design

When undertaking the appraisal of the entire concession zone for design purposes, the "probability of UXO encounter map" at Annex 21A.9 should be considered. The following actions (summarised in Table 21A.6) are to be undertaken, in order to address the UXO risks:

Table 21A.6 – Recommended UXO Risk Mitigation Actions

UXO Probability Encounter Rating	Grading	Action Required ahead of Intrusive Works
1-2	**Remote - Possible**	Areas defined as "background residual risk". Use, wherever possible, existing geophysical datasets for UXO risk reduction. Define smallest UXO threat items, interpret the datasets for contacts similar to UXO and avoid during future works.
3-4	**Likely - Highly Likely**	Areas which display a specific significant UXO threat, there are three options for dealing with the risk in these areas: • **Option 1** - Relocate works to areas with a grading of 1 or 2; • **Option 2** – Conduct a UXO Specific Geophysical Survey and avoid targets. This survey should be designed to match the defined UXO threat and provide 100% coverage of specific threat area. Contacts modelling as UXO should then be avoided; • **Option 3** – If target avoidance is not possible, conduct either diver investigation or ROV inspection, which may discount the item or lead to UXO render safe/disposal.
5	**Almost Certain**	*6 Alpha* would strongly suggest avoiding these areas, and relocating the work, because the costs associated reducing the risk to ALARP are likely to be considerable.

21A.9.3.4 Foundation Micro-siting and Cable Route Engineering

Once the geophysical survey has been conducted to detect those items of UXO that present a threat on this project, the interpreted "contacts" should either be avoided or investigated. *A* policy of avoidance is often effective and in such circumstances, the following "typical" safety buffers are recommended (and have been successfully employed on similar projects).

Table 21A.7 – Typical UXO Safety Buffers

ACTIVITY	UXO SAFETY AVOIDANCE BUFFER
Foundation Installation	**30 m** from centre point of mono-piles
	15 m Working Space from item of suspect UXO
Inter Array Cable Installation	**15 m** from centre-line of cable route

21A.9.4 Operational Risk Mitigation

The risk mitigation for this particular project can be subdivided into two distinct phases:

- Proactive – Geophysical survey and anomaly management (avoidance and/or investigation);
- Reactive – Support to the operational team during the works on Site.

21A.9.4.1 Proactive Risk Mitigation

Proactive risk mitigation varies depending on the activity to be undertaken on the Study Area. The main activities which incur significant risk on Site and the proactive measures to mitigate against UXO encounter and discovery are outlined below:

Table 21A.8 - Proactive Risk Mitigation Procedures

Proposed Operation	Proactive Risk Mitigation Procedure
Intrusive Surveys including Boreholing, Vibrocoring, & CPT Site investigation from a Jack-up / Dynamically Positioned (DP) vessel.	1. Ensure Side Scan Sonar (SSS) and close line spaced magnetometer coverage of investigation area; 2. Avoid anomalies that model as UXO; 3. Relocate positions (micro-site) onto survey lines if required; 4. Obtain sign-off certification from a UXO consultant to provide evidence of the risk management procedure and reducing risks ALARP.
Substructure Foundation and Inter-Array Cable Installation Construction operations to be carried out on the Development Area.	1. Ensure Side Scan Sonar (SSS) and close line spaced magnetometer coverage of investigation area; 2. Avoid anomalies that model as UXO; 3. Relocate positions (micro-site) onto survey lines if required; 4. Obtain sign-off certification from a UXO consultant to provide evidence of the risk management procedure and reducing risks ALARP.
Export Cable Installation	1. Ensure Side Scan Sonar (SSS) and close line spaced magnetometer coverage of investigation area; 2. Avoid anomalies that model as UXO; 3. Relocate positions (micro-site) onto survey lines if required; 4. Obtain sign-off certification from a UXO consultant to provide evidence of the risk management procedure and reducing risks ALARP. **Additionally at the landfall locations:** Undertake land based threat and risk assessment (following a similar risk management methodology) and either avoid or investigate anomalies to evidence that UXO risks have been reduced ALARP.

21A.9.4.2 Reactive Risk Mitigation

The following reactive measures are recommended:

- **UXO Coordinators**

  An experienced crewmember should be to be nominated and trained as the "UXO Coordinator" on-board certain vessels. The UXO Coordinator should not only receive the Munitions Safety and Awareness brief (as would the other members of the crew), but they would should also be trained in greater detail and equipped with an *aide memoir* concerning "actions on" UXO discovery, in flowchart format, as well as a support guide to help recognise prospective UXO.

  The Munitions Coordinator, typically at OPST/Vessel Master and deck foreman level, should also hold the following support documents:

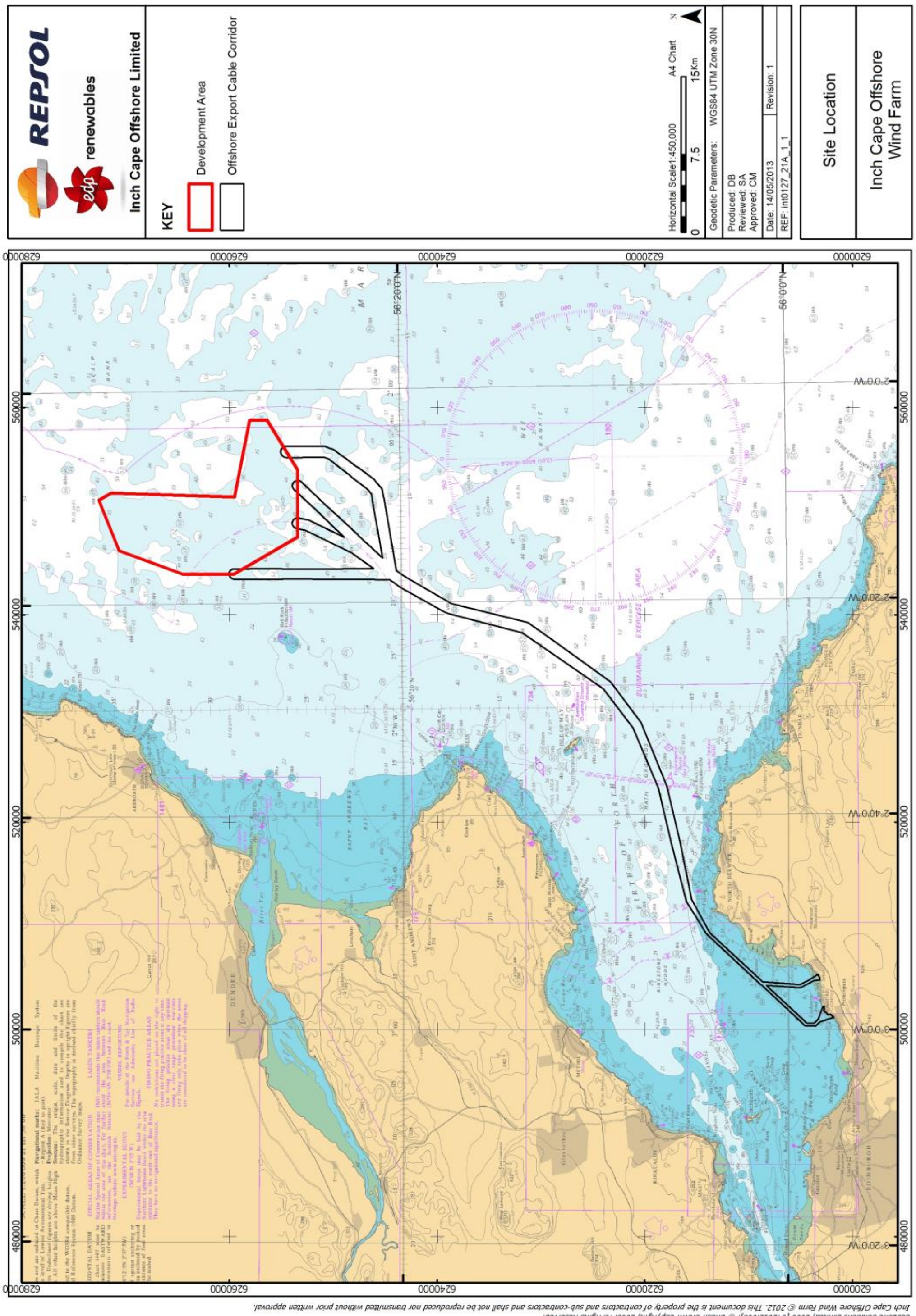
  - A laminated munitions briefing pack (an *aide memoir* concerning "actions on" in flowchart format, as well as a guide to help recognise potential munitions) - it may also be used for on-board daily "Tool Box Briefs";
  - "Munitions recognition" posters/aids and technical data for use on-board the vessel.

