Technical Appendix 5.3

Unexploded Ordnance Threat and Risk Assessment

Offshore EIA Report: Volume 2

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Unexploded Ordnance Threat and Risk Assessment

FLOTATION ENERGY

Project: *Green Volt Offshore Wind Farm*

Meeting the requirements of the UK's Construction Industry Research and Information Association's

UXO Risk Management Framework:

"Assessment and Management of the Unexploded Ordnance Risk in the Marine Environment (C754)"

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This UXO threat and risk assessment is considered a living document. Should the proposed methodologies change, further evidence of UXO sources be found, or if UXO is found during these or other operations, then this assessment for the Study Site is to be reassessed and updated by 6 Alpha Associates Ltd.

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Executive Summary

Project Overview

Flotation Energy has commissioned *6 Alpha Associates* to deliver a desk-based Unexploded Ordnance (UXO) threat and risk assessment to support the development of the *Green Volt Offshore Wind Farm* (OWF) and associated cable installations. A Risk Mitigation Strategy (RMS) has also been commissioned and will be delivered subsequently and separately.

The proposed location of *Green Volt OWF* array, together with the proposed export cable corridors, has been provided by the Client and is presented at Figure 1.

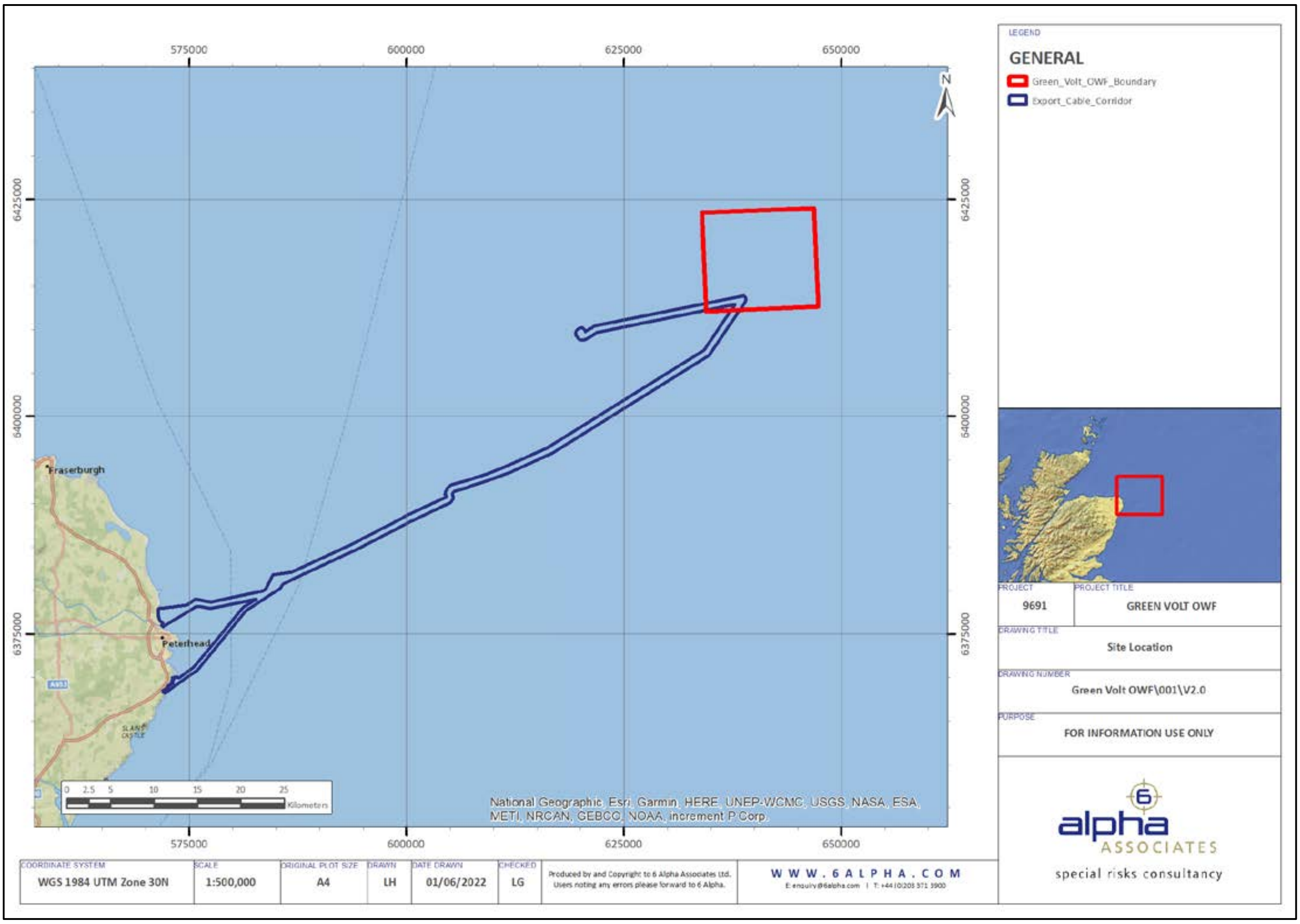

Figure 1 – Site Location

UXO Threat and Risk Assessment Summary

A tabulated summary of the findings of the threat and risk assessment is presented in Table 1:

Intrusive Operation	UXO Threat	UXO Risk (Vessels and Personnel Only)				
		Ultra-Nearshore ~10m LAT	Nearshore ~26m LAT	Shallow Offshore ~40m LAT	Offshore ~60m LAT	Deep Offshore ~100m LAT
Wind Turbine Generator Mooring Operations	Aerial Bombs	N/A: Wind turbine generator mooring and offshore substation platform installation operations will not occur at these water depths.				VERY LOW
	Torpedoes					LOW
	Naval Mines					MEDIUM
	Artillery and Naval Projectiles					VERY LOW
Offshore Substation Platform Foundation Installation Operations	Aerial Bombs					VERY LOW
	Torpedoes					LOW
	Naval Mines					LOW
	Artillery and Naval Projectiles					VERY LOW
Pre-Lay Operations	Aerial Bombs	HIGH	HIGH	MEDIUM	LOW	VERY LOW
	Torpedoes	LOW	LOW	MEDIUM	LOW	LOW
	Naval Mines	LOW	MEDIUM	MEDIUM	LOW	MEDIUM
	Artillery and Naval Projectiles	HIGH	MEDIUM	LOW	LOW	LOW

Intrusive Operation	UXO Threat	UXO Risk (Vessels and Personnel Only)				
		Ultra-Nearshore ~10m LAT	Nearshore ~26m LAT	Shallow Offshore ~40m LAT	Offshore ~60m LAT	Deep Offshore ~100m LAT
Cable Installation and Burial Operations	Aerial Bombs	HIGH	HIGH	MEDIUM	LOW	VERY LOW
	Torpedoes	LOW	LOW	MEDIUM	LOW	LOW
	Naval Mines	LOW	MEDIUM	MEDIUM	LOW	MEDIUM
	Artillery and Naval Projectiles	HIGH	MEDIUM	LOW	LOW	LOW
Protection Operations	Aerial Bombs	HIGH	HIGH	MEDIUM	LOW	VERY LOW
	Torpedoes	LOW	LOW	LOW	LOW	LOW
	Naval Mines	LOW	LOW	LOW	LOW	MEDIUM
	Artillery and Naval Projectiles	MEDIUM	LOW	LOW	VERY LOW	VERY LOW
Enabling Operations	Aerial Bombs	HIGH	HIGH	MEDIUM	LOW	VERY LOW
	Torpedoes	LOW	LOW	LOW	LOW	LOW
	Naval Mines	LOW	LOW	LOW	LOW	MEDIUM
	Artillery and Naval Projectiles	MEDIUM	LOW	LOW	VERY LOW	VERY LOW

Table 1 – Representative UXO Risk Assessment Summary

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UXO Risk Zones

The categorisation of UXO risk is not universal throughout the Study Site, and the zoning of UXO risk is based on several factors, including the nature, scope, and location of UXO threat sources within the proposed OWF array and along the export cable corridors, considering the expected water depths. As a result, there are areas of HIGH, MEDIUM and LOW UXO risks throughout the Site as depicted at Figure 2.

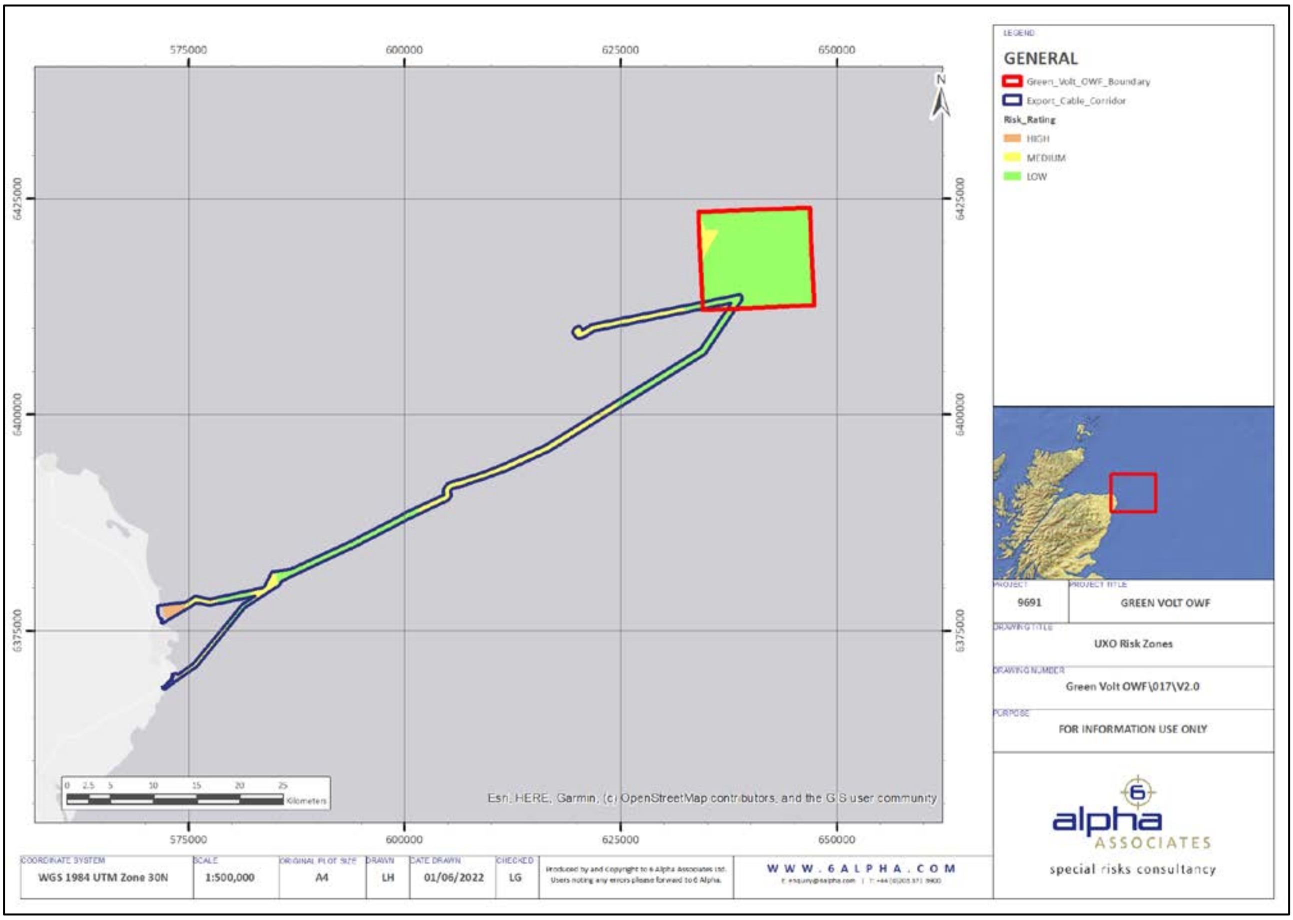

Figure 2 – UXO Risk Zones

Conclusions

The nature and scope of the UXO risks vary across the Study Site, based upon a source-pathway-receptor review in general, as well as the prospective consequences of initiating UXO and an analysis of the probability of encountering and of initiating UXO, in particular. Some UXO risks posed by the proposed operations have been categorised as HIGH because they are associated with the unplanned initiation of threat spectrum UXO – including High Explosive (HE) bombs, naval mines and anti-aircraft artillery projectiles in various areas of the Study Site; such risks are considered intolerable.

The prospective consequences for surface vessels generally reduce, as the depth of water between the vessel and the point of a UXO initiation increases. Nonetheless, the effect of the depth of water upon potential UXO initiation consequences (and *inter alia*, the resultant through-seabed and through-water shock) is unlikely to be wholly risk mitigative in all areas, given the shallow water depths present in the nearshore areas and the historical deployment of large Net Explosive Quantity (NEQ) threats offshore. Nonetheless and generally, the UXO risk is significantly reduced in most offshore areas of the Study Site due to the deep water.

Underwater installation equipment is unlikely to be sufficiently robust to withstand the consequences of an initiation of most large NEQ, threat spectrum UXO (such as HE bombs and naval mines). The prospective UXO risks posed to underwater equipment are therefore classified as HIGH or MEDIUM, in all depths of water where an evidenced UXO threat is present.

Nevertheless, the UXO risk to underwater equipment is likely to be deemed tolerable under the auspices of the As Low As Reasonably Practicable (ALARP) risk reduction principle, as long as such risks do not also pose a hazard to support vessels and their crews. Therefore, LOW category UXO risks have also been defined across large parts of the OWF array and the export cable corridors.

Recommendations

6 Alpha recommend that the UXO risks are mitigated within the bounds of the ALARP risk reduction principle and in accordance with national laws through the implementation of a suitable and cost-effective RMS, which at the time of writing, was being developed by *6 Alpha*.

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Acronyms and Abbreviations

AAA	Anti-Aircraft Artillery
AHT	Anchor Handling Tugboat
ALARP	As Low As Reasonably Practicable
BGS	British Geological Survey
CIRIA	Construction Industry Research and Information Association
cm	Centimetre
DP	Dynamically Positioned
HDD	Horizontal Directional Drilling
HE	High Explosive
JUB	Jack-Up Barge
kg	Kilogram
km	Kilometre
LAT	Lowest Astronomical Tide
LSA	Land Service Ammunition
m	Metre
mm	Millimetre
MMBA	Munitions Migration and Burial Assessment
MPa	Mega Pascal(s)
NEQ	Net Explosive Quantity
OSP	Offshore Substation Platform
OSPAR	Oslo-Paris Convention for the Protection of the North-East Atlantic
OWF	Offshore Wind Farm
PEXA	Practice and Exercise Area
PLGR	Pre-Lay Grapnel Run
pUXO	Potential Unexploded Ordnance
RAF	Royal Air Force
RC	Route Clearance
RMS	Risk Mitigation Strategy
SAA	Small Arms Ammunition
SQRA	Semi-Quantitative Risk Assessment
TARA	Threat and Risk Assessment
TNT	Trinitrotoluene
UK	United Kingdom
UTM	Universal Transverse Mercator
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
WGS	World Geodetic Survey
WTG	Wind Turbine Generator
WWI	World War One
WWII	World War Two

Key Definitions

There are several terms that are used within this UXO threat and risk assessment report, namely:

<u>**Key Industry Definitions**</u>

- **As Low As Reasonably Practicable (ALARP)** – a term used in the management of safety-critical and safety-involved systems. The ALARP principle is that risks shall be reduced as low as reasonably practicable, which is effectively a (UK) legal minimum requirement;
- **Best Practice –** those standards for controlling risk which have been judged and recognised by a regulatory body as satisfying the law, when those standards are applied in an appropriate manner;
- **Competency –** a person or organisation with sufficient training, experience, and knowledge;
- ***De Minimis*** – an abbreviated form of the Latin maxim *de minimis non curat lex*, "the law cares not for small things". In terms of risk management, risks that are defined as too small to be of concern and exempt from further consideration; the purpose being, to avoid a disproportionate use of finite resources by mitigating a virtually inexhaustible supply of insignificant or low-level risks;
- **Hazard** – anything that has the potential to cause harm or damage;
- **Precautionary Principle –** an action with the potential risk to cause harm or damage without certainty or scientific consensus that the action is not harmful or damaging. The burden of proof that the action is not harmful or damaging falls upon those undertaking risk assessment and taking risk mitigation action;
- **Risk –** the intentional interaction of something of value with the potential for danger, harm, or loss;
- **Risk Assessment** – a systematic process of identifying and evaluating the potential risks of an action or undertaking;
- **Threat** – anything that has the potential to cause harm or damage, but especially UXO;
- **Uncertainty –** an unknown element that is not fully understood to properly inform the decision-making process;
- **Unexploded Ordnance (UXO)** – any unexploded munition with an explosive or chemical fill that failed to initiate and poses a risk of causing harm or damage.

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Key Historical Definitions

- **Allies (WWI)** – the alliance between the *British Empire*, *France*, *Russia,* and the *USA*, though many other "associated powers" are sometimes labelled collectively as the "Allies";
- **Allies (WWII)** – the alliance between the *British Empire*, *France*, the *Soviet Union,* and the *USA*, though many other "associated powers" are also sometimes labelled collectively as the "Allies";
- **Axis** – the alliance between *Germany*, *Italy*, and *Japan* during WWII;
- **Central Powers** – the alliance between the *German Empire*, *Austria-Hungary*, the *Ottoman Empire* and *Bulgaria* during WWI;
- **Grand Fleet** – the main *British Royal Navy* fleet of ships during WWI;
- **High Seas Fleet** – The name of the battle fleet of the *German Imperial Navy* that was created in 1907 and saw action in WWI;
- **Luftwaffe** – the official name of the *German* air force between 1933 and 1946;
- **Kriegsmarine** – the name given to the *German* navy between 1935 and 1945.

Part I – Introduction

1 Project Overview

1.1 Scope of Work

Flotation Energy has commissioned *6 Alpha Associates* (6 Alpha) to deliver a desk-based Unexploded Ordnance (UXO) threat and risk assessment associated with Offshore Wind Farm (OWF) array and cable installation works within the bounds of the *Green Volt OWF* and the export cable corridors, up to the high-water mark – though historical UXO data relating to the onshore section is also included for analysis where it is deemed relevant to the offshore environment. A Risk Mitigation Strategy (RMS) has also been commissioned and will be delivered subsequently and separately.

1.2 Project Location

The project is located in the *North Sea*, with the OWF array situated approximately 75km to the north-east of the *Scottish* coast. Two export cable routes have been defined for the project, the first supplying the nearby *Buzzard Oil Field* and the second making landfall at one of two proposed locations near *Peterhead, Aberdeenshire*. The proposed location of the *Green Volt OWF*, together with these export cable corridors, is presented at Figure 1.2 below, as well as in Appendix 1.

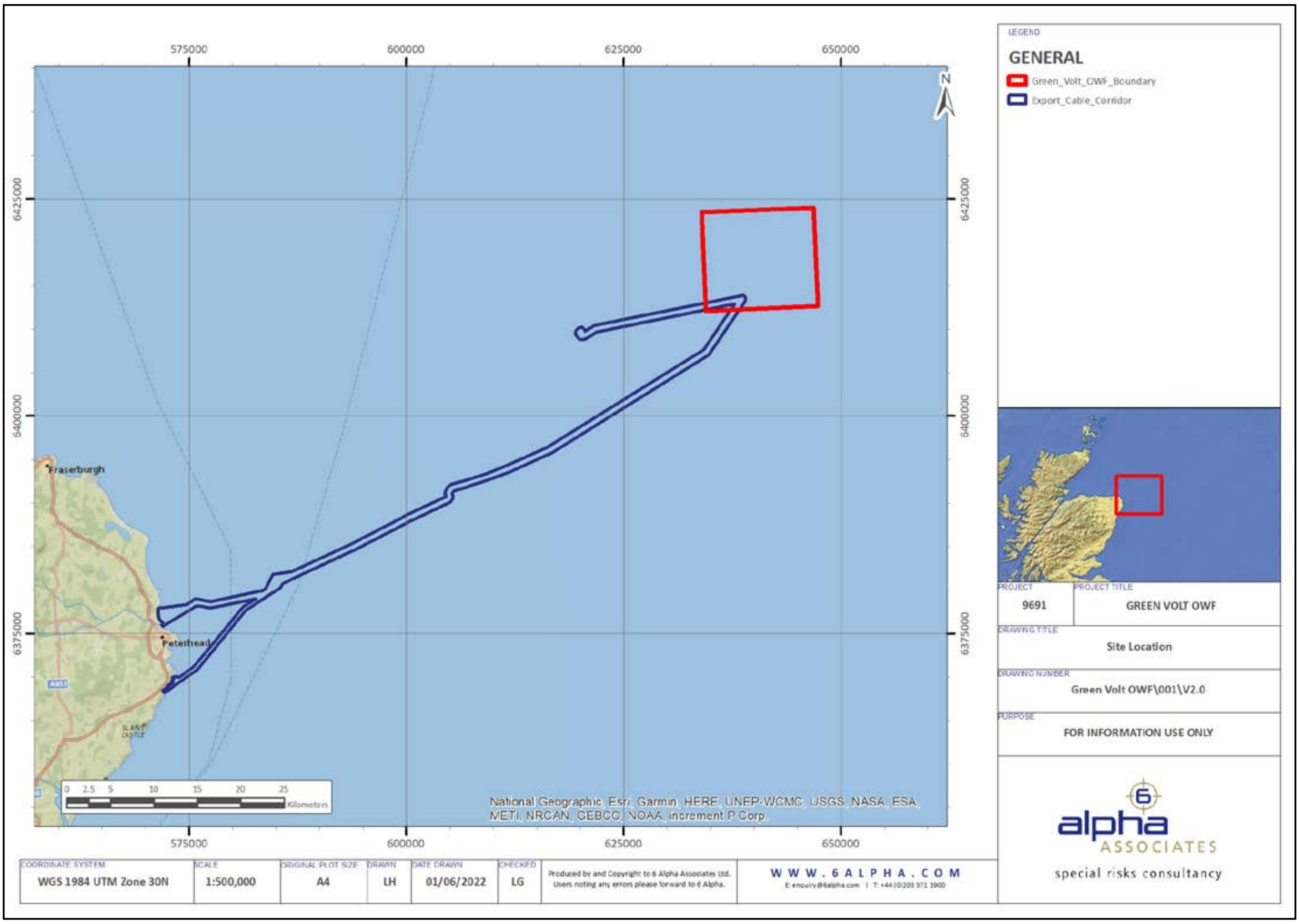

Figure 1.2 – Site Location

2 Introduction to UXO

2.1 UXO in the Marine Environment

All military technology has an inherent base-line failure rate, meaning that not all ordnance functions as the designer intended, during either its training or operational use. Consequently, the military activities and conflicts of the 20th Century have left a legacy of munitions contamination in the marine environment, and it is now a relatively common occurrence to encounter UXO during seabed intrusive activities.

2.1.1 Generic UXO Threats

In the offshore environment, there are multiple factors which may have contributed to the UXO contamination because of the warfighting activity in the region. For example, it is generally accepted that during WWII, approximately 10% of Axis aerially delivered bombs failed to explode – Allied bomb failure rates are estimated to be slightly higher. Offshore and onshore bombing targets were also simply missed, and bombs were sometimes jettisoned from aircraft when evading an adversaries' attacks and/or when seeking to reduce aircraft weight during a return journey, to deliver a higher safety margin when landing.

Wartime training and operations also employed live munitions filled with high explosives (as well as other substances and materials including toxic chemicals or ignition/burning agents in incendiary bombs), which may have remained after the training exercises and operations had been completed. During the conflicts of the 20th century, sea mines were deployed in significant quantities in both offensive and defensive naval operations and their residue poses a further UXO contamination threat to intrusive sub-seabed activities in the marine environment. Conventional and chemical munitions dumping was also prevalent in these periods with little consideration given to future safety implications. There was also widespread unrecorded dumping of Small Arms Ammunition (SAA) and Land Service Ammunition (LSA) that was not only perceived to be inconsequential, but also undertaken without regard to munitions dump positional accuracy – resulting in so-called "short dumping". Some dumped munitions may also have migrated from their original locations because of natural seabed sediment transportation and other forces. Modern military training areas, such as offshore firing ranges, may have also contributed to the background UXO contamination in the offshore environment.

Besides the clearance of naval minefields to open sea lanes, minimal effort was made in the immediate post-war periods to clear the unexploded bombs and projectiles that contaminated the seabed. As such, unexploded munitions relating to previous conflicts, but particularly WWII-era munitions, often pose a considerable contamination threat source in the marine environment.

2.1.2 Generic UXO Risks

The explosive or chemical fill within UXO rarely becomes inert or loses its effectiveness with age, but the explosive fill may change or crystallise over time – increasing the high explosive's sensitivity to a physical shock or an impact. Trigger mechanisms and fuses, which may have failed, may corrode and deteriorate in the saltwater environment becoming more sensitive to detonation. It is therefore possible that a significant impact on the UXO case, and the resultant effect upon the fuse, may cause its inadvertent detonation.

Prospective UXO incidents that may result in harm are generally considered low probability-high consequence events, which present a challenge when designing project, public and commercial safety policies. Nonetheless, there are clear safety risks associated with UXO encounters for any subsea operation that interacts with the seabed. UXO risks must be considered and managed to protect offshore personnel from injury or, in the very worst-case scenario, prospective fatalities. Such risks must also be considered, to fulfil Clients' statutory obligations under the auspices of national laws.

Further information regarding national and international legislation, and the management and reduction of UXO risk to As Low As Reasonably Practicable (ALARP), is presented at Annex A and is indicative of the safety benchmark to which *6 Alpha* adhere.

2.2 UXO Industry Best Practice

The *United Kingdom's (UK) Construction Industry Research and Information Association* (CIRIA) has published a best practice guide for the assessment and management of UXO risk in the marine environment (document reference C754, first published in February 2016). This guide not only has significant and wide-reaching offshore industry recognition, but also has been formally endorsed by the *UK*'s *Health and Safety Executive* and subsequently, by other regulatory bodies internationally. *6 Alpha* were *CIRIA's* lead technical author for this publication and as such, it guides *6 Alpha's* UXO risk management practices. *CIRIA* C754 guidance has been successfully employed on similar projects throughout the *UK*.

Therefore, in undertaking this assessment *6 Alpha* has not only brought to bear our offshore UXO risk management expertise and technical experience, but we have also benchmarked our delivery of offshore service provision with the *CIRIA* C754 guide, to ensure compliance with industry best practice and to manage UXO risks in accordance with ALARP risk reduction criteria.

Nonetheless, whilst the *CIRIA* guide outlines "what" steps are to be taken to manage the UXO risk, it lacks detail concerning "how" these steps are to be executed, to reduce such risks to ALARP. Where such finer detail is lacking in the *CIRIA* guidance, *6 Alpha* has filled those gaps through the careful and appropriate application of our UXO risk management strategic framework.

2.3 UXO Risk Management Strategic Framework

To manage and to ameliorate prospective UXO risks, *6 Alpha* has developed a detailed UXO risk management strategic framework that is not only in line with *CIRIA* guidance but also, is in accordance with ALARP risk reduction principles. At Section 5 of *CIRIA's* C754 guide, the risk management framework is divided into five key phases that correspond with those employed by *6 Alpha*, as presented at Table 2.3. A complete overview of *6 Alpha's* UXO Risk Management Framework is presented for completeness, at Appendix 2.

6 Alpha Risk Management Framework	UXO Risk Management Phase	CIRIA C754 Risk Management Framework	Delivered within Report? (✔/✘)
UXO Threat Assessment	**PHASE ONE**	UXO Threat Assessment	✔
UXO Risk Assessment	**PHASE TWO**	UXO Risk Assessment	✔
Strategic Risk Mitigation Options	**PHASE THREE**	UXO Risk Management Strategy	✘
Risk Mitigation Design and Specification	**PHASE FOUR**	UXO Risk Mitigation (Planning)	✘
Implementation	**PHASE FIVE**	UXO Risk Mitigation (Delivery)	✘

Table 2.3: *6 Alpha* and *CIRIA* UXO Risk Management Frameworks

Notwithstanding *CIRIA's* guidance, purpose of this report is to address Phases One and Two of the UXO risk management framework. This framework is applied to provide a holistic solution for managing UXO risks to ALARP, as per Appendix 3.

The potential nature and scope of the UXO threat is addressed initially (Phase One), before the potential UXO risk pathways are identified and analysed to assess the UXO risks associated with the proposed operations (Phase Two).

Once the associated UXO risks have been assessed, recommendations are outlined to offer early guidance on fulfilling Phase Three of the UXO Risk Management Framework. An RMS has been commissioned and will be delivered separately to this assessment.

2.4 Source – Pathway – Receptor Model

The source-pathway-receptor model is a conceptual risk model employed by *6 Alpha* across all marine projects (as per *CIRIA* guidance and industry best practice), that informs how UXO risks are assessed for each seabed intrusive activity associated with the project. The model also helps to explain the link between the separate sections of this report and the UXO risk assessment at Section 8. The components of the model are as follows:

2.4.1 UXO Sources

The nature and scope of the UXO threat is summarised in the UXO threat assessment (at Section 5) and it forms the source element of the source-pathway-receptor model.

2.4.2 UXO Pathways

The UXO pathways are the routes by which the sources can reach the receptors. Marine UXO pathways are likely to be either by contact and/or through soil or water energy transfer, through which the resulting shock wave (generated by a UXO source, or sources) may reach potential receptors. Nonetheless, surface events (e.g. if UXO is inadvertently brought back to the vessel and is initiated), may also generate a through-air risk pathway in which blast and fragmentation from the UXO sources may also reach the receptors.

UXO risk pathways may be generated by a variety of operations that interact with the seabed. Therefore, likely operations have been assessed and summarised (at Section 6), to demonstrate the potential risk pathway elements of the model.

2.4.3 UXO Receptors

Receptors are defined as anything which might be adversely affected by the consequences of an inadvertent detonation of any UXO source through an identified pathway. The proximity, robustness, and sensitivity of such receptors is essential in determining their capacity to withstand such high explosive effects and defining what degree of UXO risk might be tolerated (if any). For example, risks to underwater equipment might be tolerated by some (or all) stakeholders but risks to personnel that might generate injuries (in general) and fatalities (in particular), are highly unlikely to be considered tolerable.

Typically, offshore receptors include, but are not limited to, subsea equipment and infrastructure; as well as underwater (e.g. Work-Class Remotely Operated Vehicle) and surface vessels, and where appropriate, their crews. Divers are also especially vulnerable to underwater high explosive effects, as are marine mammals and fish.

3 Scope and Structure of the UXO Risk Assessment

3.1 Report Structure

This report comprises a desk-based collation and review of readily available documentation and records (which have been summarised separately in Section 3.2), relating to the types of UXO that might be encountered in order to assess the potential UXO risks at the proposed OWF array and within the export cable corridors. The threat and risk assessment element of the report is presented in Part II, including conclusions and recommendations to ensure that UXO risks are reduced to ALARP.

Therefore, the report has been structured to summarise the relevant data and to present the UXO threats. The following aspects will be covered in the assessment:

- The sources of prospective UXO contamination that might be encountered at the Study Site will be summarised;
- A variety of options for prospective floating Wind Turbine Generator (WTG) mooring, Offshore Substation Platform (OSP) installation, cable installation and burial, and associated enabling operations will be outlined;
- An assessment of the water depths (in terms of Lowest Astronomical Tide (LAT)) across the extent of the site will be considered, in order to assess the prospective UXO detonation consequences;
- The likely UXO risk receptors will be identified;
- A Semi-Quantitative Risk Assessment (SQRA) will be undertaken;
- Conclusions will be drawn, and recommendations made, in order to articulate any necessary steps required to address the prospective UXO risk to the project.

