Cenos Offshore Windfarm Limited

Cenos EIA

Appendix 6 – UXO Risk Mitigation Strategy

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01	17/07/2023			[Redacted]		Cenos Offshore Windfarm Ltd

CENOS Offshore Wind Farm

FLOTATION ENERGY

Unexploded Ordnance Risk Mitigation Strategy

Meeting the requirements of the UK's
Construction Industry Research and Information Association's UXO Risk Management Framework:
"Assessment and Management of the UXO Risk in the Marine Environment" (C754)

6 Alpha Associates Ltd

Project No.: 50024

20th July 2023

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This UXO Risk Mitigation Strategy 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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Position	Reporting Services Manager	Managing Director

Executive Summary

Project Overview

Flotation Energy has commissioned *6 Alpha Associates Ltd* (6 Alpha) to deliver an Unexploded Ordnance (UXO) Risk Mitigation Strategy to support the development of the *CENOS Floating Offshore Wind Farm* (FOWF).

This document recommends UXO risk mitigation measures associated with the proposed Geotechnical Investigation (GI) and construction phases of work within the bounds of the OWF array and its associated export cable corridor, as well as those measures associated with prospective support and enabling operations. The recommended risk mitigation measures are informed and supported by *6 Alpha*'s UXO Threat and Risk Assessment for the project, which was delivered separately.

Project Location

The *CENOS FOWF* is located in the *North Sea,* approximately 203km to the east of *Aberdeen, Scotland*. An export cable corridor has also been defined by the Client and makes landfall near *Peterhead, Aberdeenshire*. The area of the export cable situated within the territorial sea limit (12 nautical miles from the coastline), however, is outside the scope of this report.

The proposed location of the *CENOS FOWF*, together with its export cable corridor, has been provided in draft format by the Client and is presented at Appendix 1.

UXO Threat and Risk Assessment Findings

The most substantial UXO threat is likely to have been generated by the WWII-era defensive minelaying operations undertaken by *British* vessels across the *North Sea,* specifically in the western sector of the export cable corridor. Additional contamination threats might also have been generated by WWI-era naval mines associated with *German* minefields, alongside WWI-era naval engagements largely involving *German* submarine activity, located on or in close proximity to the Study Site.

The potential sources of UXO contamination have been the subject of a Semi-Quantitative Risk Assessment (SQRA), based on the likely UXO risk pathways at each Study Site during the proposed works. The Study Site has then been zoned into appropriate areas of ***MEDIUM*** and ***LOW*** UXO risk; with those associated with the construction and cable installation operations depicted at Figure I, and those associated with the GI campaign depicted at Figure II.

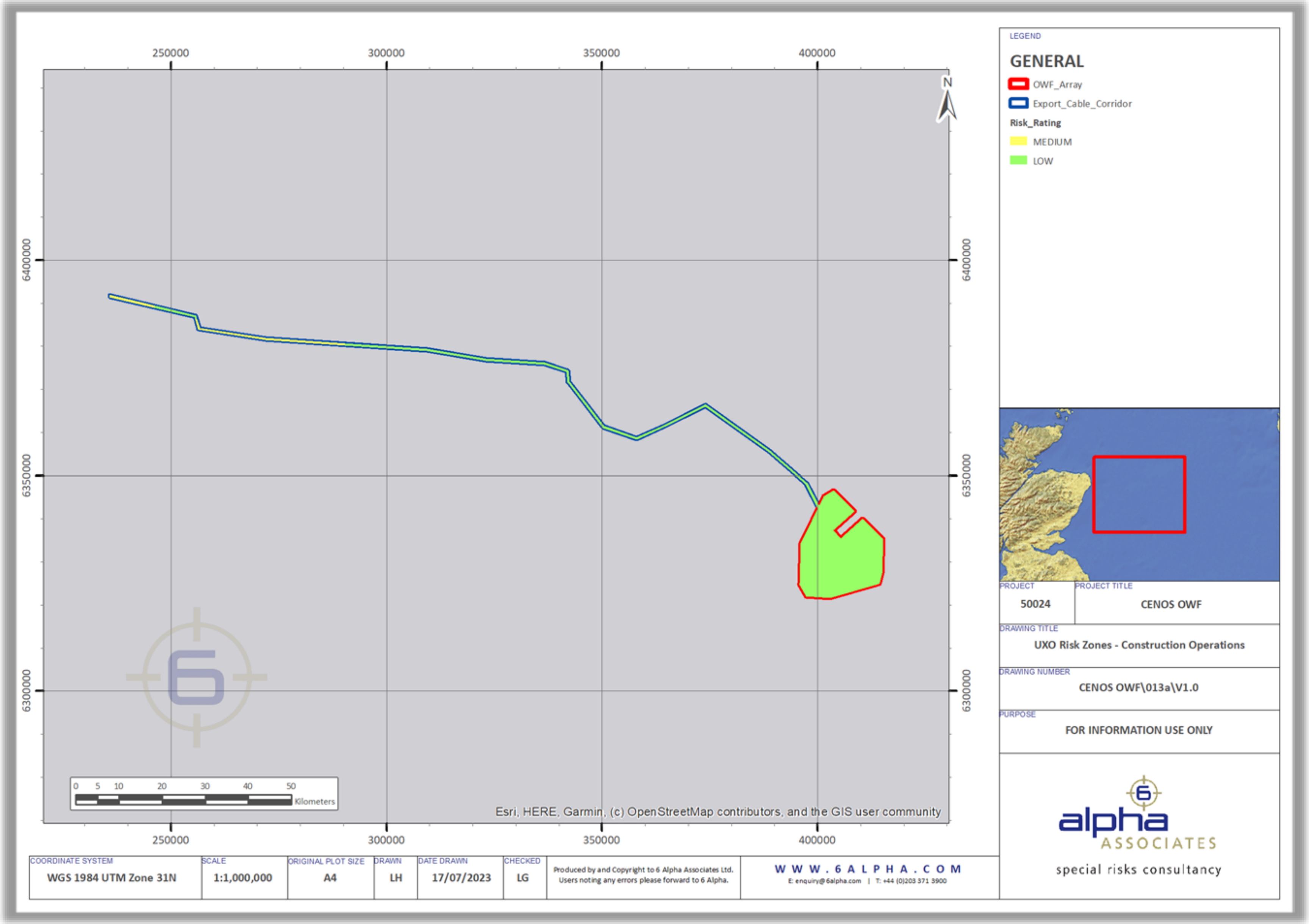

Figure I: UXO Risk Rating (Vessels and Vessel Crews) for Construction Operations

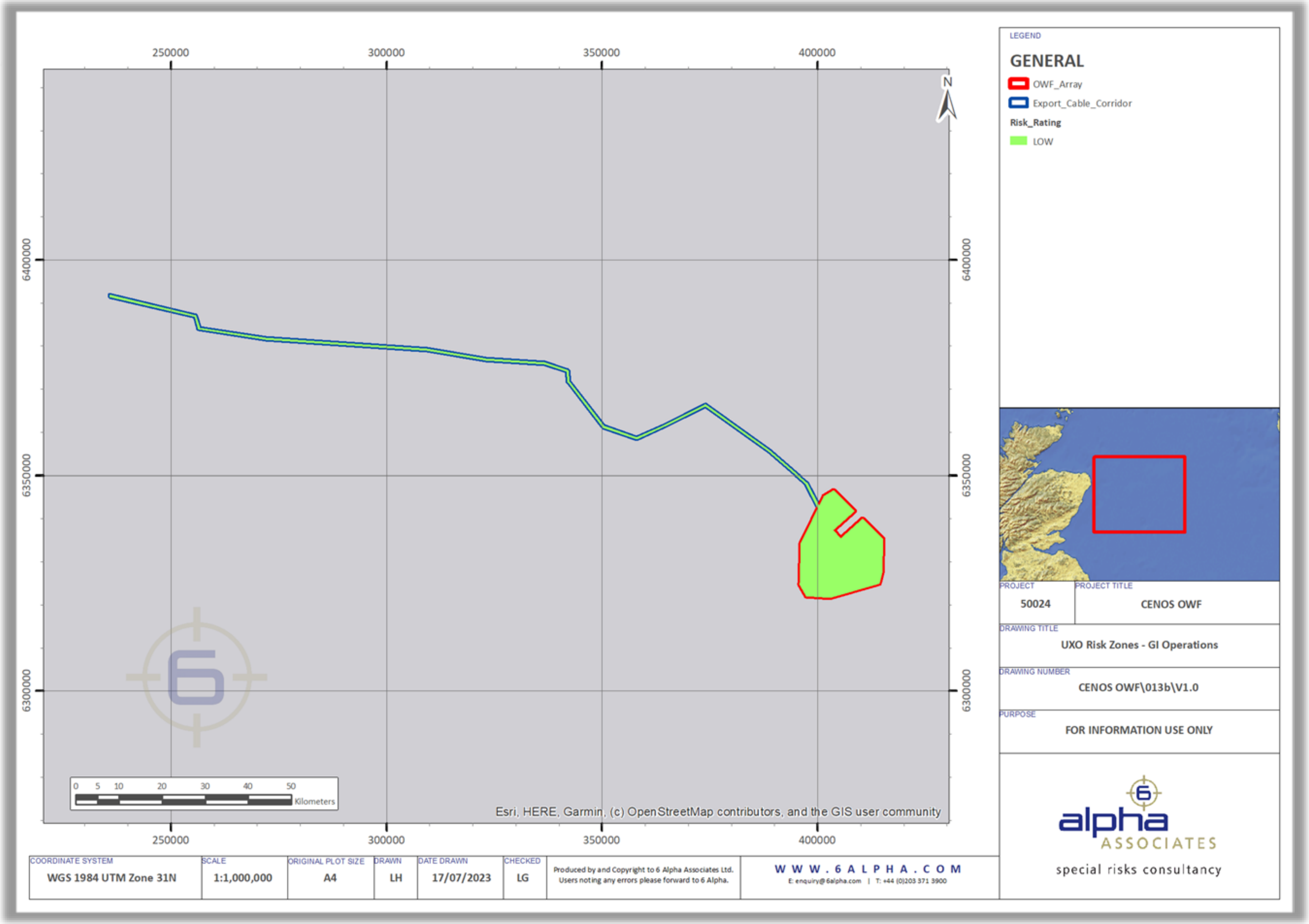

Figure II: UXO Risk Rating (Vessels and Vessel Crews) for GI Operations

Risk Mitigation Strategy

6 Alpha's approach is that there are three main strategic risk mitigation options to reduce the UXO risk As Low As Reasonably Practicable (ALARP), based upon source-pathway-receptor modelling are, in priority order:

1. **Avoidance**; by surveying for and avoiding direct or indirect contact with any potential UXO (pUXO) (the source of the risk), and by moving any intrusive activity away from such prospective hazards (wherever this is practicable), such risks are appropriately and effectively reduced;
2. **Removal of Risk Receptors**; an alternative option is to remove the receptor element (of the source-pathway-receptor model) by moving certain sensitive and vulnerable receptors (typically the crews of offshore vessels), to a safe distance from the point of the intrusive activity and thus the pUXO hazard;
3. **Removal of Threat Sources**; where pUXO cannot be avoided, an alternative option is to verify pUXO by investigation and where it is classified as confirmed UXO (cUXO), then to either move it (to a position where it cannot reasonably be initiated by project operations) and/or then rendering it safe.

Risk Mitigation Measures Overview

The UXO risk mitigation strategy ought to be enacted through the implementation of pertinent, proactive and reactive UXO risk mitigation measures. A summary of those measures is presented at Table I.