- **Crew Level Munitions Safety and Awareness Briefings**

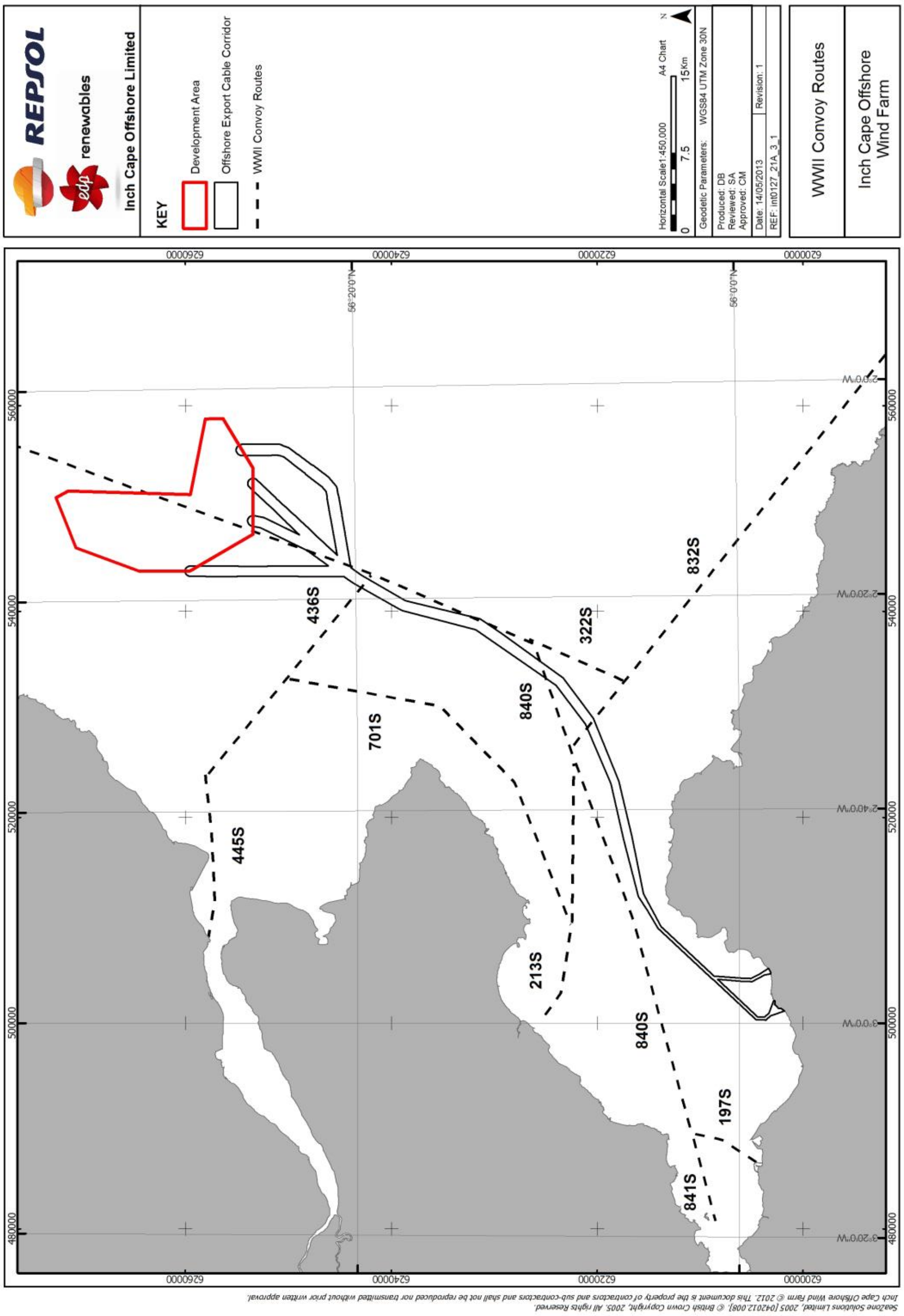
  These briefings are essential when there is a possibility of HE munitions encounter and are a vital part of the general safety requirement. All personnel working on the vessel should receive a general briefing ("Tool Box Brief") on the identification of munitions, what actions they should take to keep crew and equipment away from the hazard and to alert the "UXO Coordinator" in the event of a discovery.

Once both the proactive and reactive risk mitigation measures have been successfully implemented, 6 Alpha would consider that the risk will have been reduced to ALARP, and the geotechnical investigation and subsequent installation activities may then take place safely on the Site.

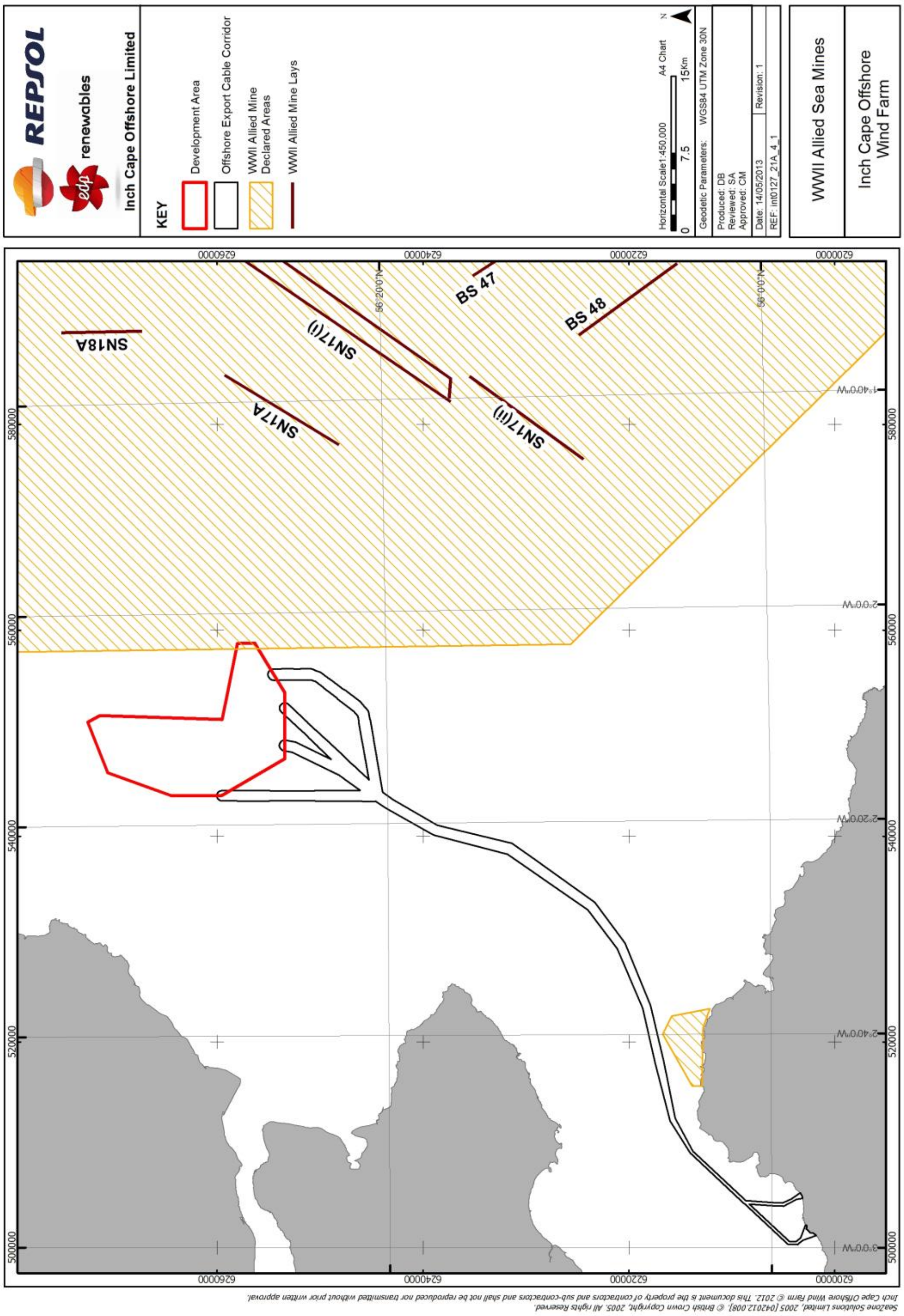
Annexes


REPSOL
edp renewables
Inch Cape Offshore Limited
KEY
Development Area
Offshore Export Cable Corridor
Horizontal Scale1:450,000
A4 Chart
Geodetic Parameters: WGS84 UTM Zone 30N
Produced: DB
Reviewed: SA
Approved: CM
Date: 14/05/2013
Revision: 1
REF: int0127_21A_1_1
Site Location
Inch Cape Offshore Wind Farm