3.2 Information Sources

The information sources employed for this threat and risk assessment have been sub-divided into two categories, namely:

3.2.1 Specific Sources of Information

6 Alpha have been supplied with the following documents by the Client that relate to various aspects of the project to date, as follows:

- Marine Scotland – Licensing Operations Team, *Scoping Opinion for Green Volt Offshore Windfarm*, April 2022;
- Nexen Petroleum UK Ltd, Ettrick and Blackbird Decommissioning Programmes, Revision U2, 20th December 2016;
- Royal Haskoning DHV, Report Reference: PC2483-RHD-ZZ-XX-RP-Z-0001, *Green Volt Offshore Windfarm - Offshore Environmental Impact Assessment: Offshore Scoping Report*, 15th November 2021.

3.2.2 Generic Sources of Information

6 Alpha has employed the following generic sources of information (amongst others) to inform and to compile this report:

- *Aberdeenshire Historic Environment Record;*
- *British Geological Survey (BGS)*;
- *European Marine Observation and Data Network*;
- *James Martin Centre for Nonproliferation Studies*;
- *Joint Nature Conservation Committee*;
- *NatureScot*;
- *Naval Historical Centre* at *Portsmouth*;
- *Oslo-Paris Conventions for the Protection of the North-East Atlantic (OSPAR)* databases;
- *Royal Navy* (Diving Units);
- *UK National Archives* at *Kew*;
- *UK Hydrographic Office* at *Taunton*.

6 Alpha's "Azimuth" database also contains digitised historic charts, aerial photographs and other extensive analogue records from an exhaustive range of additional national, regional and global archives and/or data sets that have also been digitised. That database has been heavily drawn upon to deliver the UXO threat assessment element of this report.

3.3 Constraints and Limitations

This UXO threat and risk assessment is constrained and limited by that information which is reasonably available to *6 Alpha* at the time of writing, as well as that UXO information that is reasonably accessible in a variety of archives, which *6 Alpha* have digitised and georeferenced or have otherwise summarised in written form.

This document may also require updates and changes, especially wherever and whenever the circumstances and factors associated with assessing UXO risk change. For example, if UXO threats are subsequently discovered and they are different from those that have been anticipated, and/or if proposed subsea operations are significantly changed.

In such circumstances, risks may require re-evaluation and any such changes are to be made by *6 Alpha*, to ensure the continued technical veracity and risk management efficacy of this document.

4 Risk Assessment Methodology

4.1 Overarching Methodology

The SQRA is specifically designed to assess the probability of an unplanned discovery and initiation of UXO, as well as their prospective consequences upon a range of potential sensitive receptors (e.g. surface vessels and any associated underwater equipment), in order to determine the level of UXO risk for each intrusive activity. The SQRA assessment achieved by employing the following formula, which is further described at Section 4.3:

Risk **(R)** = Probability **(P)** x Consequence **(C)**.

The risk assessment has been conducted for all types of operations, irrespective of the prospective risk mitigative effect of any prior operations which by then, may have preceded them.

A full explanation of *6 Alpha's* SQRA process is presented at Annex B.

4.2 The Precautionary Principle

Making predictions about the yet unobserved states of UXO, generates uncertainties within the risk assessment, especially when determining the probability of UXO initiation. The probability of UXO encounter and of its initiation is therefore steered by the precautionary principle that, for risk assessment and mitigation purposes, informs risk-mitigating actions in such circumstances.

The principle concludes that if there is uncertainty about the nature of the risk (e.g. but not limited to, the condition and viability of UXO), then a proportionate, transparent, and consistent approach must be taken during the decision-making process that aligns with industry best practice. Therefore, for risk assessment and precautionary purposes, it is assumed any direct kinetic energy encounter with UXO associated with the likely operations presented within Section 6, is likely to cause its initiation and generate a potential UXO risk pathway.

4.3 Risk Assessment Variables

The UXO risk level at the Study Site has been determined by considering the following factors:

4.3.1 Probability

Probability is determined by considering the likelihood of both encountering and initiating UXO.

The probability of encountering UXO is a function of the prospective nature, scope, and extent of the prospective UXO contamination at the area of search (which has been evidenced separately at Section

5) and the juxtaposition of all sub-seabed intrusive activities with respect to them. Nonetheless, the numbers, extent, and locations of all prospective UXO threats are difficult to accurately quantify due to the nature of historical records associated with depositional events (such as, and especially; unrecorded and abandoned ordnance; and/or Anti-Aircraft Artillery (AAA) gun fire; and/or jettisoned aerial High Explosive (HE) bombs that cannot be spatially defined with either certainty or accuracy). Such uncertainty is accounted for by employing the precautionary principle.

4.3.2 Consequence

The consequences of an unplanned UXO initiation are a function of the mass of high explosives in the UXO and their proximity to, and robustness of, sensitive receptors - including the support vessels, their crews as well as subsea equipment/tools.

The mass of high explosives and their underwater and/or surface effects can generally be either estimated or accurately modelled. Other assessment factors include but are not limited to; the prospective position of the UXO on the seabed at the moment of its encounter (i.e. on the surface or partially/completely shallow buried - and in the latter case to what depth), the soil type, the through soil and through water/air separation distances between the UXO; and the robustness of such receptors.

The likely through-water and/or through-air effects upon such receptors are dependent upon their juxtaposition with reference to the UXO as well as their robustness in general and their capacity to withstand such a high-explosive events in particular. Generally, personnel are very vulnerable to high explosive fragmentation, as well as underwater shock and to a reduced extent surface-blast. As long as workers are not jeopardised, limited adverse effects upon vessels, barges and subsea equipment might be tolerated.

Part II – UXO Threat and Risk Assessment

5 Sources of UXO Contamination

Significant archive research associated with the Study Site has been undertaken to corroborate and to highlight, any and all potential sources of UXO contamination as well as to assess their likelihood of encounter. This assessment is therefore, based upon defined UXO geospatial threat source positions and the anticipated level of contamination from background UXO threats situated upon and within an appropriate distance of the Study Site. Such potential sources of UXO are summarised in Table 5.1.

Potential Sources of UXO (within 5km)	Likelihood of UXO Contamination	Associated UXO Threat Items
Aerial Bombing	**Likely:** Significant aerial bombing was documented at *Peterhead* during WWII.	HE Bombs
Naval Engagements	**Unlikely:** Although, there is evidence of limited submarine activity across the Study Site.	Naval Projectiles and Torpedoes
Naval Minefields	**Likely:** The Study Site was intersected by three large WWI and WWII-era minefields.	Naval Mines
Military Practice and Exercise Areas	**Highly Unlikely:** Neither historic nor modern military training areas were recorded intersecting the Study Site.	N/A
Coastal Armaments	**Possible:** Several coastal armaments were recorded around *Peterhead*, with firing arcs intersecting the nearshore sector of the Study Site.	AAA Projectiles
Munitions Related Shipwrecks and Aircraft	**Unlikely:** Although, 11 munitions related shipwrecks were documented within 5km of the Study Site.	Shipwreck Related Munitions
Munitions Dumping (within 10km)	**Highly Unlikely:** No munitions dumps were recorded within 10km of the Study Site.	N/A

Table 5.1: Summary of Potential UXO Sources within 5km of the Study Site

The core types of UXO threats that have been summarised in Table 5.1 are presented in detail subsequently and they will be subjected to a risk assessment, based upon the proposed operations outlined at Section 6. Background information detailing generic military ordnance and UXO classification, as well as their associated high explosive and prospective detonation effects, is presented separately at Annexes C and D, respectively.

It is also important to note that the summary provided in Table 5.1 illustrates the highest level of threat generated by each prospective UXO contamination source. Not all contamination threats are generated across the entire Study Site and nor is there a universal likelihood of encountering each specific type of UXO threat. Table 5.1 is intended as a summary of the key findings, which are subsequently detailed and refined throughout this section.

5.1 Aerial Bombing

Air dropped bombs may be encountered in areas where conflict and/or an air campaign has occurred, although the precise locations of bombing raids and aerial attacks have not always been accurately documented - especially in the offshore environment. In addition, offshore bombing ranges have also been employed by military air forces which may also have contributed to the contamination of the marine environment.

A georeferenced overview of the aerial bombing threat in relation to the Study Site is presented at Appendix 4.

5.1.1 German Aerial Bombing

There is evidence to suggest that *German* WWII-era aerially delivered HE iron bombs may pose a direct UXO contamination threat at the Study Site, particularly in the nearshore sector of the export cable corridors. For example, prior to WWII the *Luftwaffe* conducted numerous aerial photographic reconnaissance missions over *Britain*, recording key military, industrial and commercial targets for attack, in the event of war. An analysis of *Luftwaffe* aerial photography and target documents identified *Royal Air Force (RAF) Peterhead* as a primary bombing target, which was situated 3.9km to the west-south-west of the export cable landfall point.

Historical records of aerial bombing raids over *Scotland* indicated that *Peterhead* (situated between the likely export cable landfall points) was subject to at least 28 major air raids over the course of WWII and is commonly considered to be the second most bombed location in the *UK*, behind *London*. Following the *German* occupation of *Norway* in 1940, the *Luftwaffe* were able to operate from air bases in *Scandinavia* with *Peterhead* being one of the first major settlements on their flight paths to the *UK*. The most intensive air raids were clustered around the town and its port infrastructure, although isolated bombing incidents were also noted in the wider area at both *Cruden Bay* and *St Fergus* (situated 3km to the north-west and 6km to the south-west, respectively).

As well as onshore targeting, *Allied* shipping was also deliberately targeted by *Luftwaffe* bombing aircraft during WWII, which might also have generated an Unexploded Bomb (UXB) contamination threat offshore. *Allied* shipping was commonly targeted while traveling along the east coast of *Scotland* and as such, it is unsurprising that at least seven bombing incidents were documented within 5km of the nearshore export cable corridors. Two of these incidents were recorded as likely occurring on-site in September and October 1940 against an unspecified shipping convoy and the *SS St Glen*, the latter vessel eventually sinking approximately 9km to the south-east.

The threat posed by *German* UXBs is most significant in the nearshore areas around *Peterhead*, although it is still possible (though not highly likely) that *German* UXBs could be encountered in offshore areas of the Study Site due to the bombing incidents recorded above.

5.1.2 British Aerial Bombing

There is little evidence to suggest that *British* aerial bombing would have generated a direct UXO contamination threat at the Study Site. Nonetheless, there is a residual, but largely unquantifiable, UXO contamination threat posed by prospective bomb-jettisoning activities associated with the military airfields situated in *Scotland*, including *RAF Peterhead* (situated 3.9km to the west-south-west), *Royal Naval Air Station Rattray* (9.8km to the north-west) *and RAF Fraserburgh* (16.6km to the north-west).

HE bombs were sometimes jettisoned at sea by military aircraft that were returning to land at airfields to ensure that for safety purposes, aircraft did not attempt to land with live bomb loads onboard that might take the aircraft beyond their weight limits designed to ensure a safe landing. Nonetheless, such a threat remains almost impossible to quantify without such instances being recorded (and often, such events were either inaccurately recorded or, more commonly, were not recorded at all).

5.2 Naval Engagements

The combatant navies of the 20th century commanded fleets that consisted of armed surface craft such as destroyers and battleships, as well as more covert craft such as submarines and motor torpedo boats – all of which were armed with a variety of weapons systems. Thus, the nature and the scope of naval engagements that were fought throughout the 20th century varied significantly from encounter-to-encounter and were dependant on the types of vessels involved. As with aerial bombardment in the offshore environment, the specific locations of the majority of naval engagements were neither commonly nor accurately recorded in contemporary records.

Such evidence is readily presented by an analysis of *6 Alpha's* in-house *Azimuth* database, however, which includes two such shipwrecks located within 500m of the export cable corridors that are indicative of historic naval engagements. The *British* cargo ships *SS St Magnus* and *SS Muriel* were both sunk by the *German* submarine *UC-58*, which torpedoed each vessel in 1918, 190m to the south and 325m to the south-east of the export cable corridor, respectively. In addition, a further six WWI-era shipwrecks resulting from submarine torpedo fire or else scuttled by gunfire and/or explosive charges.

Consequently, it is possible that naval projectiles and torpedoes might have contaminated the seabed resulting from these engagements. The prospective magnitude of these threats is however, reduced somewhat by the limited nature of these military skirmishes as well as the operational capacity of most submarines and the relative rarity of WWI ordnance encounters in the marine environment today.

The geospatial extent of the contamination threat relating to naval engagements in the wider area is presented at Appendix 5. Further corroborating evidence of the nature and scope of the naval engagements and the shipwrecks that were generated as a result, are presented at Section 5.6.

5.3 Naval Minefields

A naval sea mine is a self-contained high-explosive weapon that is placed in the water to destroy ships and/or submarines. All mines were fused so that they detonated, either upon impact or otherwise upon a close encounter with a ship. During the conflicts of the 20th century, naval mines were generally employed either offensively, to hamper enemy shipping and to blockade harbours; or defensively, to protect shipping and by creating safe movement zones through them.

During WWI and WWII, defensive minefields were often laid by surface craft, whereas offensive minefields were often laid by aircraft or submarines - the latter therefore delivering an element of secrecy to the positions of the mine-laying operations. Minefields that were deployed by aircraft or submarines, were also less likely to be accurately recorded than those laid by surface vessels and as such, the exact positions of these types of mine lays are difficult to corroborate with any degree of certainty.

Nonetheless, there is evidence to suggest that naval mining poses a potential UXO contamination threat at substantial portions of the Study Site.

5.3.1 WWI Minefields

Detailed desk-based research of historical records and charts has indicated that two large *Central Powers* minefields extended across the nearshore and central sectors of the export cable corridors. Historical records associated with these minefields suggest that they together comprised at least 126 mines, which are considered likely to have been of the E-variety, as these were the standard *German* contact mine employed during WWI. Two wartime shipwrecks resulting from WWI-era mine encounters were documented within these minefields, in close proximity of the export cable corridor; the *FV Bel Lily* (situated 195m to the north) and the *FV Windward Ho* (situated 3.9km to the south-east). Both vessels struck *German* submarine-laid mines in 1917.

Despite the evidence of minelaying occurring within the Site, WWI-era mines are typically only encountered very rarely within the marine environment and as such, is unlikely to pose a significant UXO contamination threat at the Study Site. The georeferenced location of WWI minefields, and the recorded shipwrecks resulting from WWI mines, is presented at Appendix 6.

5.3.2 WWII Minefields

Detailed desk-based research of historical records and charts identified that one large WWII-era *British* barrier minefield intersected the Study Site. Supplementary research indicated that this minefield consisted of at least two individual minelaying operations within the Study Site during WWII, with a combined total of 2,092 moored contact mines having been laid between 1940 and 1941 (including Mark XVII and XX mines in various quantities). Given that the recorded minelaying operations extended beyond the export cable routes and the OWF array however, it is highly unlikely that these mines would have all been concentrated in the immediate vicinity of the Site.

An assessment of the positions of the minefields suggests that *Allied* WWII mines are likely to pose a significant contamination threat in the offshore section of the Study Site (generally, in water depths exceeding 80m LAT). It is also considered much more likely that WWII naval mines will be encountered (by comparison with WWI mines), as they are estimated to be encountered in the marine environment at a rate of approximately once a month. Given this comparative encounter ratio, and the nature and scope of the evidenced minelaying operations that intersected the area of search, the probability that WWII-era naval mines have contaminated the area is assessed as “Likely”.

The georeferenced location of the recorded WWII minefields in relation to the Study Site is presented at Appendix 7.

5.4 Military PEXA

The *North Sea* and the coastlines of *Scotland* has been used for much of the 20th and 21st Century by various national and international military forces to conduct training and weapons’ systems testing. These activities may have employed live or practice munitions (the latter being difficult to distinguish from the former once abandoned on the surface of the seabed for many years), which in most cases are likely to have remained in the marine environment, once the training activities have ceased.

5.4.1 Historic Military Training Areas

A detailed examination of historic records has not uncovered any evidence to suggest that historic military training activities have been undertaken on-site, with the closest recorded training area designated *N241 Crimond* situated 6.5km to the north of the Site, which was used as a live bombing range.

Nonetheless, the locations of this and other historic military training areas, in relation to the Study Site, are presented for reference at Appendix 8.

5.4.2 Modern Military PEXA

An analysis of available documentation relating to modern military PEXA in the *UK* did not identify any such areas on-site, nor within a 5km radius of it. The closest modern military PEXA was recorded as *X5722 Drums Links*, an *Army* firing range situated 20.5km to the south-west of the export cable landfall.

Nonetheless, the locations of modern military PEXA, in relation to the Study Site, are presented for reference at Appendix 9.

5.5 Coastal Armaments

An assessment of local and national archive sources and databases indicated that numerous WWII-era defensive installations were constructed along the coast of *Aberdeenshire*, with an analysis of *6 Alpha's Azimuth* database indicating that at least 14 wartime concrete bunkers (commonly known as "pillboxes") were installed within 5km of the export cable landfall points either side of *Peterhead* and may have been occupied by military personnel during WWII.

Overall, it is difficult to accurately quantify the prospective contamination threat that might be posed by the proximity of such defensive features because the quantity, frequency, purpose and activities associated with wartime military personnel and their weapons systems stationed there, are not now known. Nonetheless, given the concentration of defensive features around *Peterhead*, it is possible that LSA and SAA might pose a UXO threat in the nearshore environment.

In addition, it is also likely that a prospective AAA threat may have been generated at the Study Site as a result of AAA gun battery training, testing and operations. At least three coastal artillery and AAA batteries were installed in WWII in the vicinity of *Peterhead*, and they are highly likely to have had overlapping firing templates/arcs of fire which intersected the export cable corridors. Although the calibre of guns employed by the artillery batteries around the *British* coastline varied greatly, those in the region consisted of either 3.7” Quick Firing, or 6” Breech Loading guns. Given that numerous aerial bombing raids were documented at *Peterhead*, it is almost certain that these guns would have been active operationally, in addition to the aforementioned gun training and testing exercises. A georeferenced summary of all recorded defensive features, along with the ranges of recorded coastal armaments, is presented at Appendix 10.

5.6 Munitions Related Shipwrecks and Aircraft

Merchant and naval vessels that were sunk during 20th century conflicts may have contained munitions - either as armament and/or cargo. The prospective extent of UXO contamination may vary, depending upon nature and integrity of the wrecks. Wreck investigations have found that munitions can spill from ships as they sink and break up, otherwise their ordnance may remain sealed within their holds and remain immobile. Similarly, military aircraft that were shot down or otherwise had to forcibly crash-land into the sea, may have also carried munitions.

It is unlikely that any ship would have been sunk in the first exchange of fire due to the relative inaccuracy of early 20th century and WWII era weapons and it is likely that many bombs, projectiles, and torpedoes missed their targets initially. Regardless of the type of weapons systems employed to attack ships or aircraft, it is entirely feasible that several exchanges of fire would have preceded a successful attack. There may, therefore, also be UXO (in the form of iron bombs and/or gun projectiles) situated in the regions of those wrecks that were sunk by such exchanges of fire. Generally, the closer the munitions related shipwreck is located to the Study Site, the more likely a UXO contamination threat is to have been generated in its vicinity.

Table 5.6 summarises the quantity of potential munitions related shipwrecks located within 5km of the Study Site.

Distance from Site	Cause of Sinking				Total
	Air Raid	Naval Skirmish	Mined	Other	
On-Site	0	0	0	0	0
<500m	0	2	1	0	3
500m - 1km	0	1	0	0	1
1km – 2km	0	0	0	0	0
2km – 5km	0	5	1	1	7

Table 5.7.2: Munitions related shipwrecks within 5km of the Site.

An analysis of the data presented in Table 5.6, together with corroborative evidence gathered from *6 Alpha's Azimuth* UXO database, highlights the concentration of shipwrecks located near to *Peterhead*, with a total of 10 munitions related shipwrecks located within 5km of the export cable corridor, and one further such wreck within 5km of the OWF boundary. Of these, eight originated from WWI naval engagements having been torpedoed by *German* submarines or else scuttled by submarine gunfire and/or explosive charges, In addition, two vessels were sunk by *German* naval mines during WWI, within 5km of the export cable corridors.

Consequently, it is possible that a variety of ordnance including naval projectiles and torpedoes might have contaminated the seabed resulting from these engagements. The prospective magnitude of these threats is however, reduced somewhat by the limited operational capacity of most WWI- and WWII-era submarines, as well as the relative rarity of WWI ordnance encounters in the marine environment.

A georeferenced summary of all recorded munitions-related shipwrecks in the area, combined with their high-level cause of sinking, is presented at Appendix 11.

5.7 Munitions Dumping

Stockpiles of *Allied*, *Central Powers*, and *Axis* munitions of the conventional variety (i.e. HE filled), and chemical munitions that had been earmarked for wartime use, were disposed of at the end of WWI and WWII. As a cost effective and military expedient, conventional and chemical munitions were often dumped offshore or into suitable bodies of water inland, such as lakes.

Whilst the centre of mass of such dumpsites were recorded, the logistical accuracy of dumping such munitions was then, less than perfect. Such munitions were commonly short-dumped and although some chemical and conventional munitions were dumped in small munitions containers, the effects of their break-up and subsequent munitions migration may well have further spread the theoretical extent of such contamination.

An analysis of pertinent naval and admiralty charts and relevant marine environment protection agency databases, together with specific supplementary research, did not identify any documented munitions dumps within 10km of the Study Site.

5.8 Previous UXO Encounters

An analysis of the *OSPAR* database, together with supplementary research, only identified one munitions encounter on-site. In March 2011, a partly corroded conventional anti-submarine munition (likely a torpedo) was found entangled in fishing nets and left at *Peterhead* harbour.

The georeferenced locations of the nearby munitions encounters reported by the *OSPAR* commission are presented at Appendix 12. Such encounters serve to highlight the longevity of the threat that might be posed by UXO in the marine environment in general and further information concerning *inter alia*, the longevity of the UXO threat in the marine environment is included at Annex E.

5.9 UXO Threats – Summary

Based upon the threat element of this assessment, the following types of UXO, complete with their measurements, estimated ferrous mass, and expected Net Explosive Quantity (NEQ - based upon equivalent Trinitrotoluene (TNT) masses), may pose a UXO threat at the Study Site.

A georeferenced chart depicting the considered range of prospective UXO contamination sources at the study area is presented at Appendix 13.

5.9.1 Aerial Bombs

Designation	Length x Diameter	Ferrous Mass	NEQ
SC-500 HE Bomb	1,415mm x 457mm	280kg	220kg
SC-250 HE Bomb	1,194mm x 368mm	126kg	130kg
SC-50 HE Bomb	762mm x 200mm	25-30kg	25kg

5.9.2 Torpedoes

Designation	Length x Diameter	Ferrous Mass	NEQ
50cm G7 Torpedo	7,000mm x 500mm	1,170kg	253.5kg
50cm G6 Torpedo	6,000mm x 500mm	1,364kg	213.2kg

5.9.3 Naval Mines

Designation	Length x Diameter	Ferrous Mass	NEQ
Mark XVII/XX Mine	1,321mm x 1,016mm	68-236kg	227kg
E-Mine	1,168mm x 864mm	208kg	165kg
UC-200 Mine	800mm x 800mm	191kg	141.1kg

5.9.4 Projectiles and LSA

Designation	Length x Diameter	Ferrous Mass	NEQ
6” Artillery Projectile	582mm x 152mm	39.4kg	6kg
8.8cm Naval Projectile	394mm x 88mm	12.4kg	1.42kg
3.7” Artillery Projectile	360mm x 94mm	11.6kg	0.93kg
3” Mortar Bomb	406mm x 81mm	3.99kg	0.55kg
Mills Bomb	95mm x 61mm	0.66kg	0.1kg
12 pounder Naval Projectile	210mm x 78mm	5.26kg	0.43kg
20mm Naval Projectile	83mm x 20mm	0.11kg	0.01kg

6 UXO Risk Pathways - Planned Operations

6 Alpha have been provided with a high-level outline of the possible scope of work at the *Green Volt OWF*; including the mooring of floating WTGs, OSP foundation installation, and the installation and burial of inter-array and export cables.

An outline of the expected and potential operations that may be employed is presented to evidence the potential UXO risk pathways that may be generated, should such work encounter UXO. If the planned methods are changed, then the risk assessment is to be reviewed and updated if necessary.

6.1 Floating WTG Mooring Operations

It is expected that future WTGs are to be installed and operated from floating platforms and therefore, it is the mooring points for the WTGs that present a potential UXO risk pathway because they will likely penetrate the seabed. Each floating WTG will likely require up to six mooring points (though likely only three or four each), and the installation of each mooring point into the seabed could generate sufficient kinetic energy to detonate threat spectrum UXO in their proximity. Once the mooring anchors and/or piles have been installed, subsequent works to connect catenary mooring cables should not generate a significant or further UXO risk pathway, as long as initial and subsequent anchoring is accounted for.

Various methodologies for the mooring systems are to be considered including drag-embedded anchors, torpedo anchors, gravity-based anchors, suction piles, and pin piles. Of these, the client has indicated that drag-embedded anchors are expected to be employed to support the floating WTGs. The anchors themselves typically comprise large metal flukes which are embedded into deep into the seabed, where seabed sediments are capable of providing sufficient resistance to hold the anchor securely in place. By design, such anchors have significant mass and as such, should an item of UXO be directly underneath or in their close proximity during their deployment, it is possible that sufficient kinetic energy may be generated to cause an initiation event.

Nonetheless, should other methods of securing the WTGs to the seabed through anchors or piling be used, then it is also likely that similar UXO risk pathways might be generated, given the kinetic energy involved.

6.2 OSP Foundation Installation Operations

In addition to the WTGs, the Client has indicated that up to two OSPs are likely to be required, within the OWF boundary. The most likely foundation installation method for the OSPs is through the use of jacket support structures, which would be towed into place in advance of their installation and secured to the seabed with several pin piles of between 1.5m-2m diameter. Alternatively, suction anchors might be considered instead of piling.

The potential for UXO encounter and initiation is similar to that associated with WTG mooring points although the piles used are of a much smaller diameter and are generally expected to be emplaced with less energy. Nonetheless, given that the same holistic installation methodologies are usually used for jacket support structures, the likelihood of UXO initiation remains similar.

6.3 Pre-Lay Operations

Pre-Lay Grapnel Run (PLGR) and Route Clearance (RC) will likely be employed to ensure that any inter-array and export cable routes are clear of *inter alia*, disused communication cables and other seabed debris, which may prove detrimental to the cable lay and post-lay burial equipment.

PLGR operations generally involve towing an array of spear-point grapnels along the surface of the seabed along the designated cable route. Such operations may encounter and initiate UXO that is either very shallow buried or is located on the surface of the seabed. PLGR is not a UXO risk mitigative method and nor should it be considered as such in other than the most extreme circumstances (and only where no other technique is likely to work – in such conditions it needs careful supervision and risk mitigation). RC operations also typically involve the identification and removal of specific and significant impediments to cable lay and/or burial, such as boulders, anchors, chain, steel-wire rope, disused cables, and obstructions generated by wrecks and the like.

It is possible that pre-lay operations could cause a UXO detonation event, should pre-lay equipment come into direct contact with it.

6.4 Cable Installation and Burial Operations

It is expected that inter-array/export cables could be installed using several different methodologies depending on the geological conditions, although the Client has indicated that the preference is for simultaneous lay and burial of the export and inter-array cables. Alternatively, the cables may be pre-laid on the seabed and subsequently buried.

An overview of prospective cable installation and burial methodologies is described briefly below, to inform subsequently the risks that UXO might pose to such techniques.

6.4.1 Surface Laid Cable

The inter-array and export cables may be laid on the surface of the seabed and then subsequently buried where necessary. Cables are also surface laid where they cross-existing infrastructure (such as existing pipelines and other cables), as they cannot be buried at these locations.

The kinetic energy associated with surface laying the cable might be sufficient to initiate UXO, especially if the cable makes direct contact with it - subject to, amongst other factors, the mass of the cable per linear meter, the water depth and rate of lay. Even if the cable lay energy is considered insufficient to initiate UXO (because e.g. the cable is relatively low mass and it is laid slowly), it is not considered best practice to deliberately overlay UXO with cables and in such circumstances, post-lay inspection and burial is likely to be both compromised and/or jeopardised.

6.4.2 Jetting

Where soft seabed conditions are encountered, jetting seabed sediments can be employed to bury cables either concurrently or in a separate operation once it has been laid on the surface of the seabed. Jetting functions by fluidising the seabed to enable burial of the cable, to its target depth of burial.

Jetting procedures are considered a more benign and less aggressive installation methodology (as compared with e.g. mechanical cutting) and is therefore, less likely to inadvertently initiate UXO when benchmarked with other methods. Despite this, a risk pathway may still be generated if direct contact is initiated between UXO and the jetting tool itself or the direct or indirect effects of its high-pressure water jetting system.

6.4.3 Ploughing

Displacement ploughs create an open V-shaped trench into which the cable can be concurrently laid. This process causes significant disturbance to the seabed as the trench can typically be up to 3m wide and 1.5m deep, whilst the plough can have a skid footprint of up to 10m wide, between its support skids. The open trench can be then backfilled using blades mounted to the rear of the plough, thus burying concurrently the cable behind it. The large footprint, significant mass of the machine and the kinetic energy it generates could collectively, encounter and initiate UXO.

Alternatively, a non-displacement plough could be used to cut through the seabed using a thin blade-like shear, through which the cable runs. This method generates a reduced level of disturbance to the seabed, by comparison with a displacement plough and it creates a narrow trench (usually between 0.3m and 1.0m wide). In such circumstances the trench, is normally backfilled as the cable is laid.

The risk considerations associated with plough methodologies are generated by the mass of the shear (and any supports skids) and their velocity, which in combination may be sufficient to initiate UXO either directly or indirectly.

6.4.4 Open Cut Trenching

Open cut trenching can be used to bury and thus protect the cable, at the onshore cable landing point. Trenching can be undertaken by a terrestrial-based excavator during low tide and during these operations, a transition or joint-pit(s) may also be excavated.

There are several risk factors to consider for trenching and excavation operations; firstly, the mass of the excavator bucket and its operating velocity may be sufficient to initiate any UXO that might be encountered directly and/or indirectly, if it is in close proximity. Second, the excavated material is expected to be used to back-fill the trench once the cable has been emplaced within it. If the excavated material is contaminated with UXO, the back-filling operation may also present an inadvertent risk pathway in that UXO might then be initiated.

Nonetheless, the risks that might be presented on "land" (defined for the purposes of this report, as above the high-water mark) are beyond the scope of this document. *6 Alpha* can consider separately the risks associated with trenching and excavation operations, together with those that might otherwise be presented at the export cable landing point, in line with *CIRIA* guidance for managing UXO risks in the onshore environment – which differs from the UXO risk management guidance for offshore cable installation projects.

6.4.5 Horizontal Directional Drilling (HDD)

In the nearshore environment, the export cables might instead be installed using HDD. HDD is a trenchless methodology that provides a cable installation alternative to traditional "open-cut" procedures. HDD involves drilling a small pilot hole, using tools that enable the drill to be steered 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 minimise friction and so decreases the chance of getting a cable "hung up" in the soil.

It is often used onshore, to drill though sea defences (e.g. bunds, dykes, or sea walls) and this methodology may be considered where the export cables make landfall. As such, HDD can be considered separately when assessing the UXO risks in the onshore environment, similar to open cut trenching. Nonetheless, much of the HDD route might be at such a depth that UXO encounter would be extremely unlikely (subject to maximum bomb penetration depth).

6.5 Protection and Crossing Operations

The Client has indicated that seabed scour is anticipated to be low and therefore, the WTG moorings will not require additional anti-scour protection. Nonetheless, where offshore cable burial is not possible and where existing cables or pipelines are crossed, some form of surface cable crossing and protection is likely to be required.

Options that might be considered include, but are not limited to, the following:

6.5.1 Concrete Mattress and/or Rock Placement

To protect any existing (live and in-use) cable(s), concrete mattresses and/or rock placement may be employed to facilitate cable crossing(s), or else split-piping may be applied to protect the cable. A UXO risk pathway may be generated by the emplacement of mattresses, rock (or rock-bags) or split-pipe, alongside and over the cable, although the probability of an inadvertent UXO detonation is dependent upon the resultant kinetic energy generated by the emplacement of the protection method and the juxtaposition, sensitivity and NEQ, of such UXO.

