Unexploded Ordnance (UXO) Hazard and Risk Assessment with Risk Mitigation Strategy

Project: **Biscay Gulf Western HVDC Interconnector – Geotechnical Investigation**

Client: **INELFE**

Date: **9 June 2017**

Ordtek Project Reference: **JM5353**

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Client	inelfe

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Quality Assurance

Project Number	Status	Version	Date	Written	Imagery	Reviewed	Released
JM5353	Final	3.0	09/06/2017	TC/RB	AP	HM	LG

Document Revisions and Amends

Version	Page	Section	Amends
V1.0	-	-	Issued as draft.
V2.0	-	-	Amended as per Client comments
V3.0	-	-	Amended as per Client comments
	15-16	2	Additional research information on German mines.

Executive Summary

Introduction

Ordtek Limited (*Ordtek*) has been appointed by INELFE (a company with a joint investment by Red Electrica de Espana and Reseau de Transport d'Electricite) to undertake an unexploded ordnance (UXO) threat and risk assessment with risk mitigation strategy for the 2017 geotechnical investigation campaign of the Biscay Gulf Western HVDC Interconnector project, offshore and landfall sections.

The Biscay Gulf Project is a HVDC interconnection project which runs between the coasts of the French Aquitaine and the Spanish Basque Country. The landfall sites are in the vicinity of Lacanau/Hourtin in France and the disused power station near Armintza in Spain. The approximate length of the marine cable is 280km, of which 180km is in French waters and 100km in Spanish waters (see Figure 1.1).

The proposed interconnector is for a power rating of 2000 MW and an operational life of approximately 40 years.

Military History

The Bay of Biscay has been intensively fought over for hundreds of years. The Study Area itself saw considerable military action during both World Wars and the Spanish Civil War (1936-1939), as evidenced by the many wrecks in the region sunk by mines, torpedoes, air raids and both anti-submarine and surface actions, as well as the numerous minefields from both WWI and WWII which were laid across and within the study area.

During World War Two, extensive British mining occurred along the northern French and, to a lesser extent, Spanish coasts. Multiple surface laid minefields can be found in the area, following the coastline to obstruct Axis movement and disrupt submarine operations. Several of these intersect the cable corridor. In addition to surface laid minefields, there are multiple air laid mine "gardens" at strategic points along the coast.

German submarines and E-Boats regularly operated in the Bay of Biscay, laying mines and attacking ships, as evidenced by wrecks in the area recorded as sunk by torpedo or U-Boat gunfire. In turn, submarines were attacked with depth charges. Depth charges (and depth bombs from RAF coastal patrol aircraft) were deployed in huge numbers during WWII, often at spurious targets. The presence of torpedoes, depth charges and depth bombs in the study area is almost certain and a number of different types could have been deployed.

The area was also subjected to air raids during the Spanish Civil War, similarly from the Germans (at the behest of the Spanish Nationalists). The town of Durango was bombed by the Luftwaffe; some of the first bombs fell into the church during morning Mass. In total some 300 people were killed, 2,500 were wounded, practically all of them civilians. A second air attack took place as fire brigades, police and ambulances from Bilbao tried to help the victims. The Bombing of Durango was the first attack in Europe against a civilian population and the first place in the world to be attacked by the Luftwaffe.

Another attack was launched on Guernica. One Dornier Do 17, two Heinkel He 111s, 18 Ju 52 Behelfsbomber and three Italian SM.79s were brought in for the bombing. In total, the planes carried 22 tonnes of explosives ranging from 550 lb medium explosive bombs to 2.2-pound (likely incendiary) bombs. The bombing began at 4:30 p.m. with the Dornier Do 17 dropping 12 110 pound bombs.

The probability of finding naval projectiles in the study area is likely to be elevated in areas around wrecks (shown overleaf), where ship conflicts occurred. In addition, within German convoy routes Allied airforces and ships would have battled.

Historically, extensive military action and training was undertaken along both the French and Spanish coasts. Practice area boundary constraints were not as tightly enforced during the war as they are now and it is very likely that both live and practice ordnance items were dropped outside official practice areas. Potentially almost any type of launched/fired explosive and practice ordnance could be present; the highest concentration will be within designated training areas but UXO contamination is also likely further afield. WWII armament areas cover almost the entire coast, consisting of mostly anti-aircraft (AA) and guns. Modern training areas are operational within French sector of the study area run parallel to the cable route. Zone D 31 D used for 'firing of aircraft, firing and bombing by aircraft and defence activities'.

As part of the German Atlantikwall and anti-invasion defences, the French coastline was very heavily fortified. German Teller beach mines, projectiles, mortars, grenades and small arms ammunition (SAA) contaminate the beaches and foreshore and remain a threat in the inter-tidal zone at cable landfalls.

UXO Burial

Using the information seabed conditions (see *Appendix 1*) the conclusions on the potential for UXO burial are presented below:

- UXO may be completely buried in ripple and sand wave areas, up to the full height of the bedform, which could be several metres.
- In the highly dynamic sands, in the absence of bedforms, UXO is likely to be buried to ~2m.
- In areas of sand and gravelly sand areas where there are no bedforms, UXO is likely to be partially exposed; showing around 0.4 diameter above the sediment.
- In areas of gravel, burial due to scour will be substantially less than in sandy areas and may not have occurred.
- In areas of outcropping bedrock UXO will be exposed on the seafloor.
- Over the areas within the cable corridor where burial is likely to be negligible, depending on size and orientation, large items of UXO should be visible to SSS. However, these areas often coincide with concentrations of boulders, which will complicate SSS data analysis.
- Although the probability of encounter is considered very low, in the inter-tidal zone HE bombs could be deeply buried (up to ~3.5m for the most common bomb types; ~9m for the most common large bombs).

Risk Mitigation Strategy

To conform to best practice, geotechnical contractors should adopt the following UXO risk management and mitigation actions:

- **Low-Moderate and Moderate Risk Areas (for geotechnical activities only) - UXO-specified magnetometer survey.**

- **Low Risk Areas (for geotechnical activities only) - use existing MMT SSS and MBES data.**
- Geotechnical Contractors:
    - Obtain the ALARP sign-off certificate for geotechnical investigations. Input geophysical contacts to be avoided into the on-board navigation system.
    - Obtain the ALARP sign-off certificate for each installable asset. Input geophysical contacts to be avoided into the on-board navigation system.
    - Establish the location of known wreck sites. *Ordtek* suggests that non-military related wrecks are avoided in accordance to the developer's standard protocol.
    - Ensure the Project team are aware of their internal UXO policy, including key support numbers.
    - Hold a copy of this risk assessment on-site/on-board the vessel.
    - Brief all personnel on the potential UXO risk.
    - Hold a UXO specialist on-call in the event of a suspect item being discovered unexpectedly.

Smallest Threat Item

Accordingly, *Ordtek* considers that the smallest threat items for ALARP sign-off is the **British 250lb (114kg) GP Bomb.** This has been chosen as the smallest threat item due to the number of busy coastal convoy routes running adjacent to the study area. In addition to this, German U-boat bases along the French Atlantic coast were heavily attacked by Allied bombers and the RAF delivered massive raids, with many aircraft taking part. Raids of up to 437 aircraft are documented.

Depending on the variant, the 250lb GP is cylindrical/tear-drop in shape, made of cast steel with a wall thickness of 0.6in (1.5cm). The body length is ~28in (71cm). The body diameter is ~10.2in (26cm) and the filling consists of 110lb (50kg) of TNT or Amatol. The 250lb MC dimensions are the same, except the body wall thickness is only 0.3in (0.75cm) and the charge weight is greater at ~120lbs (55kg) of Amatol or Pentolite.

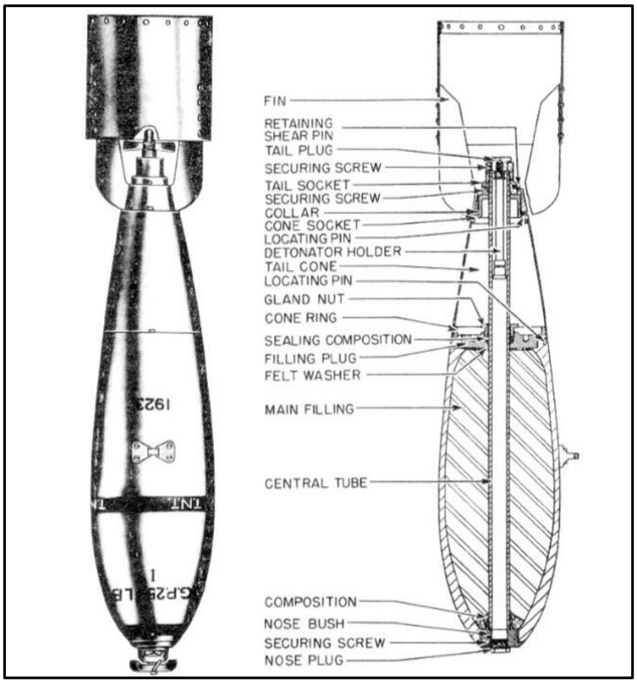


Figure ES1 – British 250lb GP Bomb: Smallest UXO item for ALARP sign off.

Contents

Appendices

Abbreviations and Acronyms

AA	Anti Aircraft	**M**	Metres
AEZ	Archeological Exclusion Zone	**MBES**	Multibeam Echo Sounder
ALARP	As Low As Reasonably Practicable	**MBD**	Maximum Burial Depth
AOI	Area of Interest	**MCM**	Mine Countermeasures
BL	Breech Loading	**MDD**	Maximum Detection Depth
BSH	Bundesamt für Seeschifffahrt und Hydrographie (German hydrographic office)	**MGS**	Mindestens Gleiche Sicherheit (German legislation)
CDM	Construction Design and Management (UK legislation)	**ML**	Muzzle Loading
CIRIA	Construction Industry Research and Information Association	**mm**	Millimetres
CW	Chemical Weapon	**MoD**	Ministry of Defence
EMC	German moored contact mine Type C	**MTB**	Motor Torpedo Boat
EMG	German moored contact mine Type G	**MW**	Megawatt
EO	Explosive Ordnance	**NEQ**	Net Explosive Quantity
EOD	Explosive Ordnance Disposal	**NM**	Nautical Mile
ERW	Explosive Remnants of War	**OSPAR**	Convention for the Protection of the Marine Environment of the North East Atlantic
EU	European Union	**PLGR**	Pre-Lay Grapnel Run
GAMAB	Globalement Au Moins Aussi Bon	**RMF**	Risk Management Framework
GC	Allied designation for German type LMB mine	**RML**	Rifled Muzzle Loading
GD	Allied designation for German type LMA mine	**RN**	Royal Navy
GG	Allied designation for German type BM1000 mine	**ROV**	Remotely Operated Vehicle
GY	Allied designation for German type EMC/EMG mine	**QA/QC**	Quality Assurance/Quality Control
GZ	Allied designation for German type UMA mine	**SAA**	Small Arms Ammunition
GIS	Geographical Information System	**SBP**	Sub Bottom Profiler
H&S	Health and Safety	**SF**	Shock Factor
HAA	Heavy Anti-Aircraft Artillery	**SOP**	Standard Operating Procedure
HE	High Explosive	**SQRA**	Semi Quantitative Risk Assessment
HSE	Health and Safety Executive	**SSS**	Sidescan Sonar
HSF	Hull Shock Factor	**TNT**	Trinitrotoluene
Kg	Kilogram	**UK**	United Kingdom

KHz	Kilohertz	**UKHO**	United Kingdom Hydrographic Office
Km	Kilometre	**UMA**	German anti-submarine mine Type A
KSF	Keel Shock Factor	**UXB**	Unexploded Bomb
Kv	Kilovolt	**UXO**	Unexploded Ordnance
LMA	Luftmine A (German air-dropped ground mine Type A)	**WWI**	World War One
LMB	Luftmine B (German air-dropped ground mine Type B)	**WWII**	World War Two
LSA	Land Service Ammunition		

Definitions

Several industry specific terminologies are used in this document. However, *Ordtek* considers the following worthy of special note.

- **Unexploded Ordnance (UXO)** – UXO is defined as military munitions that have been primed, fused, armed or otherwise prepared for action; have been fired, dropped, launched, projected or placed in such a manner as to constitute a hazard to operations, installations, personnel or material; and remain unexploded whether by malfunction, design or any other cause.
- **Globalement Au Moins Aussi Bon (GAMAB)** – The GAMAB principle (*globally at least as good*), commonly used in France, is a health and safety risk tolerance principle that assumes that there is already an "acceptable" solution and requires that any new solution shall in total be at least as good: all new systems must offer a total level of risk (globally) at least as good as the one offered by any equivalent existing system.
- **As Low As Reasonably Practicable (ALARP)** – The health and safety principle is that *any residual risk shall be as low as reasonably practicable.* For a risk to be ALARP it must be possible to demonstrate that the cost involved in reducing the risk further would be grossly disproportionate to the benefit gained. The ALARP principle arises from the fact that infinite time, effort and money could be spent on the attempt of reducing a risk to zero.
- ***De minimis*** – A residual risk that is deemed to be too trivial or minor to merit consideration, especially in law. It is the failure to reach the threshold level required to be actionable.
- **Potential UXO -** A geophysical anomaly identified by a UXO specialist as having characteristics analogous with UXO.
- **Suspect UXO –** An item investigated (usually by either ROV or diver) that suggests a high possibility of being UXO related.

1 Introduction

1.1 Background

Ordtek Limited (*Ordtek*) has been appointed by *INELFE* (a company with a joint investment by Red Electrica de Espana and Reseau de Transport d'Electricite) to undertake an unexploded ordnance (UXO) threat and risk assessment with risk mitigation strategy for the 2017 geotechnical investigation campaign of the Biscay Gulf Western HVDC Interconnector project, offshore and landfall sections.

UXO presents a potential risk to the development and continued operation of offshore projects in European waters, principally due to the UXO residue from World War One (WWI) and World War Two (WWII). Explosive Ordnance (EO), both the result of military action and planned post-war dumping, is frequently encountered off the French and Spanish coastlines.

1.2 Purpose of this Document

The purpose of the document is to serve as a valid operational risk assessment, not as a detailed historical report. Accordingly the research has drawn on the most convenient and reliable sources, cognisant of the need to limit cost and delay to the Project. Nevertheless, the data presented is complete and appropriate for risk assessment purposes and fully in line with current best practice.

This study is structured around five key components:

- **Project Description** – Those activities to be risk assessed.
- **UXO Threat Assessment** – A detailed threat assessment has already been carried out by *Geomines* and is the basis of this section of the study. However *Ordtek* will compliment this with our own historical data (if required) and provide a summary of identified threat along the cable route. Additional research provided by *Ordtek* included:
    - German convoy routes
    - Submerged munitions and obstructions
    - Zone Interdite/Le Coffre (provided by *INELFE*).
- **UXO Interaction in the Natural Environment** – How the threat items are likely to be found within the study area.
- **UXO Risk Assessment –** Using the information above *Ordtek* will then assess the risk to the proposed operations.
- **UXO Risk Mitigation Strategy -** Recommendations for a mitigation ahead of the proposed operations.

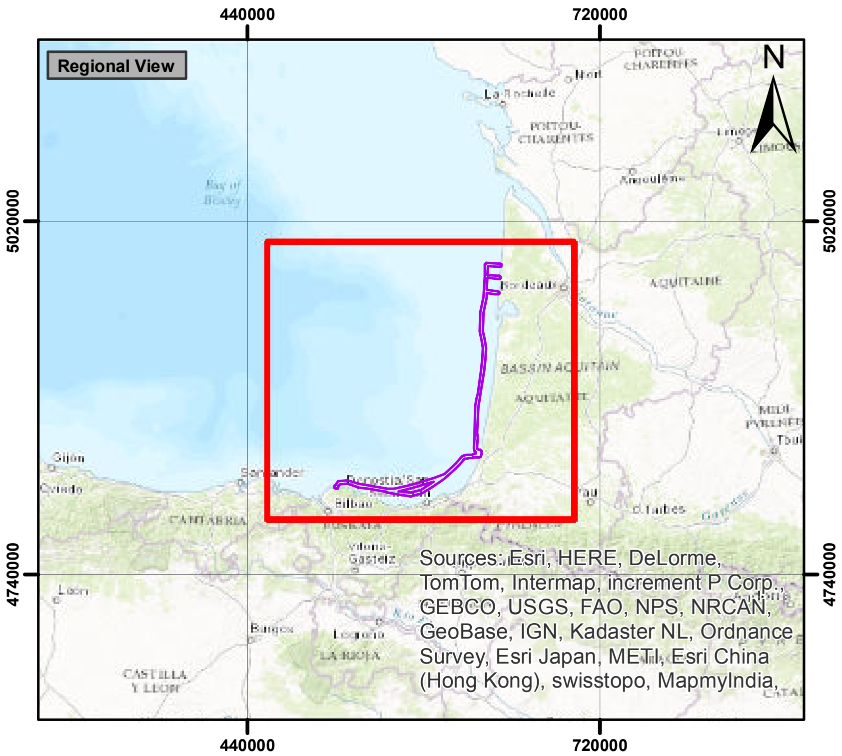
Charts have been embedded within the body of the report and will be referenced by their Chart Number.

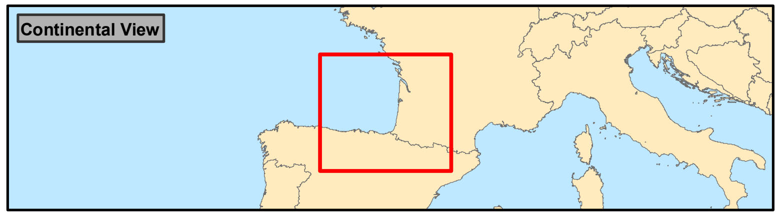
1.3 Project Details

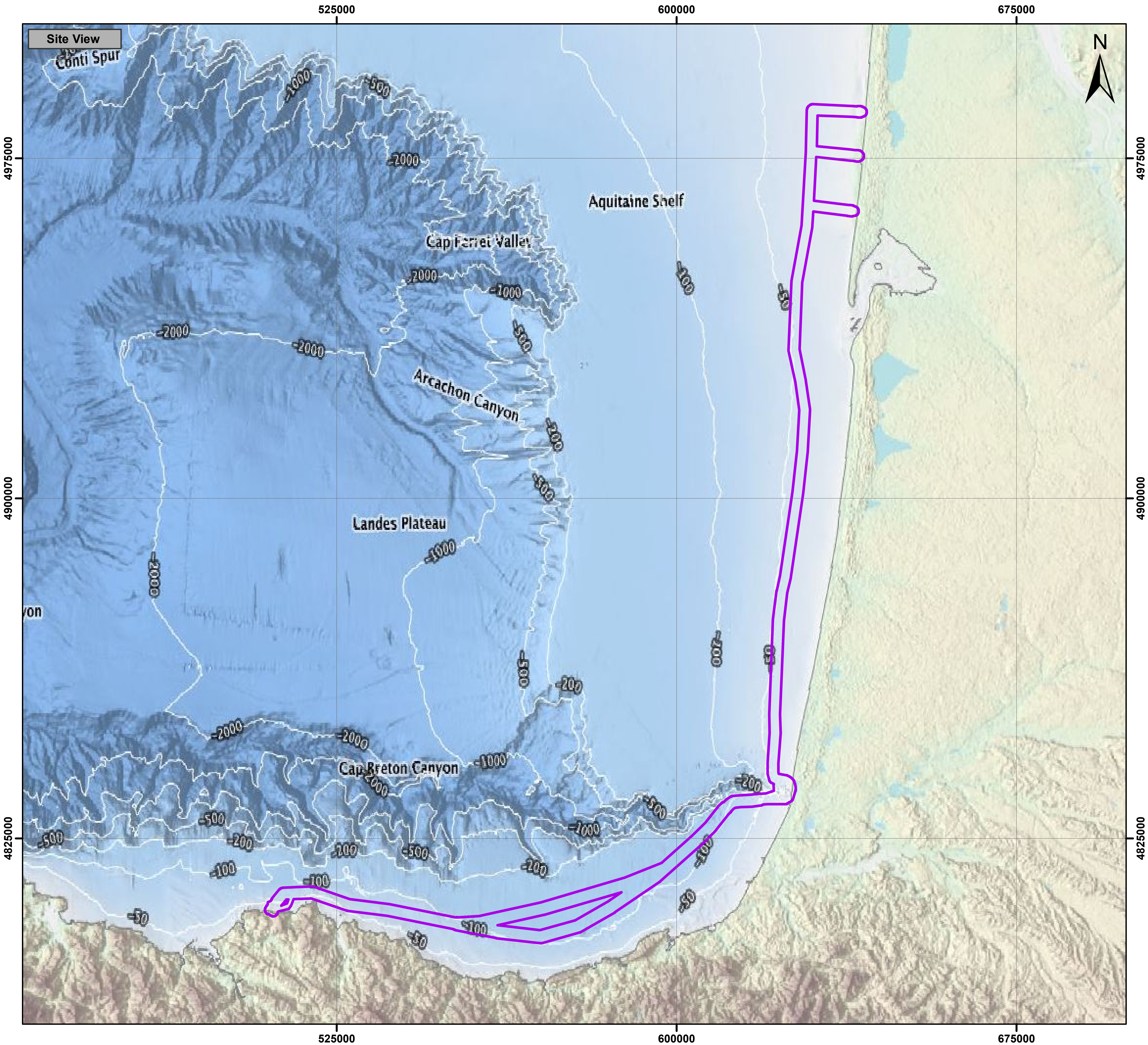
1.3.1 Background

The Biscay Gulf Project is a HVDC interconnection project which runs between the coasts of the French Aquitaine and the Spanish Basque Country. The landfall sites are in the vicinity of Lacanau/Hourtin in France and the disused power station near Armintza in Spain. The approximate length of the marine cable is 280km, of which 180km is in French waters and 100km in Spanish waters (see Figure 1.1).