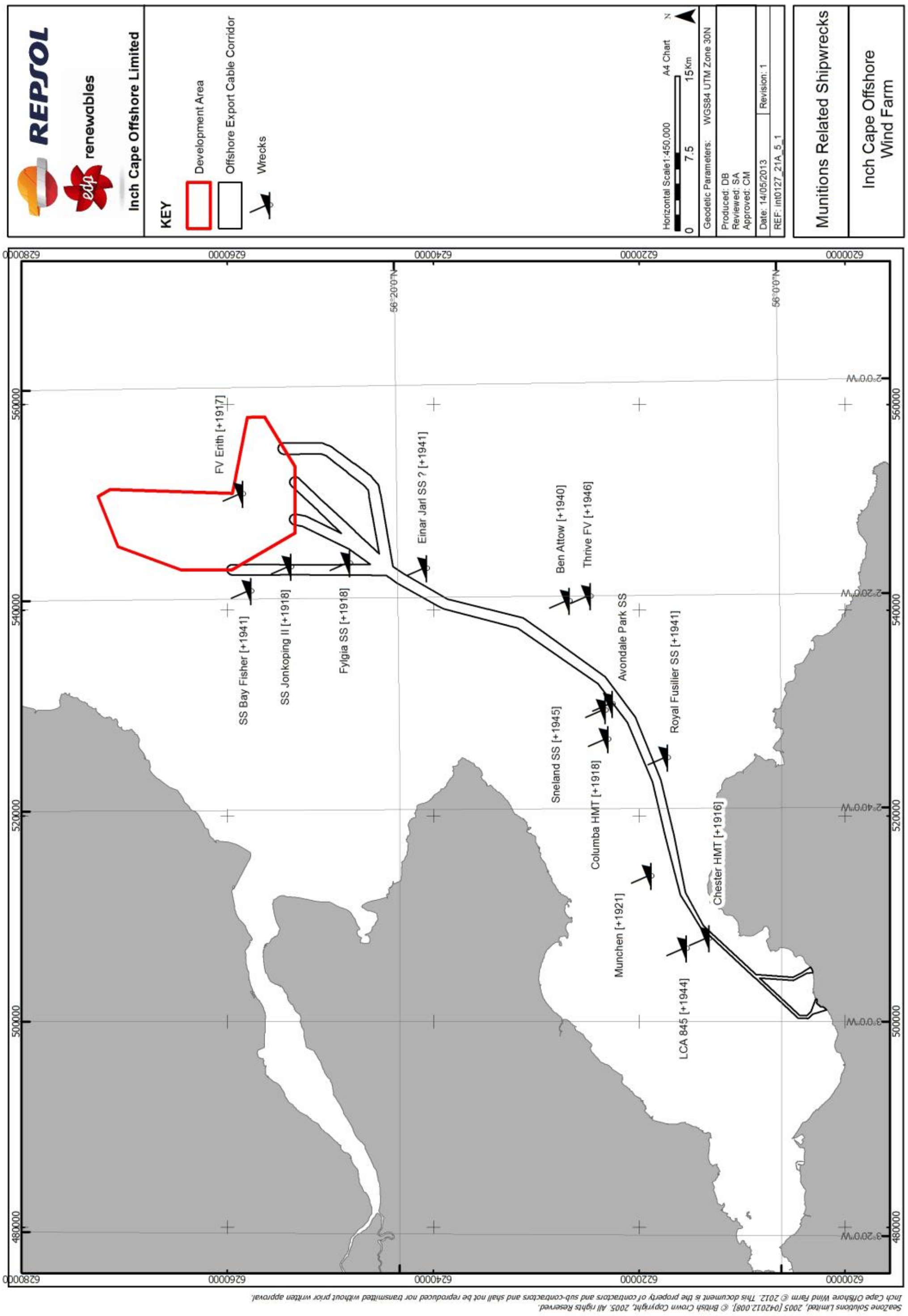
Annex 21A.2 – WWII Convoy Routes



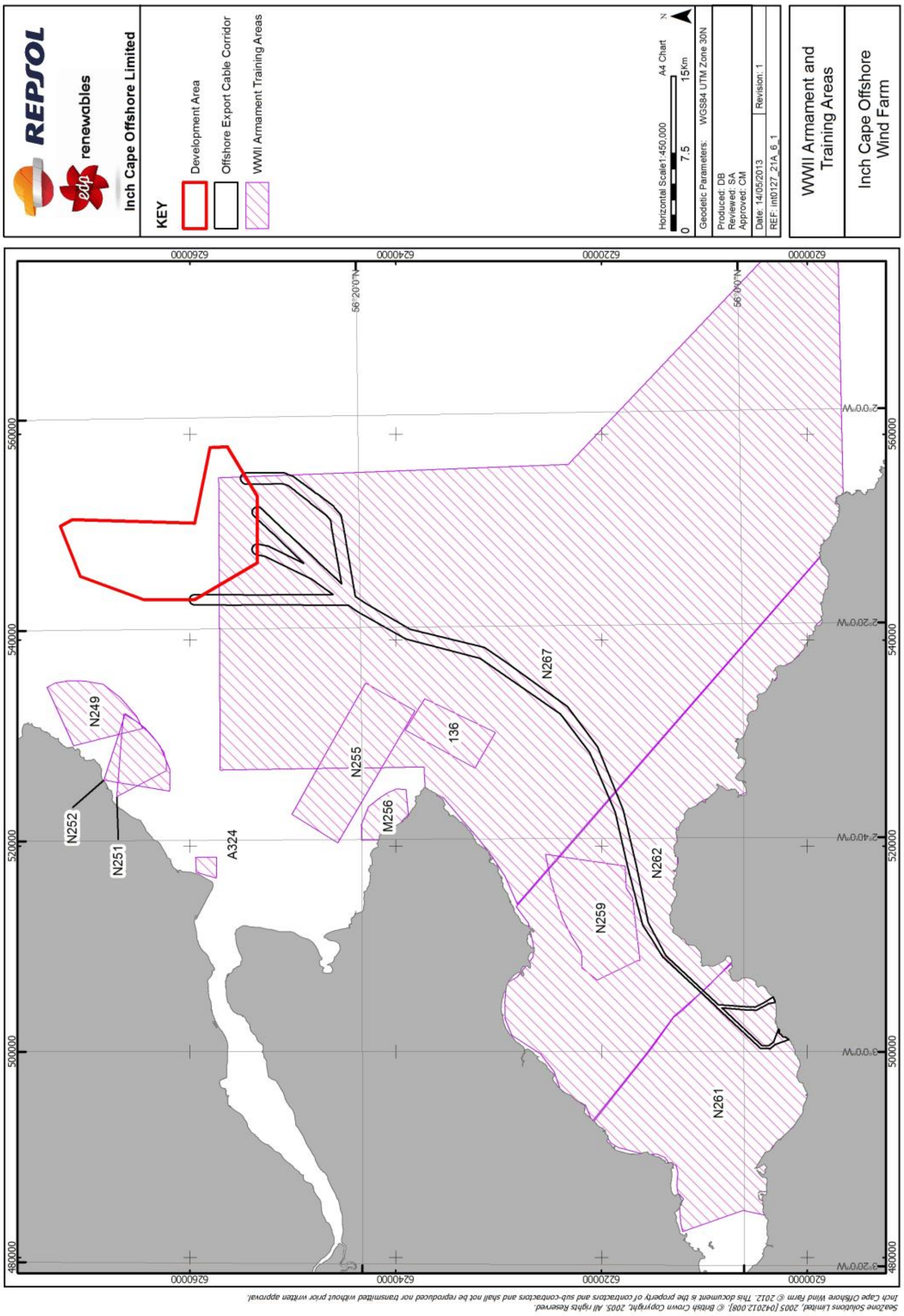
Annex 21A.3 – Allied Minefield Locations