The potential risks may well be reduced if direct contact with UXO is avoided. And where there is potential UXO (pUXO) in their close proximity, then the cable protection system(s) are not only to be deployed in a controlled fashion but also and as slowly as is reasonably practicable (because the resultant kinetic energy generated is reduced) and that minimum pUXO safety avoidance distances are adhered to.

6.5.2 Crossing Design

In consideration of third-party cable crossing and/or the removal of out-of-service cables, it is assumed that such cables would not have been (deliberately) installed on top of, or in close proximity to UXO. Nonetheless, this does not mean that UXO will not be encountered anywhere such routes, and therefore, a risk pathway may still be generated depending on the precise methodology employed to work in areas where third-party or out-of-service cables are located.

6.6 Enabling Operations

The following methodologies may be employed to facilitate the proposed works:

6.6.1 Dynamically Positioned (DP) Vessels

DP vessels employ computer-controlled systems to automatically maintain their position and heading by using propellers and thrusters. Position reference sensors and satellite navigation, combined with wind sensors, motion sensors, and gyrocompasses provide information to a computer that maintains vessels' positions, constantly accounting for the magnitude and direction of environmental forces affecting them. DP vessels are commonly used to support a wide variety of sub-seabed operations.

If a DP vessel does not contact the seabed (because it is not anchored and will not ground), then a prospective encounter with UXO from such a work platform does not presents a UXO pathway and thus a risk is not generated. A risk however might be presented in shallow water, if thrusters disturb UXO in close proximity of the influence (of the thruster), especially if the UXO is located on the surface of the seabed or shallow buried beneath it.

6.6.2 Vessel Anchoring

It is possible that other types of vessels will anchor independently or otherwise employ Anchor-Handling Tugboats (AHT), to support the proposed works. There is a risk that anchors could initiate UXO if they were to come into direct contact with it, either as they are positioned and especially emplaced. However, the deployment and post-tensioning of anchor catenaries are considered 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 may be deployed under tension and may not generally sweep extensive areas of the seabed). Nonetheless, any 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 when compared with a point induced force.

6.6.3 Jack-Up Barges (JUB)

A JUB is a type of mobile platform that consists of a buoyant hull fitted with a number of movable legs, capable of lifting it over the surface of the sea, thus affording a stable work platform for *inter alia*, the installation of piled OSP support structures. The buoyant hull facilitates relatively easy transportation of the barge between operations and once it is at the desired location, the hull is raised (jacked-up on legs), to the required elevation above the sea and its legs are supported by the seabed.

From a UXO risk perspective, the legs of such barges may be designed to penetrate the seabed, and/or may be fitted with enlarged sections or footings. Generally, JUBs are not self-propelled and rely on AHT for positioning and upon its anchors for stability and movement. Nonetheless, if the JUB leg or its anchor (deployed by an AHT) encounters UXO, then a risk pathway might be generated.

6.6.4 Diving Operations

There is no indication that divers are currently being considered to assist or undertake works. Nonetheless, divers are especially vulnerable to the types of underwater shock generated by UXO detonations and, subject to UXOs' NEQ, diver fatalities can easily be generated hundreds of metres from the seat of an underwater high explosive event. Therefore, divers should not be deployed where there is a risk of occurrence of such a detonation event.

If divers are to be used, then the risks associated with diving operations must be reassessed by *6 Alpha*.

7 Study Site Characterisation

7.1 Local Seabed Conditions

The Study Site's local seabed conditions are important influencing factors when assessing the potential for UXO burial and/or migration and the potential consequences of an unplanned encounter and initiation of UXO during the proposed operations.

7.1.1 Bathymetry

A body of water will both absorb and transmit energy, generated by either a bomb entering the water and/or a high explosive event of the sort that might be generated by a UXO detonation. In general, the consequences of a through-water UXO detonation will reduce, as the "stand-off" (or separation distance) increases between prospective receptors and the UXO either buried in or lying upon the seabed.

The water depths reported in the *North Sea*, within the proposed *Green Volt OWF* array itself, range from 91m to 114m LAT. Within the export cable corridors, water depths range from landfall (i.e., 0m LAT) up to 120m LAT. In areas of relatively shallow water (that are only likely to be present across nearshore portions of the export cable corridors), the consequences of potential UXO initiation are unlikely to be very significantly mitigated by such a body of water. In the areas of deeper water likely within offshore sectors of the export cable corridors and the OWF array, the degree of prospective risk mitigation in general and consequence mitigation in particular, of the depth of water, is likely to be more effective.

The water depths across the Study Site (in LAT) are presented at Appendix 14.

7.1.2 Seabed Sediments and Shallow Soils

The nature of local seabed sediments and shallow soils also need to be considered to determine the prospect for UXO burial in general and unexploded bomb burial in particular, upon their initial deployment and/or subsequently by seabed sediment movement. UXO scour and/or migration may also be influenced by seabed sediments.

Survey data associated with the earlier *Ettrick and Blackbird Decommissioning Programmes* showed that the proposed OWF array is situated over the *Swatchway Formation* and the *Witch Ground Formation*, which together comprise disturbed sands, silts and muds. In addition, the export cable routes cross the *Forth Formation*, which comprises sands and soft muds with sand and gravel more likely to be encountered in the nearshore sector of the corridors. This was corroborated by an analysis of *BGS* records, which indicated that muddy sand and sand sediments are likely to be present across the OWF array, whilst the export cable corridors traverse areas of sand, slightly gravelly sand and gravelly sand sediments.

Gravelly and muddy sediments are generally less likely to form a mobile seabed than one comprising solely of sandy sediments but, it is still possible that UXO may have become shallow buried (after their initial deployment, having come to rest upon the surface of the seabed), by mobile seabed sediment, particularly in those areas comprising of predominantly, sand sediments.

7.2 UXO Burial and Munitions Migration

In the offshore environment, all items are UXO are potentially subject to a variety of environmental and human factors, which may result in their scour and burial, or else migration across the seabed. Primarily, this is driven by the localised bathymetric conditions including the composition of the seabed sediments, water depth and tidal currents.

7.2.1 Initial Impact Burial

As with impact burial of UXO on land, only those munitions travelling at a high terminal velocity at the point of impact (e.g. and typically aerially delivered iron bombs and/or gun/mortar launched projectiles), have the potential to penetrate the seabed upon their initial deployment. Historically, studies of typical bomb penetration depths have been undertaken for the terrestrial environment based upon *inter alia*, the soil type in general and its shear strength in particular, as well as the UXO type, size and mass and their angle/speed of initial impact. Such studies are not directly applicable in the offshore environment, given the mitigative effects of water (e.g. in slowing and reducing the impact of munitions on the seabed). Nonetheless and in general, UXO penetration into the seabed beyond 2m below seabed level, is considered highly unlikely in water depths of more than 20m, with initial impact burial in deeper waters considered highly unlikely.

7.2.2 Munitions Migration Effects

If geophysical UXO survey data is more than one year old from its date of capture, it may compromise the subsequent longevity of an ALARP safety sign-off certificate in general and the positional accuracy of potential UXO (designated for avoidance) in particular, because of the risk of prospective munitions migration effects.

In order to address this issue and to extend the longevity of ALARP safety sign-off certification, a Munitions Migration and Burial Assessment (MMBA) can be undertaken. An MMBA can be based on existing metocean data where appropriate, which would model the potential for UXO migration based upon *inter alia* seabed geomorphology in general and the Site's seabed characteristics in particular (e.g. the seabed sediments, current direction, and strengths).

Further background information regarding UXO scour, burial and migration is presented separately at Annex F.

7.3 Marine Protection Areas

Areas of the offshore marine environment have been designated as requiring protective, conservation, restorative and/or precautionary measures and there is a growing body of regional, national and international legislation supporting offshore environmental conservation. An analysis of national databases has identified one such Marine Protected Area intersecting the nearshore area of the export cable corridors, designated as the *Southern Trench*. In addition, the *Buchan Ness to Collieston* Special Protection Area is also located across the southern export cable landfall point. As a result, should UXO disposal be required within the bounds of such areas, then specific techniques such as low-order/low-noise or deflagration might be preferred over other high-order disposal methods. This is *6 Alpha's* typical recommendation for UXO disposal regardless of location, however, it is particularly relevant in marine protection areas and similarly designated areas subject to additional regulation. If a high order disposal is required, then additional environmental protection measures - such as the deployment of bubble curtains – may also be considered, although detailed consideration of such mitigation is beyond the scope of this report.

The recorded marine protection areas in the *North Sea*, in relation to the Study Site, are presented at Appendix 15.

8 UXO Risk Assessment

8.1 Risk Assessment Findings

The results of the strategic level risk assessment at different depth intervals are presented below and are supported by an unexpurgated project SQRA, which is presented at Appendix 16. The latter presents the complete risk assessment for each individual sub-seabed intrusive activity for each UXO threat group.

8.1.1 WTG Mooring Operations

The installation of drag-embedded anchors, and/or alternate floating WTG mooring systems, is assessed to typically pose LOW levels of UXO risks, within the proposed *Green Volt OWF* array – as per Table 8.1.1. This is due to the reduced likelihood of encountering threat spectrum UXO offshore, although in extremely limited areas where the recorded WWII-era *Allied* minefield intersects the OWF boundary and where water depths are less than 100m LAT, MEDIUM category UXO risks may instead be generated by high NEQ naval mines.

<table>
<tr><th rowspan="2">Intrusive Operation</th><th rowspan="2">UXO Threat</th><th colspan="5">UXO Risk (Vessels and Personnel Only)</th></tr>
<tr><th>Ultra-Nearshore
~10m LAT</th><th>Nearshore
~26m LAT</th><th>Shallow Offshore
~40m LAT</th><th>Offshore
~60m LAT</th><th>Deep Offshore
>80m LAT</th></tr>
<tr><td rowspan="4">WTG Mooring Operations</td><td>Aerial Bombs</td><td colspan="4" rowspan="4">**N/A:**
WTG mooring operations will not occur at these water depths.</td><td>**VERY LOW**</td></tr>
<tr><td>Torpedoes</td><td>**LOW**</td></tr>
<tr><td>Naval Mines</td><td>**MEDIUM**</td></tr>
<tr><td>Artillery and Naval Projectiles</td><td>**VERY LOW**</td></tr>
</table>

Table 8.1.1. WTG Mooring Operations SQRA Summary

8.1.2 OSP Foundation Installation Operations

The UXO risks associated with OSP foundations are broadly similar to those generated by the installation of anchor moorings for the floating WTGs, as presented at Table 8.1.2. However, given the proposed locations of the two OSPs in the south-western sector of the OWF array, where the water depths are greater than 100m LAT, the risk level generated by all UXO threat groups will not exceed LOW category UXO risk. This is because the water depths will sufficiently reduce the consequences of detonating WWII-era naval mines on the seabed (for surface vessels and personnel), at this specific location.

Intrusive Operation	UXO Threat	UXO Risk (Vessels and Personnel Only)				
		Ultra-Nearshore ~10m LAT	Nearshore ~26m LAT	Shallow Offshore ~40m LAT	Offshore ~60m LAT	Deep Offshore >80m LAT
OSP Foundation Installation Operations	Aerial Bombs	N/A: OSP Foundation Installation operations will not occur in these areas.				VERY LOW
	Torpedoes					LOW
	Naval Mines					LOW
	Artillery and Naval Projectiles					VERY LOW

Table 8.1.2. OSP Foundation Installation Operations SQRA Summary

8.1.3 Pre-Lay Operations

Any PLGR and RC that is undertaken in advance of the installation of inter-array and/or export cables may generate more significant UXO risks than point focal installation works. This is because the former is considered more likely to encounter any UXO contamination as it covers a larger spatial extent and will comprise more contact with the seabed than point-intrusive works.

Consequently, pre-cable lay operations may generate HIGH UXO risks across the nearshore sectors of the export cable corridors. In addition, MEDIUM category UXO risks are also generated offshore, based on the likelihood of encountering HE bombs, torpedoes and naval mines. In areas of deeper water (~100m LAT), the risk mitigative effect of the water is sufficient to reduce the consequences of an unplanned initiation of threat spectrum UXO, so that the risk rating is lowered to MEDIUM and/or LOW – as per Table 8.1.3.

Intrusive Operation	UXO Threat	UXO Risk (Vessels and Personnel Only)				
		Ultra-Nearshore ~10m LAT	Nearshore ~26m LAT	Shallow Offshore ~40m LAT	Offshore ~60m LAT	Deep Offshore >80m LAT
Cable Pre-Lay Operations	Aerial Bombs	HIGH	HIGH	MEDIUM	LOW	VERY LOW
	Torpedoes	LOW	LOW	MEDIUM	LOW	LOW
	Naval Mines	LOW	MEDIUM	MEDIUM	LOW	MEDIUM
	Artillery and Naval Projectiles	HIGH	MEDIUM	LOW	LOW	LOW

Table 8.1.3. Cable Pre-Lay Operations SQRA Summary

8.1.4 Cable Installation and Burial Operations

The installation and subsequent burial of cables are likely to generate distinct categories of UXO risks owing to the amount of seabed interaction involved with the various installation and burial methodologies that may be considered.

Where cables are laid on the surface of the seabed and are not subsequently buried, then UXO risks are categorised as either MEDIUM or LOW in all areas. Where cable burial is likely to be undertaken using more aggressive techniques, such as jetting or in a more extreme scenario, ploughing, then such UXO risks are also categorised as HIGH in the nearshore sectors, as well as generating MEDIUM UXO risks in select areas offshore due to the (comparatively) larger footprint of such installation tools (especially a subsea cable plough), and the significant forces exerted into the seabed by such cable burial tools. Table 8.1.4 provides a summary of cable installation risk levels.

Intrusive Operation	UXO Threat	UXO Risk (Vessels and Personnel Only)				
		Ultra-Nearshore ~10m LAT	Nearshore ~26m LAT	Shallow Offshore ~40m LAT	Offshore ~60m LAT	Deep Offshore >80m LAT
Surface Lay Operations	Aerial Bombs	MEDIUM	MEDIUM	LOW	LOW	VERY LOW
	Torpedoes	LOW	LOW	LOW	LOW	LOW
	Naval Mines	LOW	LOW	LOW	LOW	LOW
	Artillery and Naval Projectiles	LOW	LOW	VERY LOW	VERY LOW	VERY LOW
Jetting Operations	Aerial Bombs	HIGH	HIGH	MEDIUM	LOW	VERY LOW
	Torpedoes	LOW	LOW	LOW	LOW	LOW
	Naval Mines	LOW	LOW	LOW	LOW	MEDIUM
	Artillery and Naval Projectiles	MEDIUM	LOW	LOW	VERY LOW	VERY LOW
Ploughing Operations	Aerial Bombs	HIGH	HIGH	MEDIUM	LOW	VERY LOW
	Torpedoes	LOW	LOW	MEDIUM	LOW	LOW
	Naval Mines	LOW	MEDIUM	MEDIUM	LOW	MEDIUM
	Artillery and Naval Projectiles	HIGH	MEDIUM	LOW	LOW	LOW

Table 8.1.4. Cable Installation and Burial SQRA Summary

8.1.5 Protection Operations

The emplacement of rock to protect unburied cables may generate HIGH category UXO risks in the nearshore areas of the export cable corridors, where large NEQ HE bombs might be encountered. In the offshore sectors, MEDIUM risks may also be generated by aerial bombs and naval mines in select areas.

Dumping rock either over the side of a rock dumping support vessel or through a pipe-fall system, may result in significant kinetic energy being transferred (in comparison with more controlled installation methods), which may cause an initiation event should the rock come into direct contact with UXO or if rocks impact the seabed in close proximity of UXO, as per Table 8.1.5.

Intrusive Operation	UXO Threat	UXO Risk (Vessels and Personnel Only)				
		Ultra-Nearshore ~10m LAT	Nearshore ~26m LAT	Shallow Offshore ~40m LAT	Offshore ~60m LAT	Deep Offshore >80m LAT
Protection Operations	Aerial Bombs	HIGH	HIGH	MEDIUM	LOW	VERY LOW
	Torpedoes	LOW	LOW	LOW	LOW	LOW
	Naval Mines	LOW	LOW	LOW	LOW	MEDIUM
	Artillery and Naval Projectiles	MEDIUM	LOW	LOW	VERY LOW	VERY LOW

Table 8.1.5. Protection Operations SQRA Summary

8.1.6 Enabling Operations

The UXO risk associated with the potential enabling operations in support of proposed installation operations also varies depending on the precise operation. Table 8.1.6 articulates the various scenarios associated with each prospective enabling operation – such risks are reduced for enabling methodologies such as vessel anchoring and the use of DP vessels, although the deployment of JUB vessels in the nearshore environment may generate HIGH category UXO risks.

Intrusive Operation	UXO Threat	UXO Risk (Vessels and Personnel Only)				
		Ultra-Nearshore ~10m LAT	Nearshore ~26m LAT	Shallow Offshore ~40m LAT	Offshore ~60m LAT	Deep Offshore >80m LAT
DP Vessel Operations	Aerial Bombs	LOW	LOW	LOW	LOW	VERY LOW
	Torpedoes	LOW	LOW	LOW	LOW	LOW
	Naval Mines	LOW	LOW	LOW	LOW	LOW
	Artillery and Naval Projectiles	LOW	LOW	VERY LOW	VERY LOW	VERY LOW
Vessel Anchoring Operations	Aerial Bombs	MEDIUM	MEDIUM	LOW	LOW	VERY LOW
	Torpedoes	LOW	LOW	LOW	LOW	LOW
	Naval Mines	LOW	LOW	LOW	LOW	LOW
	Artillery and Naval Projectiles	LOW	LOW	VERY LOW	VERY LOW	VERY LOW
JUB Deployment Operations	Aerial Bombs	HIGH	HIGH	MEDIUM	LOW	VERY LOW
	Torpedoes	LOW	LOW	LOW	LOW	LOW
	Naval Mines	LOW	LOW	LOW	LOW	MEDIUM
	Artillery and Naval Projectiles	MEDIUM	LOW	LOW	VERY LOW	VERY LOW

Table 8.1.6 – Enabling Operations SQRA Summary

8.2 UXO Receptors

8.2.1 Surface Vessels and Personnel

Although there is evidence to suggest that encountering and initiating UXO is plausible at the Study Site, such an encounter is generally considered a low probability-high consequence event. The consequences of exposing the vessels' crews to the kind of forces associated with an underwater initiation of a (project indicative) selection of high, medium, and low NEQ threat spectrum UXO has been carefully modelled and the results are summarised separately at Table 8.2.1.

UXO	NEQ	Consequence at ~10m LAT	Consequence at ~26m LAT	Consequence at ~40m LAT	Consequence at ~60m LAT	Consequence at >80m LAT
50cm G7 Torpedo	253.5kg	Vessel Sinking / Fatalities	Vessel Sinking / Fatalities	Mechanism Damage / Minor Injuries	Mechanism Damage / Minor Injuries	Light Damage
SC-250 HE Bomb	130kg	Vessel Sinking / Fatalities	Serious Structural Damage / Fatalities	Mechanism Damage / Minor Injuries	Light Damage	Light Damage
6" Projectile	6kg	Serious Structural Damage / Fatalities	Light Damage	Acceptable	Acceptable	Acceptable

Table 8.2.1: Consequences of UXO Initiation

Table 8.2.1 has been compiled using *6 Alpha's* in-house through-water, shock wave calculator, which algorithms are based on a variety of open-source academic and military studies concerning military ordnance detonations underwater, the peak pressures generated, and the effects of though water shock waves on the vessels' hulls directly as well as the indirect effects upon their crew.

Although the probability of initiating UXO varies with the types of subsea operations, the consequences of an initiation of each type of UXO is not driven by how such an initiation event might be caused. The calculations presented within Table 8.2.1 are also employed to inform *6 Alpha's* SQRA (at Appendix 16) to assess and grade potential UXO detonation consequences based upon the shock wave effects.

8.2.2 Underwater Equipment

If any size of UXO is inadvertently encountered and initiated, it is likely that underwater equipment or tools employed in their close proximity are likely to be significantly damaged and/or completely destroyed. Such risks are presented in the full SQRA (at Appendix 16) but are highly likely to be considered tolerable, under the auspices of the ALARP principle, as long as they are unlikely to also pose a concurrent risk to surface vessels and their crew.

8.2.3 Vessel and Diver Safety Distances

The SQRA assesses the risk of an unplanned initiation of UXO with reference to relevant sensitive receptors (e.g. including but not limited to, vessels and their crew and/or underwater equipment), resulting from underwater explosive shock waves and to a reduced extent, localised underwater, high velocity fragmentation effects.

Such underwater detonation effects are determined by the energy that might be generated by detonating high explosive UXO. TNT is employed as a representative baseline high explosive for the likely type of UXO that might be encountered within the Study Site (regardless of the precise nature of their high-explosive fill), as well as estimating the distances separating the source (UXO) and the sensitive receptors (equipment/vessels).

The following formula has been applied to calculate peak pressure with the resultant shock wave output (Reid, 1996):

$$Peak\ Pressure\ (MPa) = 52.4.\left(\frac{M^{\frac{1}{3}}}{R}\right)^{1.18}$$

Using this formula, Table 8.2.3 summarises the distances at which point the prospective consequences of an underwater encounter and initiation of a selection of threat spectrum UXO to the vessel(s) and their crew(s) becomes intolerable (e.g. where injuries are sustained from exposure to more than 4MPa of peak pressure). In addition, Table 8.2.3 also summarises the minimum safety distance for divers - if they are to be employed (these distances have been calculated by *6 Alpha's* UXO experts).

UXO Type	UXO NEQ	SQRA Consequence Score Peak Pressure Exposure (MPa) and Vessel Safety Distance		Swimmers and Divers Safety Distance
		1 0 – 2 (MPa)	2 2 – 4 (MPa)	Burst on seabed with diver on seabed
50cm G7 Torpedo	253.5kg	101m	56m	1,647m
SC-250 HE Bomb	130kg	81m	45m	1,460m
6” Projectile	6kg	29m	17m	839m

Table 8.2.3: **Underwater Explosion Consequences**

For the consequences of an initiation of high NEQ UXO to be completely ameliorated in terms of its effects upon the vessel (<2 MPa and see consequence column 1), the minimum vessel safety stand-off distance must be not less than 101m (this may be reduced to 81m and 29m for medium and low NEQ UXO, respectively).

Consequence column 2 articulates the depths of water at which light superficial damage to the vessel may be caused and the exposure of the vessel and its crew to intolerable and dangerous high-explosive effects is likely to occur at depths of less than 56m, if a large NEQ UXO is initiated (this may be reduced to 45m and 17m for medium and low NEQ UXO, respectively). If the vessel(s) and its crew(s) are exposed to greater than 4MPa of pressure, the likely effects are *inter alia* damage to electronics, injuring crew and partial loss of vessel steering and control. Vessel damage becomes more severe as the peak pressure exposure increases, with fatalities highly likely to be caused at 8MPa pressure and greater. These consequences have been calculated without accounting for the vessels’ age/condition nor their specific deign characteristics in general or their robustness in particular. Therefore, the precise consequence modelling and minimum safe stand-off distances are subject to change especially as additional factors such as vessel draught are introduced.

In addition, divers are highly vulnerable if they are exposed to the kind of underwater shock generated by UXO initiation. As Table 8.2.3 evidences, swimmers and divers are required to be located at between 839m and 1,647m from the seat of a seabed initiation of threat spectrum UXO (smallest to largest respectively), to be considered safe, which further evidences the risks involved with deploying divers during sub-seabed operations, wherever UXO contamination might be expected.

8.3 UXO Risk Zones

It is standard *6 Alpha* practice to divide the Study Site into a number of UXO risk zones based on one, or a combination of, the following factors:

- The nature and scope of sub-seabed activities and the distances from pertinent UXO threat sources;
- The varying water depths (in LAT) across the Study Site;
- The project stakeholders' assumed appetite for the carriage of residual UXO risks.

Given the distribution of UXO threat sources (identified in Section 5) and their various NEQ, it is possible to split the Study Site into UXO risk zones at a high-level for the key proposed works, as presented at Figure 8.3, as well as at Appendix 17.

HIGH UXO risks have been evidenced within the nearshore sector of the export cable corridors, where it has been assessed that there is an elevated probability of the proposed works encountering UXO - largely driven by potential aerial bombing and AAA projectile firing in shallow water.

Furthermore, several areas of the offshore export cable routes are classified as generating MEDIUM category UXO risks, where the likelihood of encountering large NEQ UXO such as aerial bombs and naval mines remains extent, though partially mitigated by the increased depth of water. In addition, a small section of the proposed OWF array is also categorised as holding MEDIUM UXO risks, accordingly. Finally, areas of LOW category UXO risk are also present across much of the offshore export cable routes, as well as the proposed OWF array, which is generated by a much lower probability of encountering UXO and/or areas of significantly deeper water

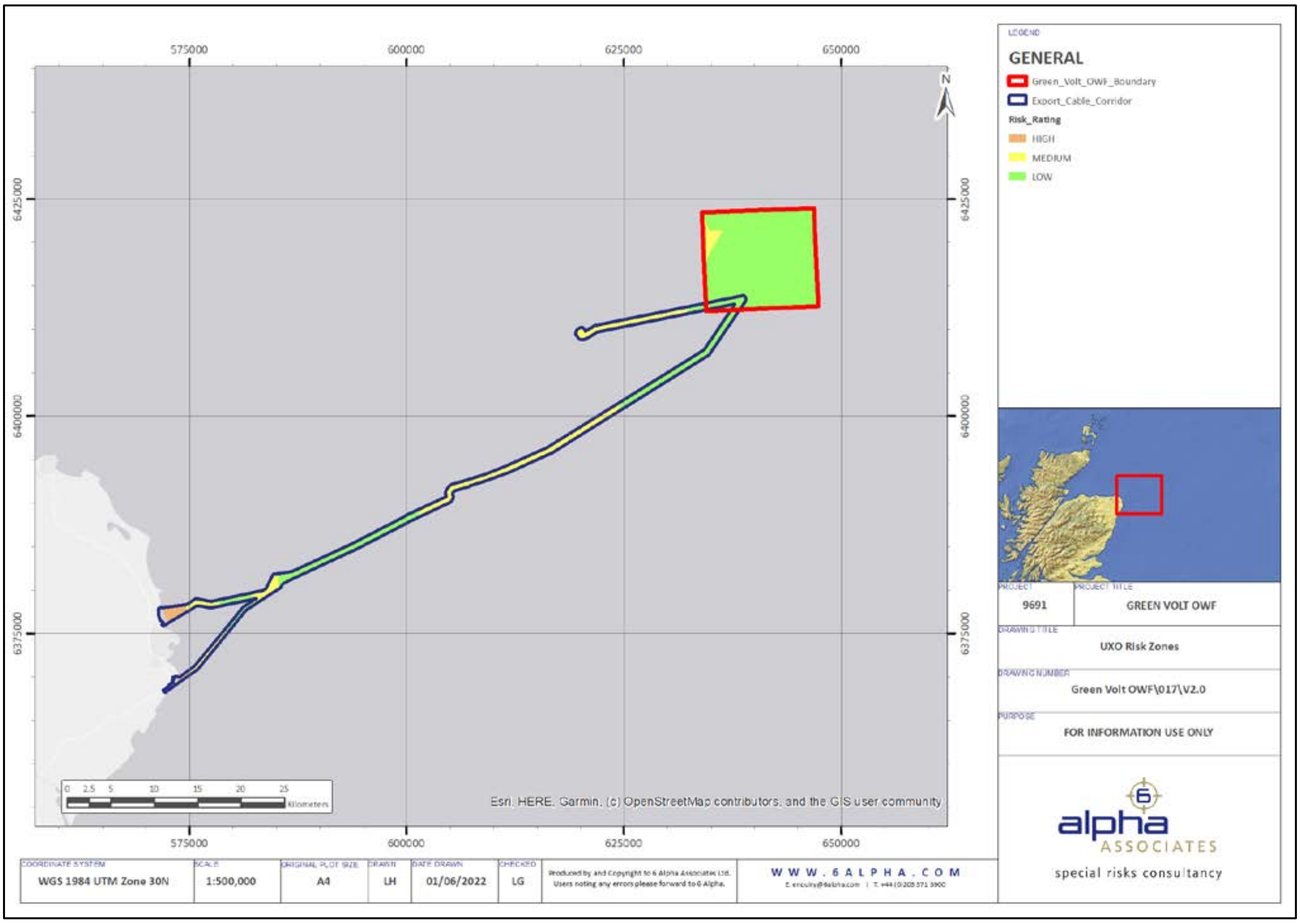

Figure 8.3 – UXO Risk Zones (Overview)

9 Conclusions and Recommendations

9.1 Conclusions

The nature and scope of the UXO risks vary across the Study Site, based upon a source-pathway-receptor review in general, as well as the prospective consequences of initiating UXO and an analysis of the probability of encountering and of initiating UXO, in particular. Some UXO risks posed by the proposed operations have been categorised as HIGH because they are generally associated with the unplanned initiation of threat spectrum UXO - including HE bombs, naval mines and AAA projectiles in various areas of the OWF array and/or the export cable corridors; such risks are considered intolerable.

In the offshore environment, the effect of the depth of water upon potential UXO initiation consequences (and *inter alia*, the resultant through-seabed and through-water shock) is unlikely to be wholly risk mitigative for large NEQ threats and therefore, the level of UXO risk remains MEDIUM in select areas. Nonetheless, the level of UXO risk across much of the Study Site is assessed to be LOW, due to the reduced probability of encountering large NEQ UXO and the risk mitigative effect of the substantial water depths in much of the proposed OWF array and its export cable corridors.

9.1.1 UXO Risks to Surface Vessels and their Crew

UXO risks that are posed to vessels and their crews in depths shallower than 40m LAT, are potentially and theoretically the most intolerable. HIGH category UXO risks have been evidenced primarily within the nearshore sections of the Study Site; primarily driven by the likelihood of encountering aerial bombs in the shallow waters, in addition to AAA projectiles.

The prospective consequences for surface vessels generally reduce, as the depth of water between the vessel and the point of a UXO initiation increases. Nonetheless, due to some large NEQ threat items such as HE bombs and naval mines across the Study Site, MEDIUM category UXO risks remain within select areas further offshore, although the proposed OWF array itself is primarily categories as being LOW UXO risk given the increased depth of water.

If divers are deployed to facilitate subsea operations, then they may be exposed to significant UXO risks because they are especially vulnerable to the effects of UXO if it is initiated underwater. In such circumstances, fatalities can be generated hundreds of meters from the seat of such explosions (subject to the NEQ of the UXO).

9.1.2 UXO Risks to Underwater Equipment

Underwater installation equipment is unlikely to be sufficiently robust to withstand the consequences of an initiation of most large NEQ, threat spectrum UXO (such as HE bombs and naval mines). The prospective UXO risks posed to underwater equipment are therefore classified as HIGH or MEDIUM, in all depths of water where an evidenced UXO threat is present.

Nevertheless, the UXO risk to underwater equipment is likely to be deemed tolerable under the auspices of the ALARP risk reduction principle, as long as such risks do not also pose a hazard to support vessels and their crews.

9.2 Recommendations

6 Alpha recommend that the UXO risks are mitigated within the bounds of the ALARP risk reduction principle and in accordance with national laws through the implementation of a suitable and cost-effective RMS, which at the time of writing, was being developed by *6 Alpha*. ALARP safety sign-off certificates should be delivered once the risk mitigation measures have been implemented.

6 Alpha also recommends that an onshore UXO Threat and Risk Assessment is undertaken to assess the UXO risk associated with any investigation, installation and/or construction works occurring above the high-water mark.