The proposed interconnector is for a power rating of 2000 MW and an operational life of approximately 40 years.







Legend for Site View

Biscay Gulf Interconnector Risk Assessment Corridor

Horizontal Scale(s)

Kilometers: 0, 12.5, 25, 50, 75

Nautical Miles: 0, 5, 10, 20, 30, 40

Consultant	Client	Drawing Title	User Notes
ORDTEK	inelfe	Biscay Gulf Interconnector Project Overview	Note 01 - Biscay Gulf Interconnector Risk Assessment Corridor dervied from INELFE file "Survey areas 2016.kmz". For the purposes of charting, the Risk Assessment Corridor includes an additional 1km either side of the INELFE survey corridor. Note 02 - Two possible alternative Spanish landfall HDD options have also been considered, as defined by REE "HDD option3 UXO risk assessment area.kmz" and "HDD option 5 UXO risk assessment area.kmz".

THE BRITISH ASSESSMENT BUREAU ISO9001

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false northing: 0.0000
central meridian: -3.0000
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latitude of origin: 0.0000
Units: Meter

Drawn by: AP
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Date Drawn: 19 May 2017
Drawing Reference: JM5353_DTS_01
Drawing Version: 1.1

1.3.2 Proposed Work for UXO Risk Assessment

A geophysical survey campaign has been carried out in 2016. A complementary geotechnical campaign is scheduled in summer 2017. The geotechnical campaign is planned to consist of a total of 220 sampling locations (195 offshore and 25 nearshore) and will be undertaken using the following equipment.

Equipment	Footprint	Comment on Energy Release
Neptune 5000 CPT rig	$4.8m^2$	70MPa push
VKG-6 3/6m vibrocorer	$16.6m^2$	Max vibrating force 3te $5cm^2$ or $10cm^2$ cones
Manta CPT rig	$4.9m^2$	100MPa push
Minidrill MDS-6000 rock corer	$18m^2$	35kN

Table 1.1 – Equipment to be used in the Geotechnical Campaign

1.3.3 Risk Assessment Study Area

This assessment will cover the offshore and landfall sections of the Biscay Gulf Western HVDC Interconnector cable route. The Biscay Gulf Interconnector risk assessment corridor is derived from INELFE file "Survey areas 2016.kmz". For charting and assessment purposes, the Risk Assessment Corridor includes an additional 1km either side of the INELFE survey corridor. However please note that this means that in the section near the French/Spanish border the corridor intersects the land, although this element will not be assessed.

For UXO risk assessment purposes and consistency with the geophysical survey reports (see the subsequent reference section), the study area will be divided in to the same route corridor sections but will exclude the “Western Route Alternative” as this was excluded from the INELFE file "Survey areas 2016.kmz”.

Route Section Name	Start KP	End KP	Main Route Split KP	Main Route Join KP
Main Route (La Cantine landing)	0.000	283.730	-	-
La Cantine	0.000	12.433	0.000	12.433
Lacanau	0.000	21.690	-	12.433
Le Grande Crohot Option Route	0.000	12.020	-	24.687
The Western Route Alternative – French Waters (not considered in this report)	0.000	38.130	115.720	150.600
Canyon Head Bypass Coast Option Route	150.500	161.900	-	-
Alternative Canyon Head Bypass Coast Option Route	0.000	4.330	-	-
HDD Canyon Crossing Route	0.000	8.595	150.460	161.923
Additional Route Spanish Waters	0.000	47.680	190.603	240.940

Route Section Name	Start KP	End KP	Main Route Split KP	Main Route Join KP
Spanish Landfall Site	No KP reference as shoaling seabed required lines to be run across route direction.			

Table 1.2 – Cable Route Divisions

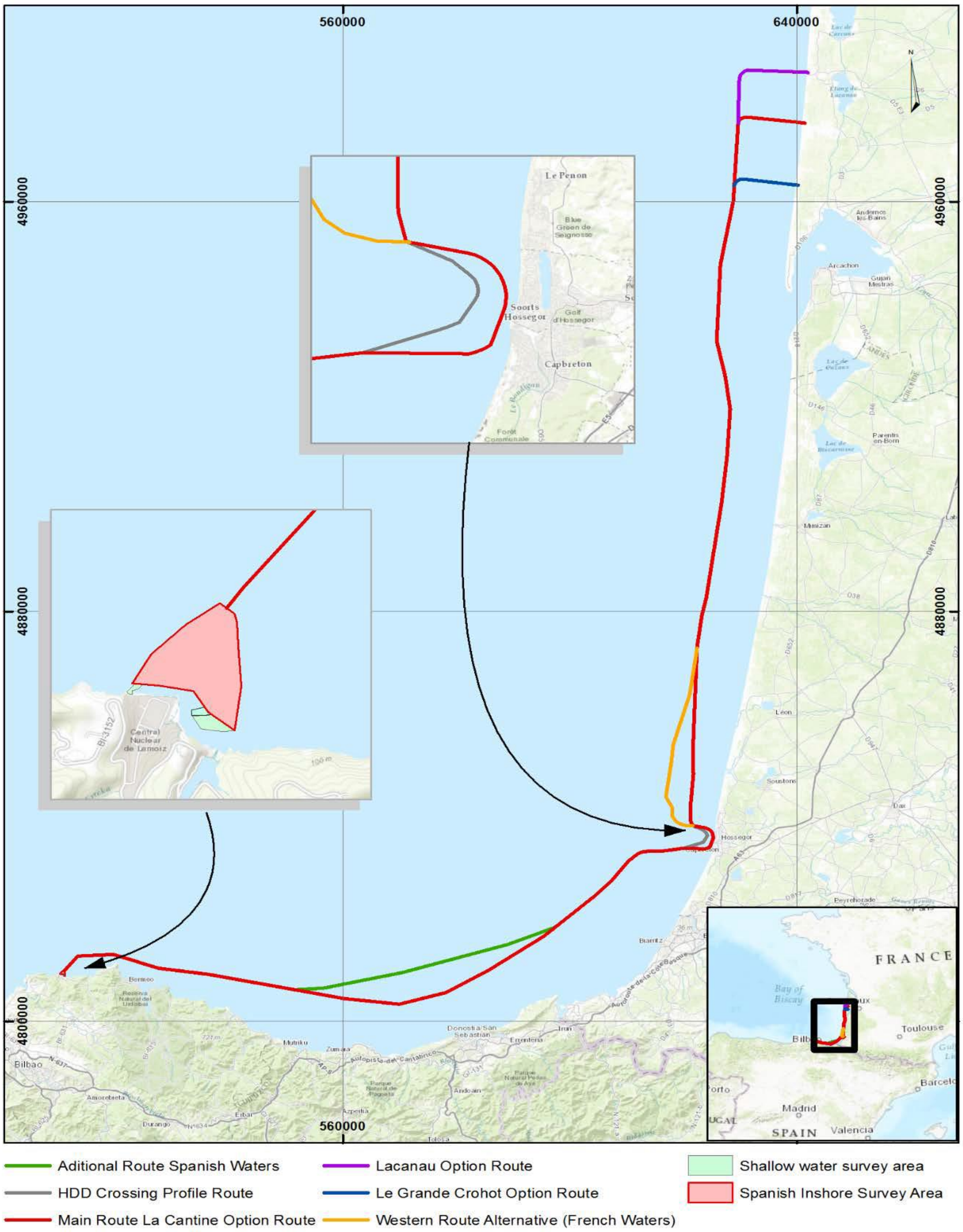
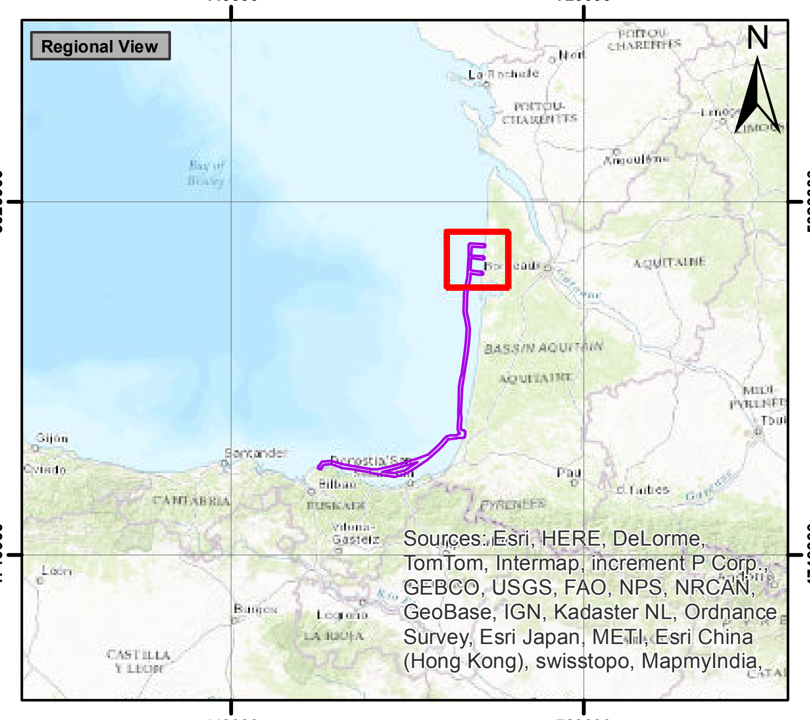
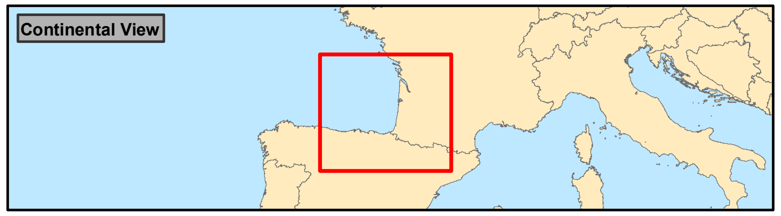


Figure 1.1 – Cable Route Options and Divisions





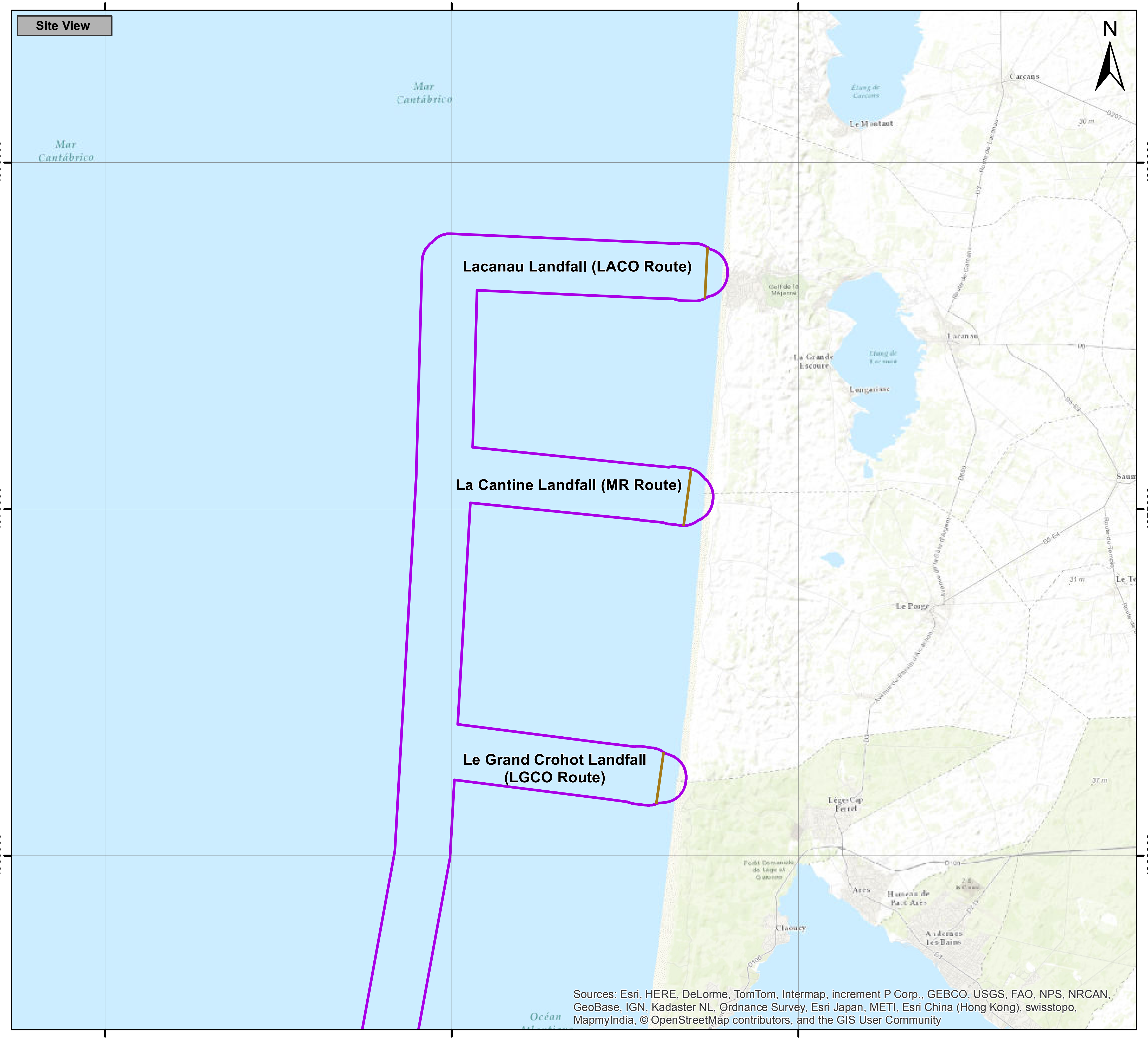
Legend for Site View

- Biscay Gulf Interconnector Risk Assessment Corridor
- Nearshore/Offshore Boundary (10m Contour)

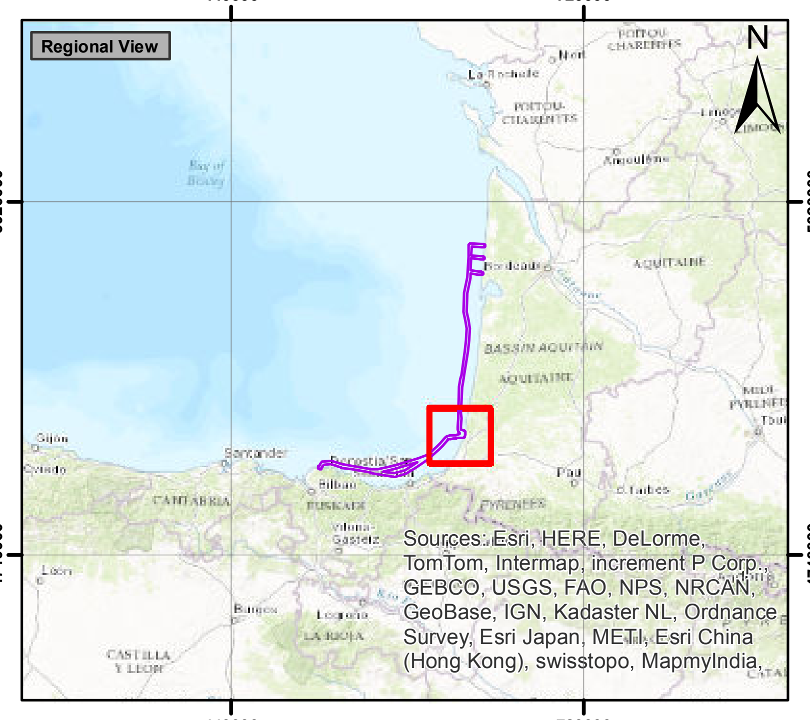
Horizontal Scale(s)

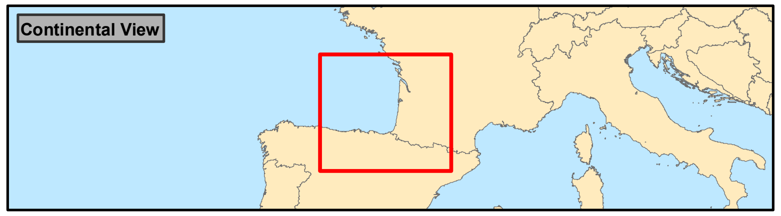
Kilometers: 0, 2.5, 5, 10, 15

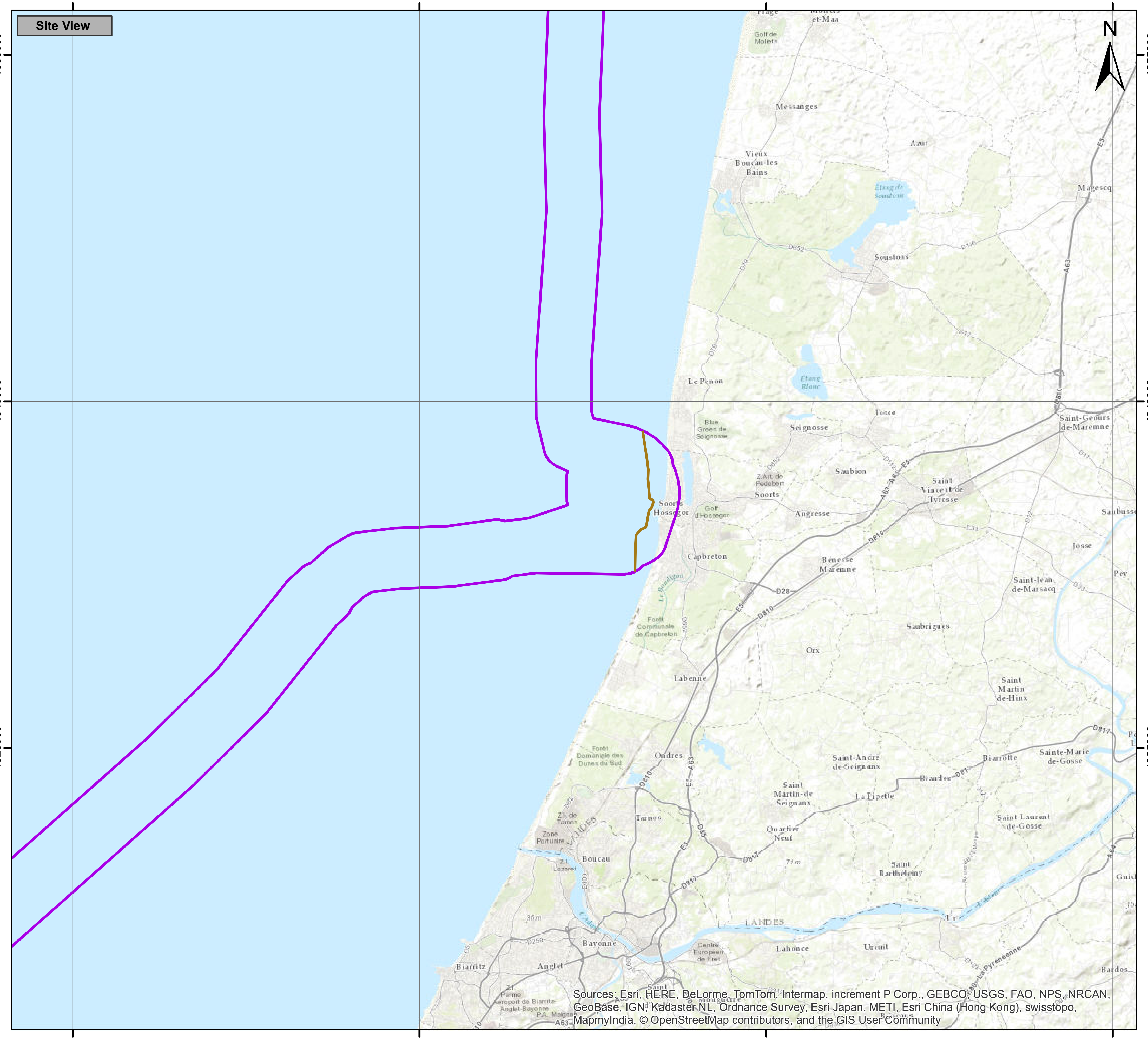
Nautical Miles: 0, 1.25, 2.5, 5, 7.5



Consultant	Client	Drawing Title	User Notes				
ORDTEK	inelfe	Biscay Gulf Interconnector France Landfalls	Note 01 - Biscay Gulf Interconnector Risk Assessment Corridor dervied from INELFE file "Survey areas 2016.kmz". For the purposes of charting, the Risk Assessment Corridor includes an additional 1km either side of the INELFE survey corridor. Note 02 - Two possible alternative Spanish landfall HDD options have also been considered, as defined by REE "HDD option3 UXO risk assessment area.kmz" and "HDD option 5 UXO risk assessment area.kmz".	THE BRITISH ASSESSMENT BUREAU ISO9001	WGS 1984 UTM zone 30N Projection: Transverse Mercator Datum: WGS 1984 false easting: 500,000.0000 false northing: 0.0000 central meridian: -3.0000 scale factor: 0.9996 latitude of origin: 0.0000 Units: Meter	Drawn by: AP Checked by: LG Ordtek Limited, Herz House, Unit B21 Owen Road, Diss, Norfolk IP22 4ER, United Kingdom. (+44) 01379 644400	**JM5353 - Bay of Biscay** Date Drawn: 03 May 2017 **Drawing Reference: JM5353_DTS_01a** Drawing Version: 1.0







Legend for Site View

- Biscay Gulf Interconnector Risk Assessment Corridor
- Nearshore/Offshore Boundary (10m Contour)

Horizontal Scale(s)

Kilometers: 0 — 2.5 — 5 — 10 — 15

Nautical Miles: 0 — 1.25 — 2.5 — 5 — 7.5

Consultant	Client	Drawing Title	User Notes
ORDTEK	inelfe	Biscay Gulf Interconnector Cap Breton Canyon Nearshore Zone	Note 01 - Biscay Gulf Interconnector Risk Assessment Corridor dervied from INELFE file "Survey areas 2016.kmz". For the purposes of charting, the Risk Assessment Corridor includes an additional 1km either side of the INELFE survey corridor. Note 02 - Two possible alternative Spanish landfall HDD options have also been considered, as defined by REE "HDD option3 UXO risk assessment area.kmz" and "HDD option 5 UXO risk assessment area.kmz".