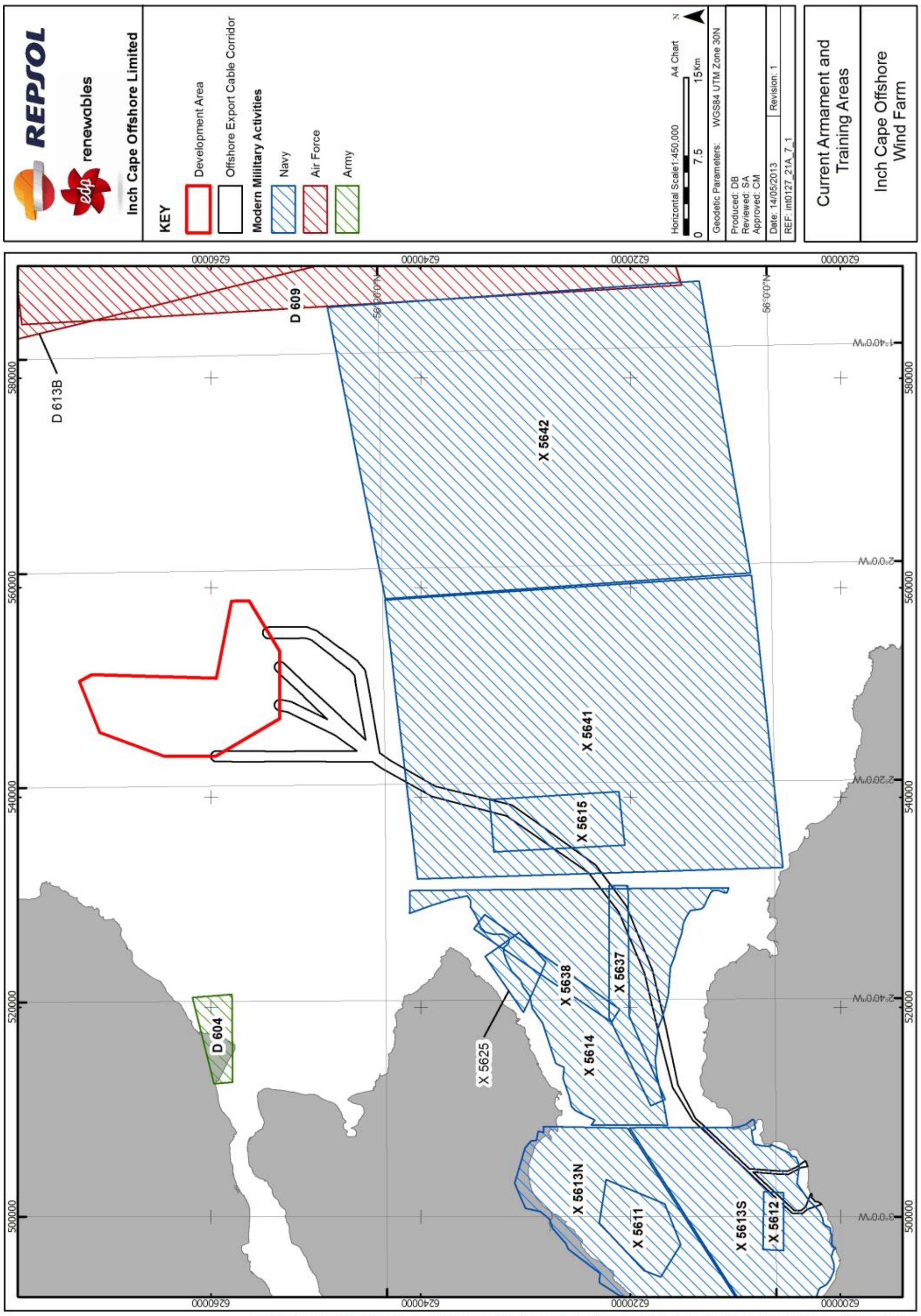
Annex 21A.4 – UXO Related Shipwreck Locations



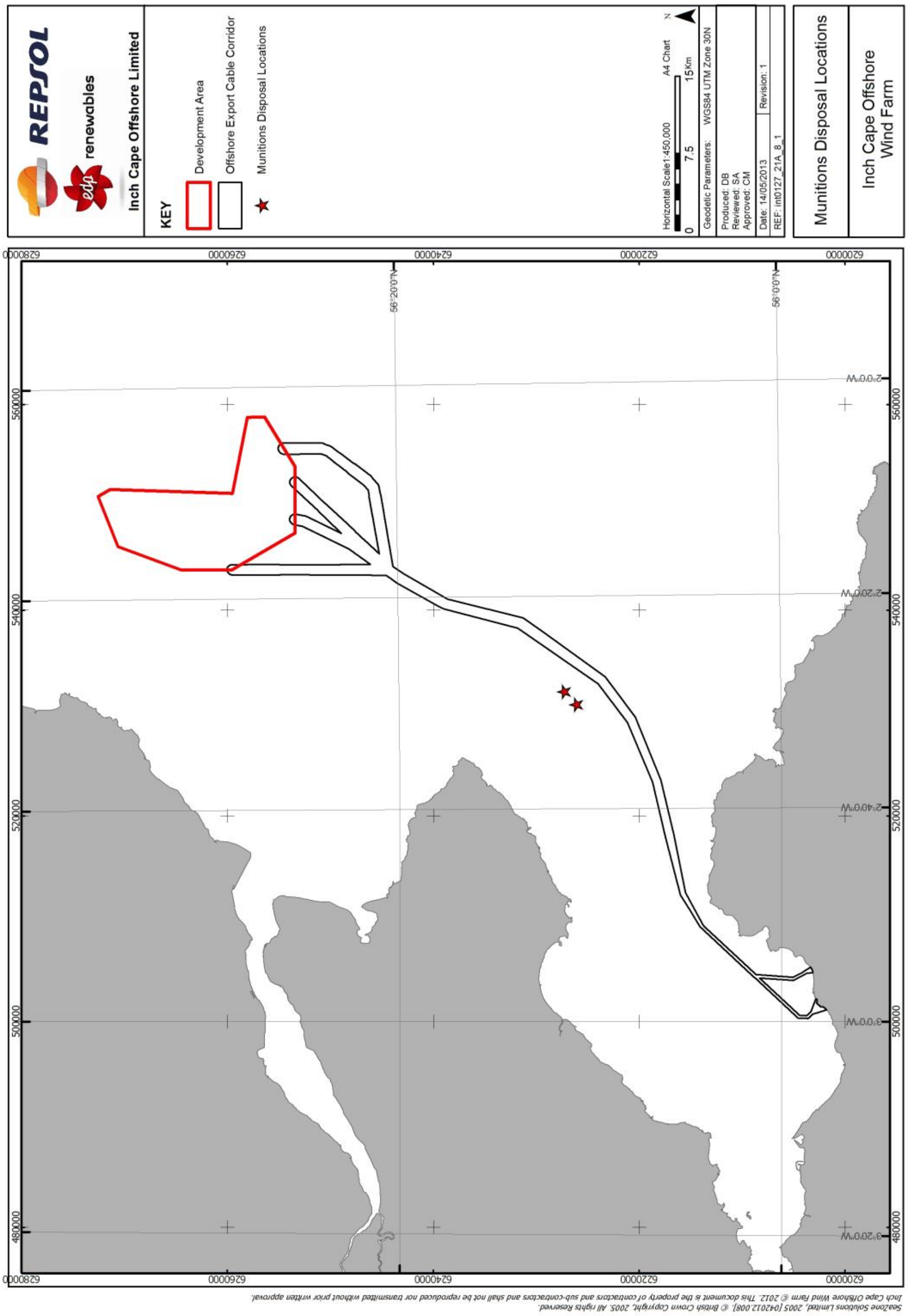
Annex 21A.5 – WWII Armament and Training Locations