Appendices

Appendix 1

Site Location

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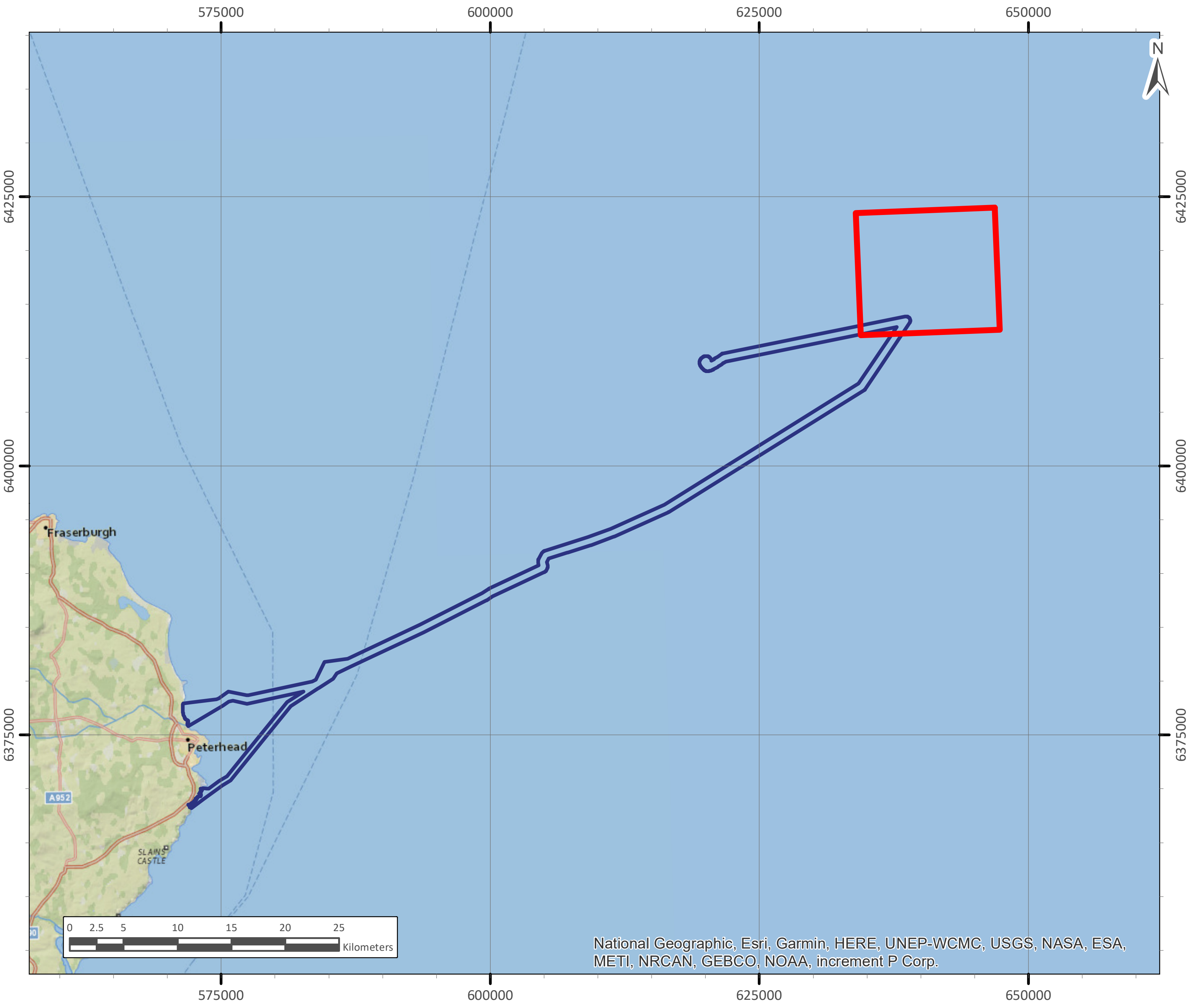
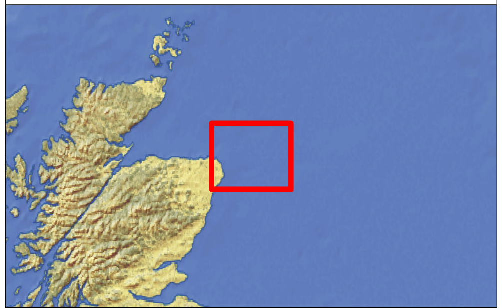
enquiry@6alpha.com



LEGEND

GENERAL

- Green_Volt_OWF_Boundary
- Export_Cable_Corridor



PROJECT	PROJECT TITLE
9691	GREEN VOLT OWF

DRAWING TITLE
Site Location

DRAWING NUMBER
Green Volt OWF\001\V2.0

PURPOSE
FOR INFORMATION USE ONLY

6 alpha ASSOCIATES
special risks consultancy

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED		
WGS 1984 UTM Zone 30N	1:500,000	A4	LH	01/06/2022	LG	Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please forward to 6 Alpha.	W W W . 6 A L P H A . C O M E: enquiry@6alpha.com | T: +44 (0)203 371 3900

Appendix 2

Marine Risk Management Framework

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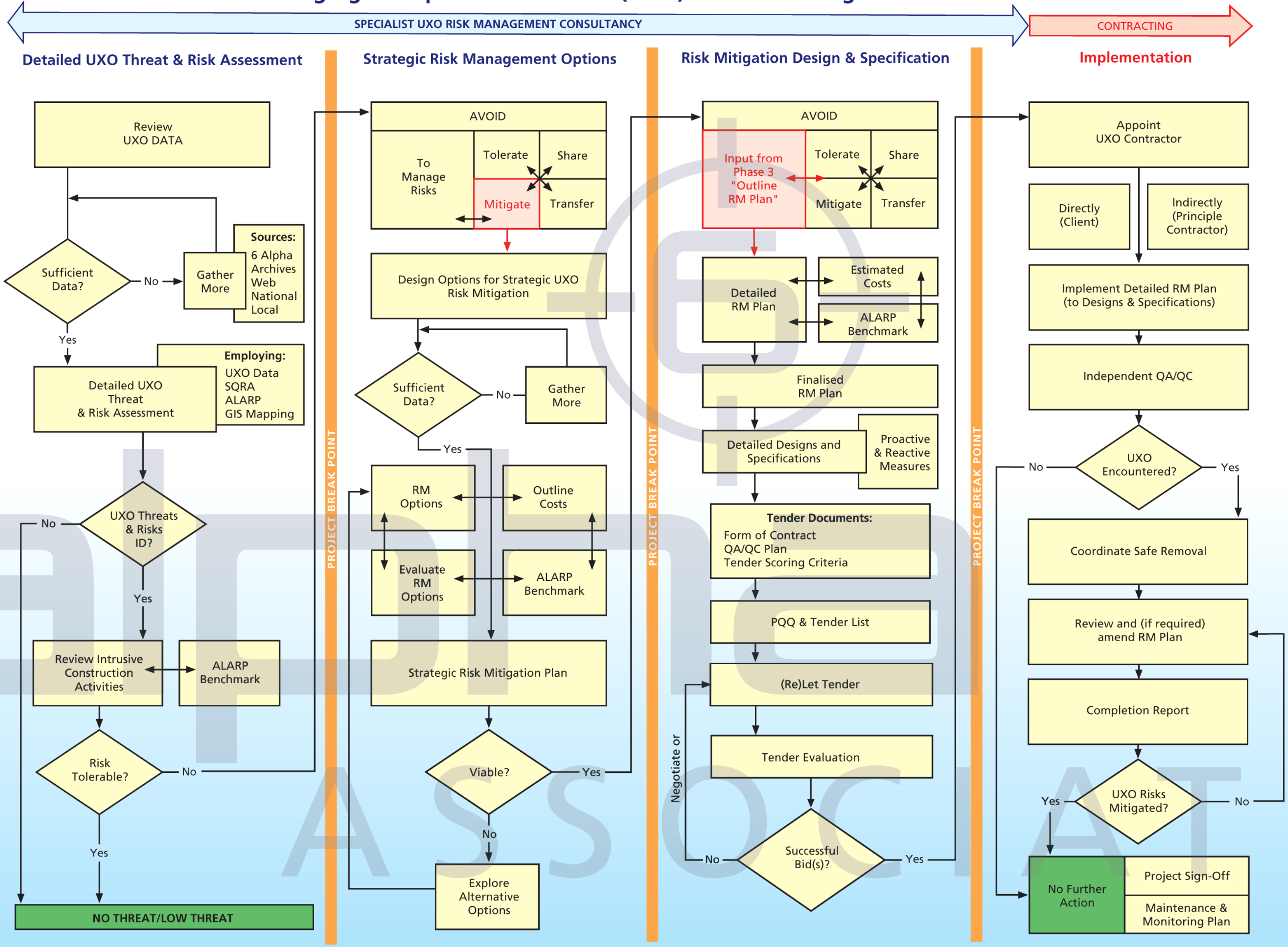
Managing Unexploded Ordnance (UXO) - A Risk Management Framework



alpha ASSOCIATES

Expected Outputs

Detailed UXO Risk Assessment
Expected Consultancy Outputs:
UXO Threat Assessment employing:
Comprehensive UXO Data Sources
Semi-Quantitative Risk Assessment (SQRA) & ALARP
GIS Mapping
Independent/Robust/Transparent Assessment
Comprehensive & Informative Report

Expected Outputs

Strategic Risk Management Options
Expected Consultancy Outputs:
Strategic Risk Mitigation (RM) options
Criteria for selection of mix of options
Selection of best mix of options
Benchmark with Client's Tolerance of UXO Risk
Strategic Risk Mitigation Plan

Expected Outputs

Risk Mitigation Design & Specification
Expected Consultancy Outputs:
Detailed Risk Mitigation Design
Accompanying Risk Mitigation Specifications
Sufficient for Incorporation into Tender Documents

Expected Outputs

Implementation
Expected Consultancy & Contractor Outputs:
Safe Removal of UXO
Independent QA/QC on Contractor
Completion Reposts
Independent Consultancy Sign-off
Post Construction Maintenance/Monitoring Plan

Appendix 3

Holistic UXO Risk Management Process

CONCEPT

There are generally, three sequential strands of Unexploded Ordnance (UXO) risk management work to consider in order to reduce risks ALARP and they have been depicted (at Figure 1) and grouped together, at the Strategic, Tactical and Operational levels.

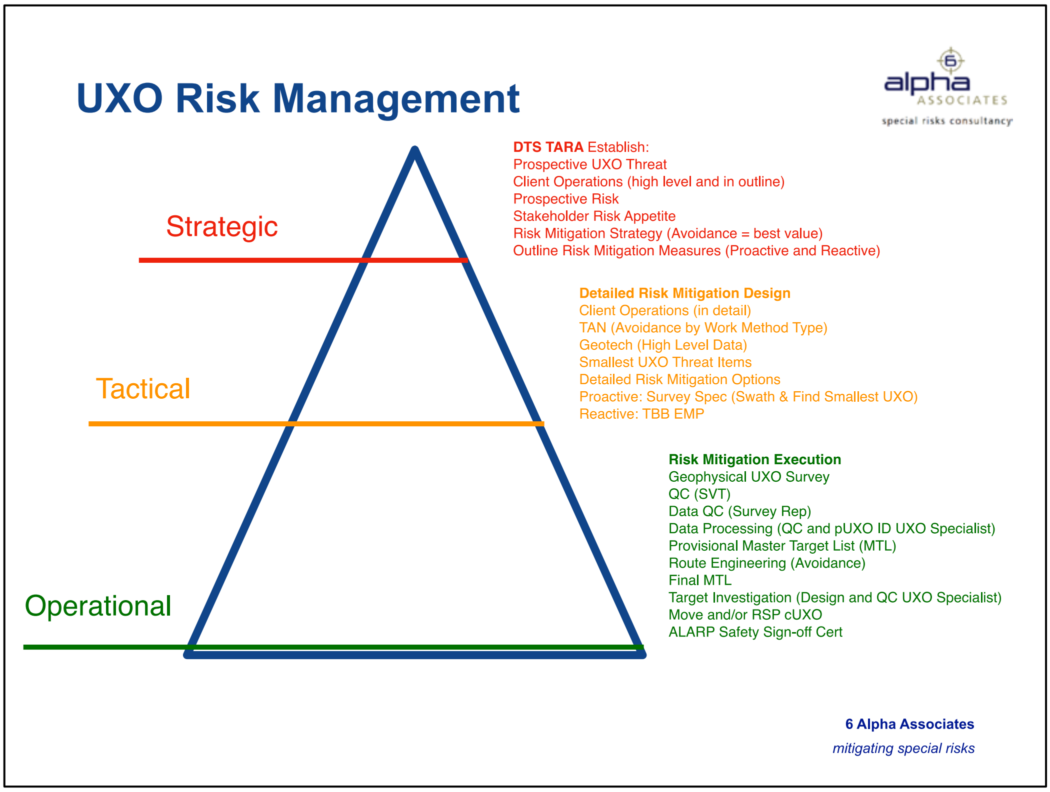


Figure 1: 6 Alpha UXO Risk Management - Concept

DETAIL

Strategic Level - A Holistic Perspective of UXO Threat, Risk and Risk Management

A UXO Desk Top Study (DTS) will establish the prospective UXO threat and risk in sequence, as follows:

- **Operations**; it will establish the nature of prospective Client operations (at high level and in outline) for example and typically:
  - Geotechnical Investigation (GI);
  - Cable Installation;
  - OWF Installation;
- **Risk**; establish prospective UXO risk by examining (using Semi Quantitative Risk Assessment), two key factors:

    - **Probability**; of UXO encounter and of its initiation (the former is driven by UXO/civil engineering juxtaposition; the latter by kinetic energy);
    - **Consequence**; of UXO initiation, which is driven by the Net (High) Explosive Quantity (NEQ) in each type of UXO. And (critically); the proximity and robustness of sensitive receptors (e.g. people, GI and/or installation equipment);
- **Stakeholder Risk Appetite**; what risks can stakeholders reasonably and legally tolerate? What cannot be tolerated (e.g. risk of injury to personnel)?;
- **Risk Mitigation Strategy**; e.g. UXO avoidance which delivers the best value for money solution;
- **Risk Mitigation Measures**; divided typically into proactive and reactive categories.

Tactical Level - Detailed Risk Mitigation Design

Following GI and/or installation solution has been designed (or concurrent with it), 6 Alpha then deliver a "Detailed UXO Risk Mitigation Design", considering the following factors, in sequence:

- The Client's and Principal Contractor's installation operations (in detail);
- Technical Advisory Notes (TAN) that deliver potential UXO (pUXO) avoidance by work method type. Benefits: reduced pUXO avoidance (initially 15m radius, but typically ~10m radii, post TAN); therefore, more freedom of pipeline manoeuvre, micro-routing and micro siting, in advance of installation; fewer pUXO to be avoided; less investigation; thus save time, reduce schedule and save money;
- Geotech input in the form of high level data on soil types and shear strengths. Detailed geotech will enable more accurate and better focussed TAN;
- Smallest UXO threat items for detection v stakeholder appetite for risk?
- Therefore, outline risk mitigation measures are typically sub-divided into the following categories:
    - **Proactive Measures** e.g.:
        - Geophysical UXO survey (accounting for the smallest UXO threat) and its avoidance
        - If pUXO cannot be avoided, then verify it by investigation;
        - If it is confirmed UXO (cUXO) then move it (if it both safe and practical to do so) and/or destroy it;
    - **Reactive Measures** eg:
        - Site Emergency Management Plans (EMP);
        - Tool Box Briefs (TBB) for site workers.

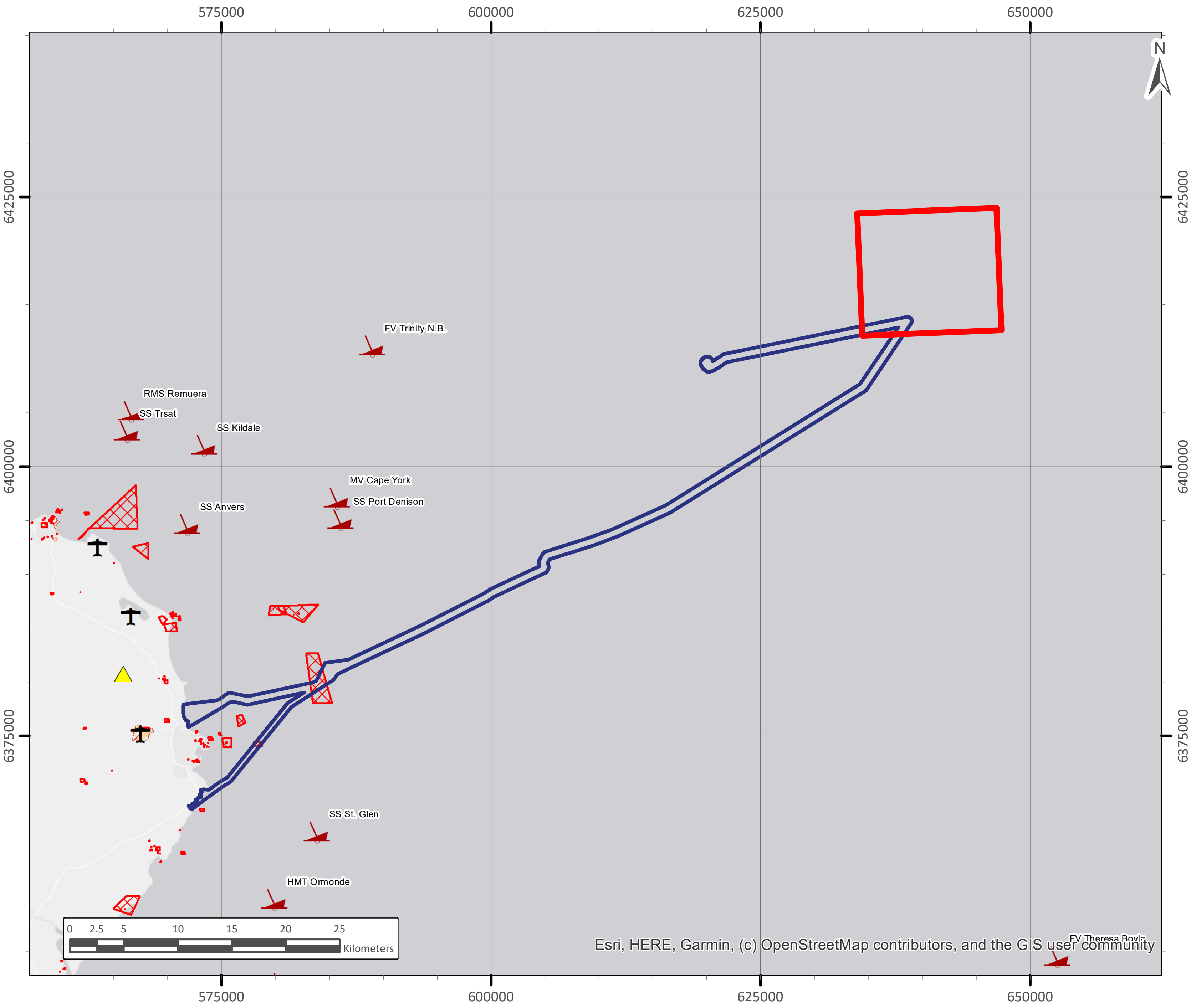
Operational Level - Delivery of UXO Risk Management and Mitigation Solutions

UXO risk mitigation execution might typically include, sequentially:

- Geophysical UXO Survey pre-installation;
- Survey Quality Control (QC) via a Survey Verification Test (SVT);
- Data QC;
- Data Processing (QC and pUXO ID - by a UXO Specialist, such as 6 Alpha), concurrent with survey operations;
- Provisional Master Target List (MTL) generated by UXO Specialist consisting of all pUXO;
- Micro-siting and/or route engineering (thus avoidance) is undertaken (benefit - saves time and money);
- Final MTL produced, which ensured that the following activities are reduced to the minimum in order to reduce risk ALARP and to save time and money:
    - Target Investigation (designed, and QC'd by a UXO Specialist such as 6 Alpha);
    - Move and/or Redner Safe Procedure (RSP) on confirmed UXO (cUXO);
    - ALARP Safety Sign-off Certs delivered for all installation methods.

Appendix 4

Aerial Bombing Threat



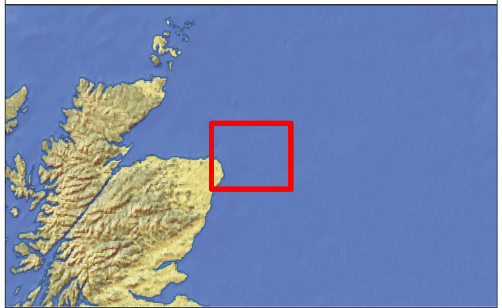
LEGEND

GENERAL

- Green_Volt_OWF_Boundary
- Export_Cable_Corridor

UXO THREATS

- Military_Airfield
- Bombing_Decoy
- WWII_Air-Raid_Wreck
- WWII_Bomb_Strikes
- WWII_Bombing_Target



PROJECT	PROJECT TITLE
9691	GREEN VOLT OWF

DRAWING TITLE
Aerial Bombing Threat

DRAWING NUMBER
Green Volt OWF\004\V2.0

PURPOSE
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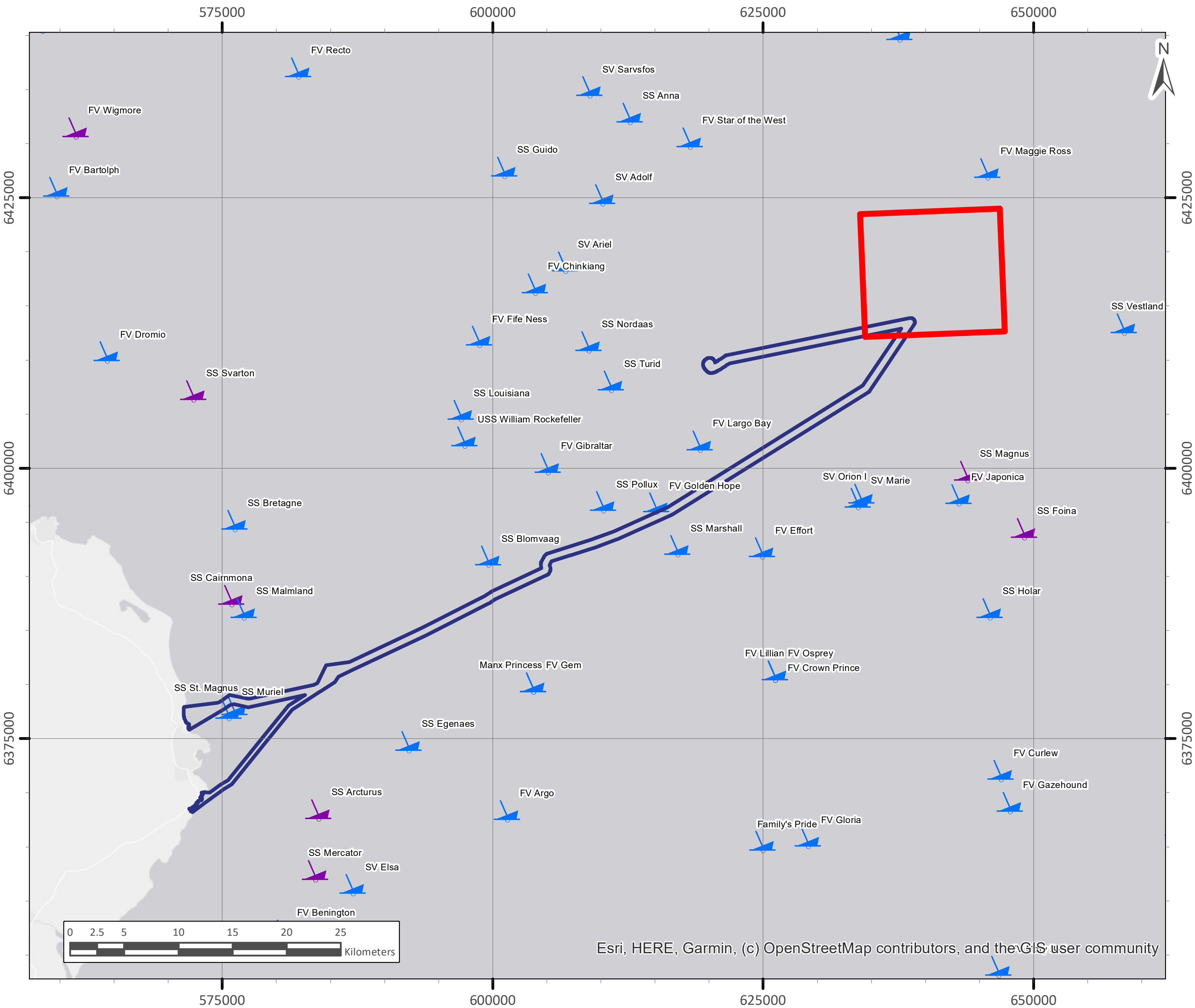
Appendix 5

Naval Engagements



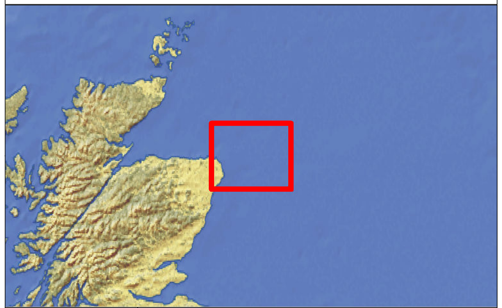
LEGEND

GENERAL

- Green_Volt_OWF_Boundary
- Export_Cable_Corridor

UXO THREATS

- WWI_Naval_Wreck
- WWII_Naval_Wreck



PROJECT	PROJECT TITLE
9691	GREEN VOLT OWF

DRAWING TITLE
Naval Engagements

DRAWING NUMBER
Green Volt OWF\005\V2.0

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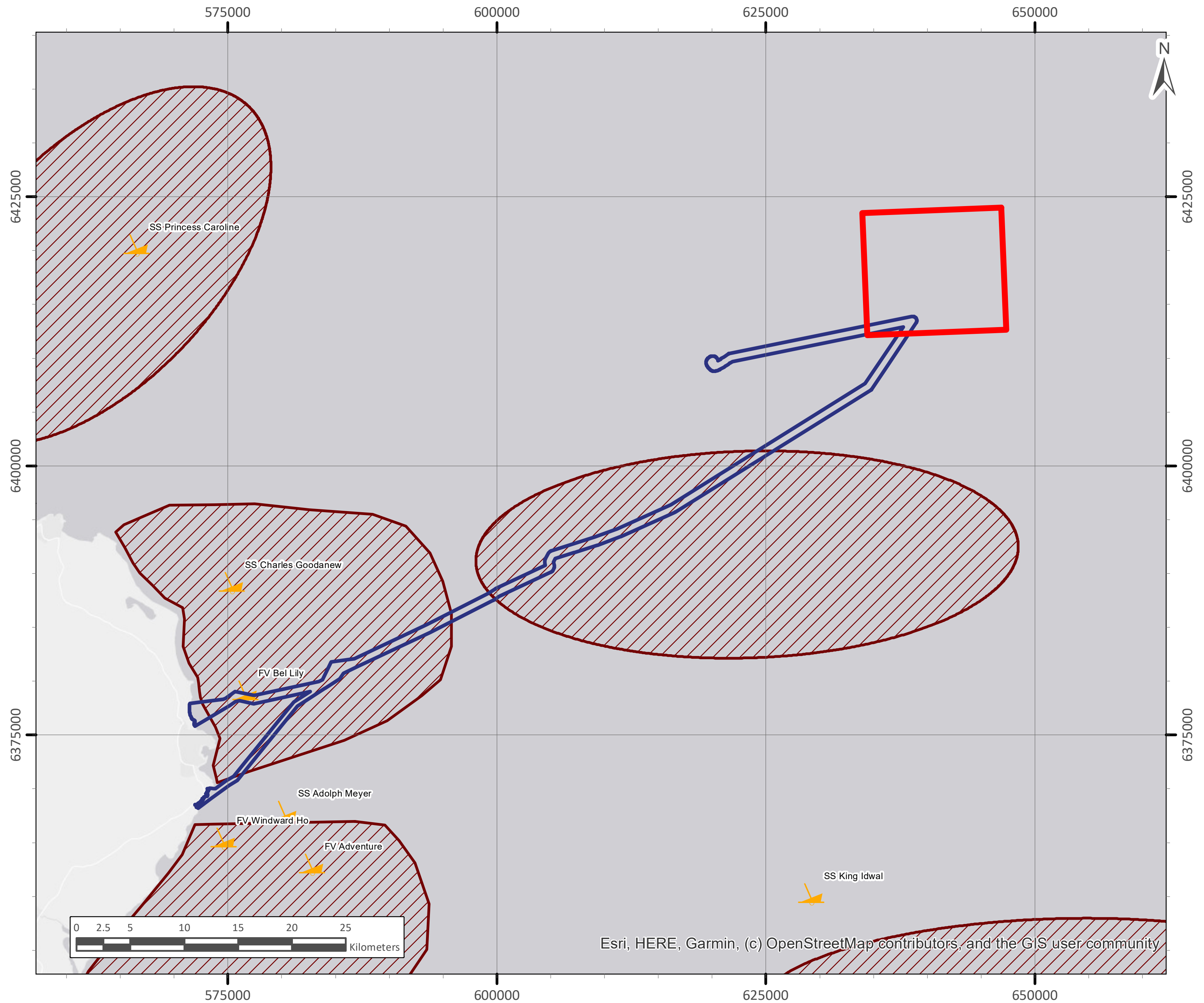
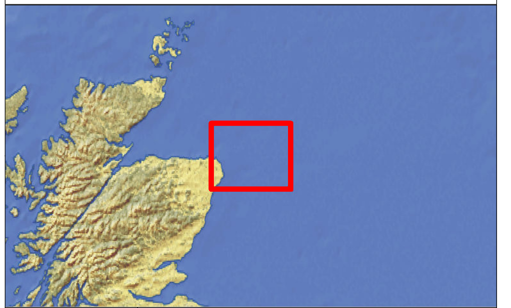
Appendix 6