Risk Mitigation Measure	MEDIUM Risk Zones	LOW Risk Zones
UXO Emergency Response Plan	✔	✔
UXO Safety and Awareness Briefing	✔	✔
Existing Geophysical Survey Analysis	✘	✔
Bespoke Geophysical UXO Survey	✔	✘
Surface UXO Detection	✔	✔
Sub-Surface UXO Detection	✔	✘
Residual UXO Risk Rating	ALARP	

Table I: UXO Risk Mitigation Measures Overview

Proactive UXO Risk Mitigation Measures

A geophysical UXO survey, appropriately designed to detect threat spectrum UXO, is recommended prior to the commencement of intrusive cable installation operations in the ***MEDIUM*** risk zones of the export cable corridor (<100m LAT), to provide the basis for a strategy of pUXO avoidance or for its identification and removal. This survey should include surface and sub-surface detection methodologies (i.e. side scan sonar, multi-beam echo sounder and magnetometer/gradiometer) and any point intrusive works within this area must also be located along the magnetometer line for safety purposes.

However, ahead of all GI operations, and any WTG construction as well as cable installation operations within the ***LOW*** risk zones, undertaking a bespoke geophysical UXO survey may not be warranted **if a suitable alternative can be implemented**. Specifically, it is highly likely that some form of general engineering geophysical survey data will be or has been collected, for other (non-UXO related) purposes. Therefore, any existing and suitable acoustic and magnetic survey data is to be employed for the purposes of pUXO identification and avoidance and/or further investigation.

Safety avoidance distances for all operations will be specified subsequently as part of the ALARP safety sign-off certification process and whilst it expected that all pUXO are highly likely to be avoided during GI operations, in the unlikely event that these activities cannot avoid pUXO, then pUXO may need to be verified (by investigation) and where they are then classified as cUXO, they may need to be either avoided by an enhanced safety distance or moved and/or rendered safe.

Reactive UXO Risk Mitigation Measures

In all risk zones across the Study Site, any vessels involved in intrusive works are to be equipped with UXO specific Emergency Response Plan(s), so that in the event of an unplanned UXO discovery the vessel Master and/or the offshore superintendent/party chief (or equivalent) are informed in advance about what immediate and subsequent safety actions must be taken.

All personnel involved with intrusive works, including operational support staff working on vessels and/or any other relevant workers that might either identify or be exposed to UXO, are to receive a UXO Safety and Awareness Briefing concerning the identification of relevant UXO and safe actions to be taken in the event of a UXO encounter.

Safety and awareness mini-posters concerning the nature of the UXO threat and the key actions to be taken, are to be displayed on operational vessels for general information and on notice boards, both for reference and as a UXO safety reminder for offshore crew.

UXO Risk Mitigation Measures - Design, Specification and Guidance

Strategic guidance concerning the design and implementation of UXO risk mitigation measures is provided at Section 6 of this report. Nonetheless and more broadly, existing geophysical survey data and any newly captured data needs to be able to detect the following type of UXO, as specified at Table II:

Minimum UXO Threat	Dimensions (L x W)	Estimated Ferrous Mass	Explosive Fill
***British* Mark XVII Naval Mine**	1,321mm x 1,016mm	313-317kg	145 or 227kg TNT/Amatol

Table II: Minimum UXO Threat Items by Water Depth

Further Recommendations

6 Alpha recommend that the Client's next steps are focused upon phase four of the UXO Risk Management Framework namely, that detailed designs and specifications to support the recommended proactive UXO risk mitigation measures (as has been outlined at Section 4 of this report), are implemented. The specifications are to be delivered and the UXO risk mitigation work is to be executed, in advance of the intrusive GI and construction works, in order to warrant and to evidence that UXO risks have been mitigated and reduced to ALARP.

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Acronyms and Abbreviations

ALARP	As Low As Reasonably Practicable
CIRIA	Construction Industry Research and Information Association
cm	Centimetre
cUXO	Confirmed Unexploded Ordnance
EOD	Explosive Ordnance Disposal
ERP	Emergency Response Plan
FOWF	Floating Offshore Wind Farm
GI	Geotechnical Investigation
kg	Kilogram
km	Kilometre
LAT	Lowest Astronomical Tide
lb	Pound (weight)
m	Metre
mm	Millimetre
MBES	Multi-Beam Echo Sounder
MMBA	Munitions Migration and Burial Assessment
NEQ	Net Explosive Quantity
OWF	Offshore Wind Farm
pUXO	Potential Unexploded Ordnance
RMS	Risk Mitigation Strategy
SSS	Side Scan Sonar
SQRA	Semi-Quantitative Risk Assessment
TAN	Technical Advisory Note
TI	Target Investigation
TNT	Trinitrotoluene
UK	United Kingdom
UTM	Universal Transverse Mercator
UXO	Unexploded Ordnance
WGS	World Geodetic System
WROV	Work-Class Remotely Operated Vehicle
WTG	Wind Turbine Generator
WWI	World War I
WWII	World War Two

References

The following reference information is provided, in the order that each documented is referenced within the report:

- **Reference A**: 6 Alpha Associates Ltd, Project Reference 50024 V1.0, Unexploded Ordnance Threat and Risk Assessment: CENOS Development, Dated 20th July 2023;
- **Reference B:** Construction Industry and Research Information Association, Document Reference C754, Assessment and Management of the UXO Risk in the Marine Environment, Dated February 2016.

Part I – Introduction

1 Project Overview

1.1 Scope of Work

Flotation Energy has commissioned *6 Alpha Associates Ltd* (6 Alpha) to deliver an Unexploded Ordnance (UXO) Risk Mitigation Strategy to support the development of the *CENOS Floating Offshore Wind Farm* (FOWF).

1.2 Document Scope

This document recommends UXO risk mitigation measures associated with the proposed Geotechnical Investigation (GI) and construction phases of work within the bounds of the FOWF array and its associated export cable corridor, as well as those measures associated with prospective support and enabling operations.

1.3 Supporting Documentation

6 Alpha were also previously commissioned to provide a UXO Threat and Risk Assessment (Reference A) for the project, which was delivered in July 2023. This UXO Threat and Risk Assessment is relied upon in this document, where information concerning the nature and scope of the UXO threat and the UXO risk generated by potential intrusive works (and any associated enabling operations) is required.

1.4 Project Location

The *CENOS FOWF* is located in the *North Sea,* approximately 203km to the east of *Aberdeen, Scotland*. An export cable corridor has also been defined by the Client and makes landfall near *Peterhead, Aberdeenshire*. The area of the export cable situated within the territorial sea limit (12 nautical miles from the coastline), however, is outside the scope of this report.

The proposed location of the *CENOS FOWF*, together with its export cable corridor, has been provided in draft format by the Client and is presented at Figure I.

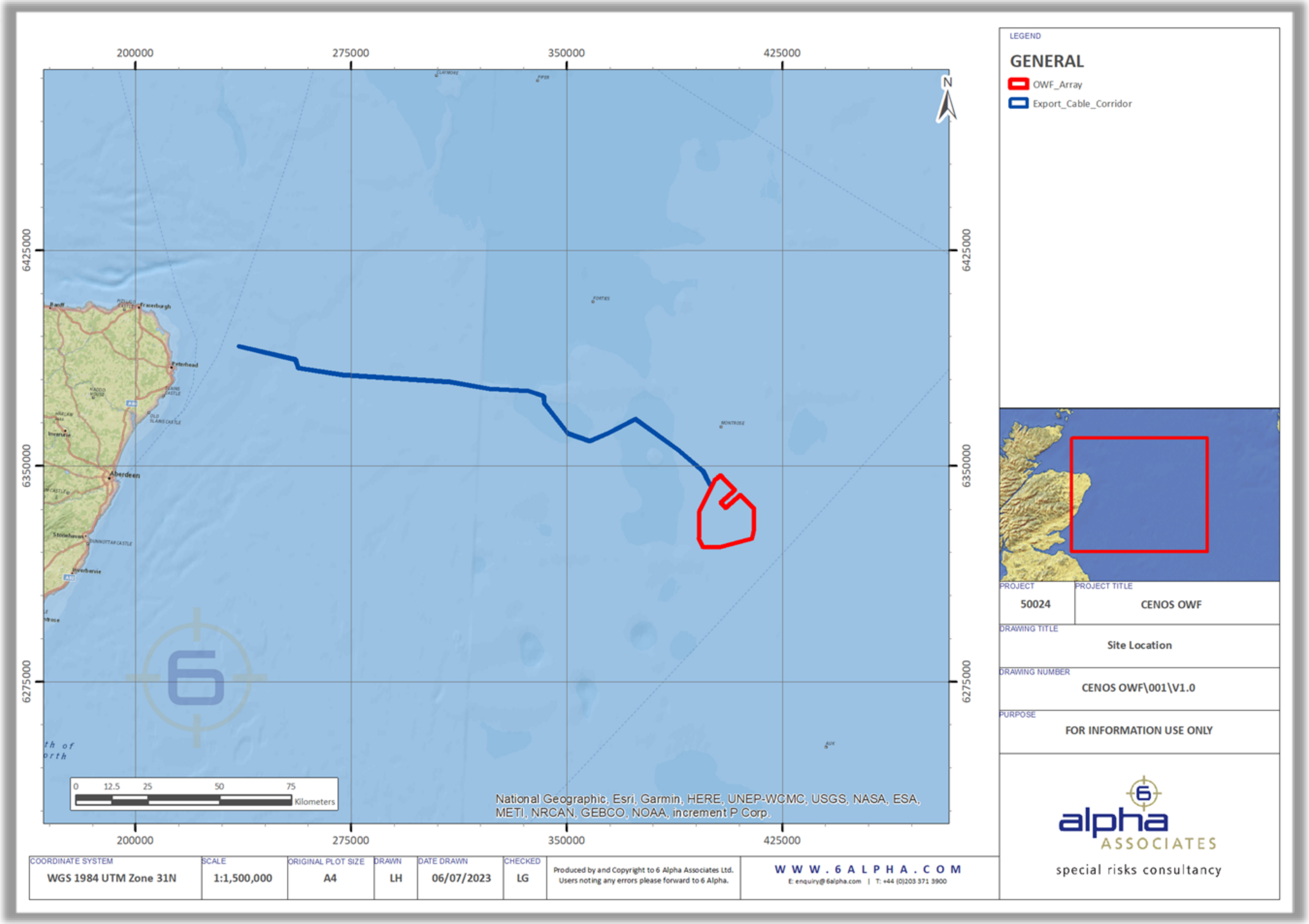


Figure 1: Site Location

1.5 UXO Industry Best Practice

In the absence of specific legislation concerning the management of UXO risks during offshore projects, the *UK*'s *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 (Reference B), of which *6 Alpha* were the lead technical author.

CIRIA C754 guidance provides a coherent framework for offshore UXO risk management projects and 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.

Therefore, in undertaking this assessment *6 Alpha* has ensured compliance with industry best practice and As Low As Reasonably Practicable (ALARP) risk reduction criteria – through continued adherence to the framework, the project stakeholder's legal obligations will be fulfilled.

Further information regarding national and international legislation within the *UK*, and the management and reduction of UXO risk to ALARP, is presented at Annex A and is indicative of the safety benchmark to which *6 Alpha* adhere.

1.6 UXO Risk Management Strategic Framework

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 1. 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 (✓/✗)
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 1: 6 Alpha and CIRIA UXO Risk Management Frameworks

The purpose of this report is to deliver Phase 3 of the above UXO risk management framework, with Phase 1 and Phase 2 previously delivered within *6 Alpha*'s UXO Threat and Risk Assessment (Reference A). This framework is applied to provide a holistic solution for managing UXO risks to ALARP, as per Appendix 3.