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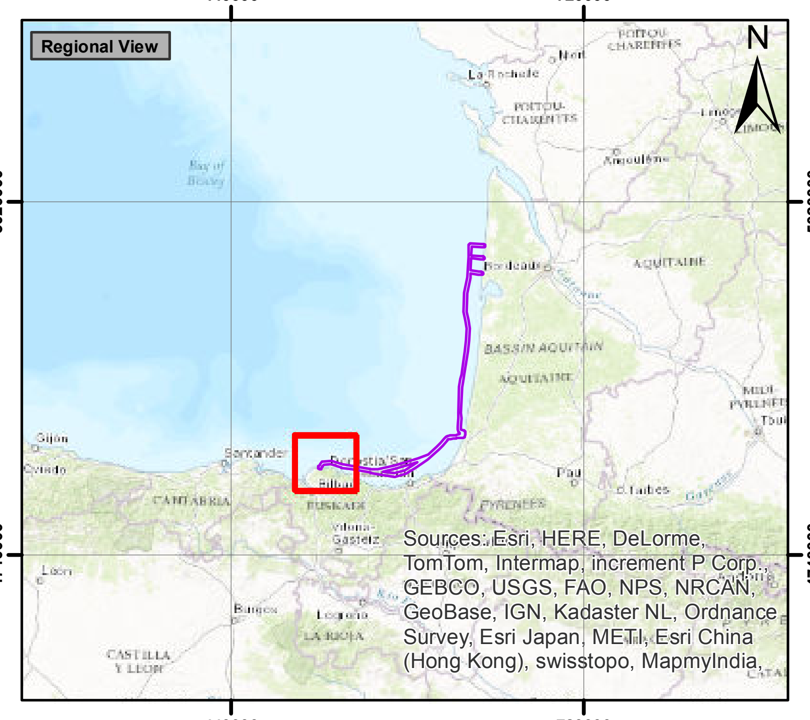

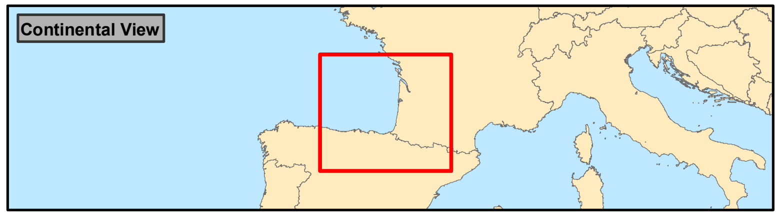

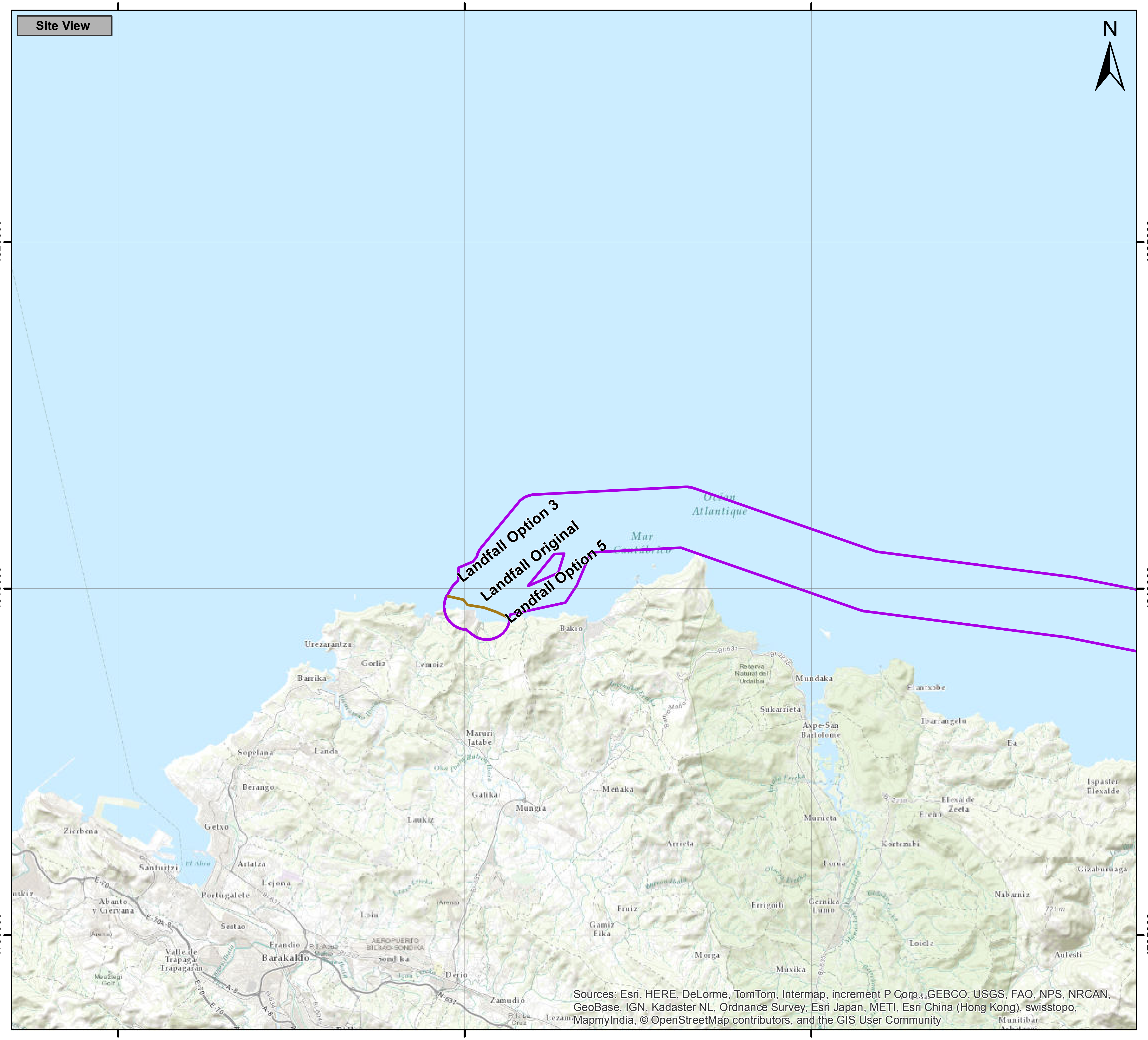

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ORDTEK	inelfe	Biscay Gulf Interconnector Spain Landfalls	Note 01 - Biscay Gulf Interconnector Risk Assessment Corridor dervied from INELFE file "Survey areas 2016.kmz". For the purposes of charting, the Risk Assessment Corridor includes an additional 1km either side of the INELFE survey corridor. Note 02 - Two possible alternative Spanish landfall HDD options have also been considered, as defined by REE "HDD option3 UXO risk assessment area.kmz" and "HDD option 5 UXO risk assessment area.kmz".

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Drawing Reference: JM5353_DTS_01c
Drawing Version: 1.0

1.4 References

Key references used for this study have been listed below:

A. CIRIA, *Assessment and Management of Unexploded Ordnance Risk in the Marine Environment (C754)*, 2015.

B. GEOMINES, *Étude Historique: Projet Golfe de Gascogne*, 2015.

C. GEOMINES, *Synthesis Table UXO Threat Assessment Study Report*, 2015.

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K. MMT SWEDEN AB, *Marine Survey Report*, 2017.

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1.5 Construction Industry Duties and Responsibilities

1.5.1 European Law

In our experience, it is generally the case across Europe that there is no specific legislation covering the management and control of the UXO risk to the offshore construction industry (especially outside the 12NM boundary). In view of the lack of specific UXO legislation, our considered opinion is that European Union (EU) law concerned with the protection of workers from work-place hazards will normally apply to offshore activities. This is the subject of *Council Directive 89/391/EEC of 12 June 1989 (amended up to 21 November 2008)*, which introduces measures to encourage improvements in the safety and health of workers at work. The Directive applies to all sectors of activity, both public and private (industrial, agricultural, commercial, administrative, service, educational, cultural, leisure etc.).

Within the Directive, “Prevention” is defined as: all the steps or measures taken or planned at all stages of work in the undertaking to prevent or reduce occupational risks (Article 3 Definitions).

The Directive lays down the obligations of both employer and workers. Article 6 sets out the general principles of prevention, which include *inter alia*:

a) Avoiding risks;
b) Evaluating the risks which cannot be avoided;
c) Combating the risks at source;
d) Adapting the work to the individual …
Etc.

Article 18, directs that “Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive by 31 December 1992.”

Both UK and French health and safety law are therefore adopted from European Union directives and codified into National law.

1.5.2 French Law

In French law, there are two types of regulations that apply to health and safety; there are mandatory rules enshrined in the written law of the land and there are technical standards, which exist to help the developer but are usually not binding (only around 3%-4% of these technical standards are binding). The difference between the two is sometimes subtle. Employers have a legal obligation under the mandatory rules to ensure the health and safety of their employees. Technical standards are also available to harmonise practices in certain work processes. These will often include design standards which allow the user, in certain circumstances, to hold the manufacturer liable for accident.

The main health and safety obligations are set out in the Labour Code (Code du Travail and Code du Travail Maritime). The Labour Code can be found at http://www.legifrance.gouv.fr. In France, most safety obligations are placed upon an individual, termed the Head of the Establishment, who will be either a company director (or equivalent) or a senior manager. The Labour Code requires the head of the establishment to “take the necessary action in order to ensure the safety and protection of the physical and mental health of the people working in the respective establishment, including temporary workers.” It goes on to say that in doing so he or she should adopt the following general preventative principles:

- Avoid risks
- Assess the risks that cannot be avoided
- Tackle risks at source
- Adapt work to the respective person, in particular as regards workplace design, the choice of equipment and working and production methods
- Take account of changes in the state of technology
- Replace what is dangerous with something that is not dangerous or less dangerous
- Plan for prevention by incorporating technology, working structures, working conditions, labour relations and the influence of environmental factors into a coherent whole
- Implement collective protective measures by giving these priority over individual protective measures
- Give workers appropriate instructions

Risk assessment is a critical step in the prevention process. It is the starting point. The identification, analysis and classification of risk are used to define the most appropriate preventive actions, covering technical, human and organisational dimensions. The risk assessment must be renewed regularly.

Evaluating the risks that cannot be avoided is one of the general principles of prevention in the present French Labour Code (*Code du Travail 2017*, Article L4121-2: "*Evaluer les risques qui ne peuvent pas être évités…").* The results of the occupational risk assessment are encompassed in a single document, which includes an inventory of identified risks, risk ranking and the proposed mitigation actions to be implemented. The production of this document is mandatory for all French companies (public and private) and must be updated at least annually.

1.5.3 Spanish Law

The new Electricity Sector Law 24/2013, of 26 December, establishes the legislation by which the activities of offshore electricity cabling are regulated within Spain. Under a regime of exclusivity, the activities related to the transmission of energy and the operation of the electricity system, as well as the function of transmission grid managers.

Of particular note within the Spanish legislation is the mandatory requirement to inform COVAM (Centro de Operaciones y Vigilancia de Acción Maritíma) of any high risk areas or any suspect UXO within Spanish waters (page 137 of the Royal Decree 130/2017, Instrucción Técnica Complementaria Número 5: Identificación y trazabilidad de explosivos con fines civiles).

1.6 UXO Risk Management Standards and Risk Assessment

Through previous engagement on projects in the UK and Europe, *Ordtek* is acutely aware of the standards and guidance that need to be adhered to when managing UXO risk. This includes working in line with national health and safety legislation and guidance and research provided by the UK Construction Information and Research Agency (CIRIA). All works would conform with French rules and specifically, but not limited to, article R733-3 of the Code de la Sécurité Intérieure; and will be in accordance with *REE's* Regulatory Framework.

Where limited official guidance exists, *Ordtek* will work within its proprietary framework (see Figure 1.2).

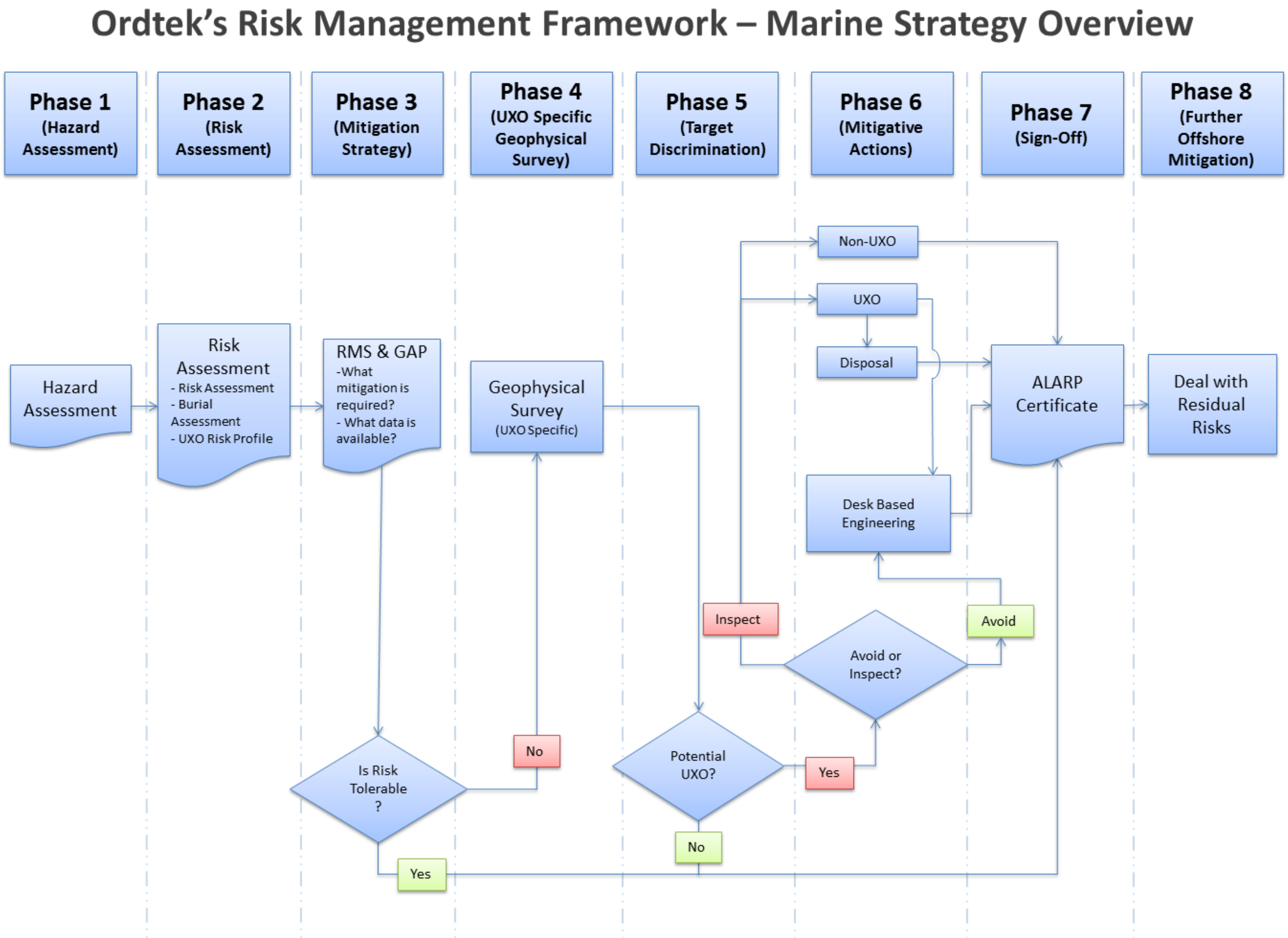


Figure 1.2 – Ordtek's risk management framework for the reduction of UXO risks.

The framework consists of 8 interrelated and sequential phases, which are specifically designed to discharge clients' legal liabilities to *de minimis* in accordance with the ALARP principle.

2 UXO Threat Assessment

2.1 Research

In this desk based study we have considered both wider regional and, where the information is available, site specific historical factors for the purpose of determining a baseline UXO hazard level.

The *Client* has provided *Ordtek* with a UXO Threat Assessment produced by *Geomines*. Therefore this *Ordtek* document will not be as comprehensive as *Ordtek* would normally provide given that historical works have already been undertaken. Its purpose is to take the *Geomines* UXO desktop study work forward and in doing so to fill any technical gaps and to review the conclusions regarding the type, characteristics, location and likely density of potential UXO hazards.

Nonetheless research has focussed on the following:

- Military history of the area
- Official and unofficial munitions dumping sites
- Current and historical military weapon ranges and training areas
- Potential migration of dumped munitions
- Wrecks of vessels or aircraft that may have a legacy of UXO contamination
- Protective, defensive and offensive minefields laid by both the German and British military forces
- Evidence of aerial warfare, including bombing, depth charge and torpedo deployment
- Bombing raid flight paths
- Evidence of naval surface and subsurface warfare and engagements

Information and data from a wide variety of sources have been collated to inform the study and risk assessment. The principal sources have been consulted from the following:

- UK Hydrographic Office (UKHO)
- The National Archives, London
- Royal Navy Historical Archive, Portsmouth
- The Ministry of Defence (MoD)
- Pertinent authoritative publications
- Web based archives
- *Ordtek's* own comprehensive internal database
- Bundesarchiv-Militaerarchiv Freiburg
- Federal Maritime and Hydrographic Agency (BSH) in Hamburg
- Naval Office of the German Federal Armed Forces, Division Geo 1, Underwater Data Centre, Rostock
- British Ministry of Defence, Air Historical Branch, RAF Northolt

2.2 Overview

The Bay of Biscay has been intensively fought over for hundreds of years. The Study Area itself saw considerable military action during both World Wars and the Spanish Civil War (1936-1939), as evidenced by the many wrecks in the region sunk by mines, torpedoes, air raids and both anti-submarine and surface actions, as well as the numerous minefields from both WWI and WWII which were laid across and within the study area.

2.3 World War I Sea Minefields

The German WWI mines laid would most likely have been type "EMA" (commonly known as "egg" mines) moored contact mines, with chemical Herz horns and with a charge weight of 160kg block-fitted Hexanite. Any British mines encountered are most likely to be Type HII. These mines are also ovoid, made of steel, have a diameter of 38 inches (0.96m) and a total weight of 295kg. The mine has a charge of 145kg of TNT and is fitted with Herz horns. Moored mines frequently broke free from their moorings and drifted many tens, sometimes hundreds, of kilometres before sinking. Their presence anywhere within the study area cannot be discounted, although by now these mines will be severely corroded and the risk they present is low.

Source of Potential UXO Hazard - Findings
Both the Germans and British navies were very active along the French coasts during WWI, laying numerous minefields along the whole length of, principally, the Normandy coast. However, there is no evidence of WWI mining within the study area.

Table 2.1 – Site Specific WWI Minefields

2.4 World War II Sea Minefields

British ground mines were used mostly as an offensive weapon in the Bay of Biscay. However, the British laid a large number of buoyant minefields. The vast majority of these mines were Vickers T III, MK17 and MK14 buoyant contact mines (or variations). The Mk14 had Herz horns while the Mk17 had switch horns (See Annex A for more explanation of horn types). In the latter case, by now, the batteries required to provide power to the detonator will have discharged and both types will have suffered significant degradation due to prolonged immersion in the water. NEQs varied depending on the precise type, but the most common NEQ was 227kg of HE.

Potentially, any one of these buoyant mines could have broken free and drifted elsewhere in the study area. Once laid, ground mines are unlikely to migrate far and so will remain in or close to the marked lay position. The exception to this is in shallow water, where the mines could be subject to swell and storm surge, or if placed on a relatively flat hard seabed where there is the potential for some cylindrical types of EO to roll under the influence of currents and other hydrodynamic forces.

In addition to surface laid British minefields, there were routinely re-seeded (replenished) mine "gardens" laid by the RAF. Aircrew slang for mine-laying operations was 'gardening' and the mines were referred to as being 'sown' when they were dropped at low-level into the sea.

British ground mine casings were generally made of steel and subject to corrosion over time unless they became buried in hypoxic sediment. The mines relied on batteries to power sensors and firing circuit; these will now be discharged and the mine will not function as designed. Charge weights were between 227kg-499kg, except for two specialist mines that had much smaller net explosive quantities (NEQs) of 45kg and 91kg. The British continued to develop ground mines throughout the war, starting with AMKs I-IV in the early years, finally progressing to the *AMk IX* by 1945.