WWI Minefields





LEGEND

GENERAL

Green_Volt_OWF_Boundary

Export_Cable_Corridor

UXO THREATS

WWI_Mined_Wreck

WWI_Central_Powers_Minefield

PROJECT	PROJECT TITLE
9691	GREEN VOLT OWF

DRAWING TITLE
WWI Minefields

DRAWING NUMBER
Green Volt OWF\006\V2.0

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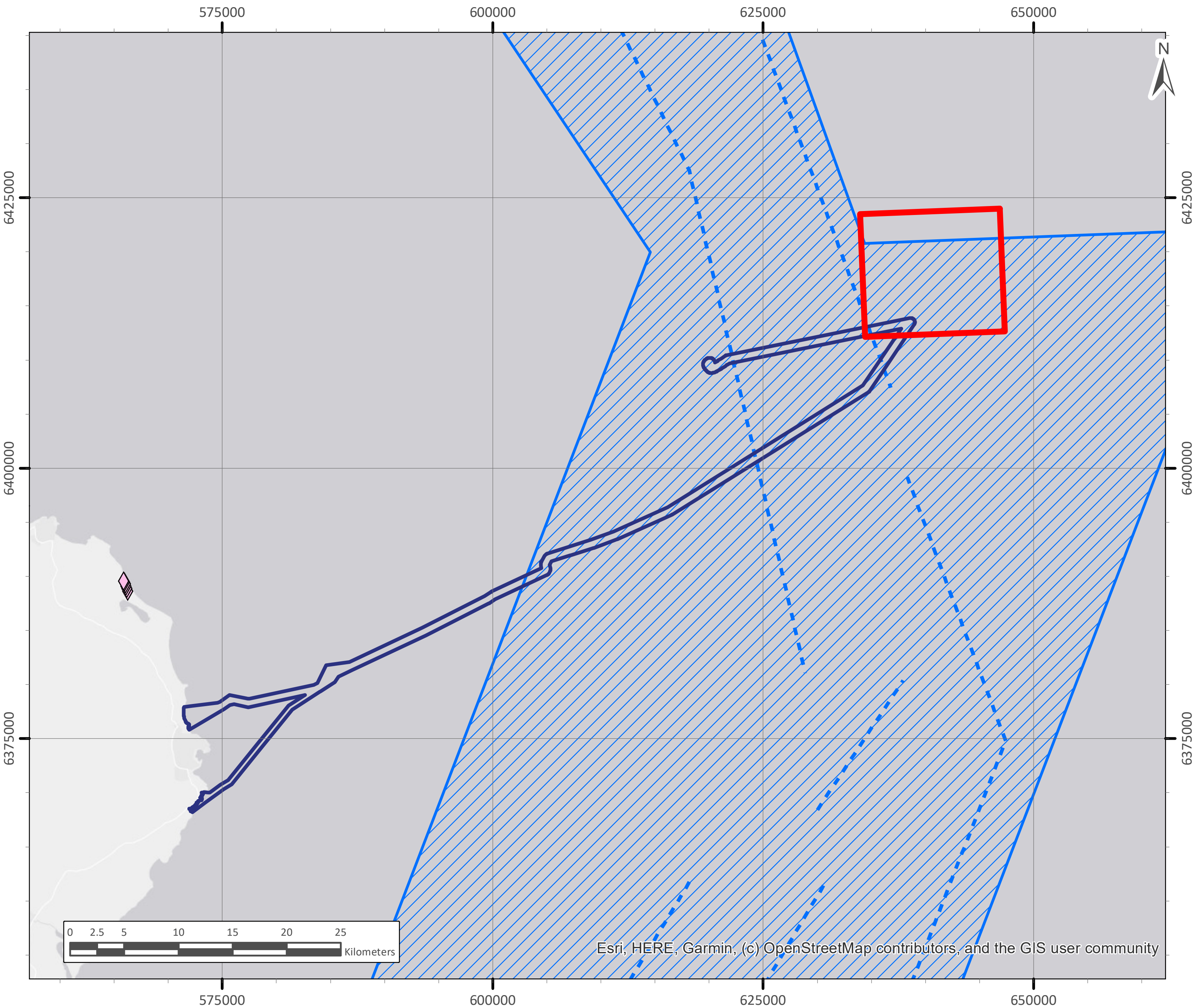
Appendix 7

WWII Minefields



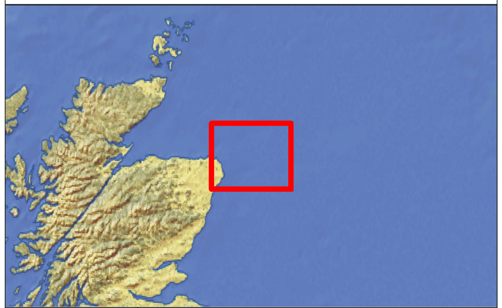
LEGEND

GENERAL

- Green_Volt_OWF_Boundary
- Export_Cable_Corridor

UXO THREATS

- Shore_Minefield
- WWII_Allied_Minelay
- WWII_Allied_Minefield



PROJECT	PROJECT TITLE
9691	GREEN VOLT OWF

DRAWING TITLE
WWII Minefields

DRAWING NUMBER
Green Volt OWF\007\V2.0

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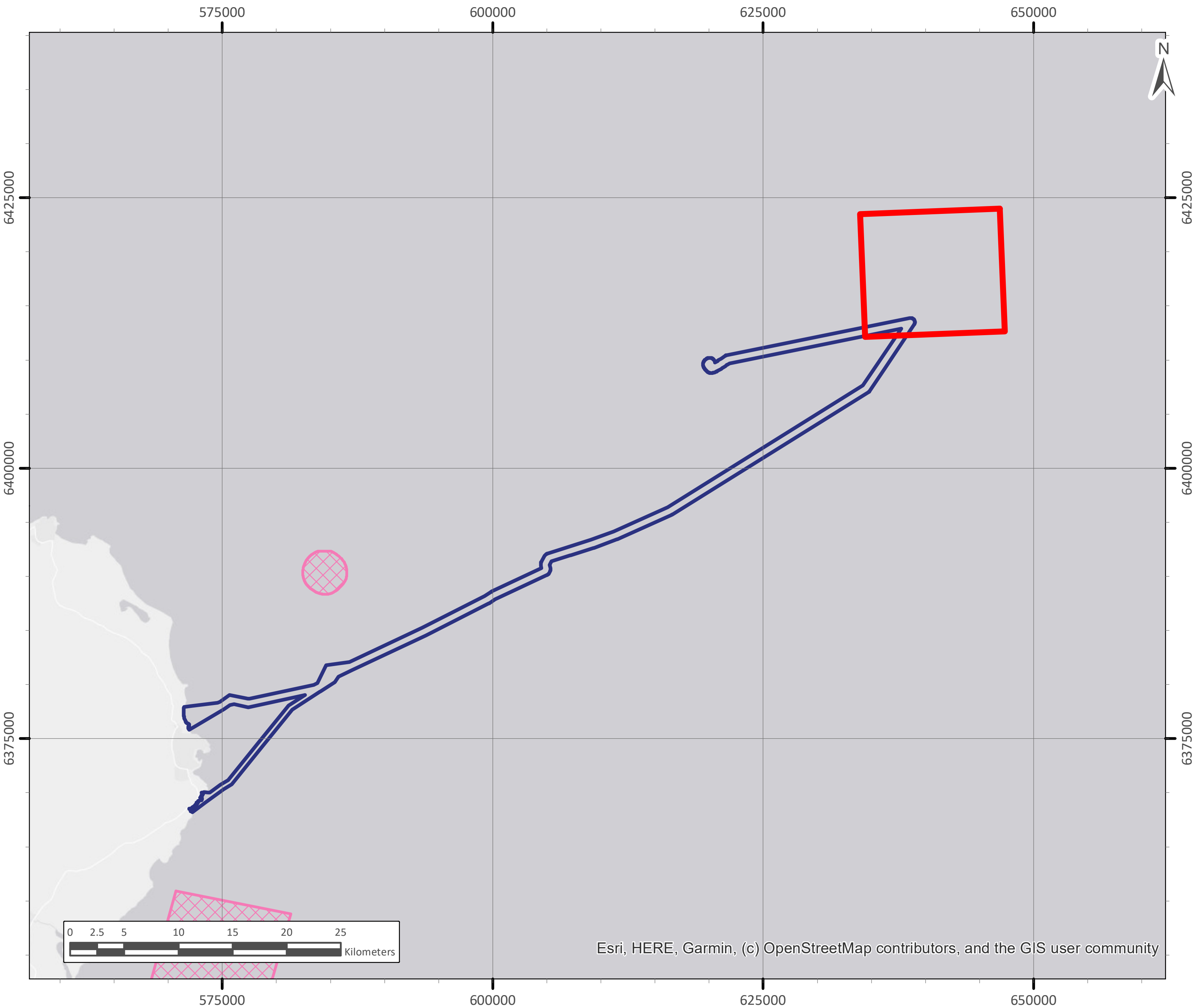
Appendix 8

Historic Military PEXA



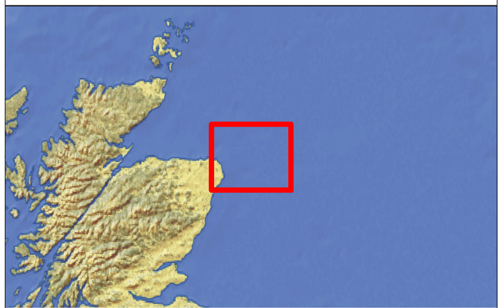
LEGEND

GENERAL

- Green_Volt_OWF_Boundary
- Export_Cable_Corridor

UXO THREATS

- Historic_PEXA



PROJECT	PROJECT TITLE
9691	GREEN VOLT OWF

DRAWING TITLE
Historic Military PEXA

DRAWING NUMBER
Green Volt OWF\008\V2.0

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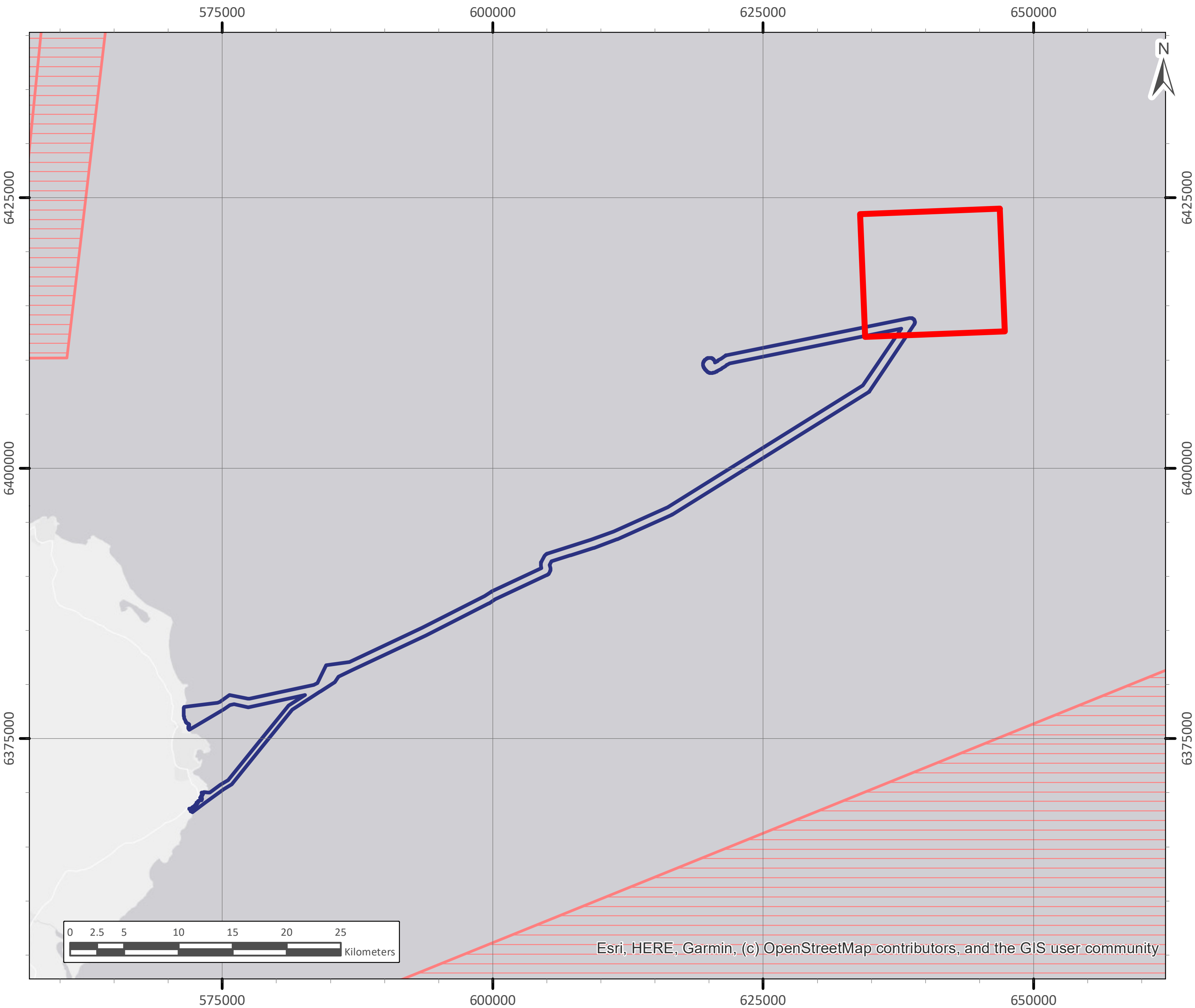
Appendix 9

Modern Military PEXA



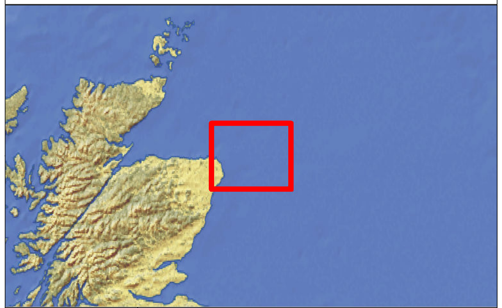
LEGEND

GENERAL

- Green_Volt_OWF_Boundary
- Export_Cable_Corridor

UXO THREATS

- Air_Force_PEXA



PROJECT	PROJECT TITLE
9691	GREEN VOLT OWF

DRAWING TITLE
Modern Military PEXA

DRAWING NUMBER
Green Volt OWF\009\V2.0

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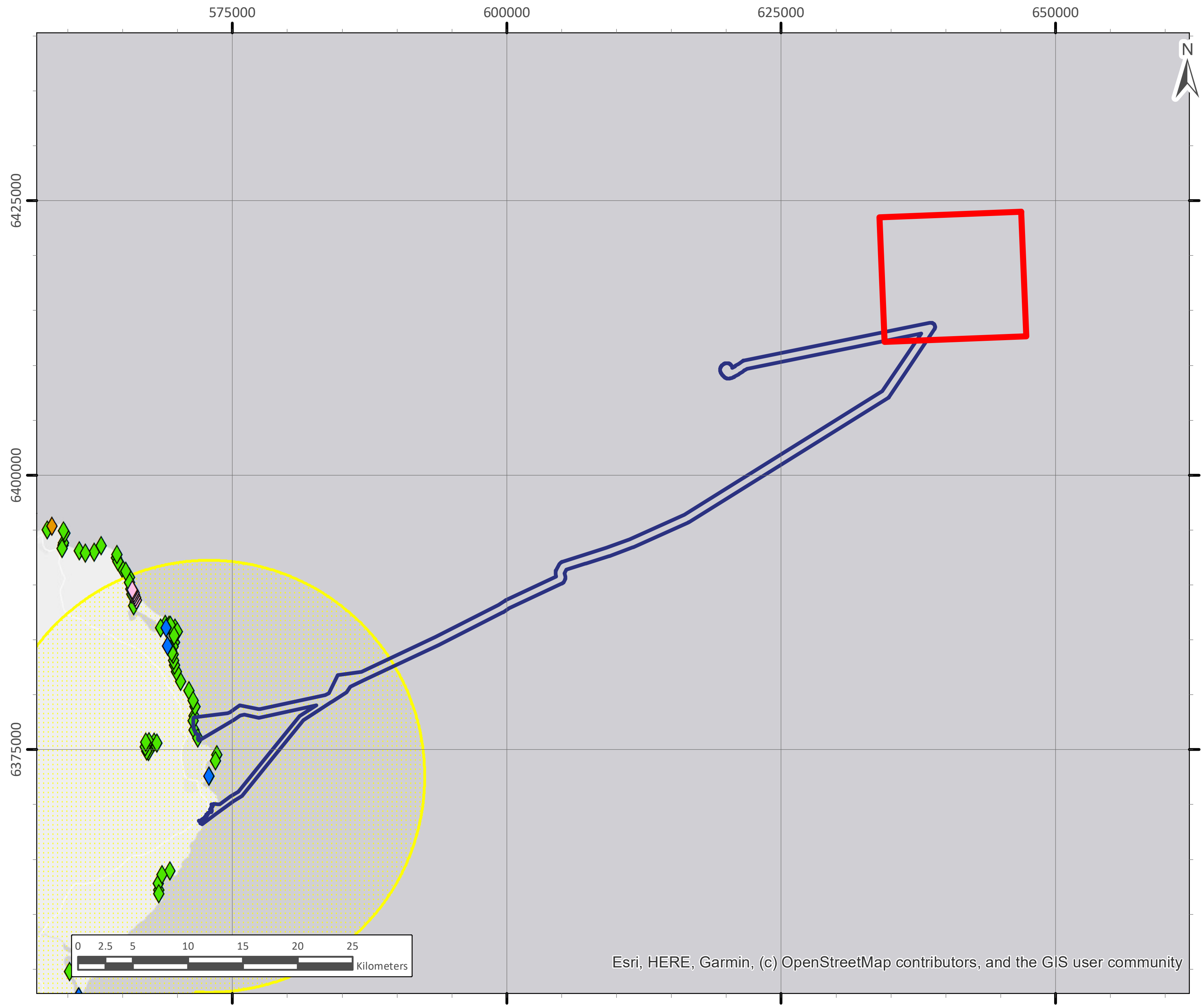
Appendix 10

Coastal Armaments



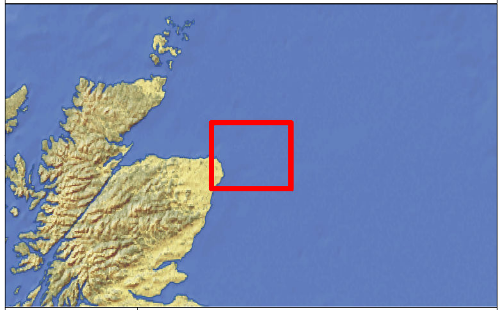
LEGEND

GENERAL

- Green_Volt_OWF_Boundary
- Export_Cable_Corridor

UXO THREATS

- Shore_Minefield
- Coastal_Armament
- AAA_Battery
- Defensive_Installation
- Coastal_Armament_Range



PROJECT	PROJECT TITLE
9691	GREEN VOLT OWF

DRAWING TITLE
Coastal Armaments

DRAWING NUMBER
Green Volt OWF\010\V2.0

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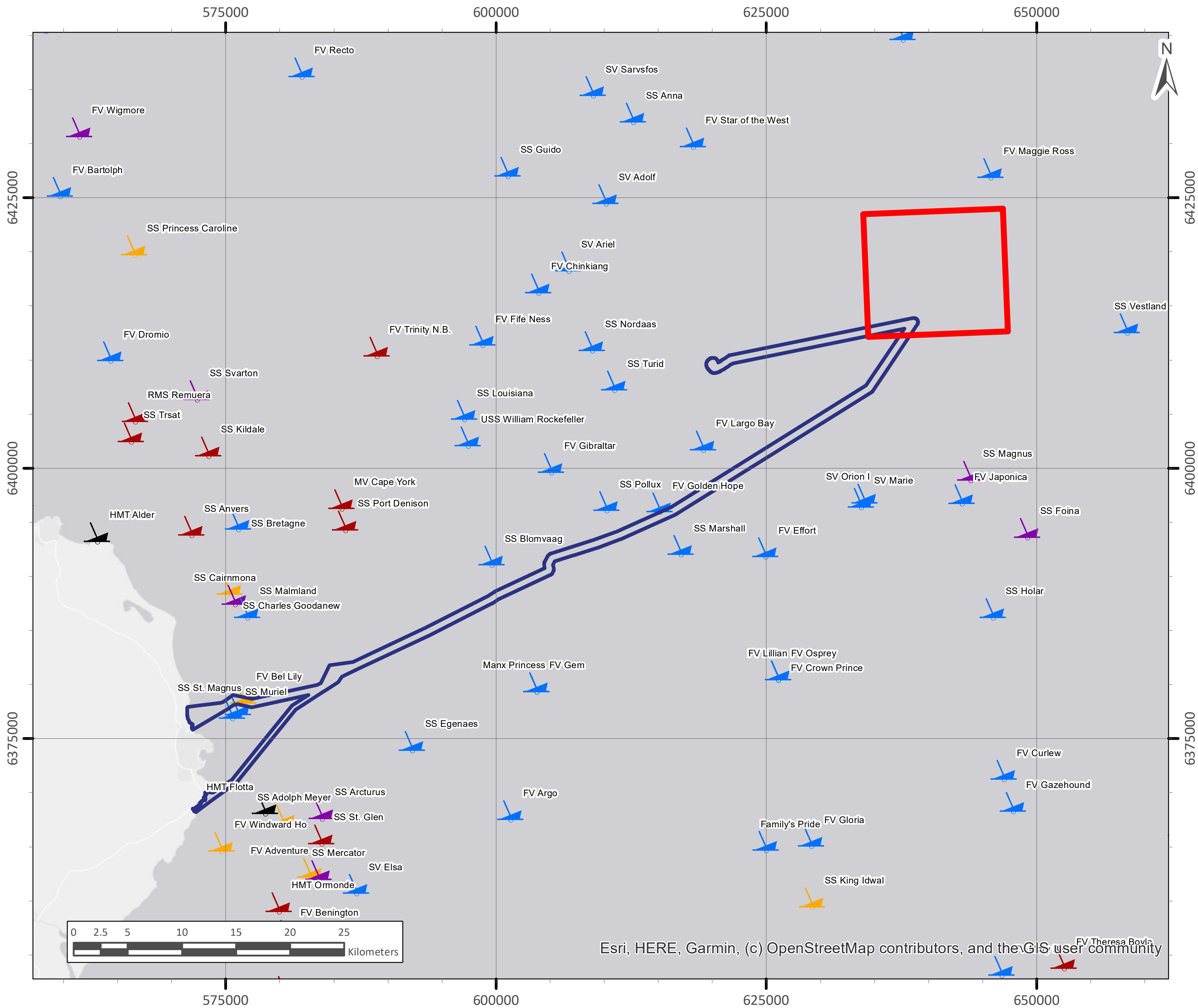
Appendix 11

Munitions Related Shipwrecks



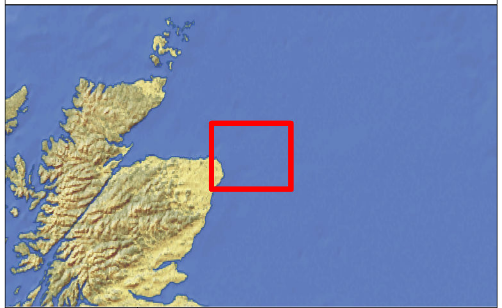
LEGEND

GENERAL

- Green_Volt_OWF_Boundary
- Export_Cable_Corridor

UXO THREATS

- WWII_Air-Raid_Wreck
- WWI_Naval_Wreck
- WWII_Naval_Wreck
- WWI_Mined_Wreck
- Other_Munitions_Wreck



PROJECT	PROJECT TITLE
9691	GREEN VOLT OWF

DRAWING TITLE
Munitions Related Shipwrecks

DRAWING NUMBER
Green Volt OWF\011\V2.0

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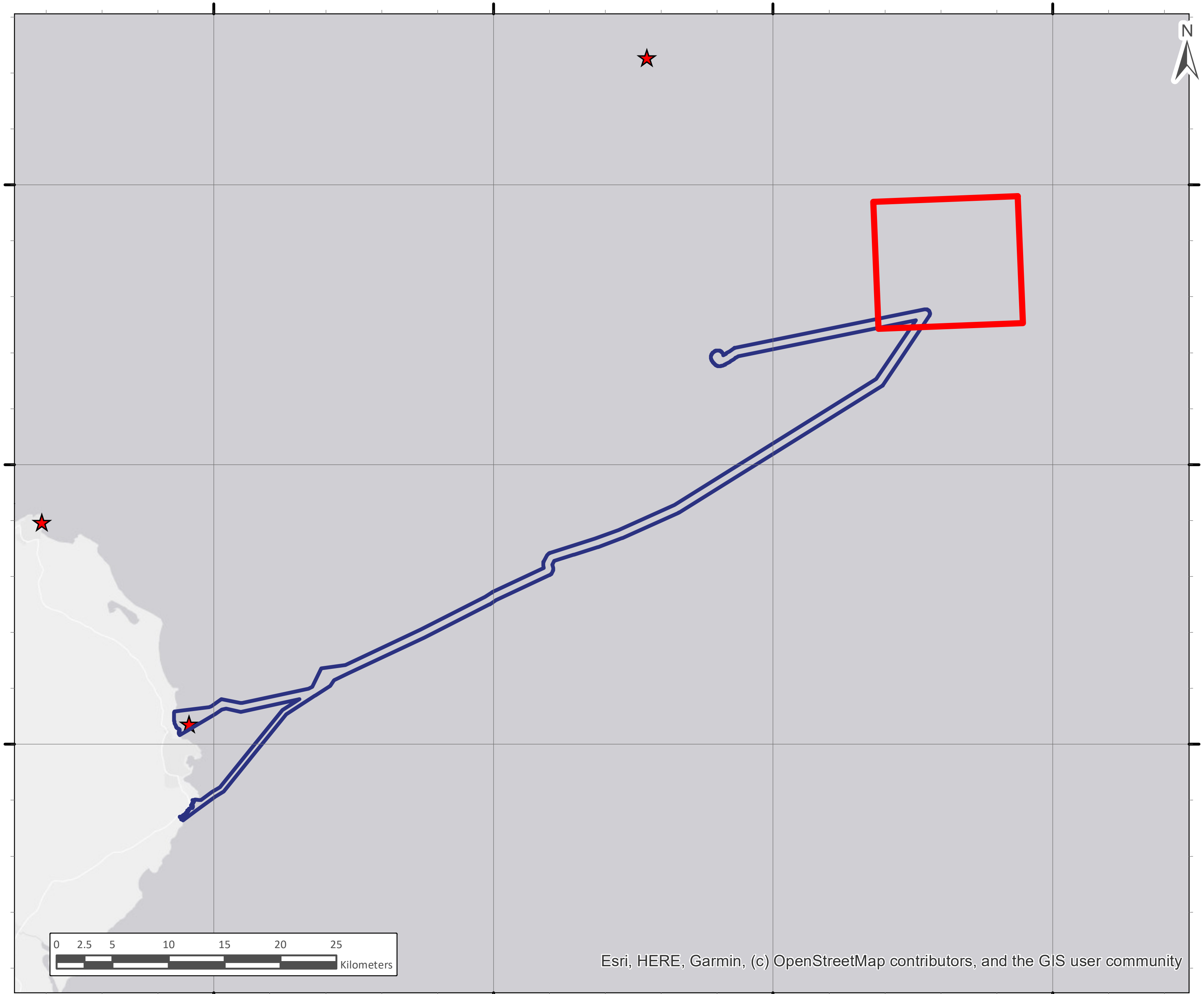
Appendix 12

Munitions Encounters



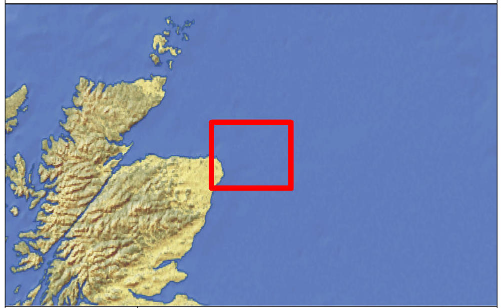
LEGEND

GENERAL

- Green_Volt_OWF_Boundary
- Export_Cable_Corridor

UXO THREATS

- OSPAR_Munitions_Encounter



PROJECT	PROJECT TITLE
9691	GREEN VOLT OWF

DRAWING TITLE
Munitions Encounters

DRAWING NUMBER
Green Volt OWF\012\V2.0

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Appendix 13

Consolidated UXO Threat

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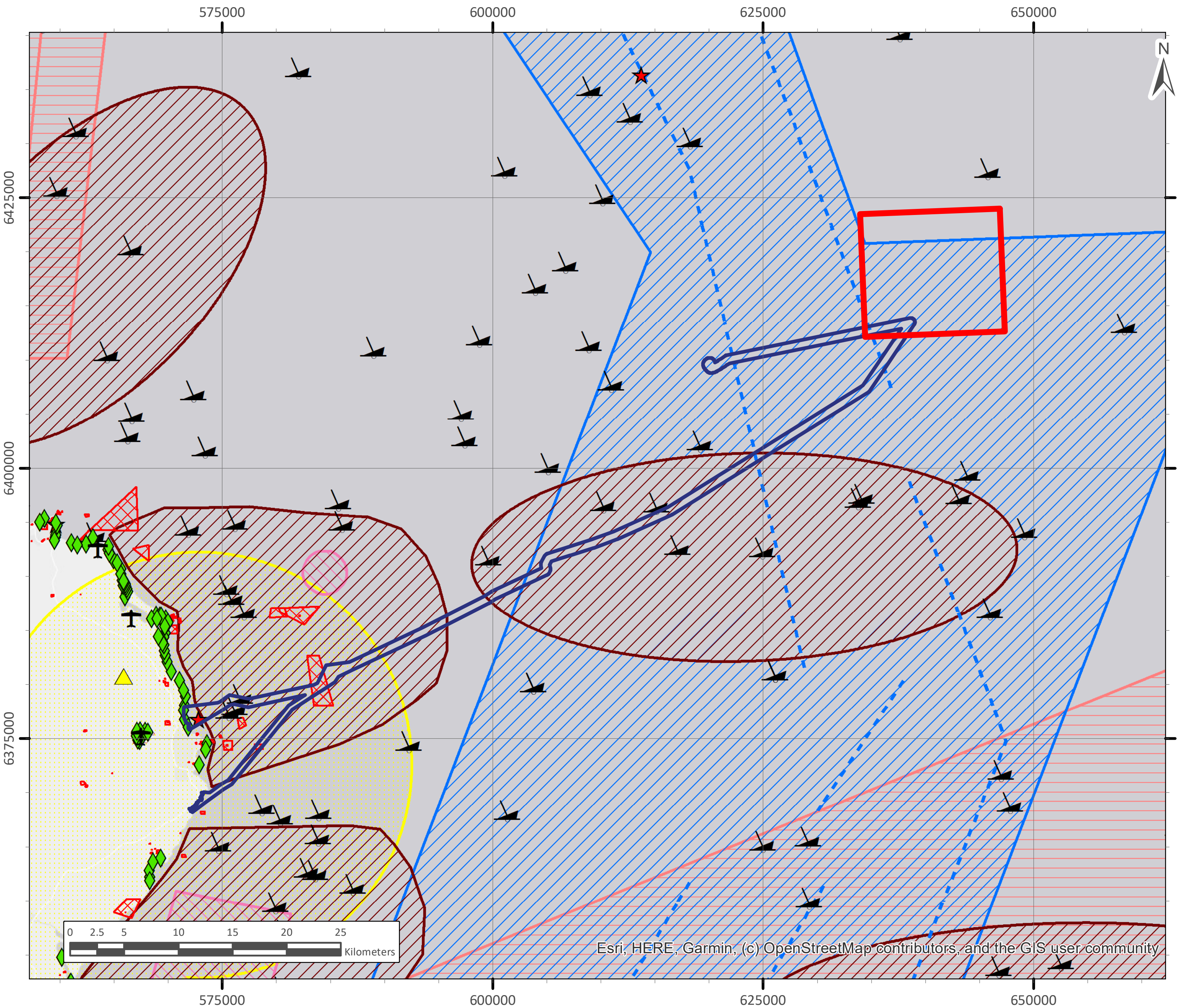


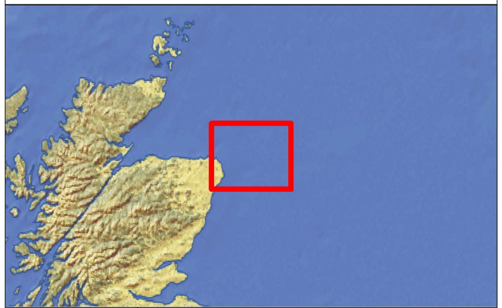
LEGEND

GENERAL

- Green_Volt_OWF_Boundary
- Export_Cable_Corridor

UXO THREATS

- Military_Airfield
- Bombing_Decoy
- Defensive_Installation
- Munitions_Related_Wreck
- OSPAR_Munitions_Encounter
- WWII_Allied_Minelay
- WWII_Bomb_Strikes
- WWII_Bombing_Target
- WWI_Central_Powers_Minefield
- WWII_Allied_Minefield
- Historic_PEXA
- Air_Force_PEXA
- Coastal_Armament_Range