This Risk Mitigation Strategy will outline the strategic risk management options and will also make recommendations for the most time-efficient and cost-effective way of mitigating the UXO risk to ALARP (the minimum legal requirement). By outlining the overall Risk Mitigation Strategy at Phase 3, the foundation is laid for Phase 4 of the framework where the specific risk mitigation measures are designed, and specifications are produced. Phase 5 is concerned with the subsequent implementation of those risk mitigation measures.

2 UXO Threat and Risk Assessment Summary

2.1 UXO Threat Assessment

Significant archive research associated with the Study Site has been undertaken in *6 Alpha*'s UXO Threat and Risk Assessment (Reference A) to corroborate and to highlight, any and all potential sources of UXO contamination as well as to assess their likelihood of encounter. Several potential sources of UXO contamination have been evidenced, though the nature and scope of the possible UXO hazard varies across the Study Site.

The most substantial UXO threat is likely to have been generated by the WWII-era defensive minelaying operations undertaken by *British* vessels across the *North Sea,* specifically in the western sector of the export cable corridor. Additional contamination threats might also have been generated by WWI-era naval mines associated with *German* minefields, alongside WWI-era naval engagements largely involving *German* submarine activity, located on or in close proximity to the Study Site.

The output of the UXO threat assessments is summarised at Table 2, and a supporting georeferenced chart evidencing the scope of historic UXO threat sources at each Site is presented at Appendix 4.

Likelihood of Encounter	UXO Threat Items
HIGHLY LIKELY	N/A
LIKELY	WWII-era *British* Naval Mines
POSSIBLE	N/A
UNLIKELY	WWI-era Naval Projectiles and Torpedoes, WWI-era Naval Mines
HIGHLY UNLIKELY	WWII-era AAA Projectiles, WWII-era *German* HE bombs

Table 2: UXO Threat Assessment Summary

2.2 Proposed Works

In order to classify the UXO risks, the potential UXO risk pathways must be assessed. *6 Alpha* have been provided with a high-level outline of the scope of works, which at this stage of the project will comprise a GI campaign ahead of the construction and installation of a FOWF.

Whilst the precise methodologies of the GI campaign have not yet been finalised, it is expected that the GI campaign might comprise seabed boreholing, cone penetration testing, vibrocoring and grab sampling.

During the construction phase, a variety of cable installation methodologies have been considered; most notably surface lay, jetting and ploughing. In addition, it is expected that the Wind Turbine Generators (WTG) will be installed on floating platforms moored to the seabed by piled and/or anchored means.

It is also likely that certain enabling operations will also be undertaken to support the proposed intrusive works, potentially including the use of Dynamically Positioned vessels, anchoring and the deployment of Jack-Up Vessels or Barges (although the latter methodology is unlikely given that substantial depth of water across the Study Site).

2.3 UXO Risk Assessment Findings

The potential sources of UXO contamination were then subject to a Semi-Quantitative Risk Assessment (SQRA), based on the likely UXO risk pathways associated with the likely GI, construction and enabling operations at the Study Site.

During the construction works, specifically cable pre-lay and installation operations, ***MEDIUM*** category risks have been defined in the western sector of the export cable corridor, in water depths <100m Lowest Astronomical Tide (LAT). In the remainder of the Study Site, including the eastern half of the export cable corridor and the entire OWF array, UXO risks have been defined as ***LOW***, largely due to the substantial depths of water that will provide sufficient amelioration of the through-water shock wave effect that might be generated by threat spectrum UXO.

During the planned GI campaign, the entire Study Site has been categorised as generating ***LOW*** UXO risks only. This is driven by the reduced likelihood of encountering and initiating UXO during the point intrusive works, together with the risk mitigative effect of the water depths across much of the area.

2.4 UXO Risk Assessment Conclusions

The Study Site was then zoned into areas of varying UXO risk, based on the output of the SQRA, as per Figures 2 and 3, as well as Appendix 5. The UXO risk zones are depicted for both the construction and GI phases of the project.

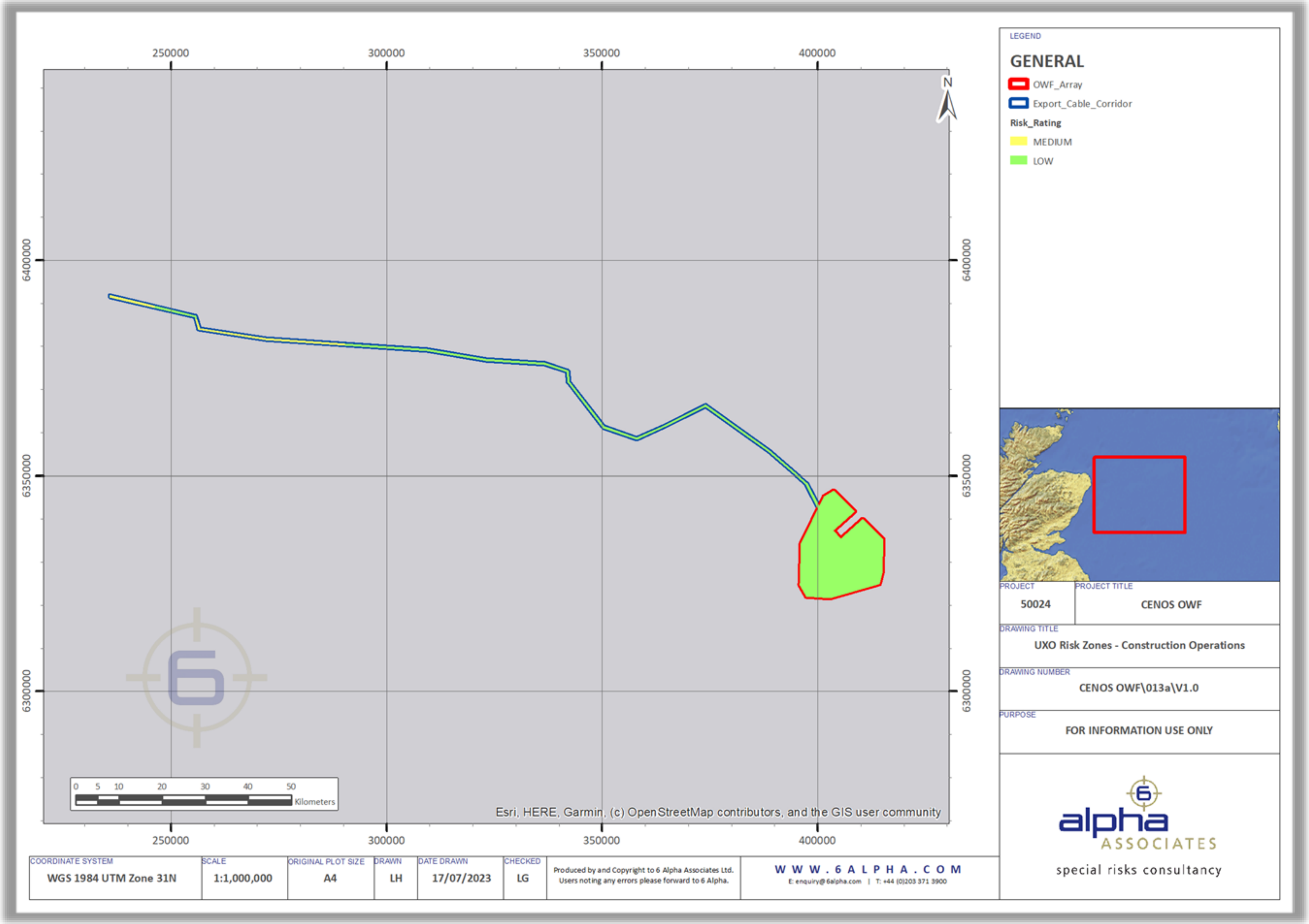


Figure 2: UXO Risk Rating (Vessels and Vessel Crews) for Construction Operations

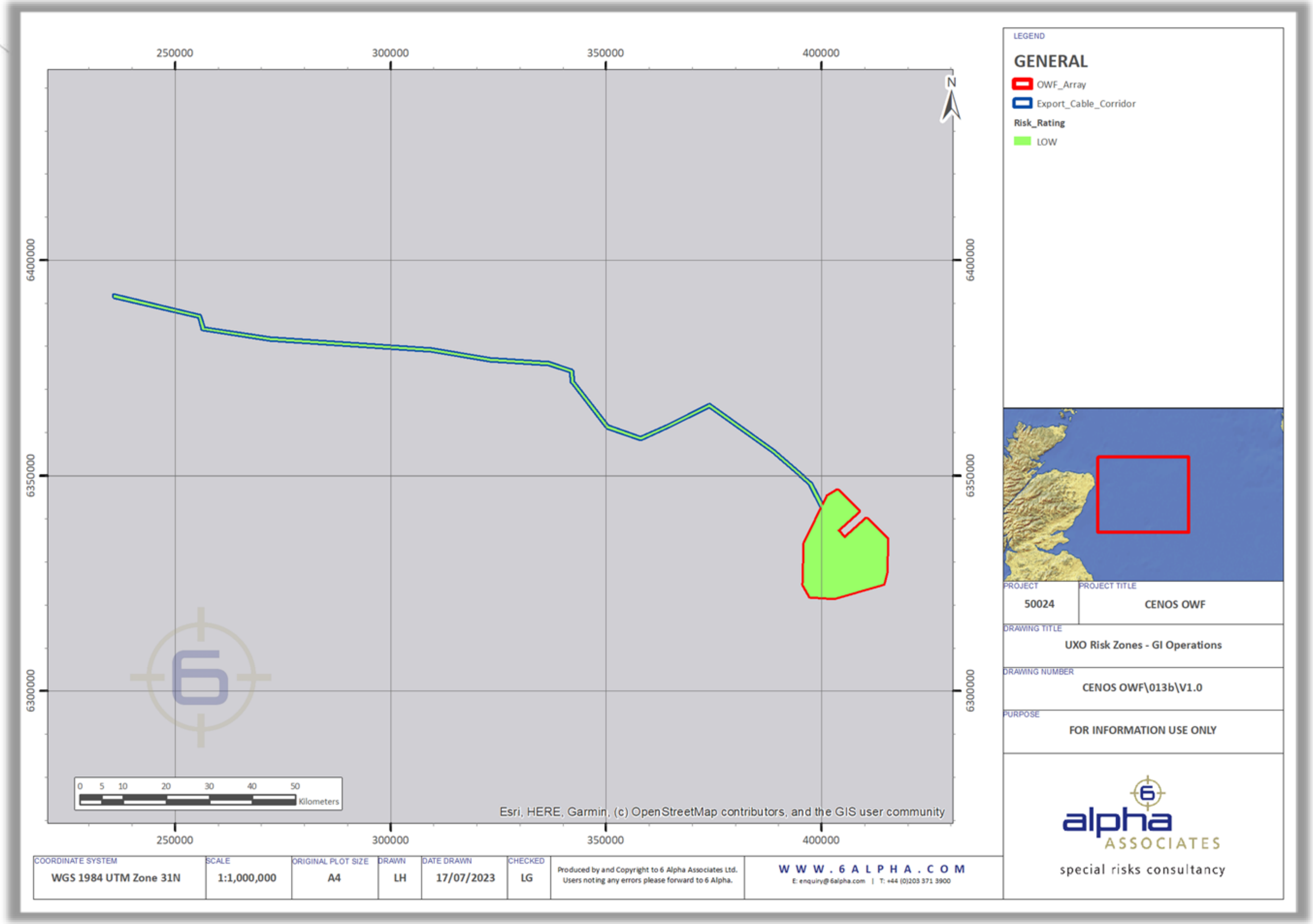


Figure 3: UXO Risk Rating (Vessels and Vessel Crews) for GI Operations

Part II – UXO Risk Mitigation Strategy

3 UXO Risk Mitigation Strategy

3.1 Risk Mitigation Strategy Options

6 Alpha's approach is that UXO risk to the intrusive operations can effectively be reduced to ALARP, by removing one (or more) element(s) of a source-pathway-receptor risk model, or otherwise mitigating the risks associated with a single element of the model.