Towards the end of WWII, KMA (Allied designation GK) shallow-water anti-invasion mines were laid along the length of “Atlantikwall”, to protect German-occupied Europe from invasion. These mines contained a 75kg Hexanite charge but were non-buoyant and static, consisting of a recessed concrete block, fitted with a 1.5m steel tri-pod and snag-line.

It is important to note that the positions shown on the charts may not always be accurate. Mine lays were conducted under the tension of war and with rudimentary navigation systems. Moreover, mining was not always accurately recorded and, after the war, many original records were lost. The positions of the minefields shown could be out by hundreds of metres or, in some cases, several kilometres.

Source of Potential UXO Hazard - Findings				
Extensive British mining occurred along the northern French and, to a lesser extent, Spanish coasts. Multiple surface laid minefields can be seen in the charted extent, following the coastline to obstruct Axis movement and disrupt submarine operations. In addition to surface laid minefields, there are multiple air laid mine “gardens” at strategic points along the coast. German KMA ground mines were laid in large numbers along the French coast as part of the anti-invasion defences, intersecting the French land fall and off the coast of Capbreton where the route returns to the French coast.				
Minefield No.	**Number of Mines**	**When Laid**	**Probable Type of Mine**	**~Distance from Cable Corridor (km)**
British Minefields				
Surface Laid				
FD32	50	28/3/1941	*MK XVI/XVI*	58.9km
FD40	13	5/6/1942	*13 x Vickers T III*	Intersecting cable corridor
FD40	10	5/6/1942	*10- Vickers T III*	Intersecting cable corridor
FD40	8	5/6/1942	*8 x Vickers T III*	Intersecting cable corridor
FD41	16	14/8/1942	*Line 16 x Vickers T III*	18.5km – 20.1km
FD41	16	14/8/1942	*Line 16 x Vickers T III*	18.5km – 20.1km
FD43	16	5/7/1943	*16 x Vickers T III*	2.8km – 22.5km
FD43	16	5/7/1943	*16 x Vickers T III*	2.8km – 22.5km
FD45	16	30/8/1942	*16 x Vickers T III*	3.8km
FD47	32	24/2/1944	*32 x Vickers T III*	Intersecting cable corridor
FD36	32	16/1/1942	*Vickers T III*	7.2km
FD39	16	5/6/1942	*16 x Vickers T III*	Intersecting cable corridor – 4.8km
FD39	16	5/6/1942	*16 x Vickers T III*	Intersecting cable corridor – 4.8km
FD45	32	30/8/1943	*Vickers T III*	0.9km

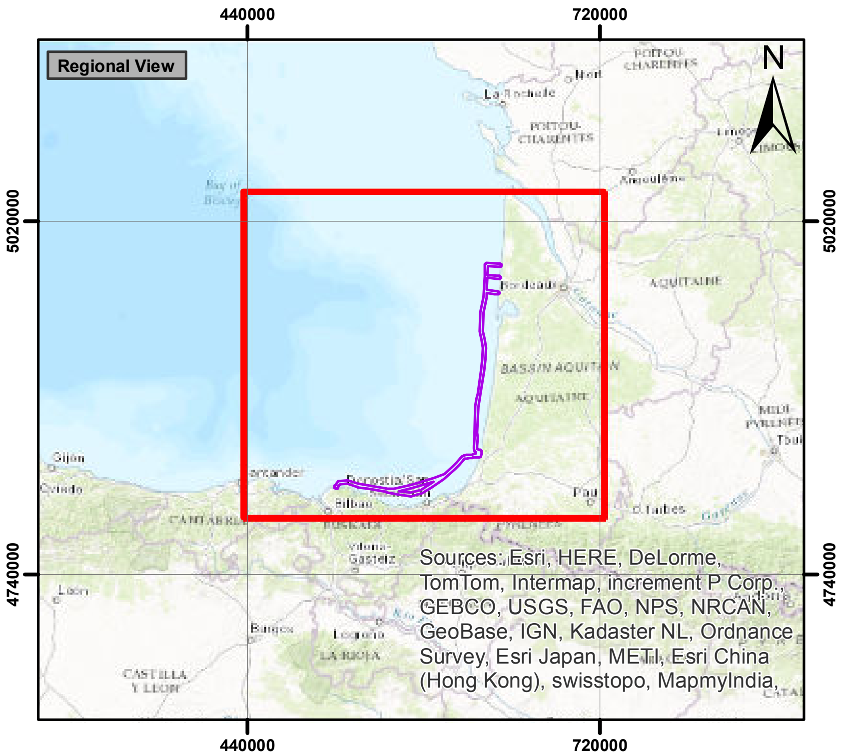
Minefield No.	Number of Mines	When Laid	Probable Type of Mine	~Distance from Cable Corridor (km)
Air Laid				
DEODAR QZX 775	3791	1940-1944	*Ground Mines A MkI –IV*	45.8km
Elderbery	786	1942- 1944	*Anchorage by plane, unknown type*	Edge Port of Bayonne 7.8km
Furze		1942- 1944	*Anchorage by plane, unknown type*	Edge Port of Saint Jean de Luz 8.5km
German Minefields				
Surface Laid				
K14	140	5/1944	*KMA (Ground Mine)*	41.7km
K15	130	5/1944	*KMA (Ground Mine)*	37.7km
K15a	220	5/1944	*KMA (Ground Mine)*	28.5km
K16	160	5/1944	*KMA (Ground Mine)*	21.5km
K17	136	5/1944	*KMA (Ground Mine)*	13.7km
K18	90	6/1944	*KMA (Ground Mine)*	8.5km
K19	76	6/1944	*KMA (Ground Mine)*	5.3km
K20	108	6/1944	*KMA (Ground Mine)*	1.5km
K21	69	6/1944	*KMA (Ground Mine)*	Intersecting cable corridor
K22	160	7/1944	*KMA (Ground Mine)*	Intersecting cable corridor
K23	160	7/1944	*KMA (Ground Mine)*	Intersecting cable corridor
K24	160	7/1944	*KMA (Ground Mine)*	Intersecting cable corridor
K25	160	7/1944	*KMA (Ground Mine)*	0.8km
K26	169	7/1944	*KMA (Ground Mine)*	6.2km
K27	160	7/1944	*KMA (Ground Mine)*	6.3km
K28	160	7/1944	*KMA (Ground Mine)*	5.5km
K29	160	7/1944	*KMA (Ground Mine)*	4.6km
K30	160	6/1944	*KMA (Ground Mine)*	3.5km
K31	130	6/1944	*KMA (Ground Mine)*	3.7km
K32	76	6/1944	*KMA (Ground Mine)*	2.9km
K33	132	5/1944	*KMA (Ground Mine)*	Intersecting cable corridor
K34	152	5/1944	*KMA (Ground Mine)*	Intersecting cable corridor
K35	152	5/1944	*KMA (Ground Mine)*	0.5km
K36	160	5/1944	*KMA (Ground Mine)*	5.8km

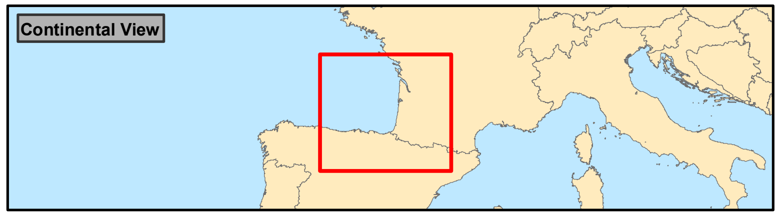
Table 2.2 – Minefields within the Study Area.

2.4.1 Minesweeping and Mine Clearance Operations

Minesweeping continued well after the armistice in November 1918 with 55 different flotillas still operating in June 1919. The British searched over 40,000 square miles until November 1919. At the end of the war when great efforts had to be made to clear the sea of mines, it was observed that about 85% of the mines laid had “disappeared” due to various causes and only a small fraction could be found and eliminated.

A similar effort was put into clearing minefields after WWII. Many reports refer to the “clearance” of barrier minefields after WWI and WWII. The term here should not be confused with what is understood by the modern usage of the word clearance, which includes removal of the UXO threat completely, usually by countermining. Minesweeping was not effective against mines that had already broken free and sunk to the seabed. And while minesweeping removed the threat for surface vessels and submarines, the practice of sinking them with gunfire has left a significant legacy hazard to modern seabed operations. The mine sinkers (anchors) also present solid targets for modern sonars and magnetic sensors that have to be identified and discounted, increasing the effort and time required for the survey of a contaminated area.





Legend for Site View

- Biscay Gulf Interconnector Risk Assessment Corridor

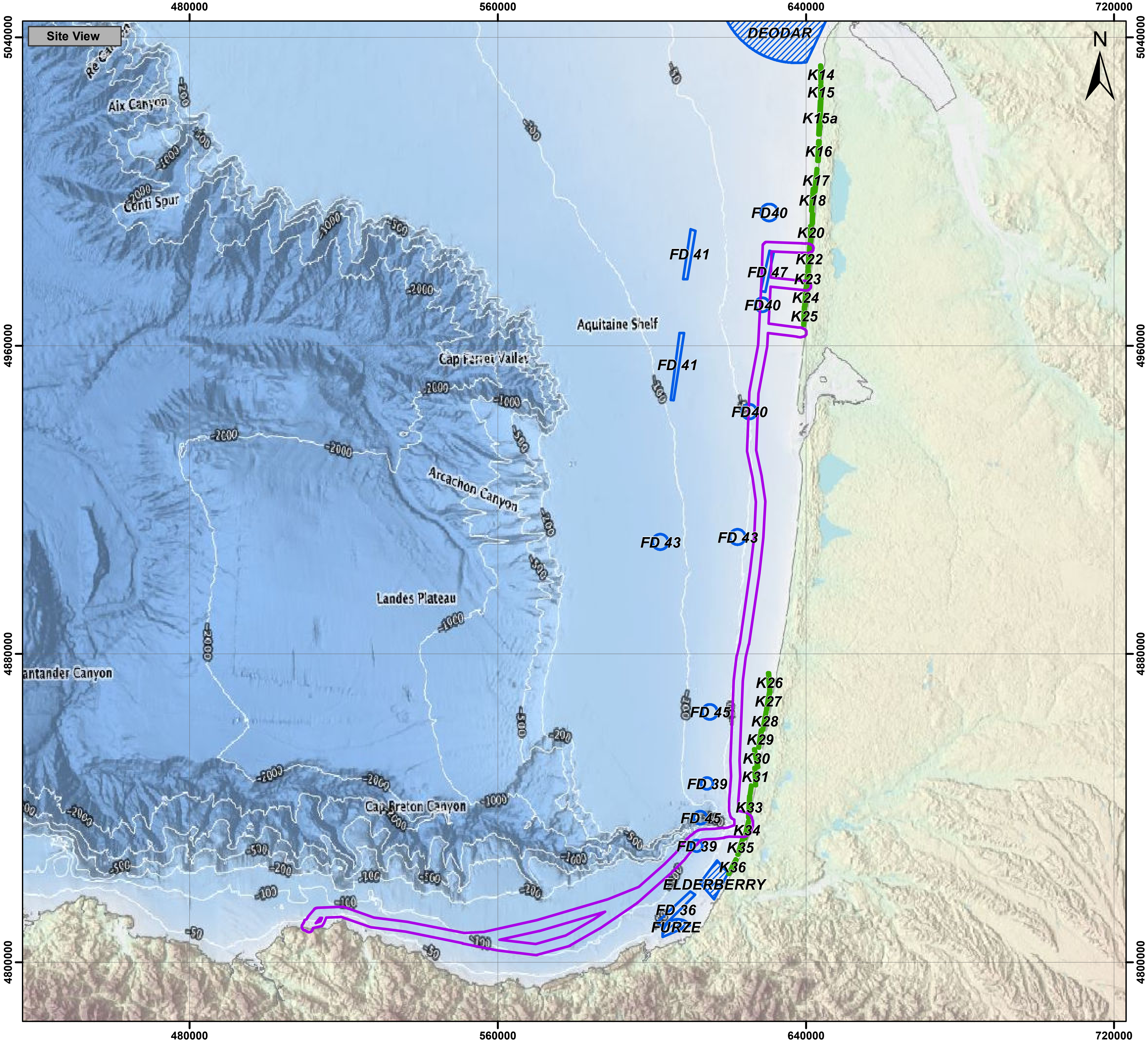
WWII British Mine Laying

- Air Laid
- Surface and Submarine Laid
- WWII German Mine Laying

Horizontal Scale(s)

Kilometers: 0, 10, 20, 40, 60, 80

Nautical Miles: 0, 12.5, 25, 50



Consultant: ORDTEK

Client: inelfe

Drawing Title

Biscay Gulf Interconnector
WWII British and German Mining

User Notes

Note 01 - Biscay Gulf Interconnector Risk Assessment Corridor dervied from INELFE file "Survey areas 2016.kmz". For the purposes of charting, the Risk Assessment Corridor includes an additional 1km either side of the INELFE survey corridor.
Note 02 - Two possible alternative Spanish landfall HDD options have also been considered, as defined by REE "HDD option3 UXO risk assessment area.kmz" and "HDD option 5 UXO risk assessment area.kmz".

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scale factor: 0.9996
latitude of origin: 0.0000
Units: Meter

Drawn by: AP
Checked by: LG

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JM5353 - Bay of Biscay

Date Drawn: 09 June 2017
Drawing Reference: JM5353_DTS_02
Drawing Version: 2.0

2.5 Torpedoes/Depth Charges

During both WWI and WWII most surface ships were fitted with torpedoes and there were many ship to ship torpedo actions, in addition to submarine attacks on shipping; and in turn, submarines were attacked with depth charges. Consequently, large and small naval projectiles, torpedoes, depth charges and other anti-submarine weapons remain an almost universal threat.

Depth charges (and depth bombs from RAF coastal patrol aircraft) were deployed in huge numbers during WWII, often at spurious targets, as this contemporary diary account illustrates:

> *"Setting sail at 5.45 am on 27 August, Rodney headed west, bound for Plymouth, a sloop and two destroyers as escort.* ***Along the way, there was the usual enthusiastic depth-charging of submarine contacts, which were, as so often was the case, probably wrecks on the seabed****".*

Depth charges and depth bombs have an NEQ in the range of 50kg - 200kg. These all would have been thin-cased and consequently subject to severe corrosion in the intervening years. They would have fired by a hydrostatic fuse or perhaps an impact bomb fuse with a delay.

During both WWI and WWII, the Germans developed torpedoes of the "wet heater" type; steam driven, with kerosene as fuel and compressed air providing oxygen for combustion. Warheads of around 250kg were detonated by means of a direct impact or magnetic fuse. WWI torpedo fusing was often unreliable and it is quite possible that attacks took place, unrecorded, when the torpedo failed to function and sank to the seabed. WWII warheads were filled with 280kg of Hexanite and were generally much more reliable.

Source of Potential UXO Hazard - Findings
German submarines and E-Boats regularly operated in the Bay of Biscay, laying mines and attacking ships, as evidenced by wrecks in the area recorded as sunk by torpedo or U-Boat gunfire. In turn, submarines were attacked with depth charges. Depth charges (and depth bombs from RAF coastal patrol aircraft) were deployed in huge numbers during WWII, often at spurious targets. The presence of torpedoes, depth charges and depth bombs in the study area is almost certain and a number of different types could have been deployed.

Table 2.3 – Torpedo/Depth Charge Sources within the Study Area

2.6 Air Dropped Bombs

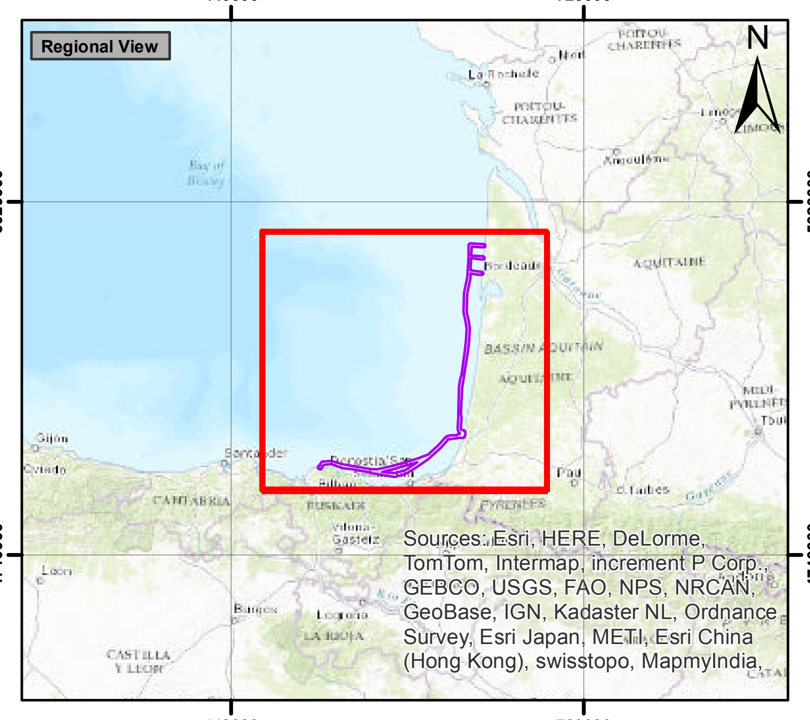
Air delivered EO is likely to come from the following sources:

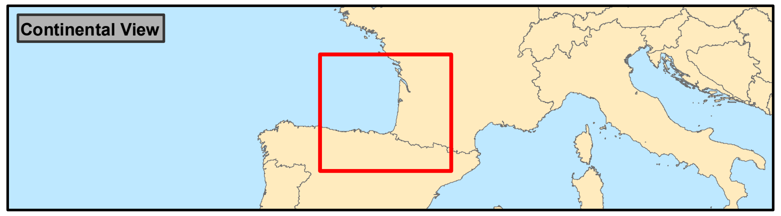
- The result of attacks on ships or submarines transitting the convoy routes, where EO missed its target. These weapons are likely to have been armed and will present a UXO risk.
- Bombs dropped in error into the sea during raids on land targets.
- Bombs jettisoned into the water by aircrew in an emergency on the way to or from an inland target. If planes had been badly damaged or were under attack, the crews often jettisoned their bomb loads to aid their evasion attempts. This was a common tactic known as "tip and run". These bombs may or may not have been armed on release. For risk assessment purposes, it must be assumed that they were armed.

Consequently almost any category of bomb could be present in the area. In addition to bombs, cannon shells are also very likely to be present. Bombs dropped from Luftwaffe bomber aircraft are likely to be in the region of 50kg - 500kg but in rare cases much larger bombs – up to 1800kg – could also be encountered, particularly any destined for inland raids but jettisoned over the sea. The charge to weight ratio of a general purpose bomb is approximately 50%, giving NEQs for the examples above of 25kg, 250kg. Of interest, approximately 70% of all bombs deployed by the Luftwaffe during WWII were 50kg varieties (we do not have the statistic for attacks on ships alone).

Findings
During the Spanish Civil War, the town of Durango was bombed by the Luftwaffe; some of the first bombs fell into the church during morning Mass. Fighters flew low and strafed the fleeing population. They also attacked a nearby cloister, killing 15 nuns. In total some 300 people were killed, 2,500 were wounded, practically all of them civilians. A second air attack took place as fire brigades, police and ambulances from Bilbao tried to help the victims. The Bombing of Durango was the first attack in Europe against a civilian population and the first place in the world to be attacked by the Luftwaffe. After this attack, another attack was launched on Guernica. One Dornier Do 17, two Heinkel He 111s, 18 Ju 52 Behelfsbomber and three Italian SM.79s were brought in for the bombing. In total, the planes carried 22 tonnes of explosives ranging from 550 lb medium explosive bombs to 2.2-pound (likely incendiary) bombs. The bombing began at 4:30 p.m. with the Dornier Do 17 dropping 12 110 pound bombs. Following this, the Italian SM.79s arrived with orders only to bomb bridges to the east of the city to limit any retreats. The SM.79s dropped 36-110 pound bombs on these parts. Damage to the city at this point was relatively light, with only a handful of buildings suffering minor damage. The bombings continued until seven p.m., with wave after wave of planes coming in and dropping bombs at varying points of the city. This was when the city took the brunt of its damage. Towards the end of the bombings, planes were advised to begin bombing roadways exiting the city. The bombing of these roads lasted for about 15 minutes and added immensely to civilian deaths. A number of busy coastal convoy routes ran adjacent to the study area. From early 1941, as part of the escalating "Battle of the Atlantic", the German U-boat bases along the French Atlantic coast were heavily attacked by Allied bombers. In addition to mining port approaches, the port facilities, U-boat pens and construction yards were all targeted. Early raids were conducted by the British, with relatively light forces (forces of between 16 and 27 aircraft are recorded); later both the 8th United States Air Force (USAF) and the RAF delivered massive raids, with many aircraft taking part. Raids of up to 437 aircraft are documented. In addition, the German Luftwaffe would have defended and attacked Allied shipping and raiding aircraft. The Germans favoured the Ju-87 (Stuka) dive bomber for the role. While attacks on convoys continued throughout WWII, using other aircraft types, this was the most intense period.