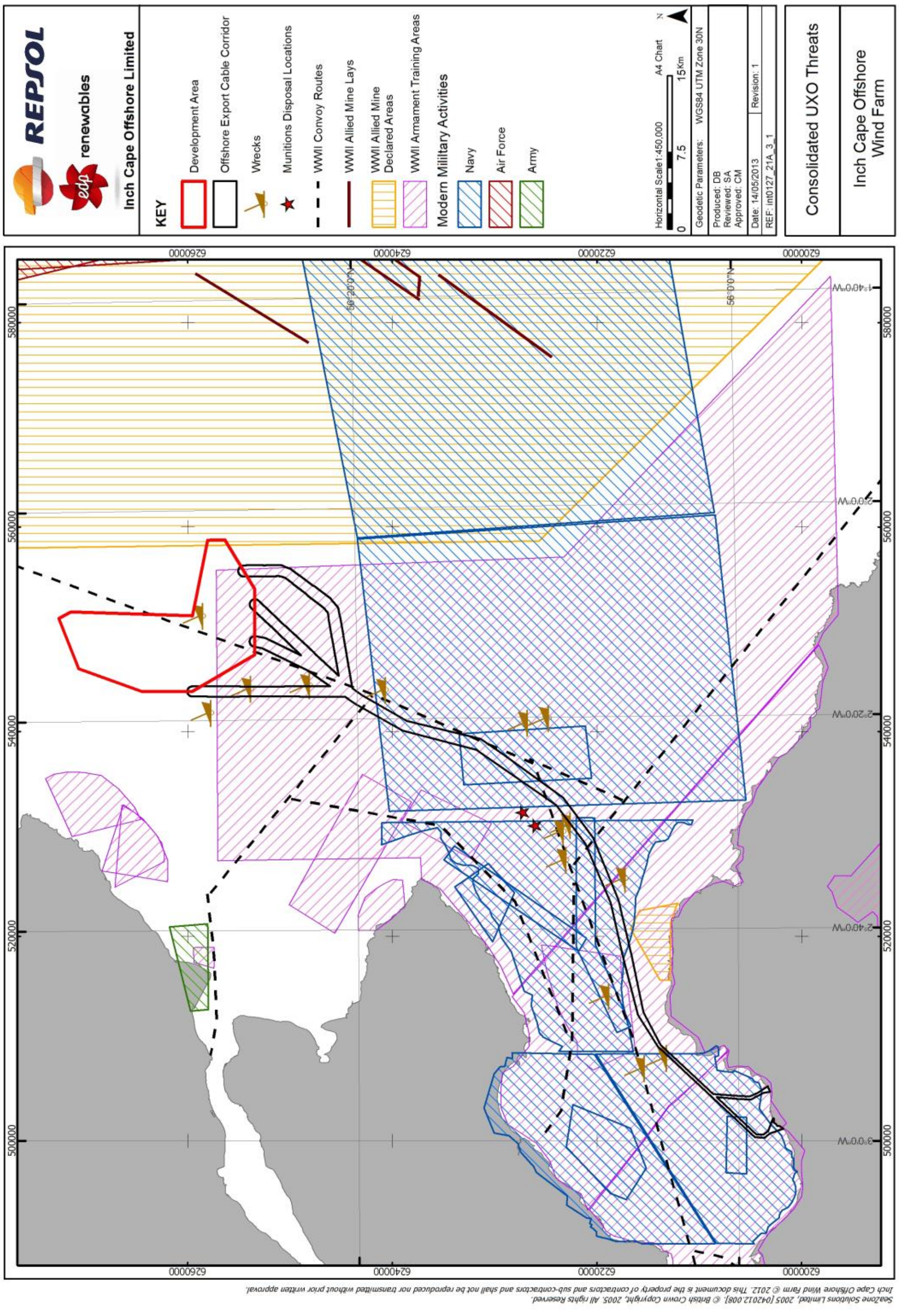
Annex 21A.6 - Current Armament and Training Locations



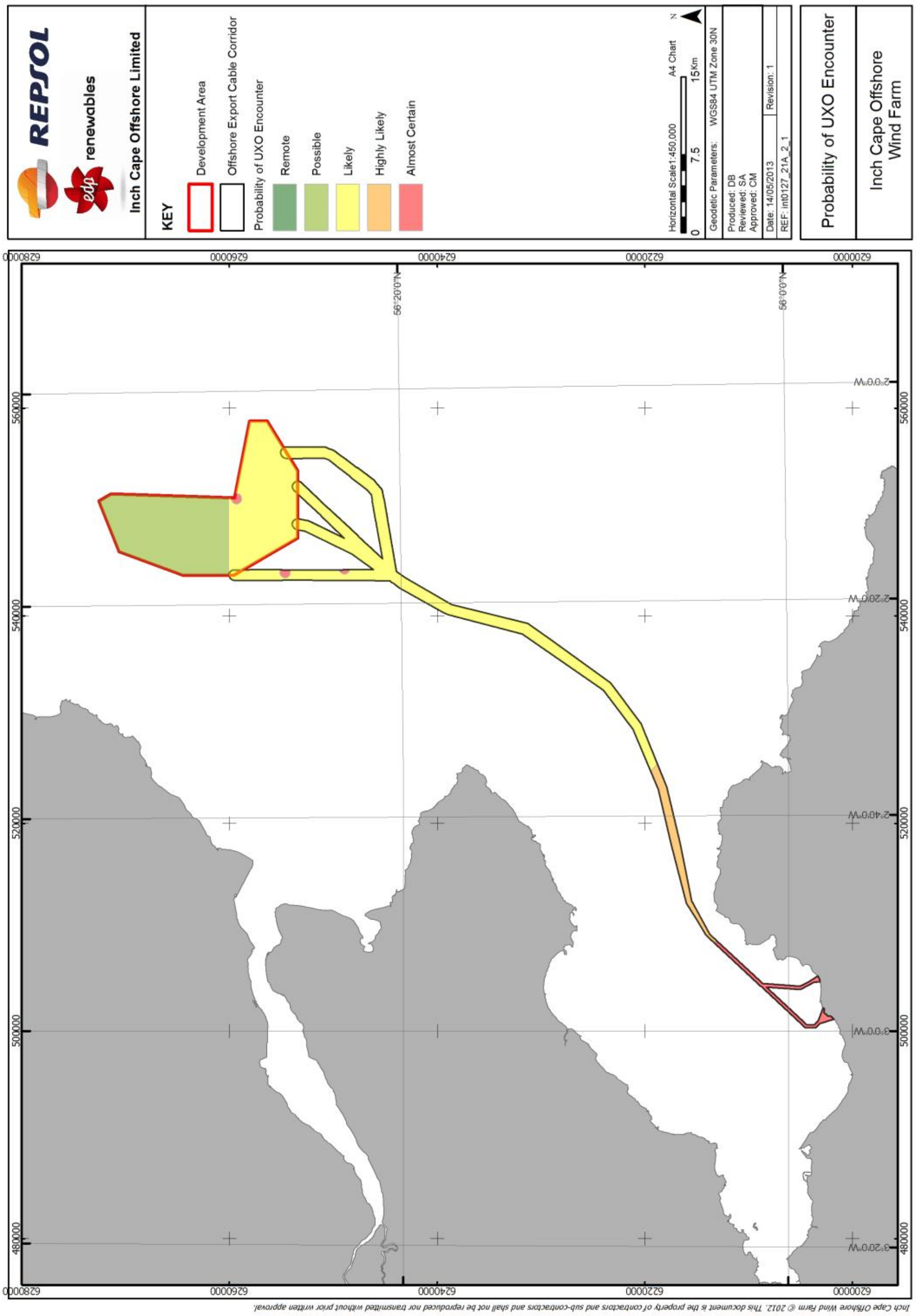
Annex 21A.7 – Munitions Dumping Locations



Annex 21A.8 – Consolidated UXO Threat Locations



Annex 21A.9 – Probability of UXO Encounter



Annex A

UXO Risk and Legal Position

Contents

1 UXO Risk and Legal Position

1.1 Introduction

It is assumed that Inchcape Offshore Limited (ICOL) will wish to have a coherent view of what the law is likely to require concerning potential UXO risk. Developers are generally expected to not only discharge their statutory and tortuous legal duties, but are also required to protect those that might be exposed to UXO risks during this project.

The consideration of the legal position *vis-à-vis* UXO risk is substantively based upon the principles and guidelines employed to assist the UK's Health and Safety Executive (HSE) in its judgment that duty-holders have to reduce risks to, "As Low As Reasonably Practicable", (ALARP). Whilst 6 Alpha acknowledge that there are differences between English and Welch law and Scottish law, our experience is that the application employment of the ALARP principal is similarly recognized and considered as effective, across national (and international) legal jurisdictions.

Although the interpretation of the HSE guidelines concerning UXO risks is 6 Alpha's, it has not been subjected to formal legal scrutiny or any form of legal test, nor has it been endorsed (formally or informally) by the HSE. Nonetheless we believe that it is accurate and founded upon significant empirical legal research as well as national and international UXO project management experience.

Ultimately however, it is for the courts to decide whether or not duty-holders have complied with the law, both national, European Union and/or international. The following legal interpretation, the subsequent UXO risk assessment and associated risk mitigation measures upon which they are founded, aim to discharge legal duties in relation to the ALARP principal in general and its applicability to UXO risk in particular.