The three main strategic risk mitigation options based upon source-pathway-receptor modelling are, in priority order:

3.1.1 Avoidance

A strategy of potential UXO (pUXO) detection and avoidance is proposed as the most cost effective and efficient method of reducing UXO risks to ALARP. By surveying for and avoiding direct or indirect contact with any pUXO (the source of the risk), and by moving any intrusive activity away from such prospective hazards (wherever this is practicable), such risks are appropriately and effectively reduced.

3.1.2 Removal of Risk Receptors

An alternative option is to remove the receptor element (of the source-pathway-receptor model) by moving certain sensitive and vulnerable receptors (typically the crews of offshore vessels), to a safe distance from the point of the intrusive activity and thus the pUXO hazard. Clearly, this is not always achievable and such a course of action is commonly impractical.

3.1.3 Removal of Threat Sources

Where pUXO cannot be avoided, another alternative option (but commonly, one that is more time consuming and costly), is to verify pUXO by investigation and where it is classified as confirmed UXO (cUXO), then to either move it (to a position where it cannot reasonably be initiated by project operations) and/or then rendering it safe (effectively removing the source element of the source-pathway-receptor model).

3.2 Risk Mitigation Measures

The UXO risk mitigation strategy ought to be enacted through the implementation of pertinent proactive and reactive UXO risk mitigation measures, based upon whether they are to be implemented before or concurrently with the proposed operations, tailored to the specific level of risk across each area of the Study Site. A summary of the recommended UXO risk mitigation measures for proposed works is presented at Table 3.

Risk Mitigation Measure	MEDIUM Risk Zones	LOW Risk Zones
UXO Emergency Response Plan	✔	✔
UXO Safety and Awareness Briefing	✔	✔
Existing Geophysical Survey Analysis	✘	✔
Bespoke Geophysical UXO Survey	✔	✘
Surface UXO Detection	✔	✔
Sub-Surface UXO Detection	✔	✘
Residual UXO Risk Rating	**ALARP**	

Table 3: UXO Risk Mitigation Measures Overview

Detailed advice concerning the specific nature of the recommended risk mitigation measures is given at Sections 4, 5 and 6 of this document.

4 Proactive Risk Mitigation Measures

The following risk mitigation measures are categorised as "proactive" measures and are recommended in advance of the intrusive works:

4.1 Bespoke Geophysical UXO Survey

A geophysical UXO survey, appropriately designed to detect threat spectrum UXO, is recommended prior to the commencement of intrusive cable installation operations only in the ***MEDIUM*** risk zones of the export cable corridor (<100m LAT), to provide the basis for a strategy of pUXO avoidance or for its identification and removal.

The risk associated with GI and WTG construction operations may not warrant the undertaking of a bespoke geophysical UXO survey at this Site (and see Section 4.2).

An overview of geophysical UXO survey methods that might be employed is presented at Annex B, but the survey must consist of surface and sub-surface survey methods.

4.1.1 Surface UXO Detection

Surface detection for threat spectrum UXO should consist of suitably specified Side Scan Sonar (SSS) and Multi-Beam Echo Sounder (MBES) over the area of the proposed intrusive phases of work. Further guidance on the implementation of such survey methods is given at Section 6.

4.1.2 Sub-Surface UXO Detection

Sub-surface detection for threat spectrum UXO should also be undertaken ahead of intrusive works in the ***MEDIUM*** risk zone only ahead of cable installation works. This should consist of magnetometer/gradiometer survey over the area of the proposed operations.

Notwithstanding the above, if there is an existing magnetometer line(s), or if additional magnetometer data is captured within the ***LOW*** risk zones, then it should be utilised to help identify pUXO. *6 Alpha* also recommend that any point intrusive works (e.g. GI positions) must be relocated upon a magnetometer line and that pUXO are avoided by a suitable and appropriate safety distance.

4.2 Existing Survey Data Analysis

Ahead of all GI operations, and any WTG construction and cable installation operations within the ***LOW*** risk zones, the undertaking of a bespoke geophysical UXO survey may not be warranted **if a suitable alternative can be implemented**. Specifically, it is highly likely that some form of general engineering geophysical survey data will be or has been collected, for other (non-UXO related) purposes. Therefore, any existing and suitable acoustic survey data (e.g. SSS and MBES) is to be employed for the purposes of pUXO identification and avoidance and/or further/investigation.

Any existing and suitable geophysical survey data will be analysed to identify pUXO and a Master Target List will be generated. If suitable data is not available, then additional survey data suitable for the purposes of pUXO avoidance may need to be acquired.

Those pUXO that require avoidance will be identified and avoidance distances can be safely established and evidenced by not only a Munitions Migration and Burial Assessment (MMBA) but also subsequently, through the medium of any Technical Advisory Notes (TANs), which can be produced for specific activities. Those pUXO that cannot be avoided may need to be verified and where they are then classified as cUXO, they will need to be moved and/or disposed of.

5 Reactive UXO Risk Mitigation Measures

5.1 Overview

Reactive risk mitigation measures are recommended across the Study Site regardless of UXO risk rating, not only to reduce intolerable risks to ALARP but also, to mitigate any residual risks that may remain once any proactive risk mitigation measures have been implemented. They are:

5.2 Operational UXO Emergency Response Plan (ERP)

Any vessels involved in intrusive works should be equipped with UXO specific emergency response plans, so that in the event of an unplanned UXO discovery the vessel Master and/or the offshore superintendent/party chief (or similar) are informed in advance about what safety actions must be taken.

5.3 UXO Safety and Awareness Briefings

Safety briefings are considered as an essential reactive risk mitigation measure, to be implemented whenever there is a possibility of UXO encounter and as such, they are considered a vital part of the general UXO safety requirement. All personnel involved with seabed intrusive works, operational support staff working on vessels and/or any other relevant workers are to receive a safety briefing concerning the identification of relevant UXO and safe actions to take in the event of a potential UXO encounter, in advance of undertaking GI and construction works.

Safety and awareness mini-posters concerning the nature of the UXO threat and key actions to be taken, are to be displayed on operational vessels for general information and on notice boards, both for reference and as a UXO safety reminder for offshore crew.

5.4 On-Call Explosive Ordnance Disposal (EOD) Engineers

Following the implementation of proactive UXO risk mitigation measures, shore-side and office-based explosive ordnance disposal engineers may be engaged to provide remote, rapid UXO recognition advice and to provide immediate safety management guidance in the event that UXO is discovered. Such a service provides UXO risk management expertise as and when it is required on a just-in-time basis and not only affords safety, but also avoids prospective project delays that might otherwise be caused by the discovery of misidentified UXO, that might prove to be benign, non-UXO debris.

6 Risk Mitigation Measures – Design, Specification and Guidance

The specific designs and specifications of the recommended UXO risk mitigation measures are part of the next phase of the UXO risk management framework. Nonetheless, it is important to evidence that the UXO risk mitigation measures are congruent and consistent with, an overarching risk mitigation strategy. Therefore, the following strategic level guidance underpins subsequent detailed designs and specifications for risk mitigation.

6.1 Geophysical Survey Specifications

In accordance with the risk management recommendations contained within *CIRIA*'s UXO guide (Reference B), the survey contractor will need to provide evidence that their proposed survey methodology and equipment is fit for the purpose of identifying threat spectrum UXO. Accordingly, a geophysical survey specification is to be drafted for each proposed survey method, outlining the required survey parameters, equipment and calibrations to ensure that the survey is fit for the purpose of threat spectrum UXO detection.

In addition, a Survey Verification Test (SVT) is to precede the main survey acquisition work itself, to validate and prove the efficacy of the survey equipment.

6.2 Minimum Size UXO Threats

The minimum size of UXO to be detected by geophysical UXO survey depend on a number of factors including but not limited to; water depth, likely intrusive methodologies, the type(s) of the UXO, prospective vessel slant range to UXO and vessels' robustness.

The minimum size UXO threat for the purposes of detection by *inter alia* magnetometer/gradiometer survey is based on UXO threats' ferrous metal contents rather than its physical dimensions, or any other factor. Figure 4 illustrates the general categorisation of minimum UXO threats for detection (and thus ALARP safety provision), at different water depths but also provides their physical dimensions.

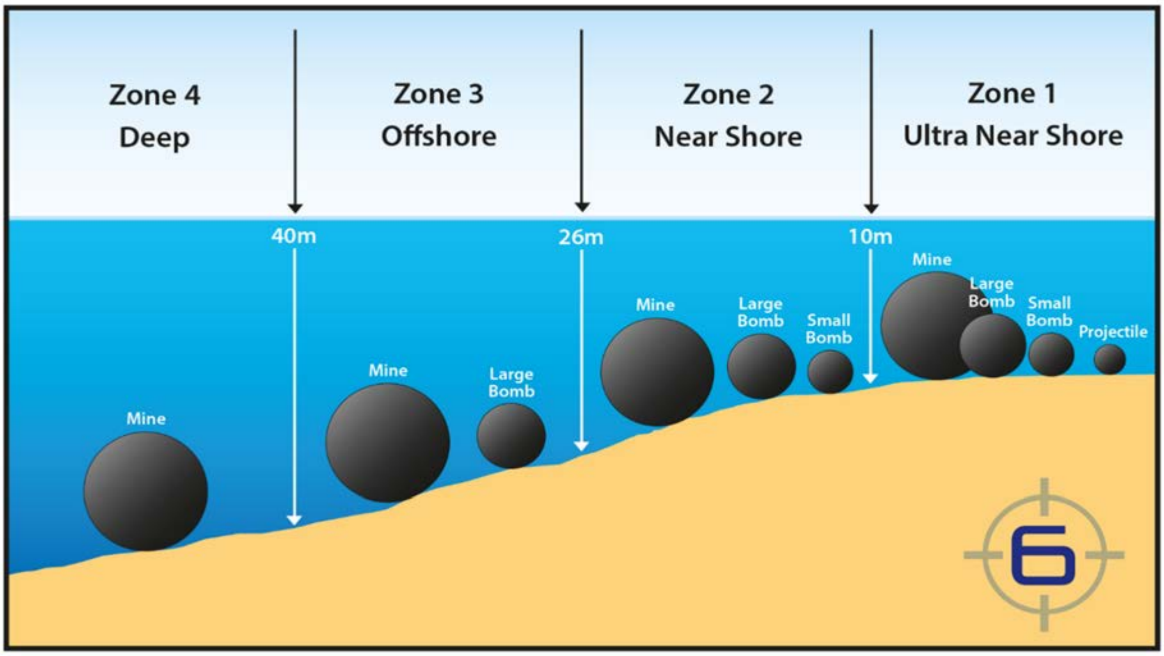


Figure 4: UXO Detection Requirement with Respect to Water Depths (in LAT)

The diagram presented at Figure 4 is intended as a general guide to minimum threat detection at those specified depths that is generally correct across all types of offshore projects but is not project specific.