Table 2.4 – Sources of Air-dropped Bombs within the Study Area





Legend for Site View

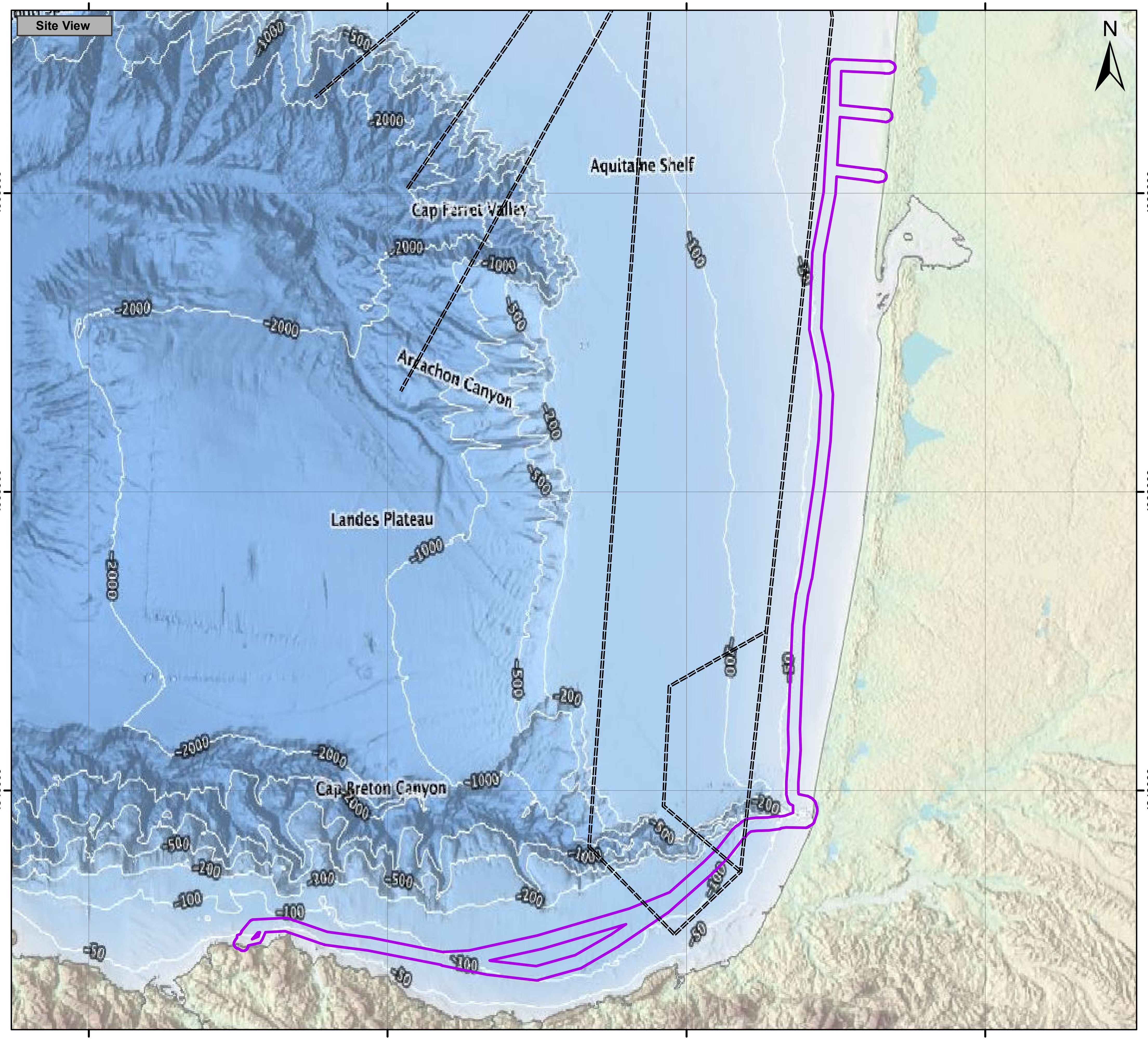
Biscay Gulf Interconnector Risk Assessment Corridor

German Convoy Routes (1943)

Horizontal Scale(s)

Kilometers: 0 10 20 40 60

Nautical Miles: 0 7.5 15 30



Consultant	Client	Drawing Title	User Notes
ORDTEK	inelfe	Biscay Gulf Interconnector WWII German Convoy Routes	Note 01 - Biscay Gulf Interconnector Risk Assessment Corridor dervied from INELFE file "Survey areas 2016.kmz". For the purposes of charting, the Risk Assessment Corridor includes an additional 1km either side of the INELFE survey corridor. Note 02 - Two possible alternative Spanish landfall HDD options have also been considered, as defined by REE "HDD option3 UXO risk assessment area.kmz" and "HDD option 5 UXO risk assessment area.kmz".

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central meridian: -3.0000
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latitude of origin: 0.0000
Units: Meter

Drawn by: AP
Checked by: LG

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JM5353 - Bay of Biscay

Date Drawn: 19 May 2017
Drawing Reference: JM5353_DTS_09
Drawing Version: 1.1

2.7 Naval Projectiles

A wide variety of calibres of guns, up to 16in (40.6cm), were fitted to ships. Depending on their role (armour-piercing, capped, HE etc.), these shells contained between 10kg-50kg of Lyddite or Shellite (HE).

While WWII saw less big-ship surface to surface action than in WWI, there was much greater use of naval weapons in the Anti-Aircraft (AA) role, particularly in the protection of convoys. Most commonly, the guns used for AA would have been 20mm and 40mm but 4in, 6in and even 8in would also have been employed.

Weapon systems of the day lacked the first time strike accuracy of modern weapons and, in an exchange of fire, projectiles are likely to have missed the target in the first instance and it is entirely feasible that a number of exchanges of fire would have preceded a successful attack, with numerous rounds sinking to the seabed.

Consequently, UXO in the form of projectiles could be present anywhere in the study area. These are most likely to be relatively small calibre shells with an NEQ in the region of 2kg-5kg but larger projectiles could be encountered and with a slightly larger NEQ – up to 25kg of Picric acid based explosives, such as Shellite.

Findings
The probability of finding naval projectiles in the study area is likely to be elevated in areas around wrecks (shown overleaf), where ship conflicts occurred. In addition, within German convoy routes Allied airforces and ships would have battled.

Table 2.5 – Naval Projectiles within the Study Area

2.8 Military Related Shipwrecks

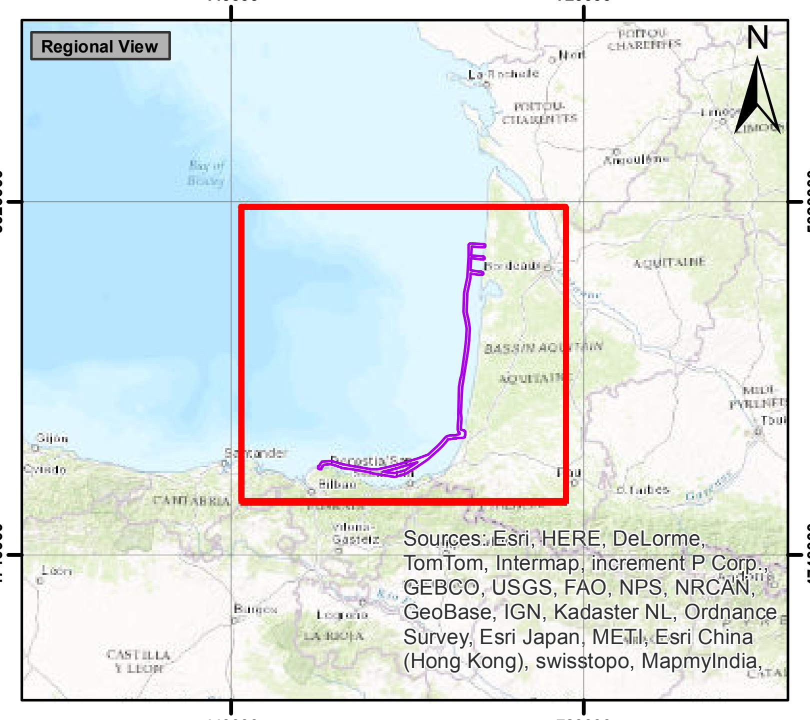
Many merchant as well as naval vessels sunk in WWI and WWII contained munitions. Similarly, aircraft that were shot down, or otherwise had to ditch into the sea, also had unexpended ammunition and other EO. There is evidence that munitions could spill and be thrown clear from a sinking ship or become exposed as the vessel broke-up on the seabed, and in due course migrate away from the original site. But the risk of EO contamination is generally less in the vicinity of wrecks (compared with munitions dump sites) as the ordnance typically remains contained and immobile within the structure of the sunken vessel. From a UXO threat perspective, wrecks of unknown origin should be avoided.

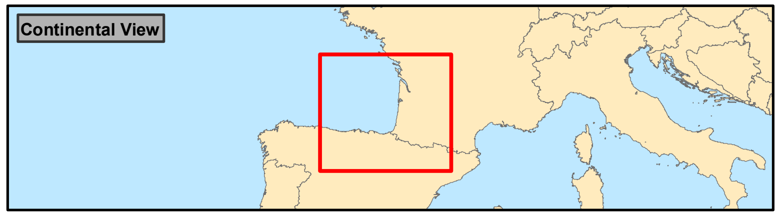
While some wrecks may contain ammunition, they are unlikely to be the source of any direct UXO contamination. However, the wrecks do provide clear evidence of military action and the potential for the presence of UXO from the action preceding the sinking. As noted in the previous section, wrecks are known to have been caused by torpedo and depth charge attack, but also from mines and air raids (bombs and depth bombs).

It is also likely that some aircraft were shot down and crashed into the sea in the wider area. It must be assumed, therefore, that aircraft debris, together with embarked bombs, torpedoes and ammunition, could be present anywhere within the study area. The circumstances of most aircraft losses offshore mean that accurate positional information of such wrecks is very rarely available.

Findings
There are a large number of wrecks in the study area that were sunk due to military action during WWI and WWII. Some wrecks may contain ammunition but are unlikely to be the source of any direct UXO contamination. However, the wrecks do provide clear evidence of military action and the potential for the presence of UXO from the action preceding the sinking. We have found no records of aircraft crash sites within the study area.

Table 2.6 – Military Wrecks within the Study Area.





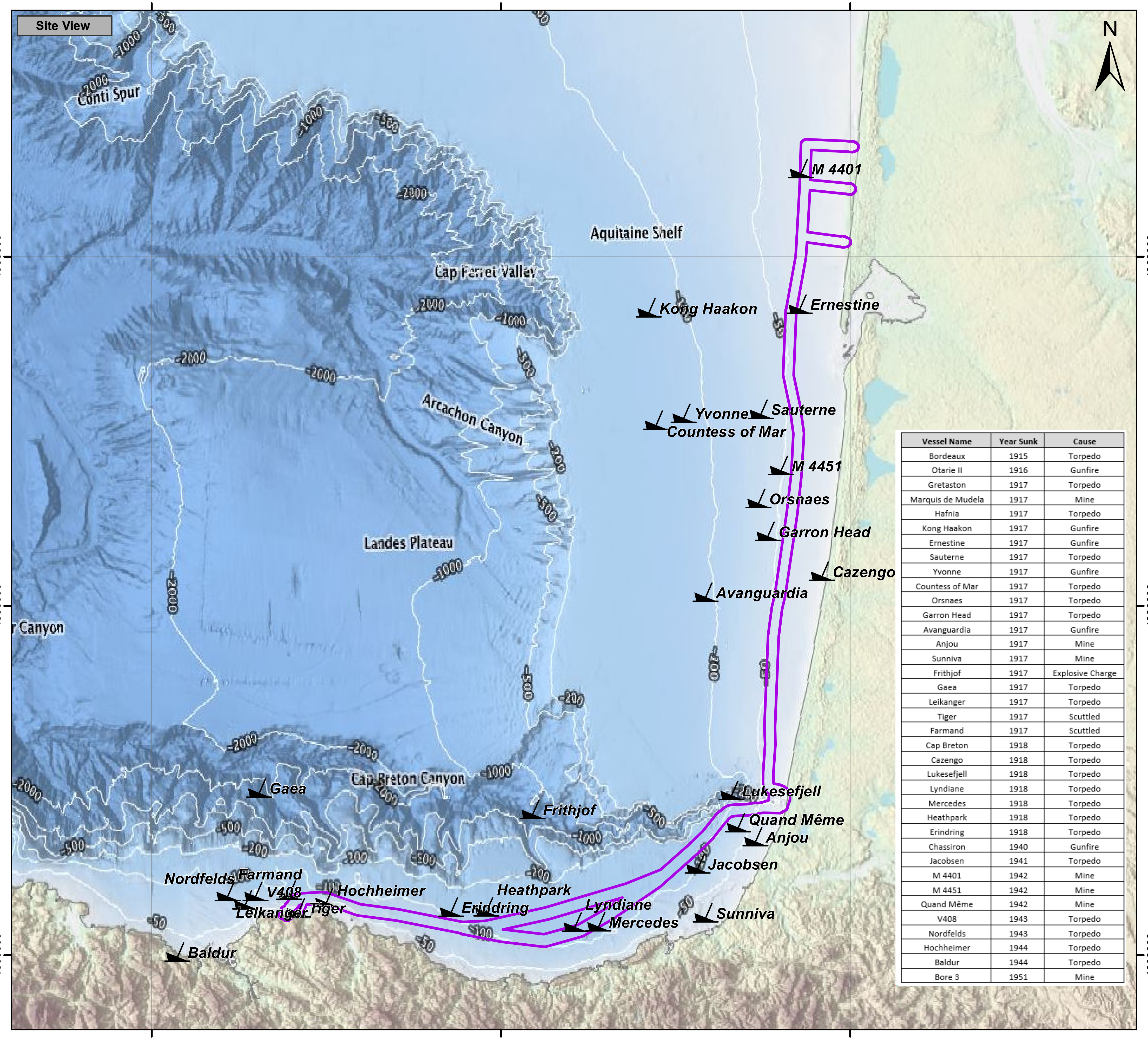
Legend for Site View

- Biscay Gulf Interconnector Risk Assessment Corridor
- Wreck of Military Interest

Horizontal Scale(s)

Kilometers: 0, 10, 20, 40, 60, 80

Nautical Miles: 0, 7.5, 15, 30, 45



Vessel Name	Year Sunk	Cause
Bordeaux	1915	Torpedo
Otarie II	1916	Gunfire
Gretaston	1917	Torpedo
Marquis de Mudela	1917	Mine
Hafnia	1917	Torpedo
Kong Haakon	1917	Gunfire
Ernestine	1917	Gunfire
Sauterne	1917	Torpedo
Yvonne	1917	Gunfire
Countess of Mar	1917	Torpedo
Orsnaes	1917	Torpedo
Garron Head	1917	Torpedo
Avanguardia	1917	Gunfire
Anjou	1917	Mine
Sunniva	1917	Mine
Frithjof	1917	Explosive Charge
Gaea	1917	Torpedo
Leikanger	1917	Torpedo
Tiger	1917	Scuttled
Farmand	1917	Scuttled
Cap Breton	1918	Torpedo
Cazengo	1918	Torpedo
Lukesefjell	1918	Torpedo
Lyndiane	1918	Torpedo
Mercedes	1918	Torpedo
Heathpark	1918	Torpedo
Erindring	1918	Torpedo
Chassiron	1940	Gunfire
Jacobsen	1941	Torpedo
M 4401	1942	Mine
M 4451	1942	Mine
Quand Même	1942	Mine
V408	1943	Torpedo
Nordfelds	1943	Torpedo
Hochheimer	1944	Torpedo
Baldur	1944	Torpedo
Bore 3	1951	Mine

Consultant: ORDTEK

Client: inelfe

Drawing Title: **Biscay Gulf Interconnector Wrecks of Military Interest**

User Notes

Note 01 - Biscay Gulf Interconnector Risk Assessment Corridor dervied from INELFE file "Survey areas 2016.kmz". For the purposes of charting, the Risk Assessment Corridor includes an additional 1km either side of the INELFE survey corridor.

Note 02 - Two possible alternative Spanish landfall HDD options have also been considered, as defined by REE "HDD option3 UXO risk assessment area.kmz" and "HDD option 5 UXO risk assessment area.kmz".

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WGS 1984 UTM zone 30N
Projection: Transverse Mercator
Datum: WGS 1984
false easting: 500,000.0000
false northing: 0.0000
central meridian: -3.0000
scale factor: 0.9996
latitude of origin: 0.0000
Units: Meter

Drawn by: AP
Checked by: LG

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JM5353 - Bay of Biscay

Date Drawn: 19 May 2017
Drawing Reference: JM5353_DTS_05
Drawing Version: 1.1

2.9 Exercise Areas and Firing Practice / Bombing Ranges

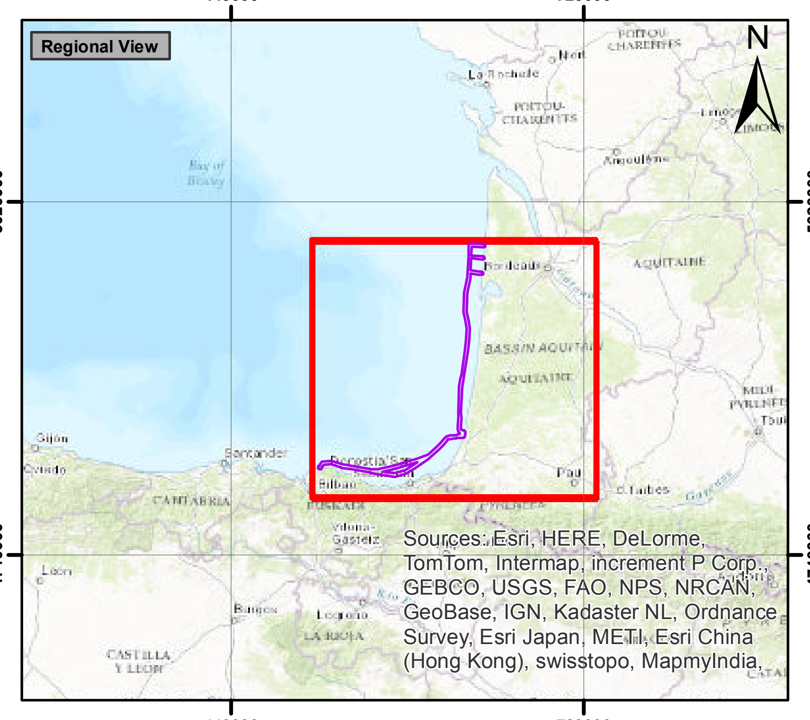
Naval vessels and aircraft carry out exercises, day and night, off all points of the coast and it very probable that some *ad hoc* training evolutions have taken place over a period of several decades outside designated areas, particularly during the war years; including live firing of small arms, naval gunfire (typically up to 105mm) and possibly larger anti-submarine weapons.

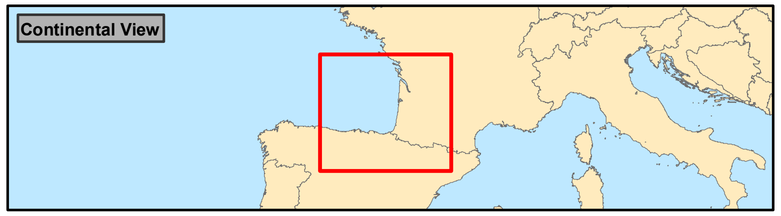
As a rule, live firing of HE munitions for practice is only conducted in designated exercise areas; however, from experience, naval ships and aircraft commonly conduct firings, as convenient, outside formal practice areas using *"clear range procedure"*.