1.2 Appropriate Legislation, UXO Guidelines and ALARP Application

In the construction/civil engineering arena (in the EU), relevant statutory instruments (with which ICOL will have to comply) are in general, likely to encompass the Health and Safety at Work legislation (namely the 1974 Act and 1999 Regulations), as well as the Corporate Manslaughter and Corporate Homicide Act, 2007.

ICOL may also face a common law liability (for negligence and a potential breach of duty) if reasonable steps are not taken to identify and appropriately ameliorate risks posed by UXO.

Additionally, and in particular, the Construction Design and Management (CDM) Regulations 2007 apply, as does CIRIA's, "*UXO – A Guide for the Construction Industry*". The CIRIA publication provides the first UK, "good practice guide", helping developers and the construction industry to deal with UXO. Whilst CIRIA's guide is concerned with UXO risk on land, the same generic principles apply to construction activities in the marine environment.

In terms of dealing with UXO hazards and risks, we believe that by applying broad HSE guidelines in terms of risk assessment, risk treatment and risk management, together with our own UXO expertise, will enable ICOL to comply with EU statutory and common law. In addition, if and when this is employed as a legal and technical benchmark (including outside UK territorial waters or overseas), it is also likely to meet with any other reasonable legislation, guidance and standards that might be encountered.

1.3 Determining that UXO Risk has been reduced to ALARP

Determining that UXO risks have been reduced to ALARP involves an assessment of the **UXO risk** to be avoided, an assessment of the **sacrifice** (in terms of money, time and effort) involved in taking control measures to avoid or mitigate that risk, and a **comparison** of the two. A diagrammatic representation for meeting with ALARP is presented at Figure 1.3.

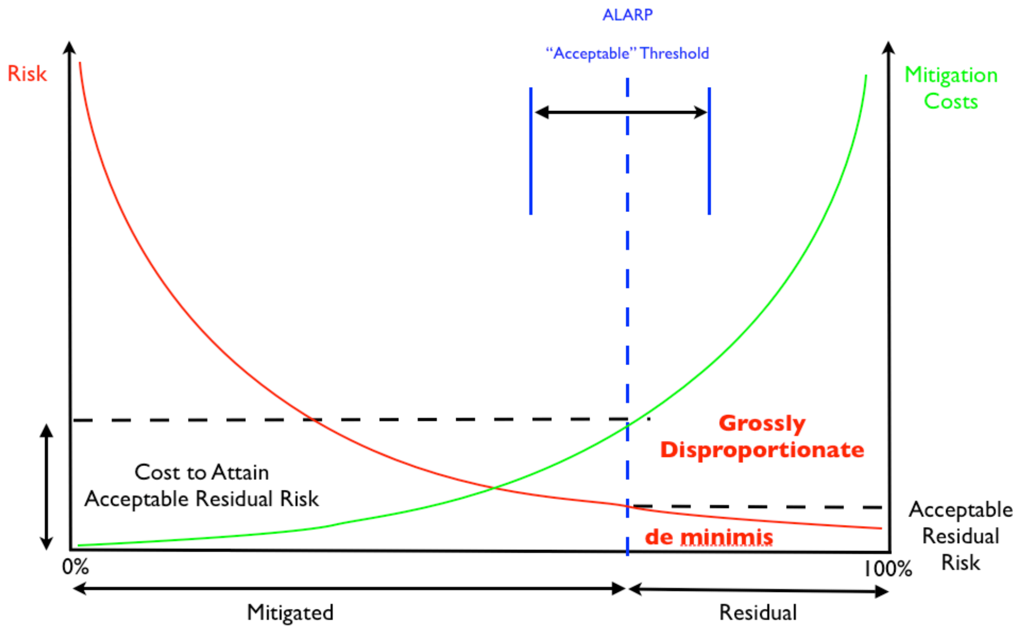


Figure 1.3 – Meeting with ALARP

This process can involve varying degrees of rigour that will depend on the nature of the UXO hazard, the extent of the risk and the control measures to be adopted. The more systematic the approach, the more rigorous and more transparent it is to any regulator and other interested parties. The greater the initial levels of risk under consideration, the greater the degree of rigor that might be required of the arguments purporting to show that those risks have been reduced to ALARP.

In terms of UXO risk, it is clear that it may present a significant hazard (as a death or deaths may be caused), and that the UXO threat should be described and the UXO risk determined in an open, systematic, rigorous, consistent and transparent way. Similarly, risk control measures should therefore be adopted to demonstrate that the risk has been reduced to ALARP, which can, in accordance with the law, be assessed by addressing the UXO risk and sacrifice and comparing the two.

1.4 UXO Risk Tolerance

6 Alpha have made certain assumptions about OWF developers as well as their individual and collective tolerance for the acceptance of UXO risk. Our assumptions include that the following interrelated elements are to be considered:

- **Corporate Governance** – is the system by which companies are managed and controlled. It is assumed that ICOL will wish to adhere to the highest international standards of corporate governance. Discharge of corporate responsibility is expected to be on risk-based criteria and it is expected that ICOL will have in place a framework for managing risk for good governance. It is anticipated that safety and risk management are integrated in ICOL's business culture.
- **Risk Management** – ICOL will expect the highest standard of risk and safety management to be applied to this project. ICOL will have a risk management system in place for responding to business, programme and project risks. Any risks posed by UXO will have to be assessed based upon probability and consequence criteria. High rated UXO risks will have to be avoided or otherwise mitigated not only in accordance with the law, but also with best proactive risk management guidelines. ICOL will not only rely upon 6 Alpha's professionalism and independence to identify UXO risks, but also to design appropriate UXO risk management solutions in accordance with the law in general and the ALARP principal in particular; and, to warrant that the UXO risk mitigation contractors responsible for the subsequent execution of those works, perform to appropriate quality and best practice standards.
- **Safety** – we assume that safety will be the highest priority for ICOL on this project. Personnel safety will assume the highest priority. The protection and preservation of equipment, property and the environment, whilst highly important, will remain subservient to the safety of personnel.

Annex B

Ordnance Technical Detail

Contents

1 Explosive Threat Items

1.1 General

Having established potential contamination sources, the following generic ordnance groups are considered likely to present a threat to the proposed development. Clearly, some varieties of UXO are likely to be more common within the project area than others.

1.2 Weapon Fill Materials

1.2.1 High Explosives (HE)

HE compounds detonate at velocities ranging from 1,000m to 9,000m per second, and may be subdivided into two explosives classes, differentiated by their respective sensitivity:

- **Primary Explosives** – are extremely sensitive to mechanical shock, friction and heat to which they will respond by burning rapidly or detonating. Examples include mercury fulminate and lead azide. This characteristic makes them unsuitable to use as base (i.e. main-fill) explosives in military ordnance. Sensitivity is an important consideration in selecting an explosive for a particular purpose, e.g. the explosive in an armour-piercing projectile must be relatively insensitive, or the shock of impact would cause it to detonate before it penetrated the target.

- **Secondary Explosives** – are relatively insensitive to shock, friction and heat. They may burn when exposed to heat in small-unconfined quantities, although the risk of detonation is always present (especially when they are confined and/or are burnt in bulk). Dynamite, TNT, RDX and HMX are classed as secondary high explosives, which are commonly used as, base explosives in military ordnance. PETN is the benchmark compound; those explosives that are more sensitive than PETN are classed as primary explosives.

1.2.2 Low Explosives

A low explosive is usually a mixture of a combustible substance and an oxidant that decomposes rapidly (in a process akin to very rapid burning and known as deflagration).

Under normal conditions, low explosives undergo deflagration at rates that vary from a few centimetres per second to approximately 400m per second. Low explosives are normally employed as propellants, included in this group are, for example; gun-powders, pyrotechnics and illumination devices such as marine markers or flares.

1.2.3 Propellants

In ballistics and pyrotechnics, a propellant is a generic name for those chemicals used for propelling projectiles (e.g. artillery shells or mortars) from a weapon system.

Propellants are always chemically different from high explosives (as compared with those used in munitions for "target effect" for example) they are not designed to release their energy as quickly and as a result do not produce a blasting/shattering effect (because such an effect would significantly damage or destroy the associated weapons platform e.g. gun/howitzer or mortar).

However, some explosive substances can be used both as propellants and as "burster charges", (e.g. gunpowder), and some of the ingredients of a propellant may be similar to those employed to make explosives. If bulk propellants are confined and burn very rapidly the result can be similar to that witnessed by a (small) high explosive charge. Propellants therefore remain highly dangerous and can come in various forms, e.g. powder or thin sticks and can be contained in pre-formed containers or bags.