At the strategic level, it is possible to broadly refine the minimum UXO threats that require detection in any newly captured data, as presented in Table 4.

Minimum UXO Threat	Dimensions (L x W)	Estimated Ferrous Mass	Explosive Fill
British Mark XVII Naval Mine	1,321mm x 1,016mm	313-317kg	145 or 227kg TNT/Amatol

Table 4: Minimum UXO Threat Items by Water Depth

6.3 Geophysical Survey Data Longevity

In accordance with *CIRIA* UXO guidance (Reference B pp 91-92 and 149), geophysical survey data is generally employed for up to 12 months (from the time of its final capture), for UXO risk management and mitigation purposes. Once the survey data is more than 12 months old and subject to *inter alia* environmental conditions, additional risk mitigation measures may need to account for the potential changes in position of the pUXO, especially in highly mobile seabed circumstances.

In such circumstances, an MMBA can be undertaken to gain a better understanding of the type of UXO that might move, as well as the magnitude and direction of its likely migration path.

6.4 pUXO Avoidance Radii

Any geophysical UXO survey anomaly that is classified as pUXO is to be avoided, by the following distances:

- By not less than 10m from the leading edge of any underwater equipment or platform during GI works;
- By not less than 15m from the leading edge of any underwater equipment or platform during construction and installation works, with the exception of piling, where a 25m avoidance would be applied.

These avoidance distances are to be followed wherever possible, provided the survey data positional accuracy is demonstrated to be suitably accurate. Such safety avoidance is designed to ensure that if non-verified pUXO is in fact cUXO, it will neither be encountered nor initiated (directly or indirectly). Thus, safety is afforded.

If such a safety avoidance distance proves problematic to implement (for example, because there is a profusion of pUXO anomalies), such avoidance might be safely reduced through the medium of a TAN. A TAN can consider, *inter alia*: the kinetic energy generated by the type and nature of the intrusive activity; high-level and shallow sub-seabed geotechnical considerations, and the prospective detonation sensitivity of those types of UXO that might be encountered. Typically, such (*6 Alpha* produced) TAN can reduce safety avoidance distances by about one third.

6.5 pUXO Verification by Investigation

In the unlikely event that pUXO cannot be avoided, they might instead be verified by a campaign of Target Investigation (TI) to classify them as cUXO, or otherwise as benign debris. Such TI operations require professional quality control and independent oversight, to ensure that its outputs can properly inform and support the subsequent production of ALARP safety sign-off certification.

6.6 cUXO Disposal

Where pUXO is investigated and classified as cUXO, it will require safe disposal either in situ or, if it is considered safe to do so, through it being removed and subsequently rendered safe. For safety reporting and third-party avoidance purposes, the relevant local and national *Coast Guard* authorities - amongst a variety of other stakeholders - will also require notification upon discovery of cUXO.

Necessary cUXO render safe (typically by UXO low-order destruction) may subsequently be undertaken by a suitable and appropriate contractor, although permitting licensing and consent will need to be sought in advance, which can take a number of weeks or months to acquire. Details of the planned disposal methodology and accompanying risk assessments will usually be required prior to consent being given and the award of a licence/permit/consent.

7 Residual Risk Tolerance

Following the implementation of suitable risk mitigation measures, UXO risks will not usually be reduced to “zero”, nor need they be under the auspices of ALARP risk reduction principle. Residual UXO risks may remain in the offshore environment due to *inter alia*, the limits of geophysical UXO survey technology, data interpretation limitations and the fact that low Net Explosive Quantity (NEQ) UXO threats might be tolerated - which is acceptable under the principles of ALARP risk reduction.

Project stakeholders are therefore, requested to consider and to formally endorse *6 Alpha*’s assumed level of Client risk tolerance and thus our residual UXO risk recommendations, as presented and labelled as Option 2, in Table 5.

UXO Risk Tolerance	Prospective Residual UXO Risk	Project Implications
Option 1: Very Conservative	Damage to subsea equipment, of any kind, will not be tolerated.	Most expensive and time-consuming option but the risk of damaging the subsea equipment is significantly reduced.
Option 2: Recommended (within ALARP threshold)	Damage/destruction of subsea equipment will be tolerated – although it remains undesirable. Significant damage to vessels that may injure or endanger personnel (either directly or indirectly), is intolerable and will require proactive risk mitigation.	Time and cost efficient, although carries the risk of repair and/or replacement of equipment in the event of unplanned low NEQ UXO encounter and detonation.

Table 5: Residual UXO Risk Tolerance Levels

7.1 ALARP Safety Sign-Off Certification

ALARP safety sign-off certification provides an independent source of evidence that a Client has followed industry best practice and has successfully managed and reduced UXO risks to ALARP. Following the execution of *6 Alpha’s* UXO risk mitigation measures, we can deliver ALARP safety sign-off certification, in advance of the proposed operations.

In such circumstances the project will be able to certify for the benefit of all of its stakeholders, that all reasonably practicable measures have been taken to protect contractors from UXO hazards and that the commissioning Client will have acted in compliance with industry best practice as well as the national safety legislation.

In accordance with best practice therefore, *6 Alpha* ALARP safety sign-off certification does not imply that any site is free from UXO, rather, that the necessary and appropriate UXO risk mitigation measures have been appropriately applied to evidence that UXO risks have been reduced ALARP.

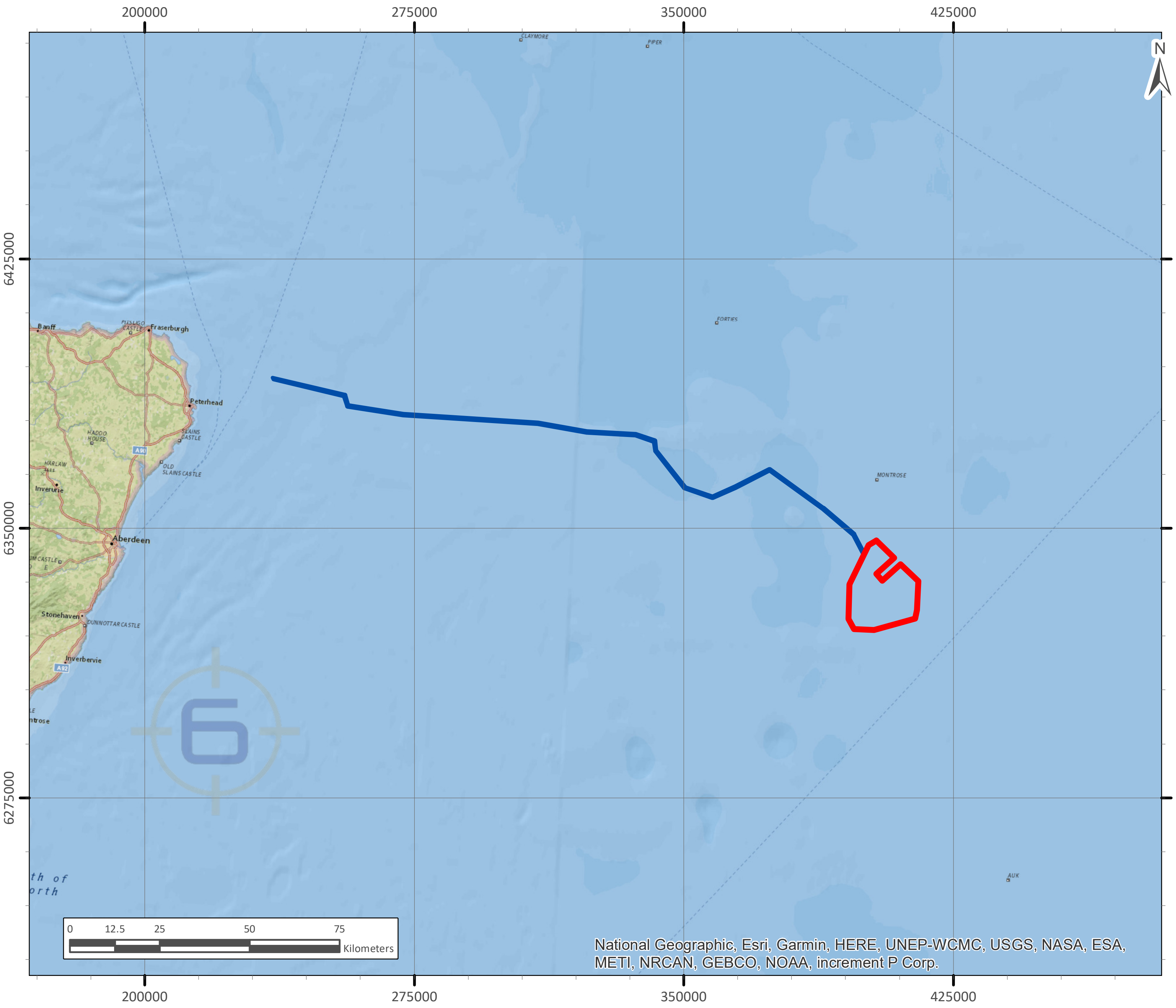
7.2 Next Steps

We recommend that the Client's next steps are focused upon phase four of the UXO Risk Management Framework namely, that detailed designs and specifications to support the recommended proactive UXO risk mitigation measures as outlined at Section 4 of this report are implemented. The specifications are to be delivered and the UXO risk mitigation work is to be executed, in advance of the intrusive GI and construction works, in order to warrant and to evidence that UXO risks have been mitigated and reduced to ALARP.

Appendices

Appendix 1

Site Location



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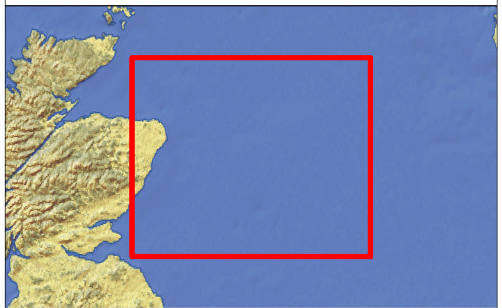

PROJECT	PROJECT TITLE
50024	CENOS OWF

DRAWING TITLE

Site Location

DRAWING NUMBER

CENOS OWF\001\V1.0

PURPOSE

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COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
WGS 1984 UTM Zone 31N	1:1,500,000	A4	LH	06/07/2023	LG