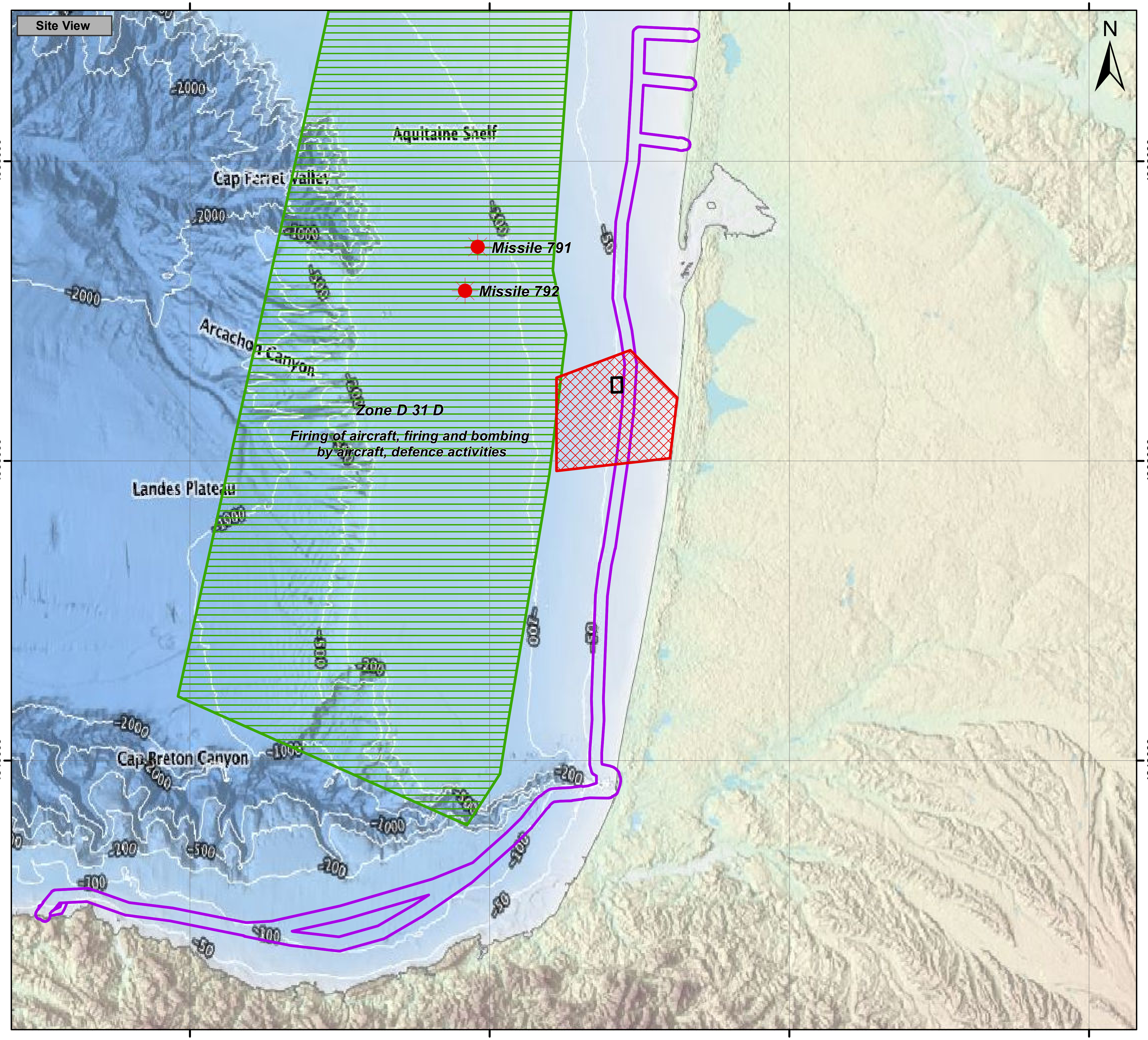
In such exercises, ships, submarines and aircraft would have used a wide variety of munitions, including flares, smoke and starshell. It is impossible to determine the detail of precisely what activities might have been conducted over so many years but it is very possible that a combination of both HE and "practice" ammunition contaminate the area. Practice munitions usually contain a Low Explosive spotting charge and/or a pyrotechnic element. These present a minimal risk to Project activities. However, given the corrosion that will have occurred in the intervening years, it is unlikely that practice munitions will be readily distinguish from similarly shaped HE versions. We have seen on other projects that it is usually necessary to dispose of "inert" items of UXO using high-order methods (counter-mining with a HE charge).

Findings
Historically, extensive military action and training was undertaken along both the French and Spanish coasts. Practice area boundary constraints were not as tightly enforced during the war as they are now and it is very likely that both live and practice ordnance items were dropped outside official practice areas. Potentially almost any type of launched/fired explosive and practice ordnance could be present; the highest concentration will be within designated training areas but UXO contamination is also likely further afield. WWII armament areas cover almost the entire coast, consisting of mostly anti-aircraft (AA) and guns (*See Coastal and AA Defences below*). Modern training areas are operational within French sector of the study area run parallel to the cable route. *Zone D 31 D* used for 'firing of aircraft, firing and bombing by aircraft and defence activities'. In such exercises aircraft would have used a wide variety of munitions, including flares, smoke and starshell. It is impossible to determine the detail of precisely what activities might have been conducted over so many years but it is very possible that a combination of both HE and "practice" ammunition contaminate the area. Practice munitions usually contain a Low Explosive spotting charge and/or a pyrotechnic element. These present a minimal risk to project activities. However, given the corrosion that will have occurred in the intervening years, it is unlikely that practice munitions will be readily distinguishable from similarly shaped HE versions. Of note, illustrated on Admiralty Charting is an area marked 'Submerged Munitions and Obstructions' that intersects the cable corridor, in the area of minefield FD 43 and multiple shipwrecks, however is also likely to be linked to historic training areas. This is likely due to "Le Coffre", a firing target area immediately adjacent to the cable corridor. Therefore the area illustrated on the admiralty chart takes into account munitions that may have fallen outside this area, but were related to the firing range.

Table 2.7 – Exercise Areas within the Study Area.







Legend for Site View

- Biscay Gulf Interconnector Risk Assessment Corridor
- Unexploded Missiles from French Military Training
- Military Exercise Area
- Submerged Munitions and Obstructions
- Zone Interdite/Le Coffre (Firing Box)

Horizontal Scale(s)

Kilometers: 0, 10, 20, 40, 60

Nautical Miles: 0, 7.5, 15, 30

Consultant	Client	Drawing Title	User Notes
ORDTEK	inelfe	Biscay Gulf Interconnector Military Exercise Zones and Submerged Munitions	Note 01 - Biscay Gulf Interconnector Risk Assessment Corridor dervied from INELFE file "Survey areas 2016.kmz". For the purposes of charting, the Risk Assessment Corridor includes an additional 1km either side of the INELFE survey corridor. Note 02 - Two possible alternative Spanish landfall HDD options have also been considered, as defined by REE "HDD option3 UXO risk assessment area.kmz" and "HDD option 5 UXO risk assessment area.kmz".

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WGS 1984 UTM zone 30N
Projection: Transverse Mercator
Datum: WGS 1984
false easting: 500,000.0000
false northing: 0.0000
central meridian: -3.0000
scale factor: 0.9996
latitude of origin: 0.0000
Units: Meter

Drawn by: AP
Checked by: LG

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JM5353 - Bay of Biscay

Date Drawn: 19 May 2017
Drawing Reference: JM5353_DTS_08
Drawing Version: 2.0

2.10 Coastal Defences

German coastal artillery often consisted of 305mm naval guns with a maximum range of between ~51km and ~32km depending on the type of shells being fired. Its firepower allowed it to dominate large swathes of coastline and offshore. 170mm guns were also present; these had a range of ~26km. Smaller batteries of 128mm, 105mm and 75mm AA guns also protected harbour areas.

The 6in guns had a maximum range of around 20km and projectiles could easily have reached nearshore and offshore. The 3.7in HAA gun had a maximum range of around 12km and, although the trajectory would usually have been high, unexploded projectiles could have fallen into the beach or sea out to that distance. Similarly, the 40mm LAA gun had a range of around 7km and rounds from these guns could potentially contaminate the nearshore areas.

It follows, therefore that coastal artillery and AA projectiles have the potential to contaminate the cable corridor out to the maximum range of the gun.

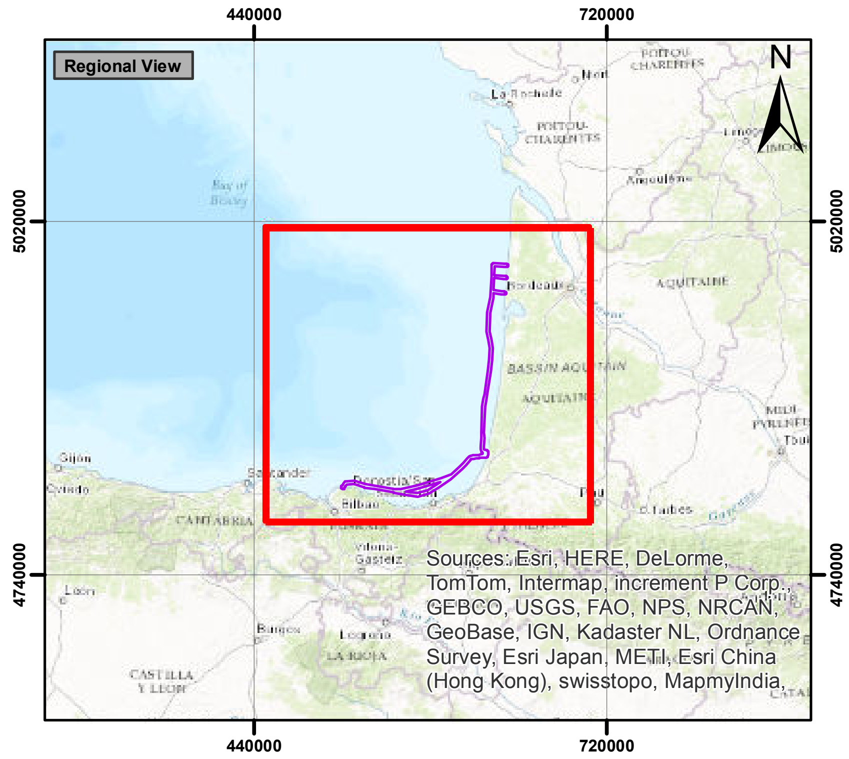
While often not recorded, it is likely that there were also mobile Light Anti-Aircraft (LAA) 40mm Bofors positions around built up areas and on the coastal approaches.

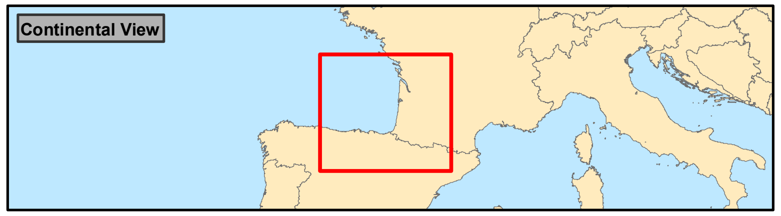
2.11 Land Service Ammunition and Small Arms Ammunition

Given the number of troops on the ground, the presence of small items of land service ammunition (LSA) and small arms ammunition (SAA) cannot be discounted near to the cable landfalls. Any EO in the water will now be severely corroded and present negligible threat to Project works as long as suitable precautions are taken.

Source of Potential UXO Hazard Findings
As part of the German Atlantikwall and anti-invasion defences, the French coastline was very heavily fortified. German Teller beach mines, projectiles, mortars, grenades and small arms ammunition (SAA) contaminate the beaches and foreshore and remain a threat in the inter-tidal zone at cable landfalls.

Table 2.8 – Coastal Defences and LSA Contamination within the Study Area





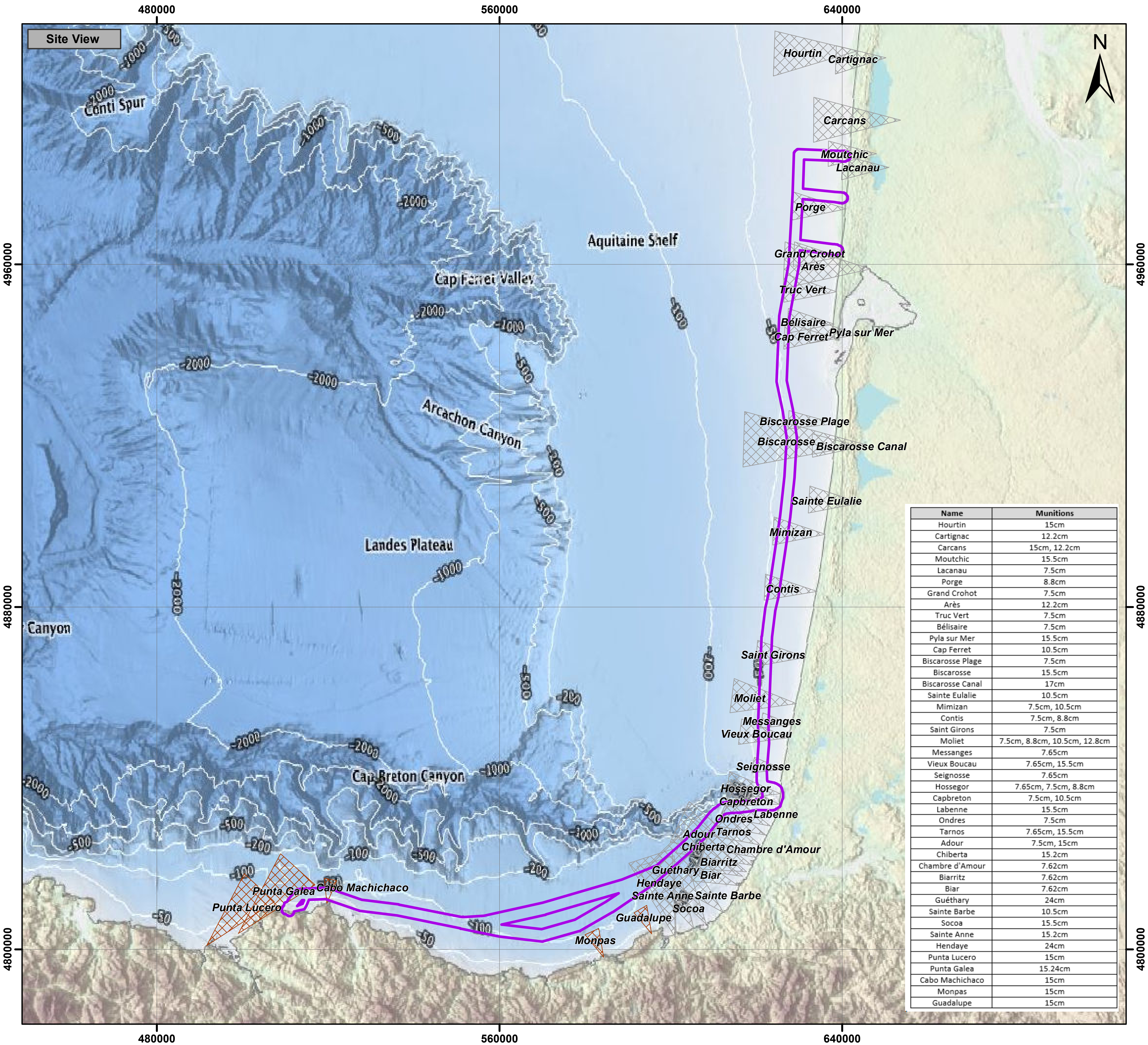
Legend for Site View

- Biscay Gulf Interconnector Risk Assessment Corridor
- WWII French Coastal Batteries
- WWII Spanish Coastal Batteries

Horizontal Scale(s)

Kilometers: 0, 10, 20, 40, 60, 80

Nautical Miles: 0, 7.5, 15, 30, 45



Name	Munitions
Hourtin	15cm
Cartignac	12.2cm
Carcans	15cm, 12.2cm
Moutchic	15.5cm
Lacanau	7.5cm
Porge	8.8cm
Grand Crohot	7.5cm
Arès	12.2cm
Truc Vert	7.5cm
Bélisaire	7.5cm
Pyla sur Mer	15.5cm
Cap Ferret	10.5cm
Biscarosse Plage	7.5cm
Biscarosse	15.5cm
Biscarosse Canal	17cm
Sainte Eulalie	10.5cm
Mimizan	7.5cm, 10.5cm
Contis	7.5cm, 8.8cm
Saint Girons	7.5cm
Moliet	7.5cm, 8.8cm, 10.5cm, 12.8cm
Messanges	7.65cm
Vieux Boucau	7.65cm, 15.5cm
Seignosse	7.65cm
Hossegor	7.65cm, 7.5cm, 8.8cm
Capbreton	7.5cm, 10.5cm
Labenne	15.5cm
Ondres	7.5cm
Tarnos	7.65cm, 15.5cm
Adour	7.5cm, 15cm
Chiberta	15.2cm
Chambre d'Amour	7.62cm
Biarritz	7.62cm
Biar	7.62cm
Guéthary	24cm
Sainte Barbe	10.5cm
Socoa	15.5cm
Sainte Anne	15.2cm
Hendaye	24cm
Punta Lucero	15cm
Punta Galea	15.24cm
Cabo Machichaco	15cm
Monpas	15cm
Guadalupe	15cm

Consultant: ORDTEK

Client: inelfe

Drawing Title: **Biscay Gulf Interconnector WWII French and Spanish Coastal Batteries**

User Notes

Note 01 - Biscay Gulf Interconnector Risk Assessment Corridor dervied from INELFE file "Survey areas 2016.kmz". For the purposes of charting, the Risk Assessment Corridor includes an additional 1km either side of the INELFE survey corridor.

Note 02 - Two possible alternative Spanish landfall HDD options have also been considered, as defined by REE "HDD option3 UXO risk assessment area.kmz" and "HDD option 5 UXO risk assessment area.kmz".

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WGS 1984 UTM zone 30N
Projection: Transverse Mercator
Datum: WGS 1984
false easting: 500,000.0000
false northing: 0.0000
central meridian: -3.0000
scale factor: 0.9996
latitude of origin: 0.0000
Units: Meter

Drawn by: AP
Checked by: LG

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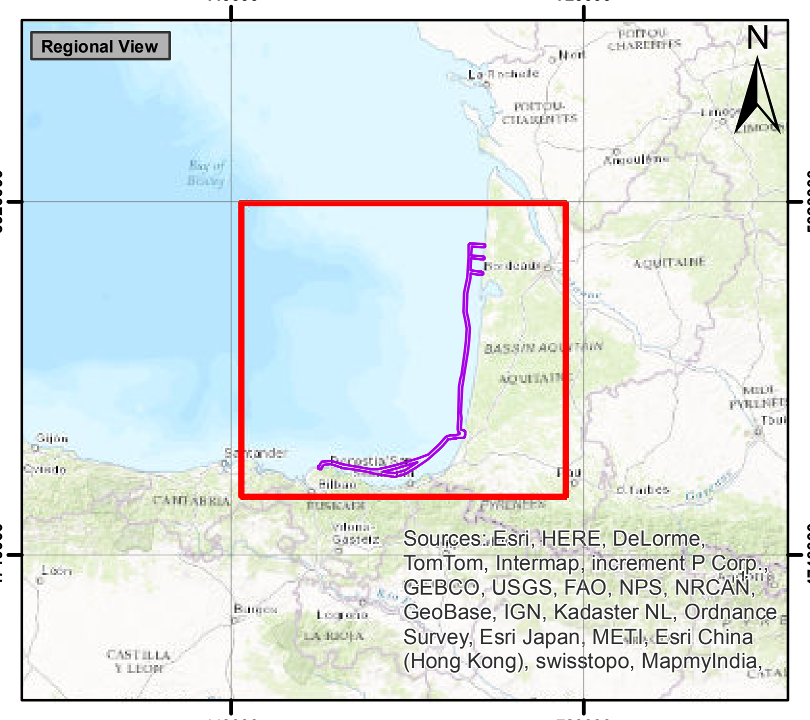
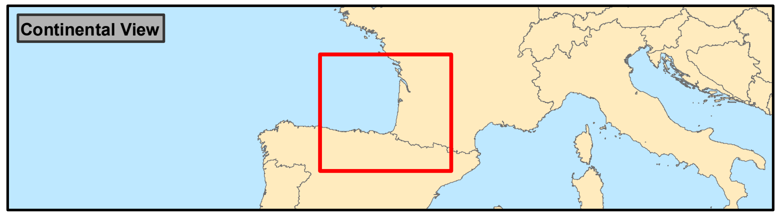
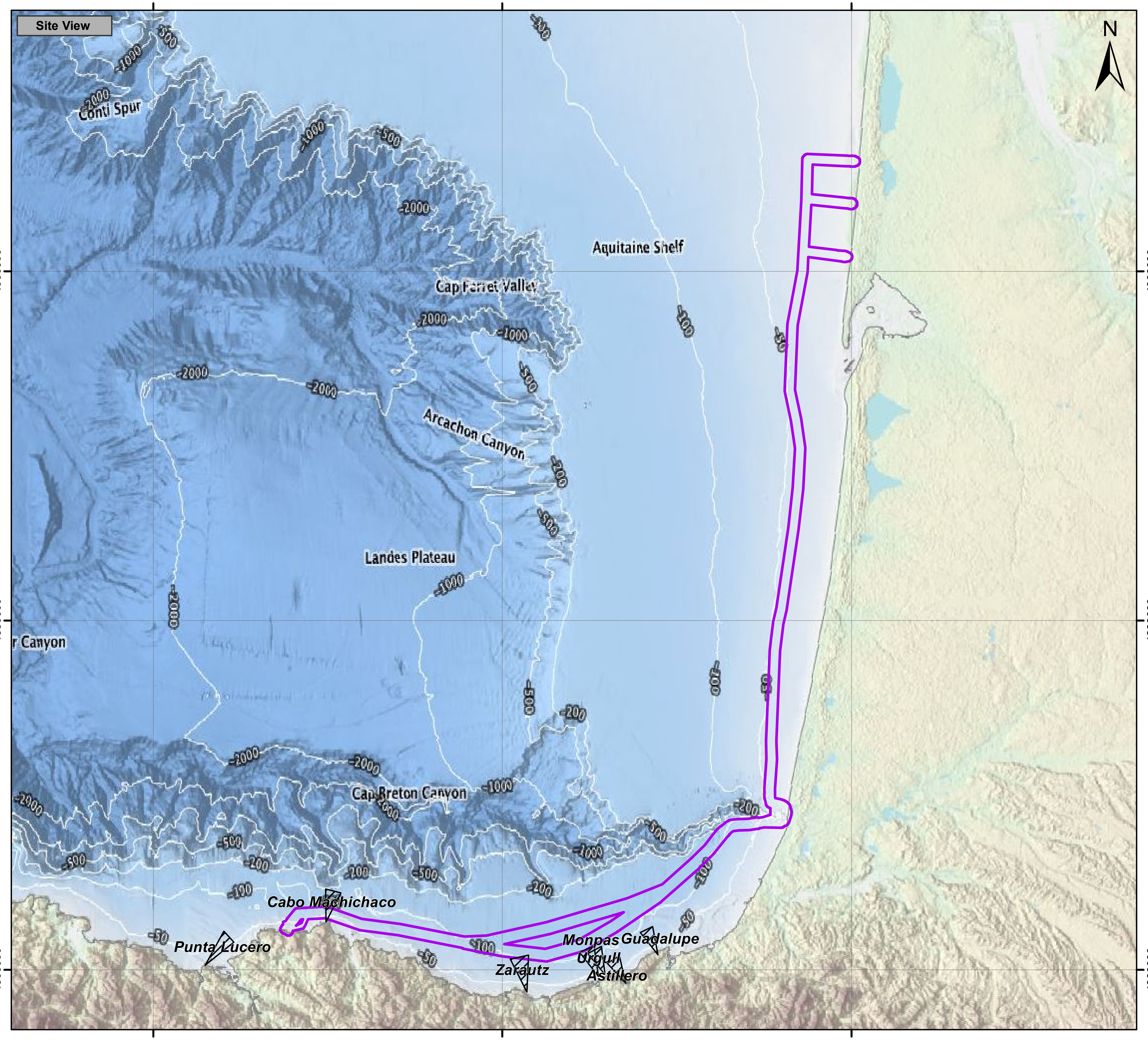
JM5353 - Bay of Biscay

Date Drawn: 19 May 2017
Drawing Reference: JM5353_DTS_03
Drawing Version: 1.1







Legend for Site View

- Biscay Gulf Interconnector Risk Assessment Corridor
- WWI Spanish Coastal Batteries

Horizontal Scale(s)

Kilometers: 0, 10, 20, 40, 60, 80

Nautical Miles: 0, 7.5, 15, 30, 45

Consultant: ORDTEK

Client: inelfe

Drawing Title: **Biscay Gulf Interconnector WWI Spanish Coastal Batteries**

User Notes

Note 01 - Biscay Gulf Interconnector Risk Assessment Corridor dervied from INELFE file "Survey areas 2016.kmz". For the purposes of charting, the Risk Assessment Corridor includes an additional 1km either side of the INELFE survey corridor.