PROJECT	PROJECT TITLE
9691	GREEN VOLT OWF

DRAWING TITLE
Consolidated UXO Threat

DRAWING NUMBER
Green Volt OWF\013\V2.0

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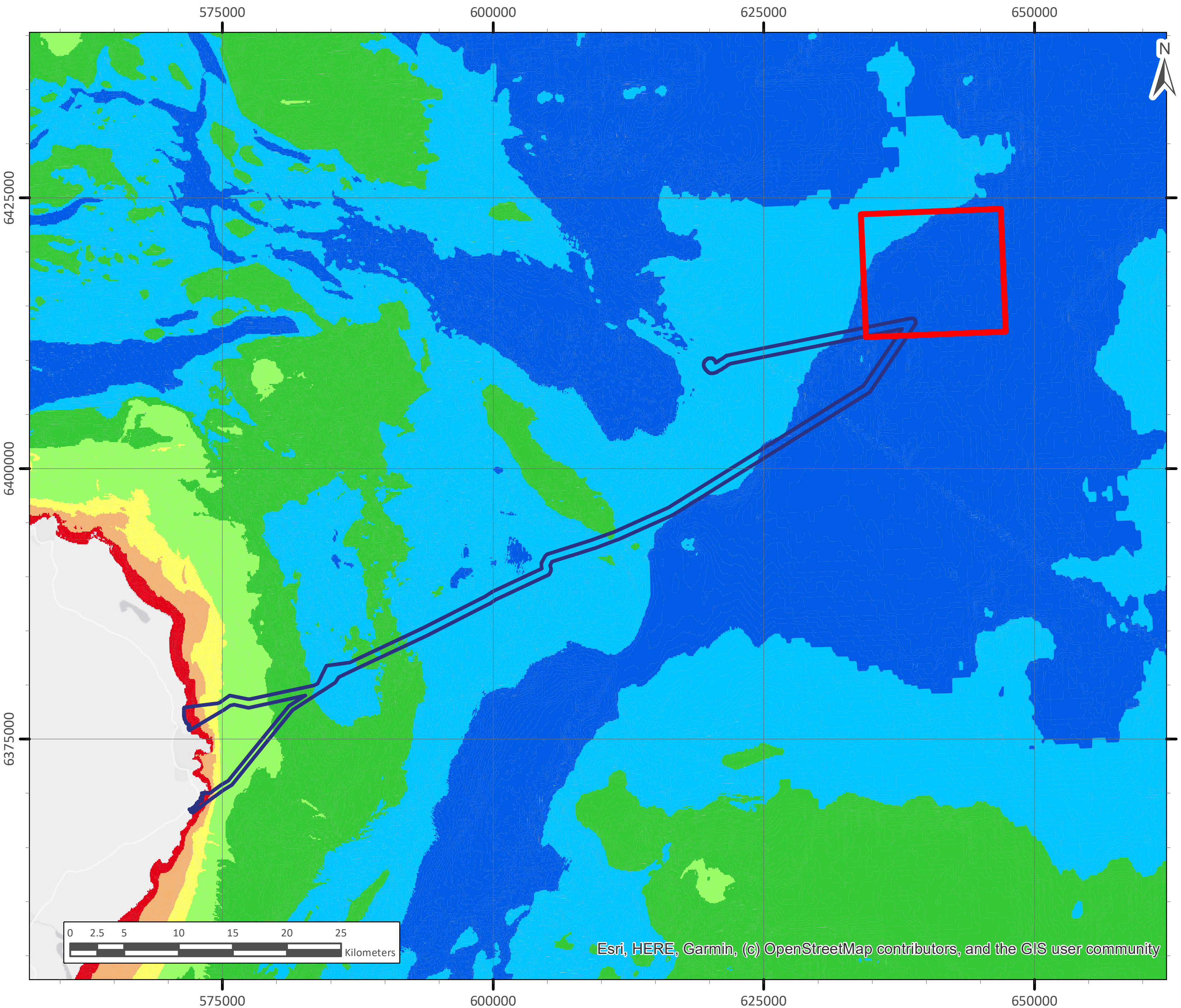
Appendix 14

Bathymetry



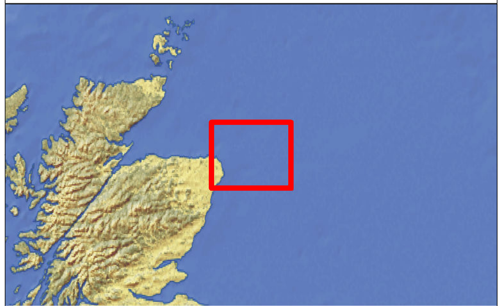
LEGEND

GENERAL

- Green_Volt_OWF_Boundary
- Export_Cable_Corridor

Water_Depth (LAT)

- <10m
- <26m
- <40m
- <60m
- <80m
- <100m
- >100m



PROJECT	PROJECT TITLE
9691	GREEN VOLT OWF

DRAWING TITLE
Bathymetry

DRAWING NUMBER
Green Volt OWF\014\V2.0

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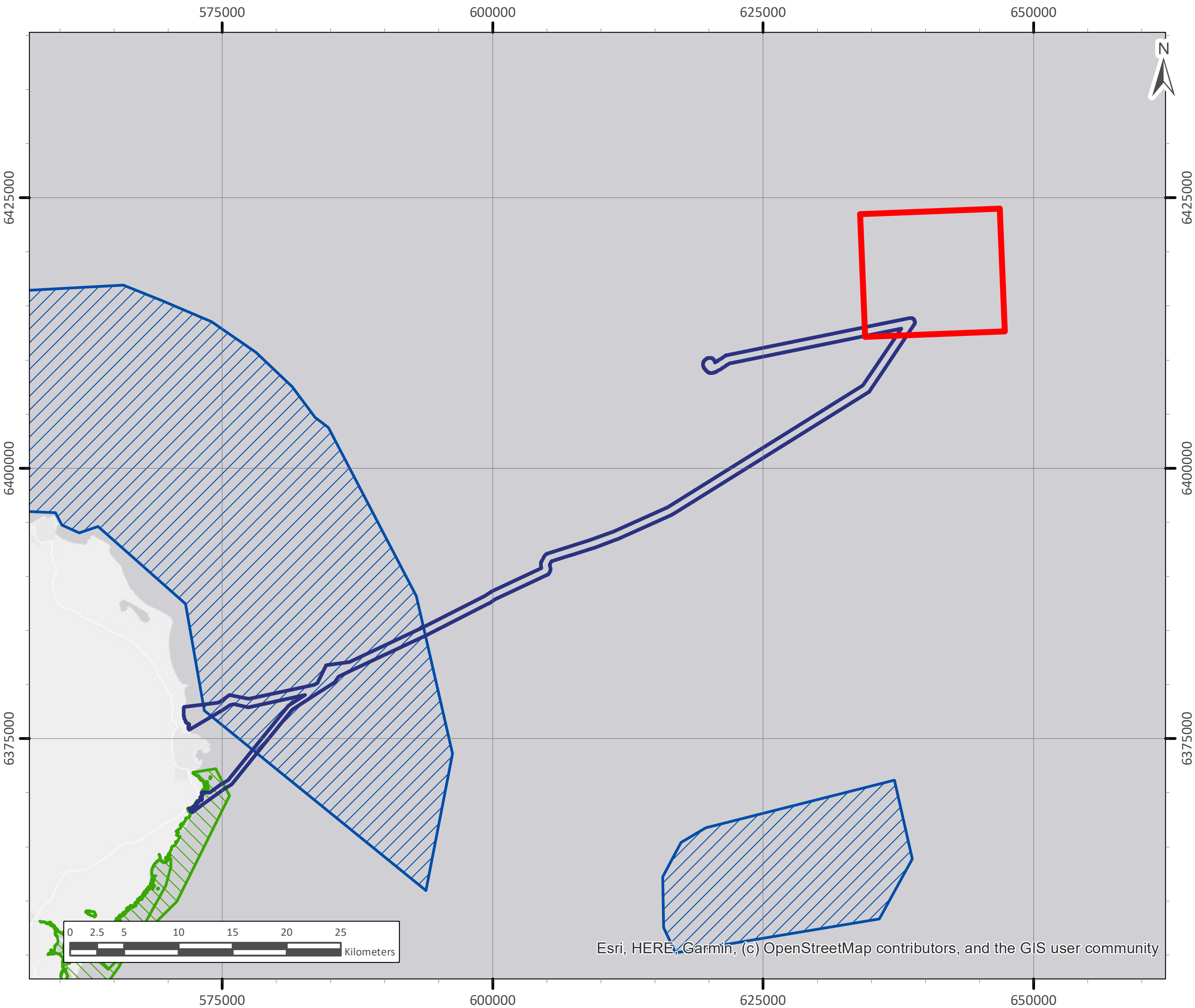
Appendix 15

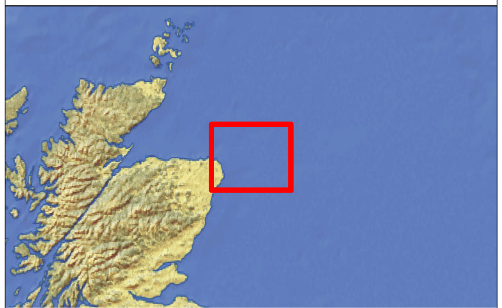
Marine Protection Areas



LEGEND

GENERAL

- Green_Volt_OWF_Boundary
- Export_Cable_Corridor
- Marine_Protection_Area
- Special_Area_of_Conservation



PROJECT	PROJECT TITLE
9691	GREEN VOLT OWF

DRAWING TITLE
Marine Protection Areas

DRAWING NUMBER
Green Volt OWF\015\V2.0

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Appendix 16

Semi-Quantitative Risk Assessment Tables

The tables produced on the following pages outline and display the numeric scored assessment for the project as well as the initial and residual UXO risk to each specific operation after mitigation measures have been appropriately applied. It is also important to note that the risk assessment for the various operations is conducted for each individual activity, irrespective of prior operations which may have taken place.

An explanation of the SQRA process and Azimuth risk matrix used by 6 Alpha Associates is presented at Annex B.

Risk (R) is calculated as a function of probability of encounter and initiation (P) and consequence of initiation (C), where R = P x C.

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Floating WTG Mooring Operations

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
WTG Anchoring Deep Offshore ~100m LAT	WWI Torpedo	253.5	1	2	2	1	2	2	1	5	5	1	5	5
	WWII Naval Mine	227	3	2	6	1	2	2	3	5	15	1	5	5
	Large HE Bomb	220	1	1	1	1	1	1	1	5	5	1	5	5
	WWI Naval Mine	165	1	1	1	1	1	1	1	5	5	1	5	5
	Medium HE Bomb	130	1	1	1	1	1	1	1	5	5	1	5	5
	Small HE Bomb	25	1	1	1	1	1	1	1	5	5	1	5	5
	Medium Artillery Projectile	6	1	1	1	1	1	1	1	4	4	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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OSP Foundation Installation Operations

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Pin Piling Deep Offshore ~100m LAT	WWI Torpedo	253.5	1	2	2	1	2	2	1	5	5	1	5	5
	WWII Naval Mine	227	3	1	3	1	1	1	3	5	15	1	5	5
	Large HE Bomb	220	1	1	1	1	1	1	1	5	5	1	5	5
	WWI Naval Mine	165	1	1	1	1	1	1	1	5	5	1	5	5
	Medium HE Bomb	130	1	1	1	1	1	1	1	5	5	1	5	5
	Small HE Bomb	25	1	1	1	1	1	1	1	5	5	1	5	5
	Medium Artillery Projectile	6	1	1	1	1	1	1	1	4	4	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Pre-Lay Operations

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
PLGR + RC Ultra-Nearshore <10m LAT	WWI Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWII Naval Mine	227	1	5	5	1	5	5	1	5	5	1	5	5
	Large HE Bomb	220	4	5	20	1	5	5	4	5	20	1	5	5
	WWI Naval Mine	165	1	5	5	1	5	5	1	5	5	1	5	5
	Medium HE Bomb	130	4	5	20	1	5	5	4	5	20	1	5	5
	Small HE Bomb	25	4	5	20	1	5	5	4	5	20	1	5	5
	Medium Artillery Projectile	6	3	4	12	1	4	4	3	4	12	1	4	4
	WWI Naval Projectile	1.42	1	2	2	1	2	2	1	2	2	1	2	2
	Small Artillery Projectile	0.93	2	2	4	1	2	2	2	2	4	1	2	2
	LSA	0.55	2	2	4	1	2	2	2	2	4	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
PLGR + RC Nearshore ~26m LAT	WWI Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWII Naval Mine	227	1	5	5	1	5	5	1	5	5	1	5	5
	Large HE Bomb	220	4	5	20	1	5	5	4	5	20	1	5	5
	WWI Naval Mine	165	2	5	10	1	5	5	2	5	10	1	5	5
	Medium HE Bomb	130	4	4	16	1	4	4	4	5	20	1	5	5
	Small HE Bomb	25	4	2	8	1	2	2	4	5	20	1	5	5
	Medium Artillery Projectile	6	3	2	6	1	2	2	3	4	12	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
PLGR + RC Shallow Offshore ~40m LAT	WWI Torpedo	253.5	2	3	6	1	3	3	2	5	10	1	5	5
	WWII Naval Mine	227	1	3	3	1	3	3	1	5	5	1	5	5
	Large HE Bomb	220	3	3	9	1	3	3	3	5	15	1	5	5
	WWI Naval Mine	165	2	3	6	1	3	3	2	5	10	1	5	5
	Medium HE Bomb	130	3	3	9	1	3	3	3	5	15	1	5	5
	Small HE Bomb	25	3	2	6	1	2	2	3	5	15	1	5	5
	Medium Artillery Projectile	6	3	1	3	1	1	1	3	4	12	1	4	4
	WWI Naval Projectile	1.42	2	1	2	1	1	1	2	2	4	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
PLGR + RC Offshore ~60m LAT	WWI Torpedo	253.5	2	2	4	1	2	2	2	5	10	1	5	5
	WWII Naval Mine	227	1	2	2	1	2	2	1	5	5	1	5	5
	Large HE Bomb	220	2	2	4	1	2	2	2	5	10	1	5	5
	WWI Naval Mine	165	2	2	4	1	2	2	2	5	10	1	5	5
	Medium HE Bomb	130	2	2	4	1	2	2	2	5	10	1	5	5
	Small HE Bomb	25	2	1	2	1	1	1	2	5	10	1	5	5
	Medium Artillery Projectile	6	2	1	2	1	1	1	2	4	8	1	4	4
	WWI Naval Projectile	1.42	2	1	2	1	1	1	2	2	4	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
PLGR + RC Deep Offshore ~100m LAT	WWI Torpedo	253.5	2	2	4	1	2	2	2	5	10	1	5	5
	WWII Naval Mine	227	4	2	8	1	2	2	4	5	20	1	5	5
	Large HE Bomb	220	1	1	1	1	1	1	1	5	5	1	5	5
	WWI Naval Mine	165	1	1	1	1	1	1	1	5	5	1	5	5
	Medium HE Bomb	130	1	1	1	1	1	1	1	5	5	1	5	5
	Small HE Bomb	25	1	1	1	1	1	1	1	5	5	1	5	5
	Medium Artillery Projectile	6	1	1	1	1	1	1	1	4	4	1	4	4
	WWI Naval Projectile	1.42	2	1	2	1	1	1	2	2	4	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Cable Installation and Burial Operations

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Surface Lay Ultra-Nearshore <10m LAT	WWI Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWII Naval Mine	227	1	5	5	1	5	5	1	5	5	1	5	5
	Large HE Bomb	220	2	5	10	1	5	5	2	5	10	1	5	5
	WWI Naval Mine	165	1	5	5	1	5	5	1	5	5	1	5	5
	Medium HE Bomb	130	2	5	10	1	5	5	2	5	10	1	5	5
	Small HE Bomb	25	2	5	10	1	5	5	2	5	10	1	5	5
	Medium Artillery Projectile	6	1	4	4	1	4	4	1	4	4	1	4	4
	WWI Naval Projectile	1.42	1	2	2	1	2	2	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	2	2	1	2	2	1	2	2	1	2	2
	LSA	0.55	1	2	2	1	2	2	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Surface Lay Nearshore ~26m LAT	WWI Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWII Naval Mine	227	1	5	5	1	5	5	1	5	5	1	5	5
	Large HE Bomb	220	2	5	10	1	5	5	2	5	10	1	5	5
	WWI Naval Mine	165	1	5	5	1	5	5	1	5	5	1	5	5
	Medium HE Bomb	130	2	4	8	1	4	4	2	5	10	1	5	5
	Small HE Bomb	25	2	2	4	1	2	2	2	5	10	1	5	5
	Medium Artillery Projectile	6	1	2	2	1	2	2	1	4	4	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Surface Lay Shallow Offshore ~40m LAT	WWI Torpedo	253.5	1	3	3	1	3	3	1	5	5	1	5	5
	WWII Naval Mine	227	1	3	3	1	3	3	1	5	5	1	5	5
	Large HE Bomb	220	1	3	3	1	3	3	1	5	5	1	5	5
	WWI Naval Mine	165	1	3	3	1	3	3	1	5	5	1	5	5
	Medium HE Bomb	130	1	3	3	1	3	3	1	5	5	1	5	5
	Small HE Bomb	25	1	2	2	1	2	2	1	5	5	1	5	5
	Medium Artillery Projectile	6	1	1	1	1	1	1	1	4	4	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Surface Lay Offshore ~60m LAT	WWI Torpedo	253.5	1	2	2	1	2	2	1	5	5	1	5	5
	WWII Naval Mine	227	1	2	2	1	2	2	1	5	5	1	5	5
	Large HE Bomb	220	1	2	2	1	2	2	1	5	5	1	5	5
	WWI Naval Mine	165	1	2	2	1	2	2	1	5	5	1	5	5
	Medium HE Bomb	130	1	2	2	1	2	2	1	5	5	1	5	5
	Small HE Bomb	25	1	1	1	1	1	1	1	5	5	1	5	5
	Medium Artillery Projectile	6	1	1	1	1	1	1	1	4	4	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Surface Lay Deep Offshore ~100m LAT	WWI Torpedo	253.5	1	2	2	1	2	2	1	5	5	1	5	5
	WWII Naval Mine	227	2	2	4	1	2	2	2	5	10	1	5	5
	Large HE Bomb	220	1	1	1	1	1	1	1	5	5	1	5	5
	WWI Naval Mine	165	1	1	1	1	1	1	1	5	5	1	5	5
	Medium HE Bomb	130	1	1	1	1	1	1	1	5	5	1	5	5
	Small HE Bomb	25	1	1	1	1	1	1	1	5	5	1	5	5
	Medium Artillery Projectile	6	1	1	1	1	1	1	1	4	4	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Jetting Ultra-Nearshore <10m LAT	WWI Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWII Naval Mine	227	1	5	5	1	5	5	1	5	5	1	5	5
	Large HE Bomb	220	3	5	15	1	5	5	3	5	15	1	5	5
	WWI Naval Mine	165	1	5	5	1	5	5	1	5	5	1	5	5
	Medium HE Bomb	130	3	5	15	1	5	5	3	5	15	1	5	5
	Small HE Bomb	25	3	5	15	1	5	5	3	5	15	1	5	5
	Medium Artillery Projectile	6	2	4	8	1	4	4	2	4	8	1	4	4
	WWI Naval Projectile	1.42	1	2	2	1	2	2	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	2	2	1	2	2	1	2	2	1	2	2
	LSA	0.55	1	2	2	1	2	2	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Jetting Nearshore ~26m LAT	WWI Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWII Naval Mine	227	1	5	5	1	5	5	1	5	5	1	5	5
	Large HE Bomb	220	3	5	15	1	5	5	3	5	15	1	5	5
	WWI Naval Mine	165	1	5	5	1	5	5	1	5	5	1	5	5
	Medium HE Bomb	130	3	4	12	1	4	4	3	5	15	1	5	5
	Small HE Bomb	25	3	2	6	1	2	2	3	5	15	1	5	5
	Medium Artillery Projectile	6	2	2	4	1	2	2	2	4	8	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Jetting Shallow Offshore ~40m LAT	WWI Torpedo	253.5	1	3	3	1	3	3	1	5	5	1	5	5
	WWII Naval Mine	227	1	3	3	1	3	3	1	5	5	1	5	5
	Large HE Bomb	220	2	3	6	1	3	3	2	5	10	1	5	5
	WWI Naval Mine	165	1	3	3	1	3	3	1	5	5	1	5	5
	Medium HE Bomb	130	2	3	6	1	3	3	2	5	10	1	5	5
	Small HE Bomb	25	2	2	4	1	2	2	2	5	10	1	5	5
	Medium Artillery Projectile	6	2	1	2	1	1	1	2	4	8	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Jetting Offshore ~60m LAT	WWI Torpedo	253.5	1	2	2	1	2	2	1	5	5	1	5	5
	WWII Naval Mine	227	1	2	2	1	2	2	1	5	5	1	5	5
	Large HE Bomb	220	1	2	2	1	2	2	1	5	5	1	5	5
	WWI Naval Mine	165	1	2	2	1	2	2	1	5	5	1	5	5
	Medium HE Bomb	130	1	2	2	1	2	2	1	5	5	1	5	5
	Small HE Bomb	25	1	1	1	1	1	1	1	5	5	1	5	5
	Medium Artillery Projectile	6	1	1	1	1	1	1	1	4	4	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Jetting Deep Offshore ~100m LAT	WWI Torpedo	253.5	1	2	2	1	2	2	1	5	5	1	5	5
	WWII Naval Mine	227	3	2	6	1	2	2	3	5	15	1	5	5
	Large HE Bomb	220	1	1	1	1	1	1	1	5	5	1	5	5
	WWI Naval Mine	165	1	1	1	1	1	1	1	5	5	1	5	5
	Medium HE Bomb	130	1	1	1	1	1	1	1	5	5	1	5	5
	Small HE Bomb	25	1	1	1	1	1	1	1	5	5	1	5	5
	Medium Artillery Projectile	6	1	1	1	1	1	1	1	4	4	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Ploughing Ultra-Nearshore <10m LAT	WWI Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWII Naval Mine	227	1	5	5	1	5	5	1	5	5	1	5	5
	Large HE Bomb	220	4	5	20	1	5	5	4	5	20	1	5	5
	WWI Naval Mine	165	1	5	5	1	5	5	1	5	5	1	5	5
	Medium HE Bomb	130	4	5	20	1	5	5	4	5	20	1	5	5
	Small HE Bomb	25	4	5	20	1	5	5	4	5	20	1	5	5
	Medium Artillery Projectile	6	3	4	12	1	4	4	3	4	12	1	4	4
	WWI Naval Projectile	1.42	1	2	2	1	2	2	1	2	2	1	2	2
	Small Artillery Projectile	0.93	2	2	4	1	2	2	2	2	4	1	2	2
	LSA	0.55	2	2	4	1	2	2	2	2	4	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Ploughing Nearshore ~26m LAT	WWI Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWII Naval Mine	227	1	5	5	1	5	5	1	5	5	1	5	5
	Large HE Bomb	220	4	5	20	1	5	5	4	5	20	1	5	5
	WWI Naval Mine	165	2	5	10	1	5	5	2	5	10	1	5	5
	Medium HE Bomb	130	4	4	16	1	4	4	4	5	20	1	5	5
	Small HE Bomb	25	4	2	8	1	2	2	4	5	20	1	5	5
	Medium Artillery Projectile	6	3	2	6	1	2	2	3	4	12	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Ploughing Shallow Offshore ~40m LAT	WWI Torpedo	253.5	2	3	6	1	3	3	2	5	10	1	5	5
	WWII Naval Mine	227	1	3	3	1	3	3	1	5	5	1	5	5
	Large HE Bomb	220	3	3	9	1	3	3	3	5	15	1	5	5
	WWI Naval Mine	165	2	3	6	1	3	3	2	5	10	1	5	5
	Medium HE Bomb	130	3	3	9	1	3	3	3	5	15	1	5	5
	Small HE Bomb	25	3	2	6	1	2	2	3	5	15	1	5	5
	Medium Artillery Projectile	6	3	1	3	1	1	1	3	4	12	1	4	4
	WWI Naval Projectile	1.42	2	1	2	1	1	1	2	2	4	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Ploughing Offshore ~60m LAT	WWI Torpedo	253.5	2	2	4	1	2	2	2	5	10	1	5	5
	WWII Naval Mine	227	1	2	2	1	2	2	1	5	5	1	5	5
	Large HE Bomb	220	2	2	4	1	2	2	2	5	10	1	5	5
	WWI Naval Mine	165	2	2	4	1	2	2	2	5	10	1	5	5
	Medium HE Bomb	130	2	2	4	1	2	2	2	5	10	1	5	5
	Small HE Bomb	25	2	1	2	1	1	1	2	5	10	1	5	5
	Medium Artillery Projectile	6	2	1	2	1	1	1	2	4	8	1	4	4
	WWI Naval Projectile	1.42	2	1	2	1	1	1	2	2	4	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Ploughing Deep Offshore ~100m LAT	WWI Torpedo	253.5	2	2	4	1	2	2	2	5	10	1	5	5
	WWII Naval Mine	227	4	2	8	1	2	2	4	5	20	1	5	5
	Large HE Bomb	220	1	1	1	1	1	1	1	5	5	1	5	5
	WWI Naval Mine	165	1	1	1	1	1	1	1	5	5	1	5	5
	Medium HE Bomb	130	1	1	1	1	1	1	1	5	5	1	5	5
	Small HE Bomb	25	1	1	1	1	1	1	1	5	5	1	5	5
	Medium Artillery Projectile	6	1	1	1	1	1	1	1	4	4	1	4	4
	WWI Naval Projectile	1.42	2	1	2	1	1	1	2	2	4	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Protection and Crossing Operations

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Rock Emplacement Ultra-Nearshore <10m LAT	WWI Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWII Naval Mine	227	1	5	5	1	5	5	1	5	5	1	5	5
	Large HE Bomb	220	3	5	15	1	5	5	3	5	15	1	5	5
	WWI Naval Mine	165	1	5	5	1	5	5	1	5	5	1	5	5
	Medium HE Bomb	130	3	5	15	1	5	5	3	5	15	1	5	5
	Small HE Bomb	25	3	5	15	1	5	5	3	5	15	1	5	5
	Medium Artillery Projectile	6	2	4	8	1	4	4	2	4	8	1	4	4
	WWI Naval Projectile	1.42	1	2	2	1	2	2	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	2	2	1	2	2	1	2	2	1	2	2
	LSA	0.55	1	2	2	1	2	2	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Rock Emplacement Nearshore ~26m LAT	WWI Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWII Naval Mine	227	1	5	5	1	5	5	1	5	5	1	5	5
	Large HE Bomb	220	3	5	15	1	5	5	3	5	15	1	5	5
	WWI Naval Mine	165	1	5	5	1	5	5	1	5	5	1	5	5
	Medium HE Bomb	130	3	4	12	1	4	4	3	5	15	1	5	5
	Small HE Bomb	25	3	2	6	1	2	2	3	5	15	1	5	5
	Medium Artillery Projectile	6	2	2	4	1	2	2	2	4	8	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Rock Emplacement Shallow Offshore ~40m LAT	WWI Torpedo	253.5	1	3	3	1	3	3	1	5	5	1	5	5
	WWII Naval Mine	227	1	3	3	1	3	3	1	5	5	1	5	5
	Large HE Bomb	220	2	3	6	1	3	3	2	5	10	1	5	5
	WWI Naval Mine	165	1	3	3	1	3	3	1	5	5	1	5	5
	Medium HE Bomb	130	2	3	6	1	3	3	2	5	10	1	5	5
	Small HE Bomb	25	2	2	4	1	2	2	2	5	10	1	5	5
	Medium Artillery Projectile	6	2	1	2	1	1	1	2	4	8	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Rock Emplacement Offshore ~60m LAT	WWI Torpedo	253.5	1	2	2	1	2	2	1	5	5	1	5	5
	WWII Naval Mine	227	1	2	2	1	2	2	1	5	5	1	5	5
	Large HE Bomb	220	1	2	2	1	2	2	1	5	5	1	5	5
	WWI Naval Mine	165	1	2	2	1	2	2	1	5	5	1	5	5
	Medium HE Bomb	130	1	2	2	1	2	2	1	5	5	1	5	5
	Small HE Bomb	25	1	1	1	1	1	1	1	5	5	1	5	5
	Medium Artillery Projectile	6	1	1	1	1	1	1	1	4	4	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Rock Emplacement Deep Offshore ~100m LAT	WWI Torpedo	253.5	1	2	2	1	2	2	1	5	5	1	5	5
	WWII Naval Mine	227	3	2	6	1	2	2	3	5	15	1	5	5
	Large HE Bomb	220	1	1	1	1	1	1	1	5	5	1	5	5
	WWI Naval Mine	165	1	1	1	1	1	1	1	5	5	1	5	5
	Medium HE Bomb	130	1	1	1	1	1	1	1	5	5	1	5	5
	Small HE Bomb	25	1	1	1	1	1	1	1	5	5	1	5	5
	Medium Artillery Projectile	6	1	1	1	1	1	1	1	4	4	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Enabling Operations