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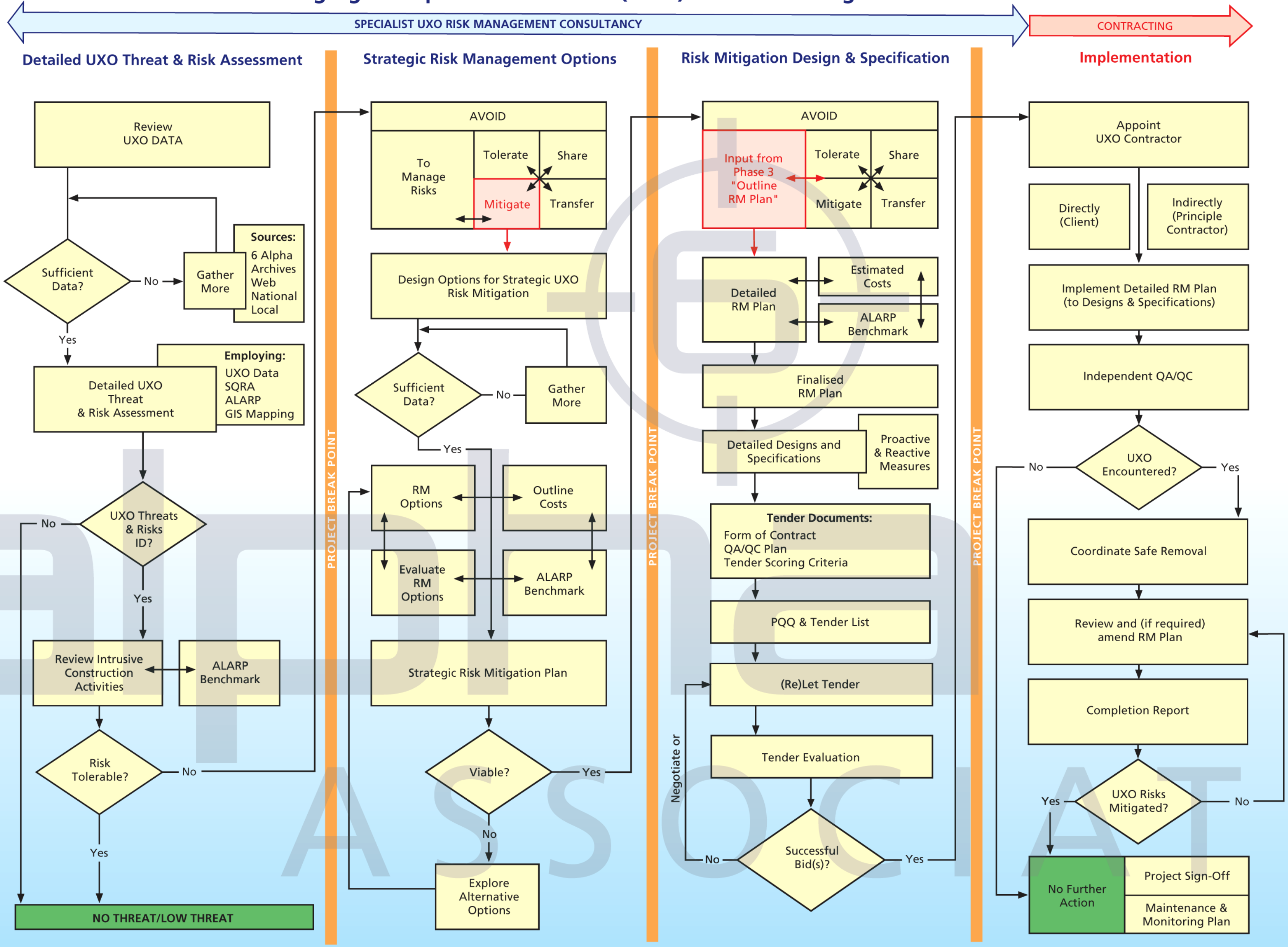
Appendix 2

Marine Risk Management Framework

Managing Unexploded Ordnance (UXO) - A Risk Management Framework



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

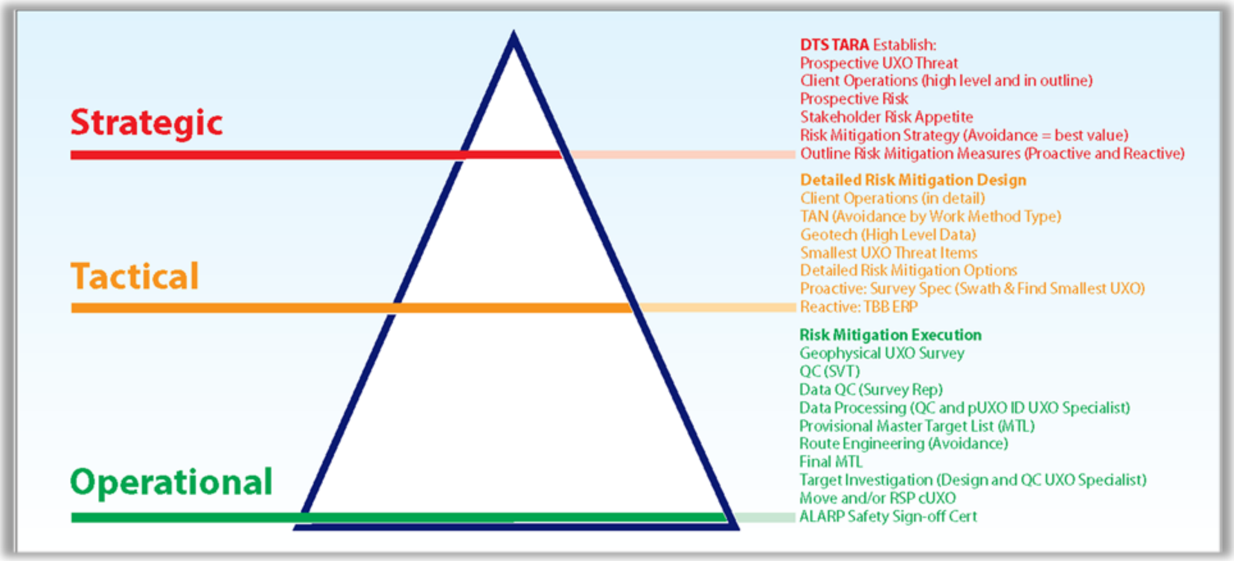
Holistic UXO Risk Management Process

1.1 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

1.2 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.

1.3 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:

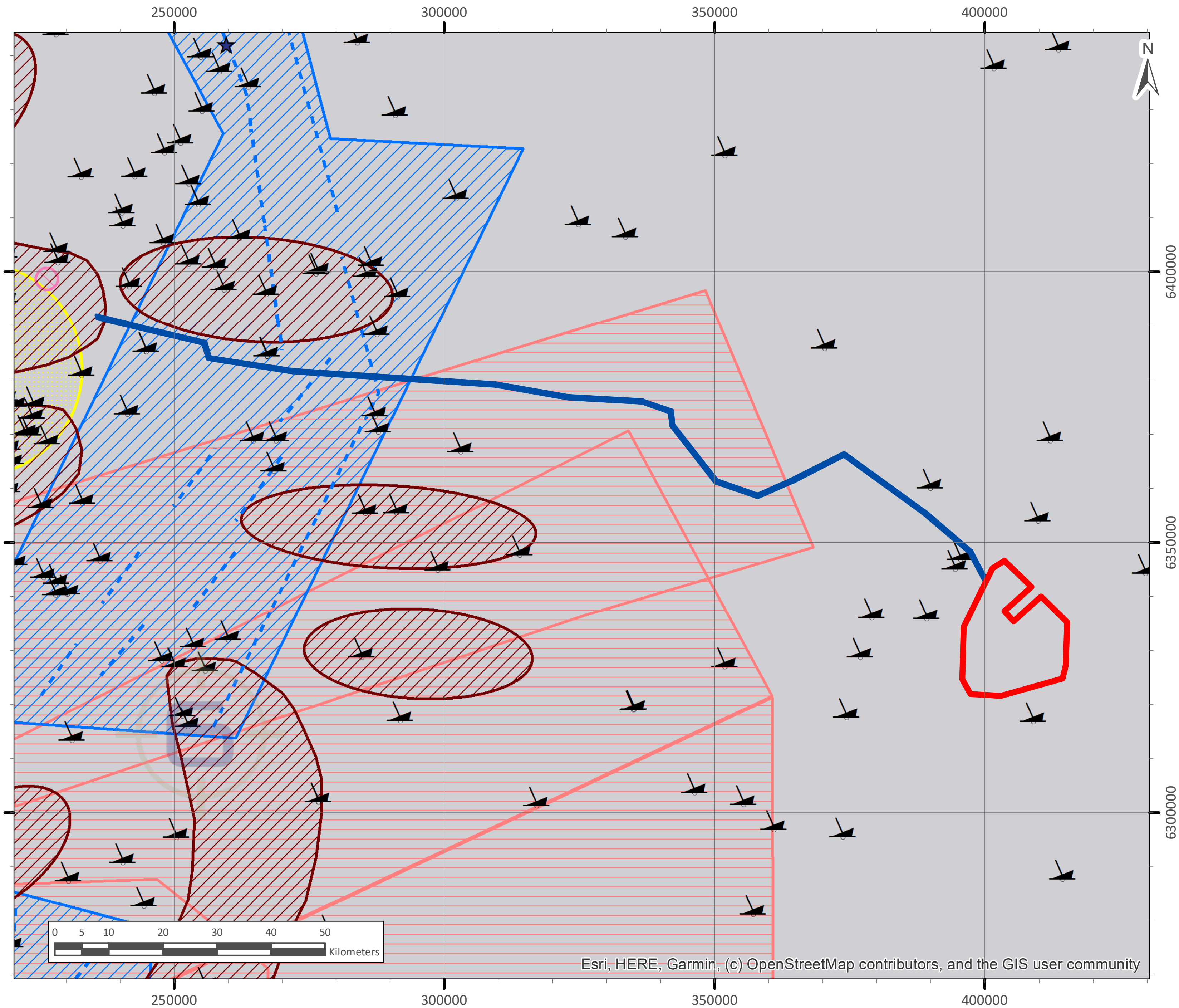
- The Client's and Principal Contractor's installation operations (in detail);
- Technical Advisory Notes (TAN) that deliver potential UXO (pUXO) avoidance by work method type. Benefits: reduced pUXO avoidance (initially 15m radius, but typically ~10m radii, post TAN); therefore, more freedom of manoeuvre, 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** e.g.:
        - Site Emergency Response Plans (ERP);
        - Tool Box Briefs (TBB) for site workers.

1.4 Operational Level – Delivery of UXO Risk Managements 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.

Consolidated UXO Threat Chart



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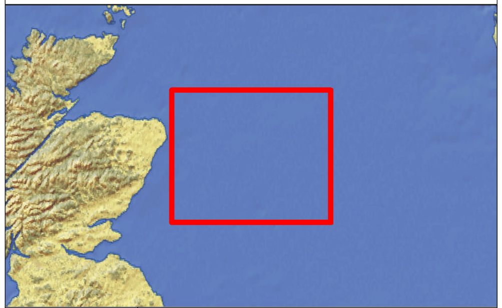
UXO THREATS

- Munitions_Related_Wreck
- OSPAR_Munitions_Encounter
- WWII_Allied_Minelay
- WWI_Central_Powers_Minefield
- WWII_Allied_Minefield
- Historic_PEXA
- Modern_PEXA
- Coastal_Armament_Range