Note 02 - Two possible alternative Spanish landfall HDD options have also been considered, as defined by REE "HDD option3 UXO risk assessment area.kmz" and "HDD option 5 UXO risk assessment area.kmz".

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WGS 1984 UTM zone 30N
Projection: Transverse Mercator
Datum: WGS 1984
false easting: 500,000.0000
false northing: 0.0000
central meridian: -3.0000
scale factor: 0.9996
latitude of origin: 0.0000
Units: Meter

Drawn by: AP
Checked by: LG

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JM5353 - Bay of Biscay

Date Drawn: 19 May 2017
Drawing Reference: JM5353_DTS_06
Drawing Version: 1.1

2.12 Dump Sites

For several decades after the World Wars, large volumes of chemical and conventional munitions were disposed of at sea. At the time, with public safety as a guiding principle, such disposal was considered best practice. The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention, 1972), ratified by many countries, now prohibits the disposal at sea of wastes, including munitions. These discarded munitions can be a significant hazard to offshore projects.

The two World Wars left a legacy of enormous quantities of munitions requiring disposal. The process had to be completed quickly and safely. Given the technical limitations of the time, sea dumping was the only practical method of disposing of the bulk of the munitions. It became the internationally accepted method of munitions disposal. Sea dumping continued until 1972 when the UK and other European nations adopted the London Convention on the Disposal of Wastes at sea.

The Oslo-Paris Convention (OSPAR), a collaborative agreement between European countries for the Protection of the Marine Environment of the North-East Atlantic, was open for signature in Paris in 1992 and entered into force on 25 March 1998. Since the end of the 1990s, the Oslo-Paris (OSPAR) Convention has systematically recorded the munitions dumping sites of the Eastern Atlantic Ocean and the North Sea. Both dumping areas and subsequent EO finds have been recorded and the distribution of activities leading to the discovery of EO plotted. Fishing vessels have found more than 50% of EO.

2.12.1 Condition of Dumped Munitions

It can generally be assumed that most of the munitions deposited at post-war dump sites were packaged robustly and dumped unfused. There is no reason to believe, therefore, that they will become unstable or present a hazard even if accidently disturbed. However, the state of corrosion of all munitions could vary from very little to completely degraded and therefore it is not possible to predict the condition of all types of EO in and around the dumping areas.

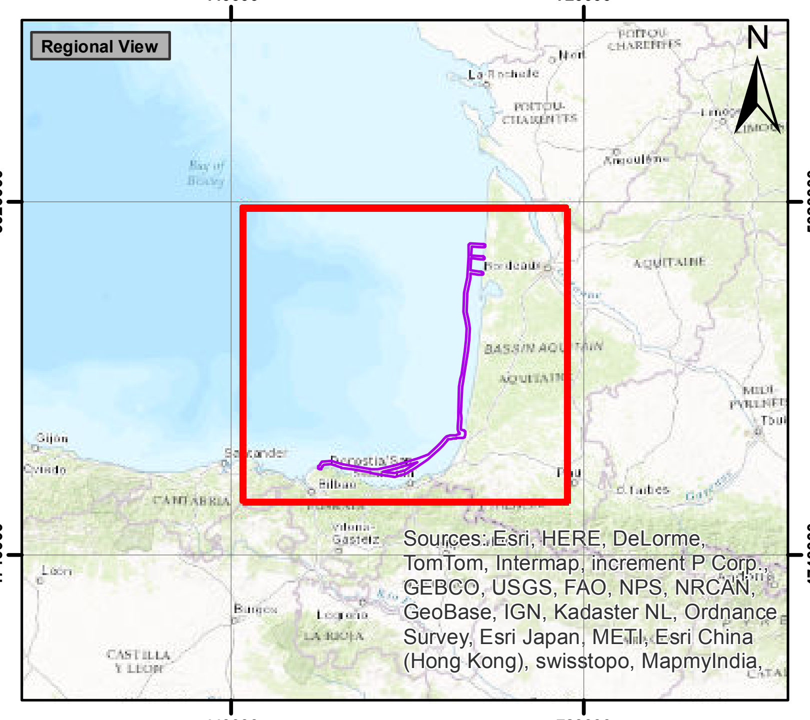
Anecdotal evidence has recorded occasional unexplained explosions in the vicinity of dump sites. No definite evidence of spontaneous detonation of dumped conventional munitions exists, but any EO which contained Shellite or Lyddite (highly sensitive picric acid based explosives) is far more likely to spontaneously detonate when disturbed than, for example, TNT filled munitions. This could arise if they were subject to an impact when the structure of a container collapsed or if they were struck by other items of ordnance falling onto them.

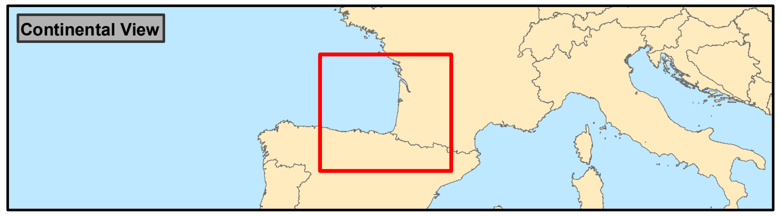
Picric acid is known to have an ageing problem through which metal picrates form, e.g. iron picrate. Such metal picrates are extremely sensitive energetic materials that can be initiated very easily. Shellite and Lyddite were a common WWI filling for large shells, including naval projectiles.

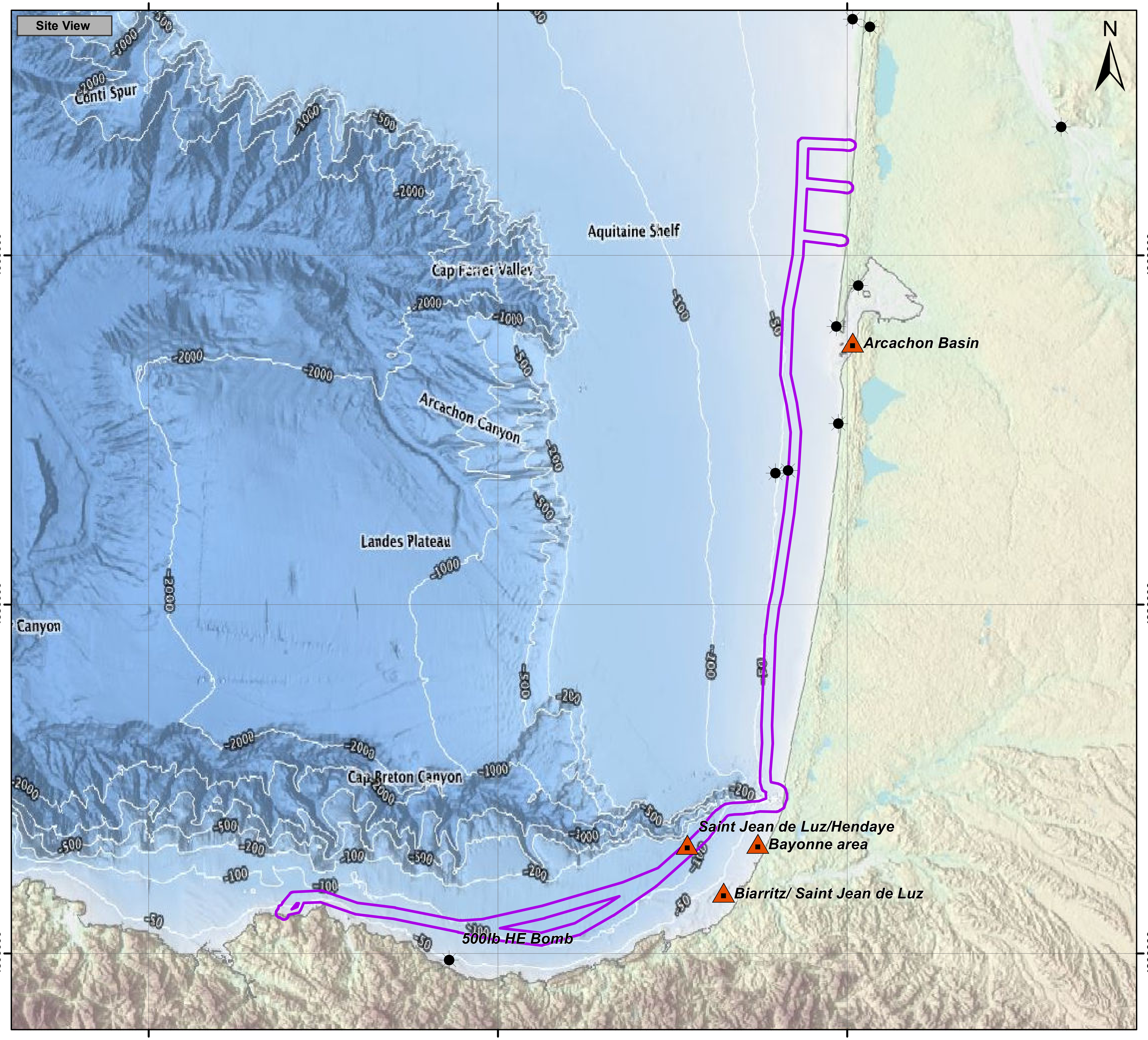
Munitions Dump Sites
The following dump sites affect the cable route: • The French maritime sector is affected by a temporary explosives dump site (No. 145 OSPAR – Arcachon Basin). • The Capbreton maritime sector is affected by three temporary explosives dump sites (No. 146, 147, 148 OSPAR - Saint Jean de Luz/Hendaye, Bayonne area and Biarritz/ Saint Jean de Luz). These types of depot, created in the 1990s, is intended to receive (temporarily) ammunition discovered during

Munitions Dump Sites
fishing activities. The affected party (fisherman) deposits the UXO at the listed point and reports it to the maritime authorities. The French authorities involve the “Groupement de Plongeurs Démineurs” (GPD; group of demining divers) relevant to the territory (for example Atlantic GPD), which eliminates the threat. The OSPAR 2010 document does not mention any permanent ammunition dumping area in the three maritime sectors of the Bay of Biscay project. Geomines conducted a search in the James Martin Center for non-proliferation studies Chemical Weapon Munitions Dumped at Sea (CWMDS) database. This database lists the known sites of voluntary immersion of chemical munitions throughout the world. There are no known sites in the vicinity of the study area of the Bay of Biscay project. **Due to the nature of these dumping sites – as temporary depots of found munitions, rather than a designated post war dumping site – it must be assumed any ordnance found in the vicinity will be fused and potentially in a sensitive state.**

Table 2.9 – Sources of Dumping within the Study Area







Legend for Site View

- Biscay Gulf Interconnector Risk Assessment Corridor
- OSPAR Temporary Conventional Munitions Dump Site*
- Conventional Munitions Encounter (to 2012)

* OSPAR munitions dump sites shown are designated temporary deposits for UXO discovered during fishing activities. UXO found are deposited at these sites and reported to the maritime authorities who arrange disposal.

Horizontal Scale(s)

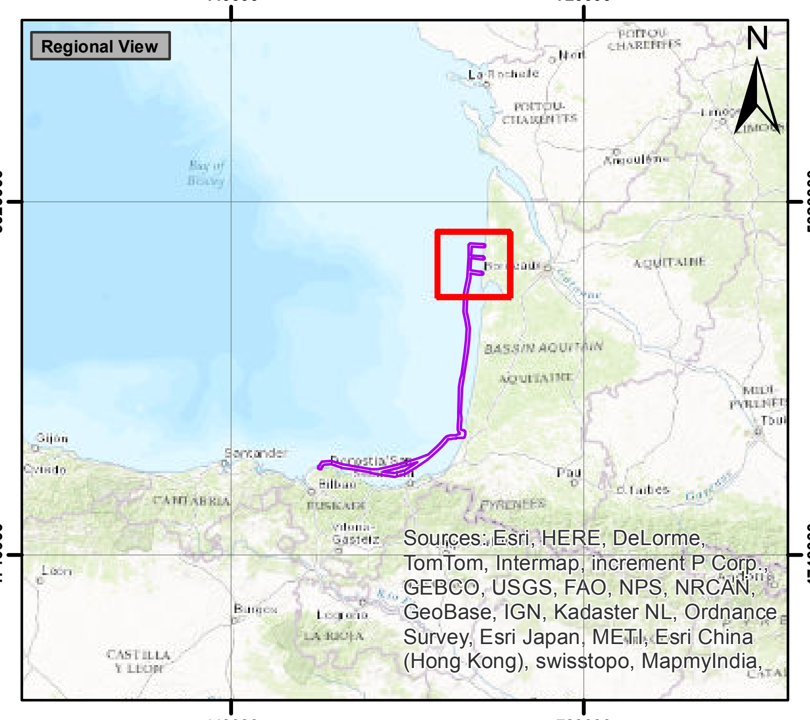
Kilometers: 0, 10, 20, 40, 60, 80

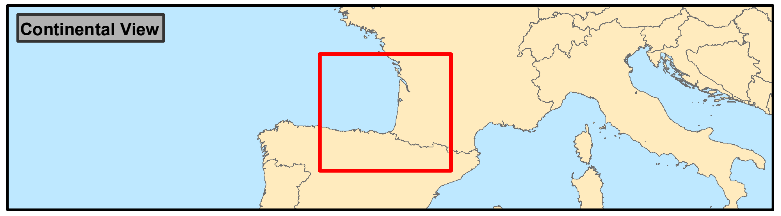
Nautical Miles: 0, 7.5, 15, 30, 45

Consultant	Client	Drawing Title	User Notes				
ORDTEK	inelfe	Biscay Gulf Interconnector OSPAR Munitions Dump Sites and Encounters	Note 01 - Biscay Gulf Interconnector Risk Assessment Corridor derived from INELFE file "Survey areas 2016.kmz". For the purposes of charting, the Risk Assessment Corridor includes an additional 1km either side of the INELFE survey corridor. Note 02 - Two possible alternative Spanish landfall HDD options have also been considered, as defined by REE "HDD option3 UXO risk assessment area.kmz" and "HDD option 5 UXO risk assessment area.kmz".	THE BRITISH ASSESSMENT BUREAU ISO9001	WGS 1984 UTM zone 30N Projection: Transverse Mercator Datum: WGS 1984 false easting: 500,000.0000 false northing: 0.0000 central meridian: -3.0000 scale factor: 0.9996 latitude of origin: 0.0000 Units: Meter	Drawn by: AP Checked by: LG Ordtek Limited, Herz House, Unit B21 Owen Road, Diss, Norfolk IP22 4ER, United Kingdom. (+44) 01379 644400	JM5353 - Bay of Biscay Date Drawn: 19 May 2017 **Drawing Reference: JM5353_DTS_04** Drawing Version: 1.1

2.13 Consolidated Threats

The following charts show the consolidated UXO threats along the route that has been used to develop the potential for UXO contamination conclusions.





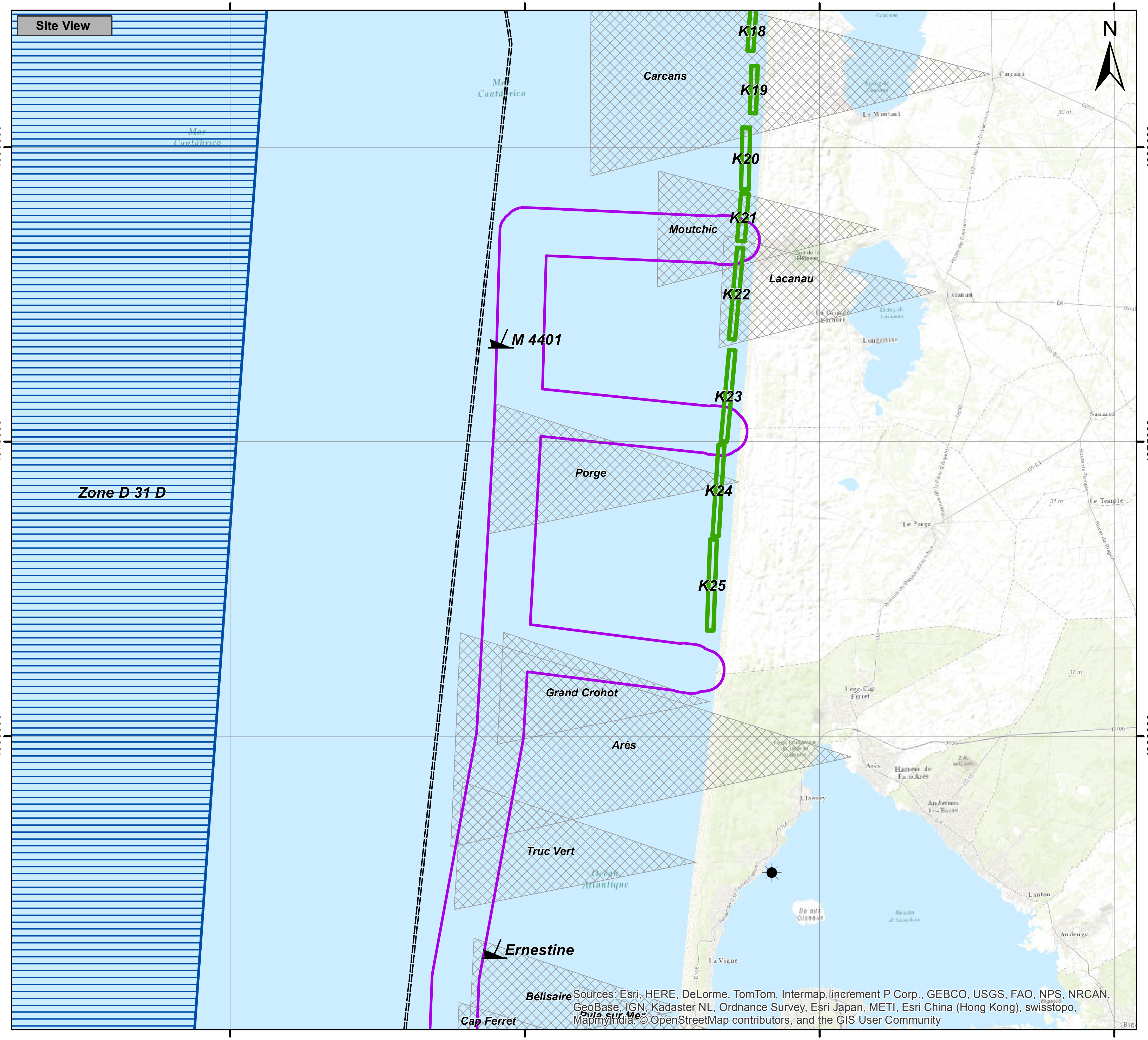
Legend for Site View

- Biscay Gulf Interconnector Risk Assessment Corridor
- Conventional Munitions Encounter (to 2012)
- WWII German Mine Laying
- Wreck of Military Interest
- WWII French Coastal Batteries
- Military Exercise Area