A very typical propellant burns very rapidly but controllably and non-explosively to produce thrust (generated by rapidly expensing gas, generating pressure) and thus accelerating a projectile/rocket from a weapon platform. In this sense, common or well-known propellants include:

- Gun propellants, such as:
    - Gunpowder (black powder);
    - Nitrocellulose-based powders;
    - Cordite;
    - Ballistite;
    - Smokeless powders.
- Compounds, which may be mixed with a solid oxidiser (such as ammonium perchlorate or ammonium nitrate) or a rubber (such as HTPB or PBAN), or a powdered metal (commonly aluminium).

1.3 Artillery Projectiles

Artillery projectiles may be classified and grouped as follows:

- **HE –** High Explosives are designed to cause damage by a combination of high explosive blast and fragmentation;
- **Fragmentation** – designed to be used primarily against personnel.

- **AP and SAP –** Armour Piercing (AP) and Semi-Amour Piercing (SAP) shells are always base fuzed and are generally designed for the attack of lightly armoured vehicles, concrete emplacements dug outs etc. they are not intended for heavily armoured targets.
- **Smoke** – Used for the production of smoke screens; various fillings are used, the most common being white phosphorous.
- **Illuminating** – designed to illuminate an area or specific target at night; a burning flare is suspended from a small parachute to provide an intense white light.
- **Practice –** Commonly a solid shot fitted with a so-called "spotting charge" which gives an indication of where it lands.

1.4 Torpedoes

Torpedoes were utilised by a range of vessels including submarines and the surface fleet. Unlike sea mines (which are a "mass-weapon" system deployed in order to strike an opportunity target), torpedoes were usually specifically targeted (i.e. fired and/or guided to a known target) rather than deployed in mass.

The guidance systems used in torpedoes are often sophisticated and include homing systems reliant upon *inter alia* acoustic signature. However, any power supply (upon which guidance and initiation systems rely) in WWII torpedoes is considered expended and it is therefore highly unlikely that any residual current in fact exists, or that a tiny amount which may theoretically exist, could not be considered sufficient to enable the torpedo to function as originally intended.

Whilst it is possible that unexploded torpedoes might be encountered, it is anticipated that their potential discovery is likely to be significantly less frequent than other "mass" naval weapons e.g. sea mines. They are nonetheless less dangerous. Given they are manufactured from ferrous metal and they have generally a very long slender profile, they are usually relatively easy to detect by geophysical survey for UXO.

1.5 Sea Mines

1.5.1 General

Sea mines (which were employed by both sides engaged in WWI and WWII), were designed either to be buoyant or to sink; the former variety tended to be moored but if they were not initiated (or cleared at the end of the war), then they often sank and drifted on the seabed with tides/weather.

Some British mines could be programmed to self neutralise, often by sinking themselves and allowing the ingress of salt water to render the firing circuit inoperable. Although self-neutralising sea mines could not function today as originally designed, the detonators and HE charges remain intact; they are dangerous. Official records also state that not all of the mines had the "sterilisation plugs" fitted to enable self-neutralisation.

Additionally, the detonators in mines are, by design, made from a sensitive explosive compound (often picric-acid based), which remains susceptible to shock to this day, although exposure to saltwater does not generally increase this sensitivity. All WWII vintage sea mines are filled with HE (usually ammonium nitrate and TNT compositions e.g. ammonal or minol), which often remains in sufficiently good condition to detonate to this day; thus they are dangerous.

1.5.2 Fuzing

Sea mines can be armed with complex fuzing and initiation mechanisms, which may be categorised as follows:

- **Hydrostatic Fuzing** – A valve that detects the difference in water pressure (i.e. generated by a passing vessel). Some sophisticated German WWII mines had this type of fuzing;
- **Magnetic Fuzing** – A fuze that detects a displacement of the ambient magnetic field, normally by the introduction of a ferrous metal object (such as a passing vessel);
- **Sonar Fuzing** – Based upon a similar principle as radar (i.e. "Doppler Shift'), whereby any "positive shift" (i.e. closing), underwater sonar signal to the sea mine, is interpreted as a potential target vessel and therefore the arming sequence is initiated.
- **Contact Fuzing** - The externally mounted chemical horns (or spikes), consisted of a lead outer sheath, which contained two separated chemical ampoules. Upon contact, the external horn would crumple, thereby crushing the ampoules and allowing the chemicals to mix. The resultant mixture would immediately produce either an electrical charge or combustion, forming the basis for an explosive chain-reaction and the detonation of the bulk high explosive contained within the main body of the mine. The older generation of moored sea mines were, more commonly, designed to function upon contact with a ship or vessel.

1.5.3 German Influence Mines

After completing their initial sea mine campaigns, the German military sought to exploit the potential value of so called "influence mines", which could be laid by aircraft. The mine was fabricated from aluminum and was cylindrical in shape with a rounded nose. Originally designed as a magnetically triggered sea mine, the two (German) designations were Luftmine A (LMA) and Luftmine B (LMB), which were 500 kg and 1,000 kg masses and 1.7 m and 2.6 m long, respectively. They were in fact modified land mines, which could be easily modified for deployment by surface craft. Although LM series of mines had a range of different initiation devices, the basic design appears to have changed little throughout WWII.

When used as parachute mines, they were armed by a clockwork fuze mechanism (although such mechanisms are considered highly unlikely to be in working order today, the HE in the adjacent fuzes remain sensitive and potentially, highly dangerous).

They were very widely used by the Germans during WWII with devastating results. The firing system was most commonly initiated by magnetic influence, but acoustic types were also used, sometimes in combination with magnetic influence (i.e. both influences were required to initiate the mine). Later in WWII, water-pressure sensing initiation systems were also developed.

The primary disadvantage of employing air delivered varieties of influence mines against shipping, was their low rate of descent which was deliberately retarded by parachute; (otherwise they may have broken up upon (un-retarded) impact with the water). It was therefore very difficult to emplace them with any accuracy, e.g. into known shipping lanes. To enhance delivery accuracy, the mines had to be dropped from a relatively low altitude, which made the deploying aircraft more vulnerable to anti-aircraft fire. These problems were probably the main reason for the Luftwaffe's development of the BM mine series, the first variant of which was dropped in the same manner as a conventional HE bomb i.e. in free-fall without any retarding features.

1.6 Depth Charges

The depth charge was designed to counter the threat posed by submarines/U-Boats. The generic design resembles a drum containing HE with a hydrostatic fuze, which initiated the main charge at a preset depth (as a result of the ambient water pressure). They were fired from the stern or sides of ships (or a combination of both). As the war progressed, the Royal Navy introduced the so-called "Hedgehog" and "Squid" systems, which enabled their depth charge to be fired forward from the bow of the ship (which were also known as forward throwing charges).

Depth charges varied in size (from 55 kg to 300 kg) and consequently the mass of HE changed to suit the type of target being attacked. Towards the end of WWII the RN were using a "Mark X" depth charge, which contained 1,000 kg of explosives; they were fired from tubes mounted on the decks of war-ships.

1.7 Air-Delivered Weapons

1.7.1 Iron Bombs

Generally, most iron (i.e. air-delivered) bombs are of similar generic construction, consisting of a steel container, a fuze either located in the nose/tail of the bomb or located laterally (though sometimes in combined locations), and a stabilizing device (i.e. the bomb "tail" to aid accurate aerodynamic flight from the aircraft to the target). The steel container (i.e. the bomb body) contains either the HE content (or other contents e.g. sub-munitions).

Iron bombs are designed in broadly similar shapes (with some variations to give shape/angle), but in a much wider variety of masses, depending on the intention of the bombing mission and the targets. Iron bombs are generally categorised as follows:

- **General Purpose** – Designed, as the name suggests, to attack a variety of targets and they normally contain an explosive content of approximately 50% of the overall mass of the bomb.
- **Armour Piercing** – Designed to create a mechanically driven entry point in the target prior to detonation, in order to maximise the consequent blast and fragmentation effect. Bunker busting systems, anti-shipping, anti-armoured fighting vehicle and counter-tunnel systems are good examples of the tactical deployment of armour piercing bombs. In general, only 30% of the overall mass contains HE with the remaining 70% made up of steel (in order to maximise penetration and any subsequent fragmentation effect). Armour piercing bombs are always fitted with tail-fuzes.
- **Anti-Submarine** – As the name suggests, primarily designed to attack known underwater targets. These types of bombs are always equipped with a tail fitted hydrostatic fuse and 85 – 90% of the overall mass consists of HE.
- **Incendiary** – These are normally constructed of a thin metal casing containing a thermite (manganese/aluminium) compound. Generally, once the compound is exposed to oxygen, an instantaneous combustion takes place with the heat generated reaching in excess of 800°C. These bombs were often targeted against high concentrations of industry, general urban development and shipping.
- **Fragmentation** – Fragmentation bombs are normally deployed to maximise the secondary effects of an explosion. The bomb is generally constructed from thick (sometimes segmented), steel, designed for maximum fragmentation effect. Fragmentation bombs are generally deployed against "soft" unprotected targets.