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
DP Vessels Ultra-Nearshore <10m LAT	WWI Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWII Naval Mine	227	1	5	5	1	5	5	1	5	5	1	5	5
	Large HE Bomb	220	1	5	5	1	5	5	1	5	5	1	5	5
	WWI Naval Mine	165	1	5	5	1	5	5	1	5	5	1	5	5
	Medium HE Bomb	130	1	5	5	1	5	5	1	5	5	1	5	5
	Small HE Bomb	25	1	5	5	1	5	5	1	5	5	1	5	5
	Medium Artillery Projectile	6	1	4	4	1	4	4	1	4	4	1	4	4
	WWI Naval Projectile	1.42	1	2	2	1	2	2	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	2	2	1	2	2	1	2	2	1	2	2
	LSA	0.55	1	2	2	1	2	2	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
DP Vessels Nearshore ~26m LAT	WWI Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWII Naval Mine	227	1	5	5	1	5	5	1	5	5	1	5	5
	Large HE Bomb	220	1	5	5	1	5	5	1	5	5	1	5	5
	WWI Naval Mine	165	1	5	5	1	5	5	1	5	5	1	5	5
	Medium HE Bomb	130	1	4	4	1	4	4	1	5	5	1	5	5
	Small HE Bomb	25	1	2	2	1	2	2	1	5	5	1	5	5
	Medium Artillery Projectile	6	1	2	2	1	2	2	1	4	4	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
DP Vessels Shallow Offshore ~40m LAT	WWI Torpedo	253.5	1	3	3	1	3	3	1	5	5	1	5	5
	WWII Naval Mine	227	1	3	3	1	3	3	1	5	5	1	5	5
	Large HE Bomb	220	1	3	3	1	3	3	1	5	5	1	5	5
	WWI Naval Mine	165	1	3	3	1	3	3	1	5	5	1	5	5
	Medium HE Bomb	130	1	3	3	1	3	3	1	5	5	1	5	5
	Small HE Bomb	25	1	2	2	1	2	2	1	5	5	1	5	5
	Medium Artillery Projectile	6	1	1	1	1	1	1	1	4	4	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
DP Vessels Offshore ~60m LAT	WWI Torpedo	253.5	1	2	2	1	2	2	1	5	5	1	5	5
	WWII Naval Mine	227	1	2	2	1	2	2	1	5	5	1	5	5
	Large HE Bomb	220	1	2	2	1	2	2	1	5	5	1	5	5
	WWI Naval Mine	165	1	2	2	1	2	2	1	5	5	1	5	5
	Medium HE Bomb	130	1	2	2	1	2	2	1	5	5	1	5	5
	Small HE Bomb	25	1	1	1	1	1	1	1	5	5	1	5	5
	Medium Artillery Projectile	6	1	1	1	1	1	1	1	4	4	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
DP Vessels Deep Offshore ~100m LAT	WWI Torpedo	253.5	1	2	2	1	2	2	1	5	5	1	5	5
	WWII Naval Mine	227	1	2	2	1	2	2	1	5	5	1	5	5
	Large HE Bomb	220	1	1	1	1	1	1	1	5	5	1	5	5
	WWI Naval Mine	165	1	1	1	1	1	1	1	5	5	1	5	5
	Medium HE Bomb	130	1	1	1	1	1	1	1	5	5	1	5	5
	Small HE Bomb	25	1	1	1	1	1	1	1	5	5	1	5	5
	Medium Artillery Projectile	6	1	1	1	1	1	1	1	4	4	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Vessel Anchoring Ultra-Nearshore <10m LAT	WWI Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWII Naval Mine	227	1	5	5	1	5	5	1	5	5	1	5	5
	Large HE Bomb	220	2	5	10	1	5	5	2	5	10	1	5	5
	WWI Naval Mine	165	1	5	5	1	5	5	1	5	5	1	5	5
	Medium HE Bomb	130	2	5	10	1	5	5	2	5	10	1	5	5
	Small HE Bomb	25	2	5	10	1	5	5	2	5	10	1	5	5
	Medium Artillery Projectile	6	1	4	4	1	4	4	1	4	4	1	4	4
	WWI Naval Projectile	1.42	1	2	2	1	2	2	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	2	2	1	2	2	1	2	2	1	2	2
	LSA	0.55	1	2	2	1	2	2	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Vessel Anchoring Nearshore ~26m LAT	WWI Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWII Naval Mine	227	1	5	5	1	5	5	1	5	5	1	5	5
	Large HE Bomb	220	2	5	10	1	5	5	2	5	10	1	5	5
	WWI Naval Mine	165	1	5	5	1	5	5	1	5	5	1	5	5
	Medium HE Bomb	130	2	4	8	1	4	4	2	5	10	1	5	5
	Small HE Bomb	25	2	2	4	1	2	2	2	5	10	1	5	5
	Medium Artillery Projectile	6	1	2	2	1	2	2	1	4	4	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Vessel Anchoring Shallow Offshore ~40m LAT	WWI Torpedo	253.5	1	3	3	1	3	3	1	5	5	1	5	5
	WWII Naval Mine	227	1	3	3	1	3	3	1	5	5	1	5	5
	Large HE Bomb	220	1	3	3	1	3	3	1	5	5	1	5	5
	WWI Naval Mine	165	1	3	3	1	3	3	1	5	5	1	5	5
	Medium HE Bomb	130	1	3	3	1	3	3	1	5	5	1	5	5
	Small HE Bomb	25	1	2	2	1	2	2	1	5	5	1	5	5
	Medium Artillery Projectile	6	1	1	1	1	1	1	1	4	4	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Vessel Anchoring Offshore ~60m LAT	WWI Torpedo	253.5	1	2	2	1	2	2	1	5	5	1	5	5
	WWII Naval Mine	227	1	2	2	1	2	2	1	5	5	1	5	5
	Large HE Bomb	220	1	2	2	1	2	2	1	5	5	1	5	5
	WWI Naval Mine	165	1	2	2	1	2	2	1	5	5	1	5	5
	Medium HE Bomb	130	1	2	2	1	2	2	1	5	5	1	5	5
	Small HE Bomb	25	1	1	1	1	1	1	1	5	5	1	5	5
	Medium Artillery Projectile	6	1	1	1	1	1	1	1	4	4	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
Vessel Anchoring Deep Offshore ~100m LAT	WWI Torpedo	253.5	1	2	2	1	2	2	1	5	5	1	5	5
	WWII Naval Mine	227	2	2	4	1	2	2	2	5	10	1	5	5
	Large HE Bomb	220	1	1	1	1	1	1	1	5	5	1	5	5
	WWI Naval Mine	165	1	1	1	1	1	1	1	5	5	1	5	5
	Medium HE Bomb	130	1	1	1	1	1	1	1	5	5	1	5	5
	Small HE Bomb	25	1	1	1	1	1	1	1	5	5	1	5	5
	Medium Artillery Projectile	6	1	1	1	1	1	1	1	4	4	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
JUB Deployment Ultra-Nearshore <10m LAT	WWI Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWII Naval Mine	227	1	5	5	1	5	5	1	5	5	1	5	5
	Large HE Bomb	220	3	5	15	1	5	5	3	5	15	1	5	5
	WWI Naval Mine	165	1	5	5	1	5	5	1	5	5	1	5	5
	Medium HE Bomb	130	3	5	15	1	5	5	3	5	15	1	5	5
	Small HE Bomb	25	3	5	15	1	5	5	3	5	15	1	5	5
	Medium Artillery Projectile	6	2	4	8	1	4	4	2	4	8	1	4	4
	WWI Naval Projectile	1.42	1	2	2	1	2	2	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	2	2	1	2	2	1	2	2	1	2	2
	LSA	0.55	1	2	2	1	2	2	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
JUB Deployment Nearshore ~26m LAT	WWI Torpedo	253.5	1	5	5	1	5	5	1	5	5	1	5	5
	WWII Naval Mine	227	1	5	5	1	5	5	1	5	5	1	5	5
	Large HE Bomb	220	3	5	15	1	5	5	3	5	15	1	5	5
	WWI Naval Mine	165	1	5	5	1	5	5	1	5	5	1	5	5
	Medium HE Bomb	130	3	4	12	1	4	4	3	5	15	1	5	5
	Small HE Bomb	25	3	2	6	1	2	2	3	5	15	1	5	5
	Medium Artillery Projectile	6	2	2	4	1	2	2	2	4	8	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
JUB Deployment Shallow Offshore ~40m LAT	WWI Torpedo	253.5	1	3	3	1	3	3	1	5	5	1	5	5
	WWII Naval Mine	227	1	3	3	1	3	3	1	5	5	1	5	5
	Large HE Bomb	220	2	3	6	1	3	3	2	5	10	1	5	5
	WWI Naval Mine	165	1	3	3	1	3	3	1	5	5	1	5	5
	Medium HE Bomb	130	2	3	6	1	3	3	2	5	10	1	5	5
	Small HE Bomb	25	2	2	4	1	2	2	2	5	10	1	5	5
	Medium Artillery Projectile	6	2	1	2	1	1	1	2	4	8	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
JUB Deployment Offshore ~60m LAT	WWI Torpedo	253.5	1	2	2	1	2	2	1	5	5	1	5	5
	WWII Naval Mine	227	1	2	2	1	2	2	1	5	5	1	5	5
	Large HE Bomb	220	1	2	2	1	2	2	1	5	5	1	5	5
	WWI Naval Mine	165	1	2	2	1	2	2	1	5	5	1	5	5
	Medium HE Bomb	130	1	2	2	1	2	2	1	5	5	1	5	5
	Small HE Bomb	25	1	1	1	1	1	1	1	5	5	1	5	5
	Medium Artillery Projectile	6	1	1	1	1	1	1	1	4	4	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Activity	UXO Threat Item	Assessed NEQ (kg TNT)	UXO Risk to Vessel/Personnel						UXO Risk to Underwater Equipment					
			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level			Initial UXO Risk Level			Recommended Mitigated UXO Risk Level		
			P	C	R	P	C	R	P	C	R	P	C	R
JUB Deployment Deep Offshore ~100m LAT	WWI Torpedo	253.5	1	2	2	1	2	2	1	5	5	1	5	5
	WWII Naval Mine	227	3	2	6	1	2	2	3	5	15	1	5	5
	Large HE Bomb	220	1	1	1	1	1	1	1	5	5	1	5	5
	WWI Naval Mine	165	1	1	1	1	1	1	1	5	5	1	5	5
	Medium HE Bomb	130	1	1	1	1	1	1	1	5	5	1	5	5
	Small HE Bomb	25	1	1	1	1	1	1	1	5	5	1	5	5
	Medium Artillery Projectile	6	1	1	1	1	1	1	1	4	4	1	4	4
	WWI Naval Projectile	1.42	1	1	1	1	1	1	1	2	2	1	2	2
	Small Artillery Projectile	0.93	1	1	1	1	1	1	1	2	2	1	2	2
	LSA	0.55	1	1	1	1	1	1	1	2	2	1	2	2

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Appendix 17

UXO Risk Zones

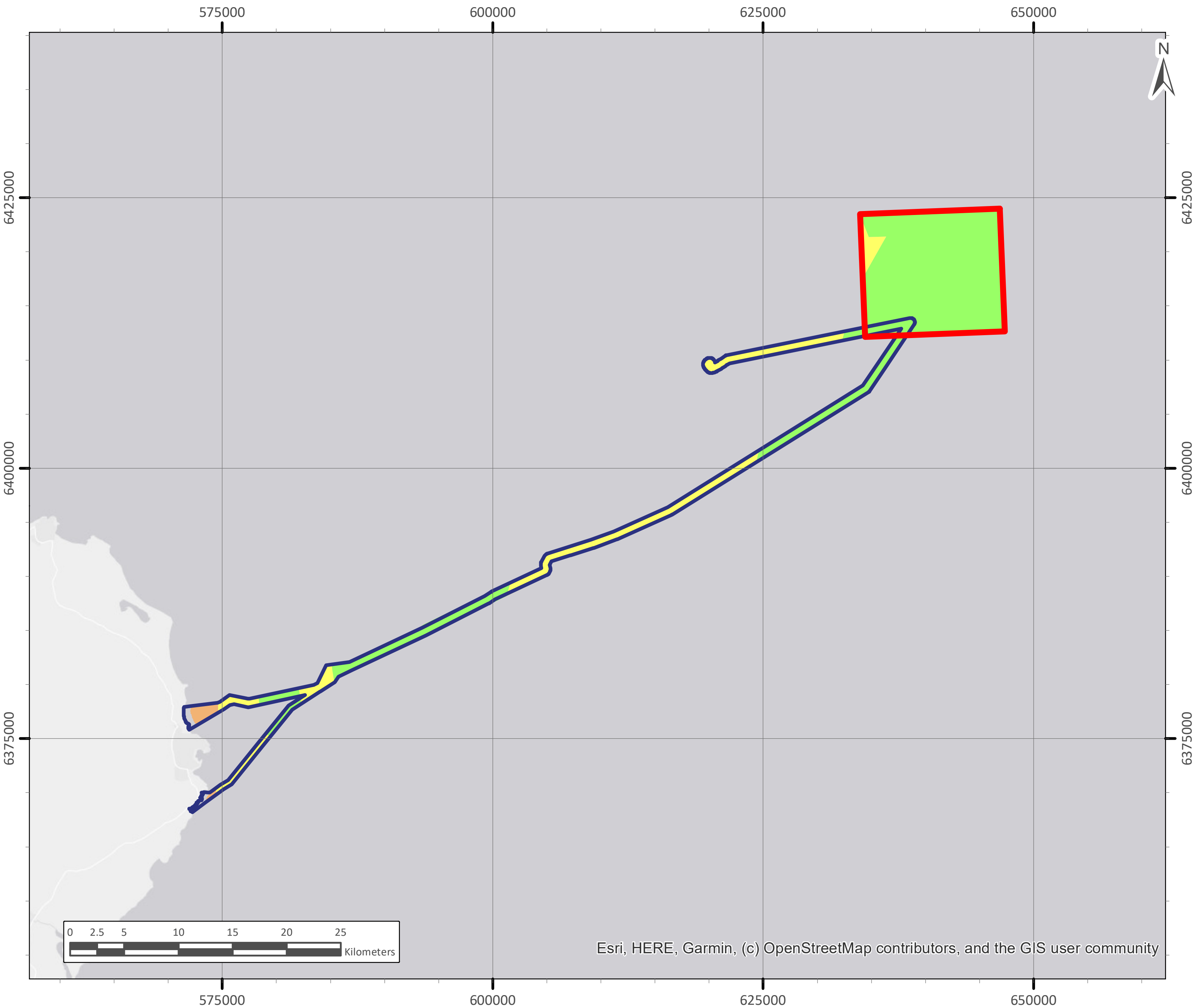
LEGEND

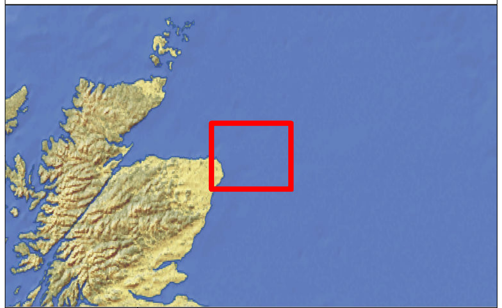
GENERAL

- Green_Volt_OWF_Boundary
- Export_Cable_Corridor

Risk_Rating

- HIGH
- MEDIUM
- LOW





PROJECT	PROJECT TITLE
9691	GREEN VOLT OWF

DRAWING TITLE
UXO Risk Zones

DRAWING NUMBER
Green Volt OWF\017\V2.0

PURPOSE
FOR INFORMATION USE ONLY

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
WGS 1984 UTM Zone 30N	1:500,000	A4	LH	01/06/2022	LG

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6 alpha ASSOCIATES
special risks consultancy

Annexes

Annex A

Legislation and UXO Risk Management

Annex A – Legislation and UXO Risk Management

Introduction

The law requires that the client fulfils both their statutory and legal duties to protect those that may be exposed to harm. In the event of an UXO incident that causes harm, failure to adequately manage the UXO risk may lead to the prosecution and imprisonment of those deemed responsible for breaching their duty of care. The following sections outline national legislation, industry best practice, the ALARP principle, the assumptions made of the client's risk tolerance, as well as the expected behavioural responses of the project stakeholders when confronted with the UXO risk.

National Legislation

The primary regulation, and minimum standard requirement for businesses residing in and/or working within the *UK*, is enforced within the *UK* by the following legislation:

- Health and Safety at Work Act 1974;
- Management of Health and Safety at Work Regulations 1999;
- CDM Regulations 2015.

By contracting a UXO risk management consultant, the client has drawn upon help from a competent person to perform a risk assessment and to assess and advise upon the UXO risk posed to the client's employees and contractors. In doing so, the client has acted in compliance with the legal duties required as dictated in the above legislation. *6 Alpha Associates* has acted based on the guidance of industry good practice, professional risk management, EOD experience, and its interpretation of the law.

In the end, it is for national courts to decide whether the client has acted in compliance with the law, and to determine if sufficient risk management and mitigation measures were undertaken and effectively applied.

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UXO Industry Guidance and Good Practice

CIRIA has published guidance on the assessment and management of unexploded ordnance risk in the marine environment (*CIRIA* C681 and CIRIA C754). CIRIA is a neutral, non-government, non-profit body linking organisations with common interests, that collaborate with the aim of improving and setting an agreed level of minimum industry standards.

CIRIA guidance, therefore, represents an industry agreed standard for the assessment and management of UXO risk, which has been judged and recognised by the Health and Safety Executive (HSE) of the *UK* as a minimum standard or source of good practice, that satisfies the law when applied in an appropriate manner.

For UXO assessment and risk management, *6 Alpha* assesses itself against the *CIRIA* C754 guide to ensure compliance with the minimum legal requirements of industry best practice to manage UXO risks to ALARP.

Reducing Risks to ALARP

Reducing risks to ALARP is the concept of weighing a risk against the resources (effort, time, and money) required to a level that adequately control the risks. The law sets this level of what is reasonably practicable, whilst stakeholders determine what is considered tolerable to the project, whilst also fulfilling their legal obligations.

Industry best practice offers the direction as to assessing both ALARP and the risk tolerance, so that an agreement amongst the stakeholders can be reached as to what the ALARP level is, and what resources are required to achieve it. ALARP therefore describes the level to which risks are controlled, as determined by good practice.

Confirming that the UXO risks have been reduced to ALARP involves weighing the residual risk against the resources to further reduce it. If it can be demonstrated that the resource requirement is grossly disproportional to the benefits of further risk reduction, then risks have been reduced to ALARP. Consequently, the principle of reducing risks to a reasonably practicable level will usually result in a residual level of risk, as well as *de minimis* risks that must be either shared, transferred, mitigated, and/or tolerated.

A diagrammatic representation for meeting with ALARP is presented at Figure 1.

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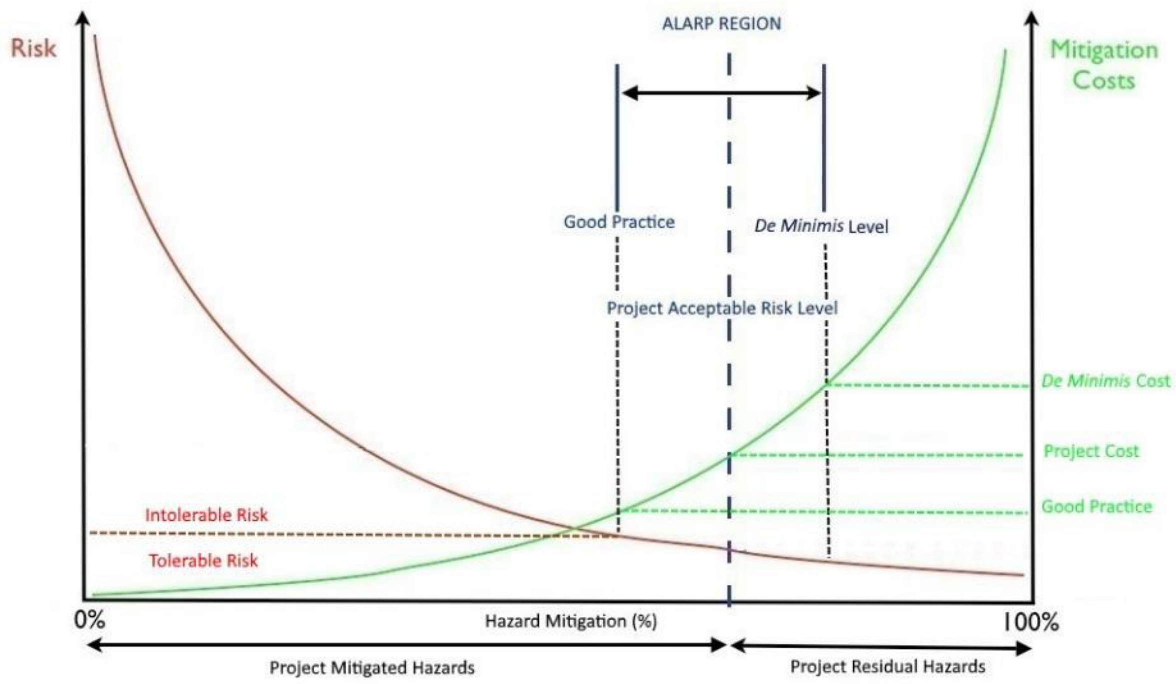

Figure 1: The ALARP principle of managing risk.

UXO Risk Tolerance

6 Alpha Associates have made certain assumptions about the client's tolerance of UXO risk. Our assumptions include that the following interrelated elements are to be considered when determining the projects UXO risk tolerances:

- **Corporate Governance** – is the system of rules, practices, and processes by which companies are managed and controlled. It is assumed that the client 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 the client will have in place a framework for managing risk for good governance. It is anticipated that safety and risk management are integrated in the client's business culture and be actively applied throughout the project;
- **Risk Management** – the client will expect the highest standard of risk and safety management to be applied to this project and will have a risk management system in place for responding to business, programme, and project risks. The client will rely upon help from a competent person to identify UXO risks, but also to design appropriate UXO risk management solutions in accordance with industry good practice. Any risks posed by UXO must be assessed based upon probability and consequence criteria. Potential UXO targets must be avoided or otherwise mitigated not only in accordance with the law, but also with CIRIA industry guidelines. A

competent person will oversee the UXO geophysical survey and UXO risk mitigation contractors responsible for the subsequent execution of those works, ensuring they are performed to appropriate quality and meet good practice standards;

- **Safety** – personnel safety will assume the highest priority for the project. The protection and preservation of equipment, property, and the environment, although important, will remain a secondary priority to that of the prevention of harm to personnel involved with the project.

UXO Risk Behaviour

UXO incidents that result in harm to construction personnel, are generally termed an extreme, or a low probability, high consequence event. Given the ambiguity and uncertainty surrounding such events, project stakeholders may respond to the risk in an extreme manner and demand a disproportionate level of risk mitigation. The client should be aware of the following common responses and attitudes to LP-HC risks, to manage stakeholder expectations of the UXO risk throughout the project's life cycle. There are three general behavioural patterns for dealing with LP-HC events (Kunreuther, 1995):

1. Individuals do not think probabilistically and demand zero risk when costs do not need to be absorbed. Alternatively, when individuals do need to absorb the cost themselves, they are more likely to tolerate very high probability risks.
2. Risk is a multidimensional problem which cannot be simply measured quantitively, such as the number of fatalities per year. Risk tends to be influenced by people's attitudes to catastrophic situations, fear, lack of familiarity, or situations they perceive to be beyond their control. By nature, humans are risk averse when exposed to uncertainty and will enhance the level of risk accordingly.
3. Given the lack of knowledge over the probability of these event, people are more likely to use simple decision making measures, such as threshold values. The general perception is, that the probability of LP-HC risks is too low to possibly occur, and as a result not take adequate steps to protect themselves.

Such behaviour patterns typically lead to one or more of the following common responses from project stakeholders:

- A desire for zero risk;
- A concern for future generations;
- Denial that the event can ever happen to them;
- A perception that the situation is under their control and therefore can never happen;
- That the hazard is perceived to be benign after a certain amount of time;
- Short sighted behaviour and an aversion to spend today to reap the potential benefits later.

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References

Kunreuther, H., 1995, Protection against low probability high consequence events.

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Annex B

Semi-Quantitative Risk Assessment Methodology

Contents

1 Semi-Quantitative Risk Assessment

1.1 Overview

6 Alpha Associates use a Semi-Quantitative Risk Assessment (SQRA) approach to assess the prospective unexploded ordnance (UXO) risk for each of the project's intrusive investigation, installation and/or construction operations that interacts with the seabed. The SQRA process relies upon *6 Alpha's* risk matrix, which is used to provide guidance on the required risk mitigation measures to be implemented, in order to manage the UXO risk to As Low As Reasonably Practicable (ALARP).

The following sections transparently outline *6 Alpha's* SQRA methodology. The risk assessment tables for each of the project's investigation, installation and/or construction operations are presented separately within the report appendices.

1.2 Risk Matrix

For the purposes of this report, **Risk** (**R**) is calculated as a function of **Probability** (**P**) of encounter and initiation of UXO and **Consequence** (**C**) of initiation:

R = P x C.

For each investigation, installation and/or construction activity that interacts with the seabed, the probability and consequence of the identified UXO threats has been assessed on a scale of 1 to 5. (Where 1 = Very Low, & 5 = Very High). These ratings are multiplied together (with a maximum of twenty-five) in order to determine a risk rating based on *6 Alpha's* UXO risk matrix. Not only does this allow relative weighting and comparison of UXO risk across the project's seabed intrusive operations, but it also ensures that *6 Alpha* assesses UXO risk in a way that is consistent across projects which is a key responsibility of a UXO consultant. 6 Alpha's risk matrix is shown below in Table 1.

		Consequences					
		Consequence of Initiation →					
Likelihood	Probability of Encounter and Initiation ↑		**1** Negligible	**2** Minor	**3** Moderate	**4** Major	**5** Severe
		5 Highly Likely	5 Low	10 Medium	15 High	20 High	25 Very High
		4 Likely	4 Low	8 Medium	12 High	16 High	20 High
		3 Possible	3 Low	6 Medium	9 Medium	12 High	15 High
		2 Unlikely	2 Low	4 Low	6 Medium	8 Medium	10 Medium
		1 Highly Unlikely	1 Very Low	2 Low	3 Low	4 Low	5 Low

Table 1: *6 Alpha Associates*' UXO Risk Matrix

The numerical values assigned to the UXO risk are compared to Table 2, which shows *6 Alpha's* risk grading and describes the recommended best practice strategic risk mitigation measures required in order to satisfactorily manage the UXO risk to ALARP.

Whilst this risk matrix is aligned with *6 Alpha's* standards in providing a UXO risk mitigation strategy, we also recognise that other UXO risk management consultancies may differ in their own assessment of the UXO risk and their recommended UXO risk mitigation measures.

Risk Rating (P x C)	Grading	Risk Tolerance	Action Required to Achieve UXO Risks ALARP
1	Very Low Risk	Tolerable	The risk is at, or below the *de minimis* level with no further action required to reduce the UXO risk to ALARP. Operations may proceed without proactive UXO risk mitigation measures in place. Nonetheless, reactive mitigation measures might be recommended in order to mitigate residual UXO risks and to align with industry best practice. Risks will be reviewed periodically to ensure risk mitigation controls remain effective.
2-5	Low Risk		
6-10	Medium Risk	Potentially Tolerable	The UXO risk may be tolerable depending on the specific nature of the UXO risk and the potential consequences of a UXO initiation and the project stakeholder's risk tolerance. Where vessel crews and/or other personnel may be exposed to harm, then the UXO risk is intolerable.
12-20	High Risk	Intolerable	Operations may not proceed without proactive risk mitigation measures being implemented prior to intrusive investigation, installation and/or construction works. Reactive risk mitigation measures must also be implemented.
25	Very High Risk		

Table 2: *6 Alpha Associates*' Project Risk Tolerability

1.3 Calculating the Project's Probability of Encounter and Initation

At the strategic level, and for risk assessment purposes, *6 Alpha Associates* applies the precautionary principle to all prospective UXO encounters within a Study Site. For example, the probability of initiating an item of UXO upon an encounter is considered certain, whereas in practice factors such as the kinetic energy transfer and UXO sensitivity will impact whether direct or indirect contact with UXO will cause an initiation event. Therefore, the probability of encountering and initiating UXO is primarily influenced by the likely level of UXO contamination within the Study Site, but also subsequently through the application of a methodology modifier (the value of which is determined by the spatial extent of the soil intrusion). Further details of *6 Alpha's* guidance on the scoring of the probability of UXO contamination can be found in Table 3 below.

Probability of UXO Contamination	Likelihood Score	Description (Based on a 5km Assessment Distance)
Highly Unlikely	1	There is no indication of historical or modern ordnance activity or discovered ordnance **within 5km of the Study Site.** Potential ordnance discoveries are, therefore, likely to be from unquantifiable sources and/or from subsequent UXO migration.
Unlikely	2	There is evidence of historical or modern ordnance activity or discovered ordnance **within 2km to 5km** (or 4km to 10km for an ordnance dump) of the Study Site's boundary.
Possible	3	There is evidence of historical or modern ordnance activity **within 1km to 2km** (or 2km to 4km for an ordnance dump) of the Study Site's boundary.
Likely	4	There is evidence of historical or modern ordnance activity or discovered ordnance **either on-site or within 1km of it**. If the prospective UXO threat source intersects the Study Site, then the precise nature of the threat source and/or the proximity and concentration of any previous UXO encounters may influence whether the assessment concludes a "Likely" or "Highly Likely" probability of contamination.
Highly Likely	5	There is significant evidence of historical or modern ordnance activity, **within the Study Site** that is corroborated with evidence that **UXO has been encountered previously** either on-site or in the immediate vicinity.

Table 3: *6 Alpha Associates'* Probability of UXO Contamination Assessment Criteria

The categorisation of UXO threats may not always be straightforward, and multiple additional factors might also be considered that result in a potential threat source being classified as a higher or lower threat than indicated by Table 3. For example, WWI-era ordnance is rarely encountered in the marine environment in the 21^{st} Century and therefore, the likelihood of encountering such ordnance may be reduced.

Additionally, the categorisation of potential threat sources such as Anti-Aircraft Artillery projectiles (or similar) might also be influenced by the total number of artillery batteries in any given area that possess a firing arc template that encompasses a Study Site and/or the likelihood that they were fired for training or operational purposes (amongst other things).

In order to calculate the overall probability of encounter, the probability of UXO contamination at the Site is modified based upon the likely spatial extent of the seabed disturbance, caused by the proposed investigation, installation or construction activity. This provides the final calculation for the probability of encounter and initiation, which is used for the risk assessment.

1.4 Calculating the Projects Consequences

The risk assessment performed by *6 Alpha* assesses the risk of an unplanned initiation of UXO to the relevant sensitive receptors (e.g. human life, the vessel(s) and/or underwater equipment), resulting from explosive shockwave and/or fragmentation effects.

This is achieved by calculating the resulting peak pressure for an equivalent mass of trinitrotoluene (TNT) representative of the likely UXO threat items within the Site, as well as estimating the distances separating the source (UXO) and the sensitive receptors.

The following formula is applied to calculate peak pressure in megapascals (MPa), of the resultant shockwave (Reid, 1996):

$$Peak\ Pressure\ (MPa) = 52.4.(\frac{M^{\frac{1}{3}}}{R})^{1.18}$$

For SQRA calculations, R is the separation distance in metres between the source and the receptor and M is the mass of TNT explosive equivalent in kilograms.

The resulting peak pressure calculated is compared to Table 5, which provides the final consequence calculation for entry into the risk matrix (Szturomski, 2015).

Peak Pressure (MPa)	Consequence Rating	Consequence Score	Description
0 – 2	**Negligible**	1	Damage to the vessel is likely to be negligible and vessel crews are highly unlikely to be hurt. Damage to underwater equipment will be influenced by the robustness of such equipment and its internal mechanisms.
2– 4	**Minor**	2	There may be minor damage to brittle materials and to the sensitive electronics. The vessel crews are unlikely to be injured. Damage to underwater equipment will be influenced by the robustness of such equipment and its internal mechanisms.
4 – 6	**Moderate**	3	More significant damage to vessel is likely and may impact vessel steering and control and light injuries might be sustained by the crew. There is also the prospect of light damage to underwater equipment.
6 – 8	**Major**	4	Serious damage to the vessels electronics, generators and control systems is likely and serious injuries and/or fatalities amongst the vessel crew are possible. Serious damage to underwater equipment is also likely.
More than 8	**Severe**	5	Catastrophic structural vessel damage is likely and it is also likely that there will be multiple injuries and fatalities to personnel aboard. Catastrophic damage to underwater equipment is likely.

Table 5: Consequence Rating of an unplanned UXO initiation based on shockwave peak pressure.

1.5 References

1) Reid, W.D., 1996, The response of surface ships to underwater explosions.

2) Szturomski, B., 2015, The effect of an underwater explosion on a ship. Scientific Journal of Polish Naval Academy.

Annex C

Classification of UXO

Contents

1 Classification of Unexploded Ordnance

1.1 General

Unexploded ordnance (UXO) is any munition, weapon delivery system or ordnance item that contains explosives, propellants, or chemical agents, after they are either:

- Armed and prepared for action;
- Launched, placed, fired, thrown, or released in a way that they cause a hazard;
- Remain unexploded either through malfunction or through design.

1.2 Classification of Unexploded Ordnance

Unexploded ordnance items can be classified into 11 broad categories which are detailed below:

1.2.1 Small Arms Ammunitions (SAA)

Small arms ammunition (SAA) is a generic catchall term for projectiles that are generally less than 13mm in diameter and less than 100mm in length. SAA is fired from various sizes of weapon, such as pistols, shotguns, rifles, machine guns. Generally, the outer casings comprise either brass or steel. As UXO, they present a minimal risk compared to other high net explosive quantity (NEQ) UXO, although SAA may explode if subjected to extreme heat, or if struck with a sharp object.

1.2.2 Hand Grenades

Hand grenades are small bombs thrown by hand and come in various sizes and shapes. Typical types of hand grenades include fragmentation, smoke, incendiary, chemical, training, and illumination. As UXO, they present a risk if mishandled, subjected to a high impact or sufficient pressure resulting in crushing or piercing of the case, and/or exposed to extreme heat.

1.2.3 Projectiles

Projectiles are munitions generally ranging in diameter from 20mm to 406mm and can vary in length from 50mm to 1,219mm. All projectiles are fired from some type of launcher or gun barrel and may comprise either an explosive, chemical, smoke, illumination, or inert/training fill. Projectiles may also be fitted with stabilising fins and their fuzes are typically located either in the nose or located at the base. As UXO, they present a risk if mishandled, subjected to a high impact or sufficient pressure resulting in crushing or piercing of the case, and/or exposed to extreme heat.

1.2.4 Mortar Bombs

Mortar bombs come in a range of shapes, sizes, and types, typically ranging between 25mm to 280mm in diameter and typically fired from a mortar; a short smooth barrelled tube. Mortar bomb types and functions can vary to include fragmentation, smoke, incendiary, chemical, training, and illumination. Mortar bombs may be found with or without stabilising fins and they present a risk if mishandled, subjected to a high impact or sufficient pressure resulting in crushing or piercing of the case, and/or exposed extreme heat.