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50024	CENOS OWF

DRAWING TITLE: Consolidated UXO Threat

DRAWING NUMBER: CENOS OWF\009\V1.0

PURPOSE: FOR INFORMATION USE ONLY

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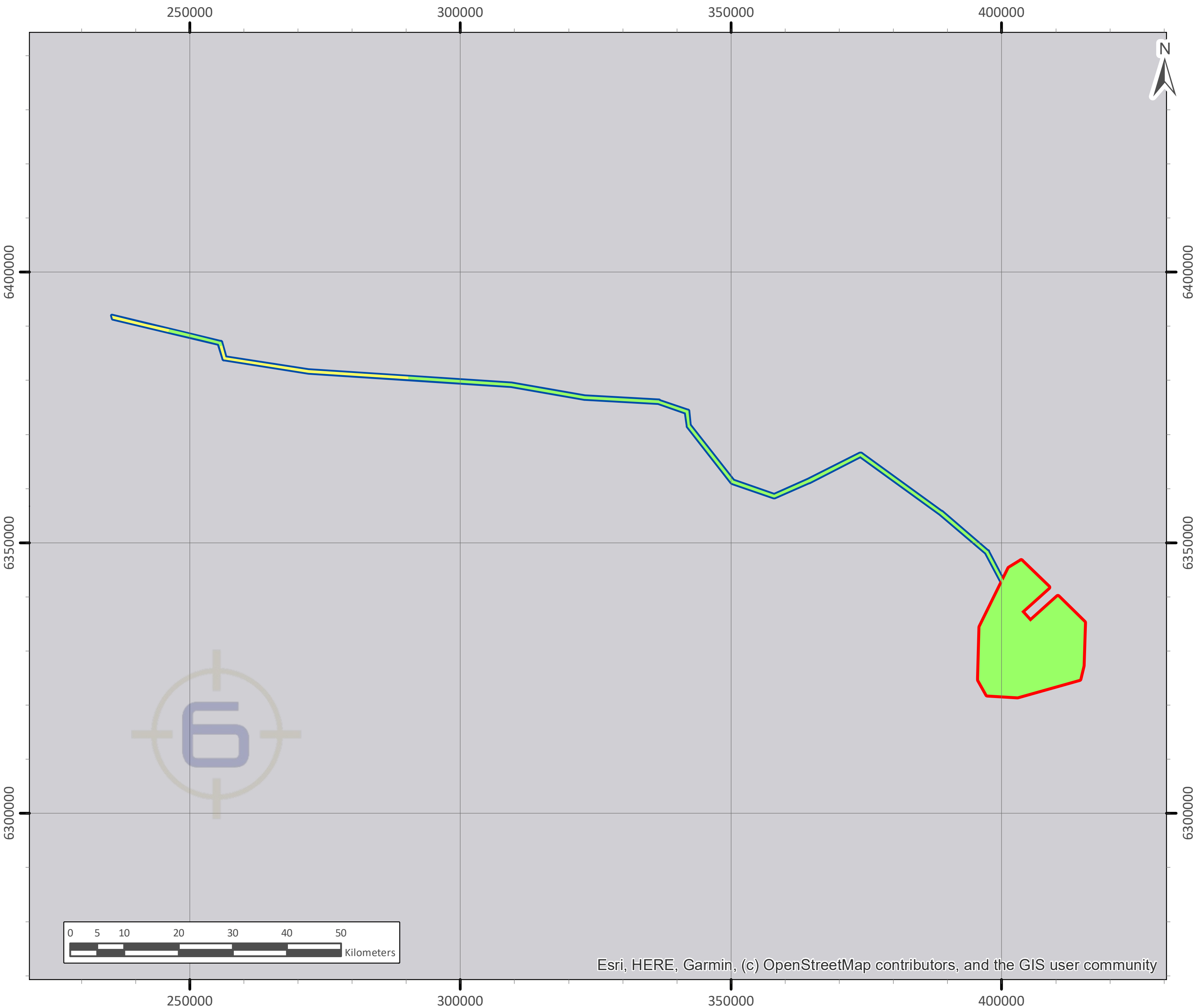
Appendix 5

UXO Risk Zones



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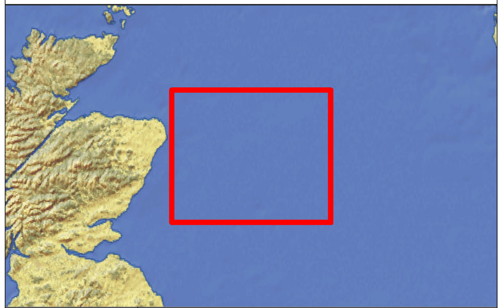

PROJECT	PROJECT TITLE
50024	CENOS OWF

DRAWING TITLE
UXO Risk Zones - Construction Operations

DRAWING NUMBER
CENOS OWF\013a\V1.0

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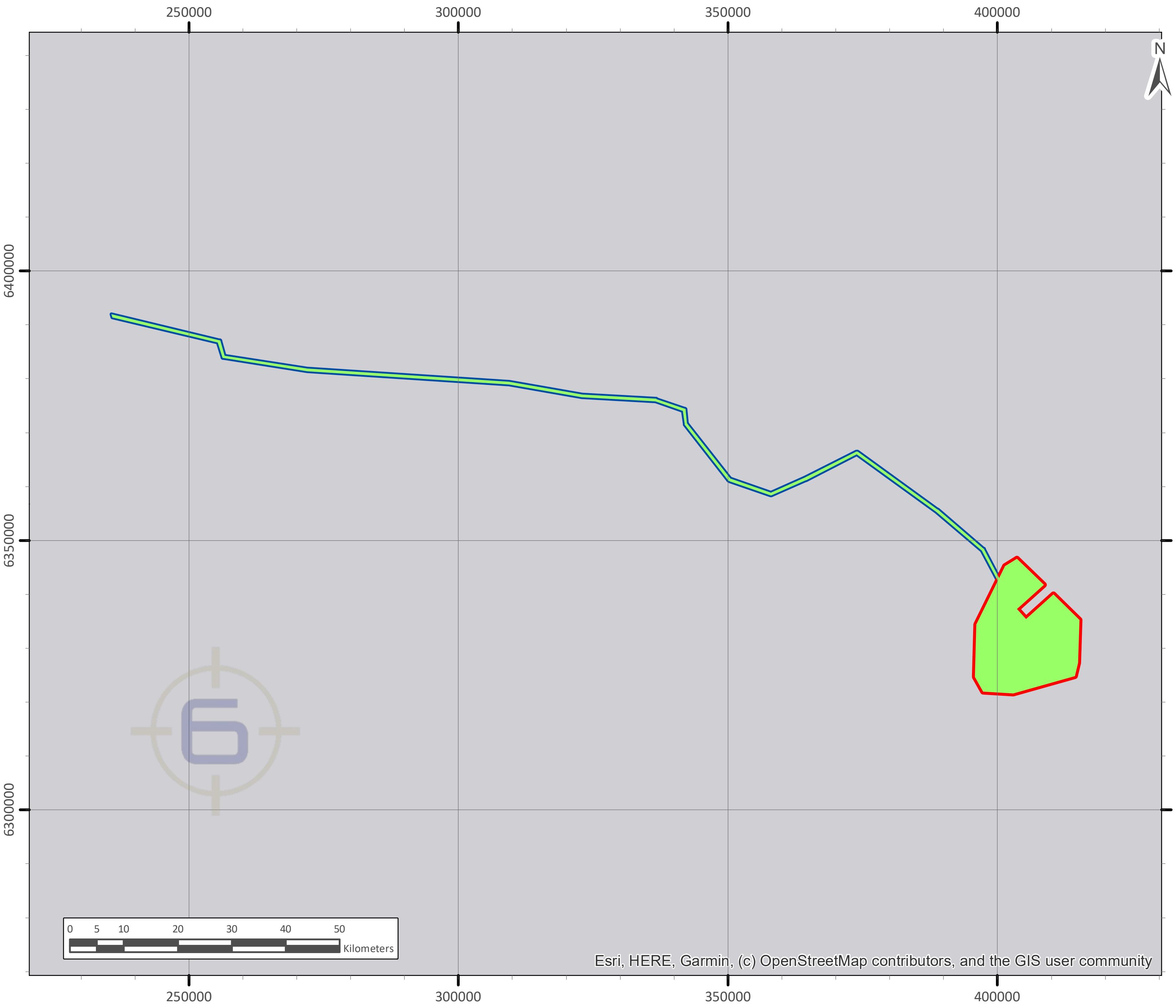

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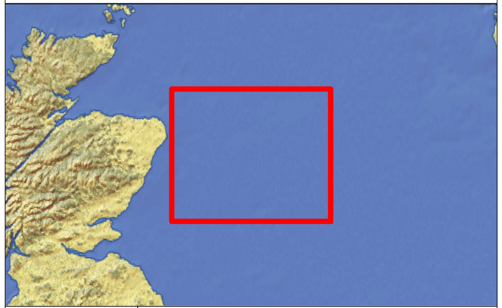
Risk_Rating

- LOW



PROJECT	PROJECT TITLE
50024	CENOS OWF

DRAWING TITLE
UXO Risk Zones - GI Operations

DRAWING NUMBER
CENOS OWF\013b\V1.0

PURPOSE
FOR INFORMATION USE ONLY

COORDINATE SYSTEM	SCALE	ORIGINAL PLOT SIZE	DRAWN	DATE DRAWN	CHECKED
WGS 1984 UTM Zone 31N	1:1,000,000	A4	LH	17/07/2023	LG

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Annexes

Annex A – Legislation and UXO Risk Management

References

A. CIRIA Assessment and Management of Unexploded Ordnance (UXO) risk in the marine environment (*C754*), 2015.

B. Schade, C., Kunreuther, H., & Koellinger, P. (2012). *Protecting Against Low-Probability Disasters: The Role of Worry.* Journal of Behavioral Decision Making.

1.1 Introduction

English (and generally, other national) law requires that Clients fulfil both their statutory and legal duties to protect those that may be exposed to harm. In the event of a UXO incident that causes harm, failure to adequately manage the UXO risk may lead to the prosecution (and prospectively unlimited fines and imprisonment), of those deemed responsible for breaching their duty of care. The following sections outline national legislation, industry best practice, the common law principle of reducing risks to As Low As Reasonably Practicable (ALARP), the assumptions made concerning organisational risk tolerance, as well as the expected behavioural responses of the project stakeholders when confronted with UXO risks.

1.2 National Legislation

In addition to common law (upon which the ALARP risk reduction principle is founded), the primary statutory UK legislation concerning health and safety is delivered by *inter alia*, the following key legislation:

- Health and Safety at Work etc Act 1974;
- Management of Health and Safety at Work Regulations 1999;
- Construction Design and Management Regulations 2015.

By seeking UXO risk management advice, organisations can evidence that their projects have taken advice from a competent UXO organisation, not only by performing UXO threat and risk assessments but also by taking advice implementing measures in order to reduce risks ALARP. In doing so, organisations can evidence that they have discharged their responsibilities associated with common and statutory duties.

1.3 UXO Industry Guidance and Good Practice

The Construction Industry Research and Information Association (CIRIA) has published guidance on the assessment and management of unexploded ordnance risks in the marine environment (Reference A). CIRIA is a neutral, non-governmental, not-for-profit body, linking member organizations with common interests, to setting and/or to improve agreed level of industry standards and good practice.

CIRIA C754 guidance therefore, represents industry agreed standards and good practice for the assessment and management of UXO risks. It has been recognised by the UK's Health and Safety Executive (HSE) as a source of good practice which when implemented, satisfies English law.

6 Alpha not only authored the technical content of the CIRIA C754 guide but also applies it, to ensure compliance with legal requirements as well as industry good practice, and to ensure that UXO risks are reduced to ALARP.

1.4 Reducing Risks to ALARP

Reducing risks to ALARP is the concept of weighing a risk against the resources required (typically measured by finical outlay), 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 whilst fulfilling their legal obligations.

Industry best practice offers guidance as to assessing both UXO threat, risk and risk tolerance, so that an agreement amongst stakeholders can be reached as to what not only a reduced risk to ALARP means but also, what resources are required to achieve it. ALARP therefore describes the level to which risks are controlled, as determined by the law through the implementation of good practice.

Confirming that the UXO risks have been reduced to ALARP involves weighing the residual risks against the resources to further reduce them. 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 risk reduction is presented at Figure 1.