The larger size high-explosive varieties were used against shipping i.e. 1,000 kg mass and greater, (compared with the smaller bombs (e.g. 50 kg and 250 kg variants), which were often used during "carpet-bombing" campaigns on land).

Annex C

Semi-Quantitative Risk Assessment

Contents

1 Semi-Quantitative Risk Assessment

1.1 Overview

In undertaking a series of Semi-Quantitative Risk Assessments (SQRA) across the project, we have employed the technical data associated with the items presented within this report and the proposed operation. The following sections outline transparently the methodology and calculations used in conducting the SQRA for the project. Risk assessment tables are presented separately, in the main report.

1.2 Risk Rating

For the purposes of this report, **Risk** (R) is a function of **Probability** of occurrence (P) and **Consequence** of occurrence (C), where R = P x C. In each case, the Probability and Consequence of the identified threats has been assessed on a scale of 1 to 5. (Where 1 = Very Low, & 5 = Very High) based on expert judgement. These ratings are multiplied together to create Risk scores with a maximum of twenty-five. This allows relative weighting and comparison of risk across the project. Colour coding is provided for ease of use, grouping figures in Green as Low Risk, in Yellow as Medium Risk and Red as High Risk.

Probability							
	Very High	**5**	5	10	15	20	25
		4	4	8	12	16	20
	Medium	**3**	3	6	9	12	15
		2	2	4	6	8	10
	Very Low	**1**	1	2	3	4	5
			1	**2**	**3**	**4**	**5**
			Very Low		Medium		Very High
					Consequence		

Table 1.2 – Risk Matrix

1.3 Risk Rating Criteria

It is important that the numerical values assigned to the potential probability and impact of a risk match the risk tolerance of the Client**.** *Table 1.3* outlines the risk rating rationale that has been applied in this analysis:

Risk Rating (P x C)	Grading	Risk Appetite (Tolerance)	Action Required
1-5	**Low**	Tolerable or Partly Tolerable	Little/No specific Risk Mitigation Required. Situation should be monitored. Reactive UXO risk mitigation required during operations, but overall, residual risks are carried.
6 - 12	**Medium**	Intolerable	Advance Mitigation Measures should be considered. Situation should be monitored. Risks to be mitigated subject to the mitigation being reasonable, practical and affordable. Note: High Consequence or High Probability that score as Medium Risk events should be afforded the same status as Highly Intolerable but assessed on a case-by-case basis.
15 - 25	**High**	Highly Intolerable	Risk Mitigation Measures should / will be implemented. All risks to be mitigated.

Table 1.3 – Risk Tolerability Table

The risk levels are used to determine the level of mitigation required to reduce the risk to conform with the ALARP principle. In producing the risk mitigation strategy the risk levels are benchmarked against the various degrees of tolerability (shown in *Table 1.3* above), in order to determine what degree of risk is considered acceptable.

1.4 Definition of Consequence and Probability

As is accepted practice in formalised Risk Management, the Risk Rating scales are dimensionless, allowing the user to apply these methods to any desired terminology in order to fit their discrete needs.

1.4.1 Consequence

If the key consequence is financial, then 5 on this scale should equate to the amount of money that will either, stop the contract, close the operation, exceed agreed budget or any other defined critical financial figure. The scale then sub-divides that amount into 5 equal portions down to zero financial impact.

If the key impact figure is the loss of a vessel, then 5 on the scale is equal to total loss of the vessel as an operational asset and the sliding scale represents vessel operational efficiency loss i.e. 1 = loss of 0% to 20% operational efficiency, while 5 = loss of 81% to 100% operational efficiency.

If the critical impact figure is loss of 50% of operational efficiency, then the scale represents loss of between 0% and 50% in 5 equal steps. This can be applied to any number of scenarios.

The critical consequence associated with UXO however is that associated with injury or death. Both are considered unacceptable and therefore such circumstances should be avoided or the risk appropriately managed or otherwise mitigated to ameliorate such a consequence.

1.4.2 Consequences Specific to this Project

The detonation consequence assessment assigns a site-specific consequence level to any potential UXO that may be encountered at the site. This is achieved by combining the UXO impact distance from sensitive receptors, the Net Explosive Quantity (NEQ) of the item and, where applicable, the average water depth range.

A rating system for assigning impact levels has been derived based on the expected effects of a detonation event on each of the receptors identified in the project consequence matrix, which is presented at *Table 1.4.2*. The expected impacts are ranked from 1 (no significant effect) to 5 (major widespread effects / catastrophic).

Impact Level	NEQ	Expected Consequences			
		Human Health	Plant and Equipment	Vessels	Environment
1	*Low Explosive <10kg & High Explosives <5 kg*	Injury requiring medical treatment	No noticeable effect	No noticeable effect	Minor disturbance
2	*High Explosive 5-15 kg*	Lost time injury < 3 days	Slight superficial damage	Slight superficial damage	Significant disturbance
3	*High Explosive 15-50 kg*	Serious debilitating injury	Minor component replacement repair	Repairs - non-structural	Moderate damage to habitats.
4	*High Explosive 50-250 kg*	Localised fatalities	Significant component replacement repair	Repairs – structural	Moderate damage to habitats. Some long term effects.
5	*High Explosive >250 kg*	Multiple fatalities over extended area	Unit destruction	Localised structural failure and collapse	Localised destruction of habitats. Moderate long-term effects.

Table 1.4.2 – Consequence Matrix

1.4.3 Probability

The Probability scale is simply the assessed likelihood of an event-taking place. If units are required, then the scale frequently used on Project Risk Registers may be utilised.

1.4.4 Probabilities Specific to this Project

Based on 6 Alpha's significant experience of assessing the probability of UXO contamination, it is not always possible to present an accurate statistical (or purely quantitative) measure, simply because the base data is largely qualitative i.e. it is drawn from a variety of different historical and environmental sources.

However, 6 Alpha's semi-quantitative approach blends together professionally informed judgements made upon empirical, qualitative evidence and introduces a transparent statistical approach which has been successfully employed on a variety of marine (and land) based sites where the environmental context remains relatively constant and the quantity and type of munitions employed, together with expected failure rates, is recorded.

For this purposes of this study the probability levels presented in the matrix at *Table 1.4.4*, which have been employed together to chart and to code the overarching probability ratings for this specific project:

Probability Level	Probability of Encountering UXO
1	Remote
2	Possible
3	Likely
4	High Likely
5	Almost Certain

Table 1.4.4 – Probability Matrix

6 Alpha have collated, reviewed and analysed the historical data presented in our desk study and conducted a separate assessment based on the levels in *Table 1.4.4* to produce a chart that demonstrates “probability of UXO encounter”. The chart is an important tool not only in informing the subsequent and associated risk management process but also in helping to reduce risks to As Low as Reasonably Practicable (ALARP), because it visually displays areas as false colours, showing which might require UXO risk mitigation as well as others, which might be avoided.

However, there are some limitations associated with practical employment of this chart. Primarily, it should not be used as a “risk chart” as it does not incorporate the construction activities that might be associated with a UXO “encounter”. Moreover, it does not consider the complete threat (i.e. net explosive quantity (NEQ) and fuzing) posed by any particular item. Therefore, this chart cannot address the cause and initiation, nor the likely consequences; therefore it only informs one part of the risk process (i.e. part of the probability element); it does not address potential types of encounter nor the potential consequences.

The UXO threat locations and safety buffering have been produced by digitising *inter alia* historical naval records and/or plotting coordinates provided by third parties. Because much of this data was gathered in a wide variety of circumstances, by different agencies, to different standards, over a long time-frame, some of that data may not be accurate or as detailed as 6 Alpha would like. Nonetheless, this data is the best that can be obtained and although 6 Alpha have relied upon it, and we have employed our best endeavours to ensure that it is both relevant and accurate, we are not responsible for any inherent historical inaccuracies that it might contain.

Notwithstanding this, 6 Alpha have taken all reasonable care to ensure that all base data employed is as accurate as possible and any potential inaccuracies have been taken into consideration in the final “probability” buffering. Moreover, UXO buffer areas also take into consideration potential for drift/movement since the time of UXO placement.