1.2.5 Landmines

Landmines are an explosive device typically shallow buried or concealed on the ground and used to defend vulnerable areas or to deny the area completely for any use. After WWII, the defensive minefields around the coastlines were swept clear and the munitions either buried or dumped at sea. Landmines come in various sizes, shapes and types including fragmentation, incendiary, chemical, training and illumination. The cases of landmines are typically made of metal but can comprise any non-magnetic material such as wood, clay, glass, concrete, or plastic so that they are harder to detect. As UXO, they present a risk if mishandled, subjected to a high impact or sufficient pressure resulting in crushing or piercing of the case, and/or exposed extreme heat.

1.2.6 Bombs

Bombs come in a range of size and types, generally weighing from 0.5kg to 10,000kg with typical components of a metal casing, a mechanical or electrical fuze, a main charge, a booster charge, and stabilising fins. The metal casing contains the explosive or chemical fill and may be compartmentalised. Bomb types include high explosive, incendiary, chemical, training, and concrete. As UXO, they present a risk if mishandled, subjected to a high impact or sufficient pressure resulting in crushing or piercing of the case, and/or exposed extreme heat.

1.2.7 Sea Mines

Sea mines are self-contained explosive devices either placed on the seabed or moored in the water column to damage or destroy surface ships or submarines. Like land mines, they are typically used to defend vulnerable areas or to deny the area completely for any use. After WWI and WWII, sea minefields were swept, with surface vessels working in tandem to cut the mooring tether so that the sea mine would float to the surface. The sea mine was then shot with SAA so that it either exploded or flooded and sank to the seabed. Some sea mines were also simply lost or were not recovered and remain unaccounted for. Sea mines come in all shapes and sizes and as UXO, they present a risk mishandled, subjected to a high impact or sufficient pressure resulting in crushing or piercing of the case, and/or exposed extreme heat.

1.2.8 Rockets

Rockets are self-propelled unguided munitions that generally vary in diameter from 37mm to more than 380mm and can vary in length from 300mm to 2,743mm. All rockets comprise a warhead, fuze and motor section, with the warhead typically containing either an explosive or chemical fill. As UXO, they may or may not be present with tail fins and present a risk if mishandled, subjected to a high impact or sufficient pressure resulting in crushing or piercing of the case, and/or exposed extreme heat.

1.2.9 Depth Charge

A depth charge is a container, typically barrel or drum shaped, of high explosive fitted with a hydrostatic pistol, designed to trigger at a pre-programmed depth. As UXO, they present a risk if mishandled, subjected to a high impact or sufficient pressure resulting in crushing or piercing of the case, and/or exposed extreme heat.

1.2.10 Torpedo

Torpedoes are guided or unguided, underwater, self-propelled weapons typically fitted with a high explosive warhead. The dimensions of complete torpedoes vary but are generally between 400mm to 600mm in diameter and between 4,500mm to 7,500mm in length. As UXO, torpedoes are they are rarely found completely intact with the warhead and propulsion stages often discovered separated. Both the warhead and propulsion stages of the torpedo present a hazard if mishandled, subjected to a high impact or sufficient pressure resulting in crushing or piercing of the case, and/or exposed extreme heat.

1.2.11 Guided Missiles

Guided missiles are similar in design to rockets, with the exception being that they are guided to their targets by some form of guidance system and can be either self-adjusting or operator controlled. Guided missiles can be found in a variety of size, shape and colour and may be found with or without stabilising fins attached. As UXO, they present a hazard if mishandled, subjected to a high impact or sufficient pressure resulting in crushing or piercing of the case, and/or exposed extreme heat.

Annex D

Explosives and Detonation Effects

Contents

1 Explosives and Detonation Effects

1.1 Introduction

Explosives can be categorised into two broad categories, namely: those designed to be detonating (or high explosives) and those designed to be deflagrating (or low explosives). In the case of unexploded ordnance (UXO) risk management in the marine environment, the primary concern is associated with ordnance comprising high explosive content.

Due to the infrequency of UXO initiation events that cause harm, it is a commonly held notion that World War One and Two (WWI and WWII) ordnance devices may have deteriorated and no longer function as designed, presenting a false sense of tolerable risk to project stakeholders. The precautionary principle of risk management prevents this misplaced assumption from being carried throughout the risk assessment and project life cycle. Ordnance must, for the purposes of risk management, be assumed to be fully functional until determined safe by an explosive ordnance disposal (EOD) operative.

This annex describes the classification of explosives, the generic design of the explosives train and the effects of a detonation in the marine environment.

1.2 Classification of Explosives

1.2.1 Detonating or High Explosives

Detonating or High Explosive (HE) compounds are characterised by their very rapid decomposition and development of a high-pressure shock wave. These explosives detonate at velocities ranging from 1,000m/s to 9,000m/s and may be subdivided into two explosives classes, differentiated by their respective sensitivity or ease with which an explosive may be ignited or initiated:

- **Primary Explosives** – are extremely sensitive to impact, friction, sparks, flames or other methods of generating heat to which they will respond by burning rapidly or detonating. Examples include mercury fulminate and lead azide. This high sensitivity to initiation makes them unsuitable to use as a base explosive (i.e. main-fill explosive in military ordnance).
- **Secondary Explosives** – are relatively insensitive to impact, friction, sparks, flame or other methods of producing heat. They may burn when exposed to heat in small-unconfined quantities, although the risk of initiation is always present especially when they are confined and/or burnt in bulk. Dynamite, trinitrotoluene (TNT), RDX and HMX are classed as secondary high explosives, which are commonly used as base explosives in military ordnance.

Pentaerythritol tetranitrate (PETN) is the benchmark compound for comparative purposes, with those explosives that are more sensitive to initiation than PETN classified as primary explosives.

1.2.2 Deflagrating or Low Explosives

A low explosive is usually a mixture of a combustible substance and an oxidant that decomposes rapidly, a process known as deflagration which produces a relatively low pressure, shock wave. Under normal conditions, low explosives undergo deflagration at rates that vary from a few centimetres per second to approximately 400m/s, yet when concentrated and confined may be caused to detonate and produce a relatively high-pressure shock wave.

Deflagration processes of low explosives are easier to control than the detonations of high explosive, that they are typically used as ballistic propellants for rockets, artillery projectiles and bullets. Typical ballistic propellants include the family of smokeless propellants known as cordite which was used extensively during WWII.

1.3 Generic Design of Ordnance

In general, explosive ordnance items, such as bombs or sea mines tend to have the following basic components:

- **Case** – the casing or body of the ordnance item is typically manufactured from a ferrous metal such as steel. The *German* Luftmine A and B (LMA and LMB respectively) parachute mines used during WWII, were however manufactured from aluminium. The case shatters during detonation of the high explosive fill, fragmenting at high velocity to increase the potential damage and harm.
- **Main Charge** – the main charge makes up most of the explosive mass of the ordnance item comprising a high explosive fill with a relatively low sensitivity to initiation.
- **Booster** – a secondary high explosive booster charge is used to ignite the main charge component and comprises a more sensitive, albeit smaller quantity of high explosive.
- **Fuze** – a small quantity, high explosive charge is usually incorporated into the device which is sensitive to initiation. The fuze acts as the primary explosive which is used to ignite the booster. The fuze is relatively small when compared to the booster and housed with a fuze pocket within the casing of the ordnance item, located immediately adjacent to the booster charge.

- **Trigger** – a mechanical, electrical, or chemical mechanism is used to initiate the fuze at the appropriate time, such as upon impact, hydrostatic depth, magnetic field distortion or time. The trigger is the most sensitive component to the firing train and the primary method of ignition, that if interfered with may cause an inadvertent detonation.

An explosive chain reaction is therefore started when the sufficient energy (kinetic, electrical, or chemical) is generated to initiate the explosive content of the fuze, which in turn detonates the booster and finally the main charge. These components form the explosive train of the ordnance device.

1.4 Underwater High Explosive Detonations

An explosion underwater differs from that within air due to the formation of a gas bubble within the water in addition to the fragmentation and shockwave effects. Upon detonation, the ordnance case will fragment and cause damage to proximal receptors such as underwater equipment, with the main hazard to the surface vessel, personnel aboard, and underwater equipment being from the resulting gas bubble and shockwave.

An underwater explosion results in the change of solid matter (the main charge) into a gas of high temperature and pressure (the gas bubble) as well as a spherical shockwave. The pressure acting outwards from the gas bubble is opposed by the hydrostatic pressure of the surrounding water, which causes an oscillating effect of expansion and contraction as the gas bubble moves towards the water surface.

Each expansion of the gas bubble causes a shockwave that is propagated outwards throughout the water in all directions. Although these shockwaves gradually become weaker as the gas bubble rises through the water column, it may close with nearby receptors such as surface vessels, situated offset or directly above the gas bubble causing damage. When the gas bubble reaches the surface, a columnar plume is formed from the sudden release of the gas into the atmosphere as well as carrying water. Should a vessel be directly in the path of the gas bubble as it contracts, the vessel may be subjected to bubble jetting loads; a high-energy jet of water capable of rupturing the vessel's hull.

The shockwave from an underwater explosion propagates radially outwards from the source location. Possessing an initial high velocity, the shock wave decelerates over distance from the source location, eventually decreasing to the underwater speed of sound. As the distance from the source location increases, the peak pressure of the shockwave decreases reducing the damage potential of the shockwave.

A surface vessel must therefore be kept a safe distance away from a source of an explosion so that resultant shockwave causes no damage.

If a nearby surface vessel is struck by the shockwave, the vessel can experience significant vibrations resulting in the damage to underwater hull mounted equipment and the dislodgment of loose objects, machinery, and power cables on board the vessel. Both the initial vibrations and secondary effects resulting from the vessel damage, have the capacity to cause disabling injuries to personnel aboard, from being struck by loose objects, trips and falls, and joint damage (ankles, knees, hips, spine, and neck) from a sudden acceleration.

A second damage mechanism may arise from the whipping effect. The whipping effect occurs when the frequency of the expansion and contraction of the gas bubble matches the vessels natural oscillating frequency. The vessel's hull will be driven to vibrate at its natural resonating frequency, vibrating at a greater amplitude than that of the initial pressure wave from the expanding gas bubble.

A badly affected ship usually sinks quickly due to cracking and deformation of the hull, resulting in flooding across the length of the ship and eventual sinking.

Divers, as well as marine mammals, are especially vulnerable to underwater shockwave effects and can be seriously injured or killed by the detonation of relatively small, high explosive charges.

Annex E

UXO Discovery, Detonation and Sympathetic Detonation Risks

1 UXO Discovery, Detonation and Sympathetic Detonation Risks

1.1 Introduction

A host of theoretical and empirical studies have provided strong evidence that Unexploded Ordnance (UXO) becomes more sensitive to trigger events that transfer kinetic energy (such as a physical impact or shock) and/or chemical energy (such as heat) as they age. Theoretically, a spontaneous detonation of UXO may occur but such instances are exceptionally rare. Therefore, UXO risk management focuses on the avoidance of known trigger events, even those of small magnitude, that may cause UXO to detonate.

Subject to its size and Net Explosive Quantity (NEQ), significant risks may be present by the discovery and accidental detonation of a singular item of UXO. Additionally, it is not uncommon for UXO to be discovered in close proximity to one another, in the offshore environment especially. For example, UXO might be found in very close proximity in munitions dumps, within the body of a shipwreck, or clustered together due to underwater topography. These circumstances are not unusual, with numerous 20th century shipwrecks and munitions dumps having been discovered around the world. Given that UXO becomes more sensitive to trigger events as they age, it is reasonably foreseeable that one detonation may trigger others in close proximity to explode in a chain reaction, a process known as sympathetic detonation.

1.2 Objectives

The objective of this annex is to present open-source examples of UXO discovery in individual and group circumstances that evidences the longevity and severity of UXO threats in the marine environment. Secondly, this annex aims also to highlight the potential hazards associated with a prospective UXO detonation and/or a sympathetic detonation event and the emergency reaction of the authorities to such discoveries.

1.3 Open Source Examples

The *North Sea* was a significant a naval theatre of war in both WWI and WWII, given its location adjacent to the *United Kingdom* and its proximity to *Luftwaffe* bases in *Norway*. Numerous submarine engagements and offensive and defensive mine campaigns have specifically involved the deployment of munitions across the region. With the advances in aircraft technology and understanding in the mid-20th century, the coastline of *North-Eastern Scotland* was also in range of bomber aircraft during WWII, which also resulted in deliberate air-to-surface vessel attacks, air mining and bomb jettisoning at sea. As such, both WWI and WWII have left a legacy of unexploded munitions along the *Scottish* coastline which are still encountered to the present day. Although almost 75 years have passed since the end of the WWII, associated UXO are still located and discovered within the coastline and offshore environments of *Scotland* to this day, as demonstrated by the following publicly accessible news article summarising encounters with historic munitions.

BP oil pipeline closed to remove unexploded war mine

Second world war mine off Peterhead coast in Scotland forces five-day closure of BP Forties pipeline for safe removal

BP's Forties oil pipeline has been closed for five days for the safe removal off an unexploded second world war mine off the coast of Peterhead in Scotland. Photograph: Graham Turner for the Guardian

An oil pipeline off the north-east coast of the UK, responsible for delivering around 40% of oil produced in UK waters into the country, has been shut down for five days so that an unexploded mine from the second world war can be removed.

The German-build sea-mine will be transported four kilometres (2.5 miles) away and detonated safely underwater, the operator of the Forties pipeline, BP, said.

The explosive was found in 300ft of water 25 miles off the coast of Peterhead, Scotland, in late March.

"It didn't pose any risks where it was, but we knew pretty quickly we didn't want it there," a BP spokesman said on Monday.

"It's very rare that the whole system is shut down, but we are not taking any chances."

BP has decided to shut down the pipeline now to deal with it because demand is typically lower around this time of year. The downtime will allow BP to carry out essential maintenance on the pipeline.

BP said on Monday: "The Forties pipeline system has started a five-day planned shutdown, to enable the safe removal and disposal of ordnance lying next to the pipeline. BP is also taking the opportunity to conduct some important maintenance while the system is shut down. All users of the Forties pipeline system have been kept regularly informed and are fully aware of the plan. The plans have also received full regulatory approvals and support."

Alex Hawkes, *BP oil pipeline closed to remove unexploded war mine*, 1st August 2011.

https://www.theguardian.com/business/2011/aug/01/bp-oil-pipeline-closed-unexploded-mine

Police shut off harbour following discovery of unexploded bomb

A HARBOUR was closed for six hours today after a fishing boat brought in what was thought to be a torpedo caught in its nets.

A HARBOUR was closed for six hours today after a fishing boat brought in what was thought to be a torpedo caught in its nets.

The crew brought the object into Peterhead harbour, Aberdeenshire, this morning after finding it at sea.

Police were contacted at around 8.30am after a "torpedo-shaped" object was brought ashore.

The harbour was cordoned off until the device was inspected and removed. The area was reopened at 3.20pm.

Explosive experts from the Royal Navy travelled to the harbour and inspected the torpedo-shaped object on a quayside.

A spokeswoman for Grampian Police said: "The explosive ordnancedisposal team have removed the device and will perform a controlled detonation offshore.

"Grampian Police realise that the incident has causedconsiderable disruption to the Peterhead area today and wish to thank the public for their co-operation and patience during this time."

Charlie Gall, *Police shut off harbour following discovery of unexploded bomb*, 30th March 2011.
https://www.dailyrecord.co.uk/news/scottish-news/police-shut-off-harbour-following-discovery-1098916

ACCIDENT REPORT

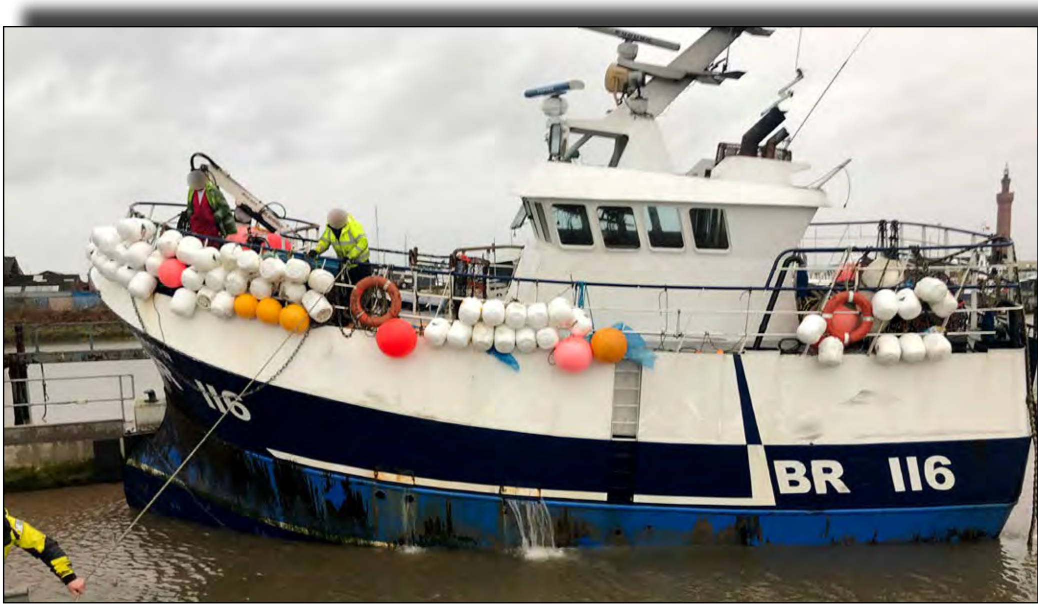
MAIB

MARINE ACCIDENT INVESTIGATION BRANCH

Report on the investigation of a subsea explosion resulting in crew injuries and vessel damage to the crab potting vessel ***Galwad-Y-Mor* (BRD 116)**

22 nautical miles north of Cromer, England

on 15 December 2020



SERIOUS MARINE CASUALTY REPORT NO 1/2022 JANUARY 2022

The United Kingdom Merchant Shipping

(Accident Reporting and Investigation)

Regulations 2012 – Regulation 5:

"The sole objective of the investigation of an accident under the Merchant Shipping (Accident Reporting and Investigation) Regulations 2012 shall be the prevention of future accidents through the ascertainment of its causes and circumstances. It shall not be the purpose of an investigation to determine liability nor, except so far as is necessary to achieve its objective, to apportion blame."

NOTE

This report is not written with litigation in mind and, pursuant to Regulation 14(14) of the Merchant Shipping (Accident Reporting and Investigation) Regulations 2012, shall be inadmissible in any judicial proceedings whose purpose, or one of whose purposes is to attribute or apportion liability or blame.

Front Cover image courtesy of Andrew Oliver

All MAIB publications can be found on our website: www.gov.uk/maib

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SYNOPSIS

On 15 December 2020, the 14.95m crab potting vessel, *Galwad-Y-Mor*, disturbed a piece of unexploded ordnance on the seabed while recovering crab pots in the North Sea, approximately 22 nautical miles off Cromer, England. The ordnance detonated and the ensuing explosion threw *Galwad-Y-Mor* up from the surface of the sea, causing significant crew injuries and damage to the vessel. The crew were rescued and evacuated to local hospitals and *Galwad-Y-Mor* was later towed to Grimsby.

The MAIB investigation found that:

- The ordnance was an air-dropped bomb that had remained intact on the seabed since The Second World War.
- The bomb detonated on the seabed and the shock wave and gas bubble from the explosion hit *Galwad-Y-Mor*.
- The position of most seabed unexploded ordnance is unknown and *Galwad-Y-Mor*'s crew could not have anticipated the fouling of a bomb in the crab potting string.
- *Galwad-Y-Mor*'s crew training, experience, length of service together and emergency preparedness improved their survival chances.
- *Galwad-Y-Mor*'s hull was well constructed and able to withstand the force of the nearby seabed explosion.

Based on this accident's circumstances, no action has been taken by external stakeholders and no recommendations made.

The aim of this report is to highlight the dangers that still exist with unexploded ordnance in the seas around the UK, and the actions to take should fisherman encounter any. In this case, the skipper and crew could not have foreseen the explosion and their level of preparedness to deal with such an emergency saved lives.

SECTION 1 – FACTUAL INFORMATION

1.1 PARTICULARS OF *GALWAD-Y-MOR* AND ACCIDENT

SHIP PARTICULARS	
Vessel's name	*Galwad-Y-Mor*
Flag	United Kingdom
IMO number/fishing numbers	BRD 116
Type	Crab potting vessel
Registered owner	The *Galwad-Y-Mor* Shellfish Company
Manager(s)	Not applicable
Construction	2007
Year of build	Steel
Length overall	14.95m
Registered length	12.90m
Gross tonnage	63.23

VOYAGE PARTICULARS	
Port of departure	Grimsby
Port of arrival	Grimsby
Type of voyage	Commercial
Cargo information	Shellfish
Manning	7

MARINE CASUALTY INFORMATION	
Date and time	15 December 2020 at 1122
Type of marine casualty or accident	Serious Marine Casualty
Location of accident	53°18.59'N 001°15.46'E
Place on board	Hull and all compartments
Injuries/fatalities	Significant injuries to crew members
Damage/environmental impact	Extensive deformation to hull plating, engine room flooded and severe shock damage in all internal compartments
Ship operation	Fishing, recovering pots
External & internal environment	Wind, south-westerly force 3-4, sea state slight/moderate, visibility good
Persons on board	7

Reproduced from Admiralty Chart 0002 by permission of HMSO and the UK Hydrographic Office

Reproduced from Admiralty Chart 2182A by permission of HMSO and the UK Hydrographic Office

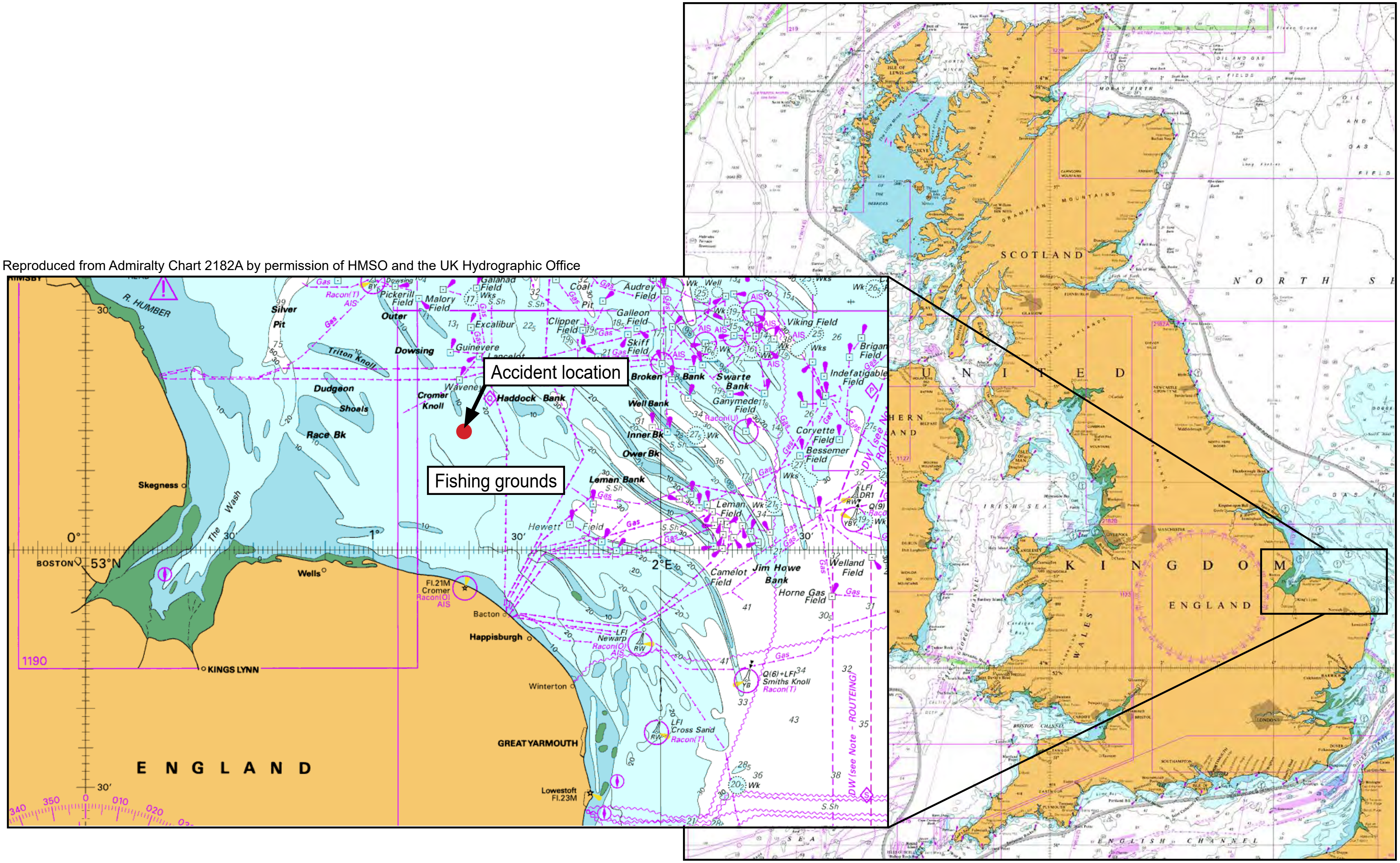


Figure 1: Location of the accident

Marine Accident Report

INVESTORS IN PEOPLE

Annex F

Ordnance Burial, Scour and Migration

1 Ordnance Scour, Burial and Migration

1.1 Overview

Unexploded ordnance (UXO) is typically found washed up on the coastlines, typically during severe weather periods, that strongly suggests movement from their originally deployed position. Consequently, any item of UXO detected during the geophysical UXO survey will be subjected to similar forces and processes and may therefore migrate and change position over time. The following annex provides an overview of the forces and processes to be considered for the assessment of UXO migration, to inform the UXO consultant of the longevity of the UXO risk ALARP sign-off certificate, as well as the expansion size of the avoidance radii.

1.2 Physical Environment

1.2.1 Bathymetry

Both the local bathymetry and the seabed morphology have a significant influence on where munitions are likely to be situated, as well as their prospective mobility. For instance, ordnance located in shallower water depths will be exposed to higher wave generated forces than in deeper water depths. High seabed gradients will also promote migration downslope under the force of gravity.

Whilst it may take relatively little force for an item of UXO to roll or slide downslope into a topographic low, such as a depression or a channel, an increased amount of force will be required to transport the UXO item back upslope. It is widely accepted that any UXO items found in such areas will effectively become trapped and is highly unlikely to move any further.

1.2.2 Tidal Currents

The force generated at the seabed by the tidal current flow will determine the rate and direction of movement of mobile sediments and hence bedform features, but also any debris on the seabed including UXO items.

Tides may be semi-diurnal (generating two low and two high tides within a 24-hour period) or diurnal (generating one high and one low tide during a 24-hour period). Localised tidal variations vary by the alignment of the Sun and Moon, by the pattern of tides in the deep ocean, by the amphidromic systems of the oceans and by the shape of the coastline and near-shore bathymetry. Analysis of metocean data is necessary to fully understand the localised tides and currents which operate within a region to understand the potential for UXO migration.

Depending on the local region, a tidal system will generate either a stronger ebb or flood tide and, dependent on the tidal current vector (magnitude and direction), will influence the predominant direction and rate of movement of an item of UXO.

1.2.3 Wind Generated Surface Waves and Storm Events

Long periods of high wind speeds associated with storm events, which can generate large surface waves, have the highest potential to mobilise items of UXO on the seabed.

The frequency, direction and duration of these storm events is difficult to predict, and therefore there is no proven way to accurately predict the net rate of mobility of UXO on Site without direct observation. Nonetheless, if a 1:50 year storm was to take place on the site after a geophysical UXO survey had already been undertaken, then some form of confirmatory geophysical survey (and investigation) may be required to evidence that the potential UXO targets have not moved, or to scope the magnitude and direction of any such movement.

1.2.4 Seabed Sediments

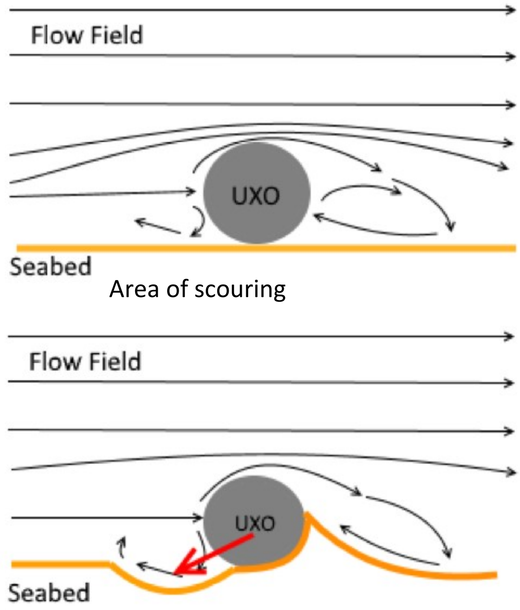
The nature of the sediments on any site is important for understanding the prospective movement of UXO. The ability of sediments to allow for either full or partial burial of such objects, is key to understanding the potential for scour, burial and the future mobility of the UXO item.

UXO can become buried, either by penetrating the seabed upon its initial deployment (subject to its residual energy upon impact with the seabed) or subsequently, over time, because of scour. UXO items that do become partially or fully buried are unlikely to migrate any further, due to requiring a significantly greater force to mobilise them from their partially buried position. If a UXO item is situated above the mean seabed level and covered by mobile bedforms, such as megaripples or sand waves, they may potentially become uncovered if the bedform position migrates over time.

UXO items are likely to be found on the surface of the seabed of consolidated cohesive sediments as well as bedrock. In comparison, UXO items located on granular soils or unconsolidated cohesive soils may be subjected to greater a potential of scouring and subsequent burial.

The disturbance of the water flow across the UXO item itself causes scouring. Vortices are generated in front of the UXO item, which in turn exerts a shear force at the seabed and mobilise the seabed sediments away from the UXO item. This process is periodic, accelerating with energetic wave and tidal current conditions, and will continue until the UXO item is of a similar roughness to the surrounding seabed. Eventually, the UXO item will be undermined by the scouring action and fall into its own scour pit as shown in Figure 1.

1. Vortices are produced in the front of the UXO scouring sediment away.



2. The UXO is eventually undermined by the scouring action and rolls/slides into the scour pit.

3. Scour – burial cycle begins again until vortices are too weak to transport the seabed sediments.

Figure 1: Vortex scouring and burial mechanism for UXO.

1.3 Human Factors - Fishing

Commercial fishing activities have the capability to inadvertently snag and move items of UXO, particularly in areas where dredging, beam and pair trawling is prevalent and nets are in contact with the seabed. These snagged UXO items may have been transported with the movements of the vessel's nets for considerable distances before they are returned to the seabed or recovered to the vessel.

Fishing boats which accidentally recover items of UXO have also been known to dispose of them/cut them free once they have been brought up to the surface, rather than inform the authorities (which involves considerable delay, but reduced risk).

1.4 Munitions Properties - Size, Shape and Density

The density, which is dependent on the mass and volume of the ordnance item, the cross-sectional area presented to the residual flow direction, and the hydrodynamic shape are primary factors considering an ordnance item's propensity to migrate.

In general, the denser and smaller an item of UXO is, the less likely it is to migrate. A large cross-sectional area will experience a higher hydrodynamic drag force than a smaller cross-sectional area, and a more streamlined body will experience a lower hydrodynamic drag force than a non-streamlined body.

Items of UXO, particularly high explosive bombs, are effectively hollow cases filled with an explosive fill. A large proportion of the bomb's volume is therefore dedicated to this low-density explosive fill. In comparison, a heavy anti-aircraft artillery projectile is significantly smaller and lighter, but is also denser, with a larger proportion of the volume dedicated to the casing to maximise the fragmentation effect. The projectile will also have a much smaller area exposed to the water flow. Given these circumstances, it is likely that the heavy anti-aircraft projectile will have a lower propensity to migrate than the high explosive bomb.

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GREEN VOLT

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