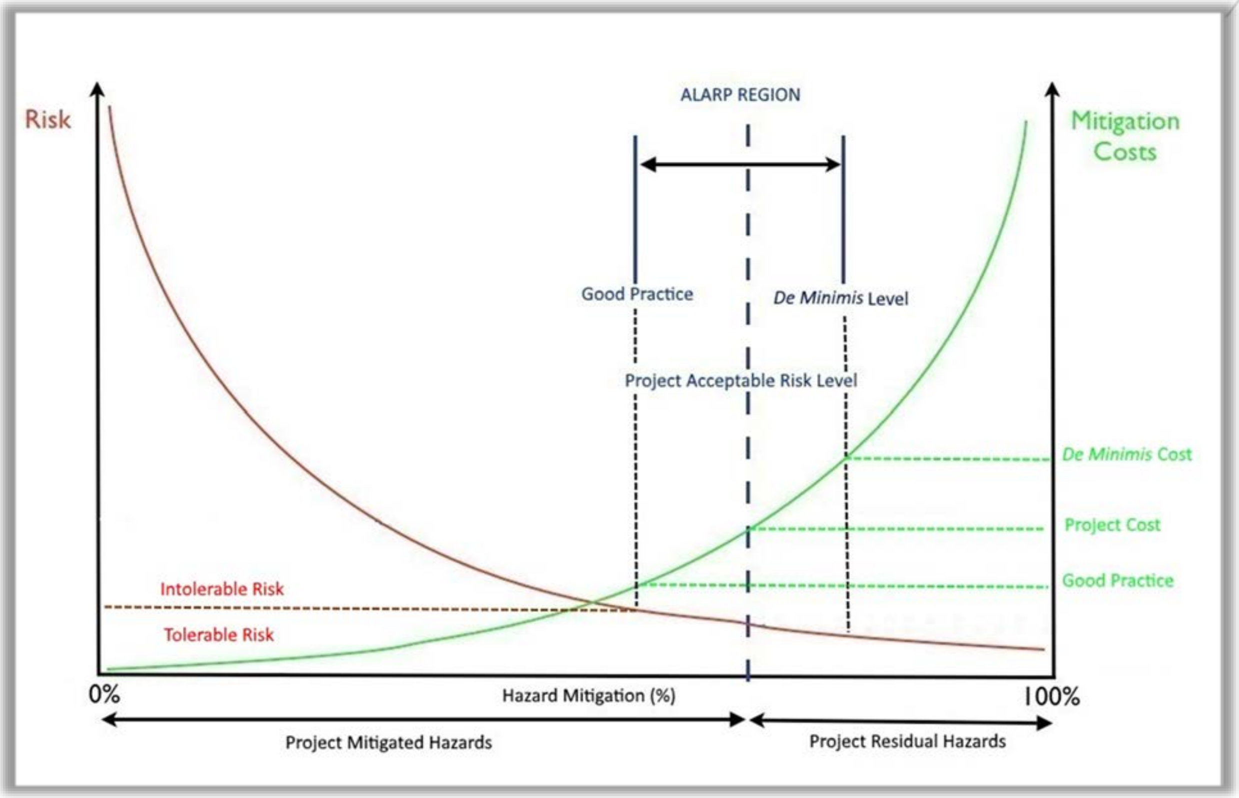

Figure 1: The ALARP Principle of managing risk.

1.5 UXO Risk Tolerance

6 Alpha Associates have made certain assumptions about the reasonable tolerance of UXO risks. Our assumptions include that the following interrelated elements that might be considered when determining UXO risk tolerance:

- **Safety**; personnel safety will assume the highest priority for any 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;
- **Corporate Governance**; is a system of rules, practices, and processes by which companies are managed and controlled. It is assumed that any Client will wish to adhere to high standards of corporate governance. Discharge of corporate responsibility is expected to be on risk-based criteria and it is expected that the Clients will have in place a framework for managing risks for good governance. It is anticipated that safety and risk management are integrated in Client business culture and that such measures will be actively applied throughout the execution of any project;
- **Risk Management**; high standards of risk and safety management are expected to be applied to any project and that a risk management system is expected to be in place to deal with business, programme, and project risks. Projects will commonly engage with competent

consultants not only to identify UXO risks, but also to design appropriate UXO risk management solutions in accordance with the law and industry good practice. The latter demands that any risks posed by UXO must be assessed based upon probability and consequence criteria. Potential UXO are best avoided (as this provides a best value-for-money solution) or the risk that they pose ought to be mitigated and reduced ALARP not only in accordance with the law, but also in accordance with CIRIA best practice guidelines. A competent consultant is to be expected to deliver *inter alia* desk studies and to design and oversee any UXO geophysical surveys and subsequently a suite of UXO risk mitigation measures, ensuring they are performed to appropriate quality and good practice standards.

1.6 UXO Risk – Probability, Consequence and Perception

UXO incidents that result in harm are may be classified as Low Probability, High Consequence (LP-HC) events. Given the ambiguity and uncertainty surrounding such events, project stakeholders might respond to such risks in an extreme manner but with good intent, but in doing so demanding a disproportionate level of risk mitigation. Stakeholders should be aware of the following common responses and attitudes to LP-HC risks, in order to manage stakeholder expectations concerning UXO risks, throughout project life cycles. There are a number of common general behavioural patterns for dealing with LP-HC events (see Reference B), namely:

- Individuals do not think probabilistically and seek zero risk when costs do not need to be absorbed. Alternatively, when individuals do need to absorb costs themselves, they are more likely to tolerate very high probability risks;
- Risk is a multidimensional problem which cannot be simply measured quantitively, such as by the number of fatalities generated annually;
- Risk tends to be influenced by 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 mitigation accordingly;
- Given the lack of knowledge over the probability of UXO events, organizations are more likely to use simple decision-making measures;
- The general perception is, that the probability of LP-HC risks is low and as a result they might not be mitigated appropriately.

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

- A desire to seek zero risks;

- A perception that the situation is under their control and therefore a UXO event might never happen;
- That the hazard is perceived to be benign with the passage of time (especially when a risk has not materialised).

Such perceptions can be overcome through the expert application of risk analysis based upon probability and consequence criteria and then tailoring the delivery of UXO risk mitigation measures in accordance with ALARP risk reduction principles.

Annex B – UXO Detection Methods

1.1 Overview

There are several systems and underwater tools available on the commercial market for detecting unexploded ordnance (UXO). Generally, UXO detection methods rely on either one or more of the following ordnance properties: the known physical dimensions of the threat items likely to be encountered upon the site, whether the ordnance casing is metallic, and/or whether the ordnance casing comprises a ferrous metal for most ordnance types. The other property that an item of UXO has which classifies it from benign debris, is the explosive content. However, marine explosive detectors are still at the experimental stage and currently not widely utilised.

UXO detection is accomplished by utilising one or more of the following methods:

- Visual detection methods;
- Magnetic methods;
- Electromagnetic methods;
- Acoustic methods.

1.2 Visual Detection

A visual inspection typically employs a remotely operated vehicle (ROX) or diver, to inspect the seabed at the site of the intrusive investigation, installation or construction operation and detect any UXO present. The classification of any potential UXO targets found is performed simultaneously during the visual inspection. An ROV or diver is typically equipped with a pulse induction metal detector, to detect any shallow buried potential UXO targets, or to search for and relocate any marked potential UXO targets. The costs of performing a visual inspection across an extensive area of the seabed makes visual detection of UXO a more appropriate method for small specific locations.

1.3 Magnetic Methods

Th Magnetic methods for UXO detection, relies on the ferrous metal content of the UXO item producing a local magnetic distortion/anomaly of the Earth's magnetic field. This magnetic distortion will occur even when the ferrous source is buried under the seabed. Magnetometer sensors are typically employed to provide a scalar or vector measurement of the Earth's magnetic field. A suitably qualified interpreter may then record the positions of these anomalies for further target classification.

Magnetometers for UXO detection are generally regarded as the main detection methods for UXO and allow flexibility in the towing arrangement for rapid geophysical acquisition of extensive survey areas. Diurnal fluctuations of the Earth's magnetic field may be eliminated by towing two or more magnetometers in a gradiometer arrangement. As a gradiometer, the magnetometers measure the rate of change of the magnetic field distortion in one or more axial planes and have the benefit over a conventional single magnetometer of an improved signal to noise ratio, permitting the detection of smaller ferrous sources. Geology with a high susceptibility to magnetisation, will act as a source of magnetic noise potentially masking potential UXO targets from detection. Ordnance casing made from non-ferrous metals, such as aluminium, are undetectable by magnetometers as are any other non-ferrous debris occurring upon the site.

1.4 Electromagnetic Currents

UXO detection using electromagnetic methods classifies UXO targets by their electrical conductivity and will detect both ferrous and non-ferrous metallic targets. Pulse induction is an electromagnetic method, commonly employed for the detection of UXO, although the system is generally mounted upon an ROV during relocation of potential UXO targets.

Pulse induction works by generating a pulse of electrical current, within a few microseconds through a coil of wire. Each pulse produces a brief magnetic field which collapses with the stoppage of the current resulting in a large voltage spike across the coil and a second current or reflected pulse flowing through the coil. If there is a conductor present, the pulsing magnetic field induces eddy currents. These eddy currents produce a second magnetic field which propagates back to the detector inducing a small voltage within the coil. The eddy currents generated by a conductor are scaled with the item's inherent conductivity, which is dependent on the item's material, thickness, and length.

If a target is purely magnetic and non-conductive (e.g. a boulder), no eddy current would be generated and nothing would be detected on the sensor. One of the advantages of electromagnetic methods over magnetic methods is that geology is not detected, removing a potential source of false positive potential UXO targets to be investigated.

However, the range of detection is inferior to that of magnetic methods with EM methods possessing a faster signal falloff rate proportional to 1/r6 compared to a total magnetic field falloff rate of 1/r3 (r being the separation distance between the detector and the target). Boat towed metal detectors are commercially available; however, they are required to be flown very close to the seabed which may prove difficult. For increased control, pulse induction detectors are generally mounted on an ROV, making this method suitable for potential UXO target relocation, and to limited survey areas where there is a threat of non-ferrous UXO.

1.5 Acoustic Methods

Acoustic methods for UXO detection rely on the distinguishable contrasts in reflected acoustic energy between a UXO item and the surrounding seabed.

Sound navigation and ranging (sonar) is a method of using acoustic energy to determine distance and direction. Single and multi-beam echo sounders (MBES) use this method to determine distance to the seabed. Side scan sonars (SSS) are used to insonify and produce an image of the seafloor. SSS is generally used during geophysical surveys for the locating of boulders and debris, as well as mapping the boundaries of sediment types and bedforms. Classification of potential UXO targets from non-UXO targets is typically based on matching the SSS contacts' dimensions to the physical dimensions of possible UXO threat items.

Although SSS is used to detect potential UXO (pUXO) items on the seabed, sonar methods are unable to detect fully buried targets. Instead, seismic reflection methods are used, specifically 3D chirp and other high-resolution seismic systems, which rely on variations of density and therefore acoustic impedance, to detect buried contacts.

Acoustic methods of UXO detection are susceptible to error during the classification of contacts, particularly when using SSS and/or MBES. Partial burial of the UXO within the seabed may reduce the dimensions of targets (length and width), resulting in pUXO targets being incorrectly graded as benign debris. Further errors may also be introduced via human error during the measuring process of the contacts' dimensions, leading to false classifications of targets.

For UXO detection, acoustic methods are ideally combined with either magnetic or electromagnetic methods to provide a further method of target classification. Without a second method to classify between targets, the client may be overwhelmed by the sheer number of SSS contacts that have dimensions like that of UXO, which are subsequently graded by the UXO consultant as pUXO targets and would require either avoiding or further target investigation.