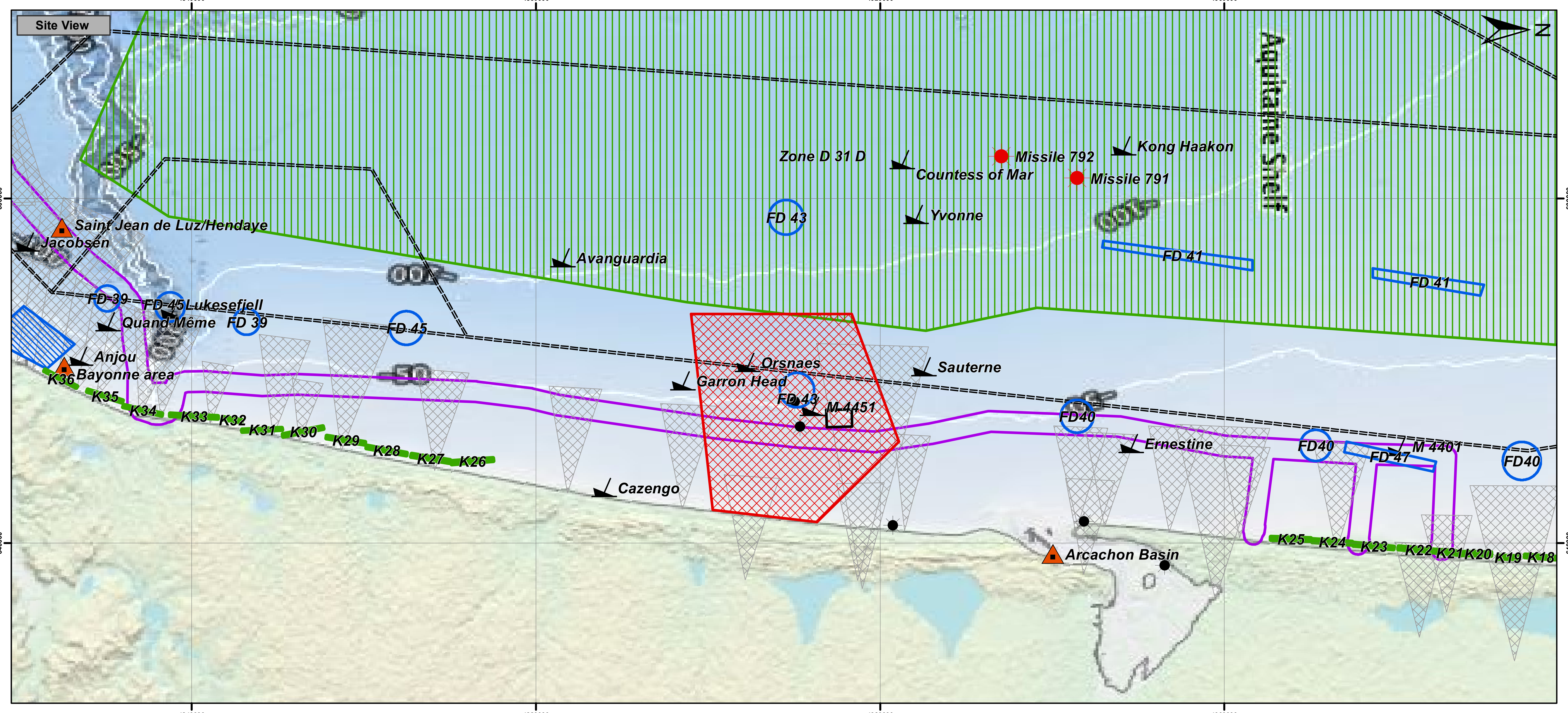
Horizontal Scale(s)

Kilometers: 0, 2.5, 5, 10, 15

Nautical Miles: 0, 1.25, 2.5, 5, 7.5



Consultant	Client	Drawing Title	User Notes				
ORDTEK	inelfe	Biscay Gulf Interconnector Cable Landfall - French Coast	Note 01 - Biscay Gulf Interconnector Risk Assessment Corridor dervied from INELFE file "Survey areas 2016.kmz". For the purposes of charting, the Risk Assessment Corridor includes an additional 1km either side of the INELFE survey corridor. Note 02 - Two possible alternative Spanish landfall HDD options have also been considered, as defined by REE "HDD option3 UXO risk assessment area.kmz" and "HDD option 5 UXO risk assessment area.kmz".	THE BRITISH ASSESSMENT BUREAU ISO9001	WGS 1984 UTM zone 30N Projection: Transverse Mercator Datum: WGS 1984 false easting: 500,000.0000 false northing: 0.0000 central meridian: -3.0000 scale factor: 0.9996 latitude of origin: 0.0000 Units: Meter	Drawn by: AP Checked by: LG Ordtek Limited, Herz House, Unit B21 Owen Road, Diss, Norfolk IP22 4ER, United Kingdom. (+44) 01379 644400	**JM5353 - Bay of Biscay** Date Drawn: 09 June 2017 **Drawing Reference: JM5353_DTS_11** Drawing Version: 2.0



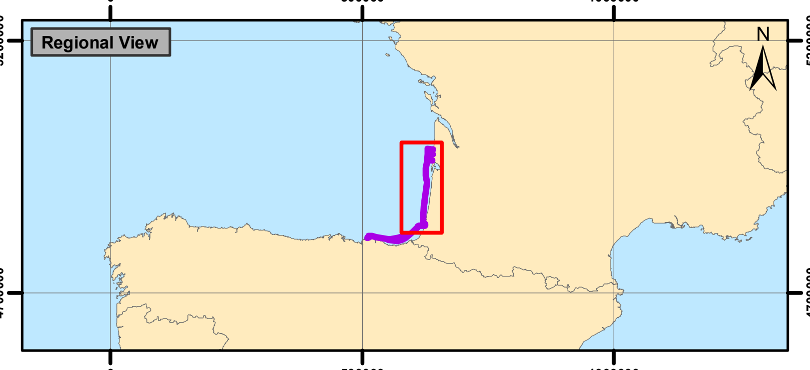
Legend for Site View

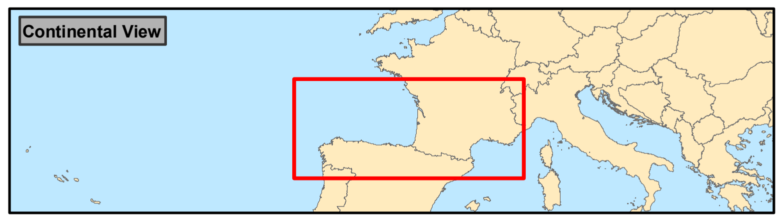
- Biscay Gulf Interconnector Risk Assessment Corridor
- WWII German Mine Laying
- WWII British Mining - Air Laid
- WWII British Mining - Surface and Submarine Laid
- Unexploded Missiles from French Military Training
- Conventional Munitions Encounter (to 2012)
- OSPAR Conventional Munitions Dump
- Submerged Munitions and Obstructions
- Zone Interdite/Le Coffre (Firing Box)
- Wreck of Military Interest
- German Convoy Routes (1943)
- WWII French Coastal Batteries
- French Military Exercise Area

Horizontal Scale(s)

Kilometers: 0 10 20 40

Nautical Miles: 0 5 10 20





Consultant	Client	Drawing Title	User Notes
ORDTEK	inelfe	Biscay Gulf Interconnector Sources of UXO Contamination	Note 01 - Biscay Gulf Interconnector Risk Assessment Corridor dervied from INELFE file "Survey areas 2016.kmz". For the purposes of charting, the Risk Assessment Corridor includes an additional 1km either side of the INELFE survey corridor. Note 02 - Two possible alternative Spanish landfall HDD options have also been considered, as defined by REE "HDD option3 UXO risk assessment area.kmz" and "HDD option 5 UXO risk assessment area.kmz".

THE BRITISH ASSESSMENT BUREAU ISO9001

WGS 1984 UTM zone 30N
Projection: Transverse Mercator
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false northing: 0.0000
central meridian: -3.0000
scale factor: 0.9996
latitude of origin: 0.0000
Units: Meter

Drawn by: AP
Checked by: LG

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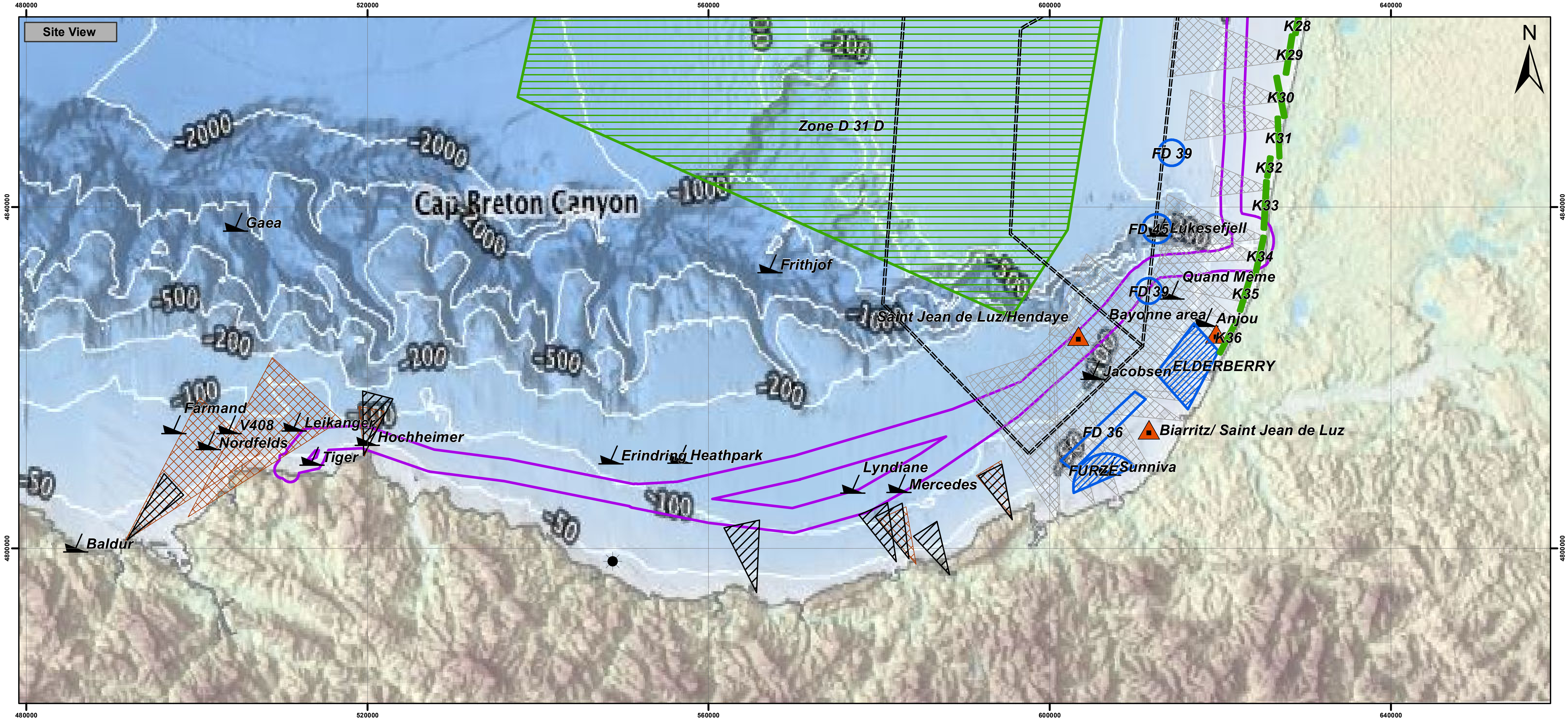
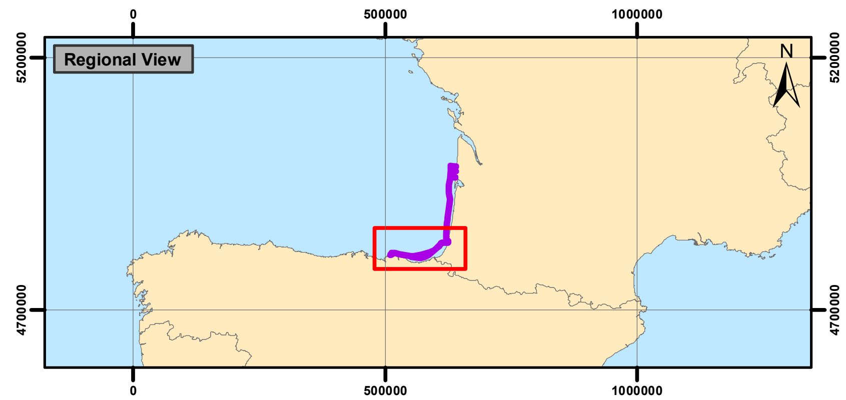
JM5353 - Bay of Biscay

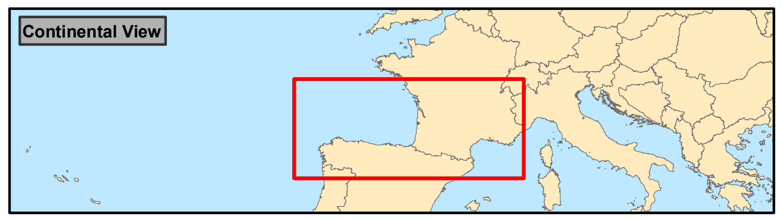
Date Drawn: 09 June 2017
Drawing Reference: JM5353_DTS_12
Drawing Version: 3.0



Legend for Site View

- Biscay Gulf Interconnector Risk Assessment Corridor
- WWII German Mine Laying
- WWII British Mining - Air Laid
- WWII British Mining - Surface and Submarine Laid
- Conventional Munitions Encounter (to 2012)
- OSPAR Conventional Munitions Dump
- Wreck of Military Interest
- German Convoy Routes (1943)
- WWI Spanish Coastal Batteries
- WWII Spanish Coastal Batteries
- WWII French Coastal Batteries
- French Military Exercise Area





Consultant

ORDTEK

Client

inelfe

Drawing Title

Biscay Gulf Interconnector Sources of UXO Contamination

User Notes

Note 01 - Biscay Gulf Interconnector Risk Assessment Corridor dervied from INELFE file "Survey areas 2016.kmz". For the purposes of charting, the Risk Assessment Corridor includes an additional 1km either side of the INELFE survey corridor.
Note 02 - Two possible alternative Spanish landfall HDD options have also been considered, as defined by REE "HDD option3 UXO risk assessment area.kmz" and "HDD option 5 UXO risk assessment area.kmz".

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WGS 1984 UTM zone 30N
Projection: Transverse Mercator
Datum: WGS 1984
false easting: 500,000.0000
false northing: 0.0000
central meridian: -3.0000
scale factor: 0.9996
latitude of origin: 0.0000
Units: Meter

Drawn by: AP
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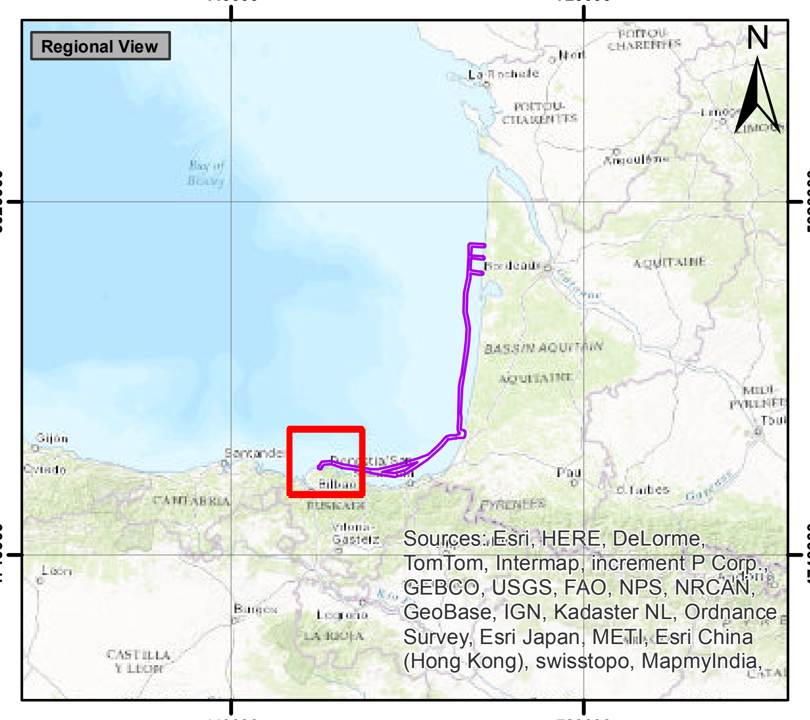
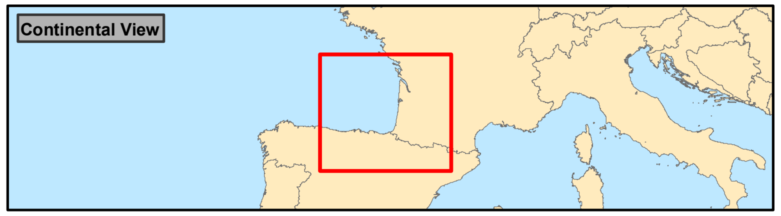
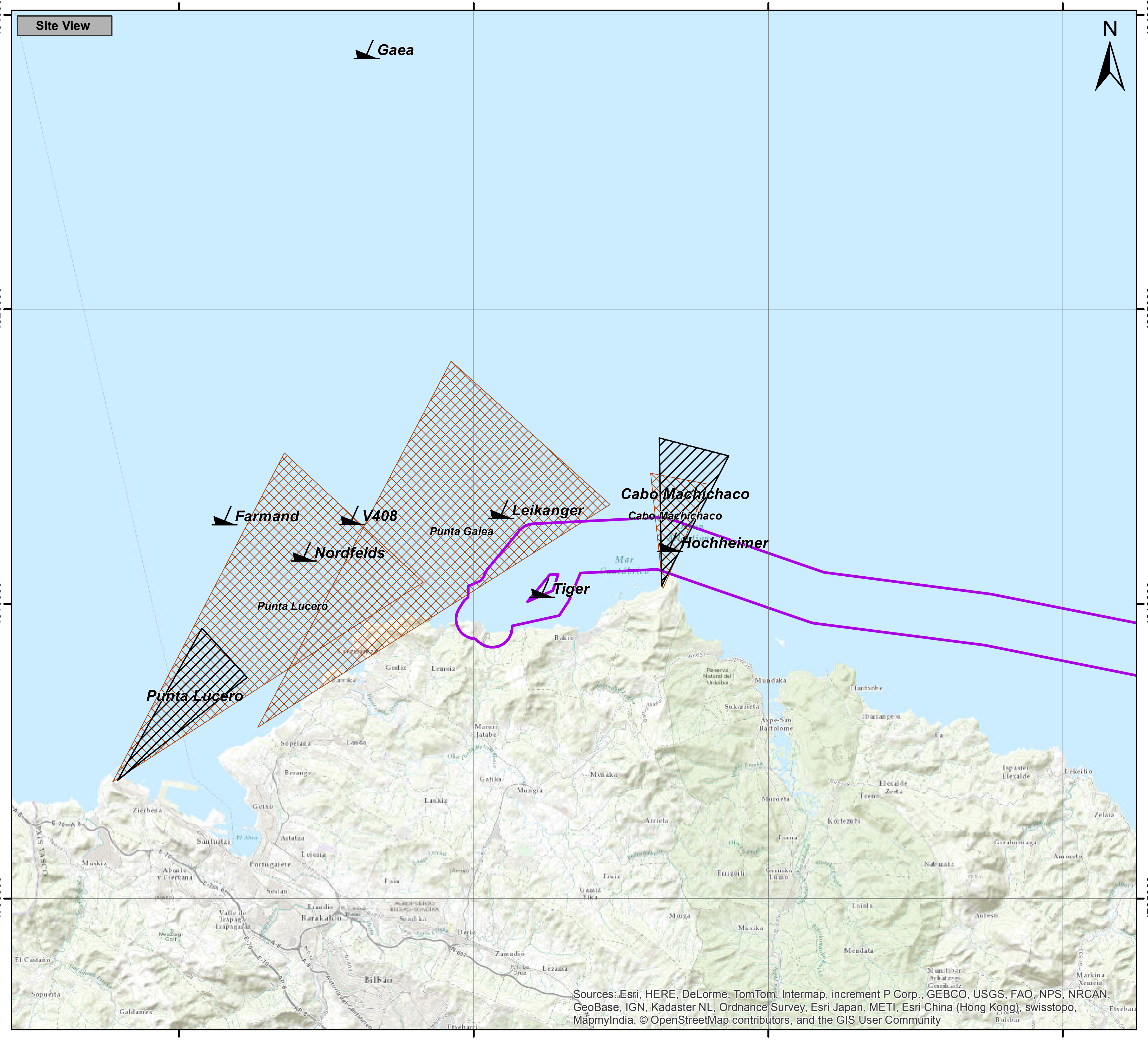
JM5353 - Bay of Biscay

Date Drawn: 09 June 2017
Drawing Reference: JM5353_DTS_13
Drawing Version: 2.0







Legend for Site View

- Biscay Gulf Interconnector Risk Assessment Corridor
- Wreck of Military Interest
- WWI Spanish Coastal Batteries
- WWII Spanish Coastal Batteries

Horizontal Scale(s)

Kilometers: 0, 2.5, 5, 10, 15

Nautical Miles: 0, 1.25, 2.5, 5, 7.5

Consultant	Client	Drawing Title	User Notes
ORDTEK	inelfe	Biscay Gulf Interconnector Cable Landfall - Spanish Coast	Note 01 - Biscay Gulf Interconnector Risk Assessment Corridor dervied from INELFE file "Survey areas 2016.kmz". For the purposes of charting, the Risk Assessment Corridor includes an additional 1km either side of the INELFE survey corridor. Note 02 - Two possible alternative Spanish landfall HDD options have also been considered, as defined by REE "HDD option3 UXO risk assessment area.kmz" and "HDD option 5 UXO risk assessment area.kmz".

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WGS 1984 UTM zone 30N
Projection: Transverse Mercator
Datum: WGS 1984
false easting: 500,000.0000
false northing: 0.0000
central meridian: -3.0000
scale factor: 0.9996
latitude of origin: 0.0000
Units: Meter

Drawn by: AP
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JM5353 - Bay of Biscay

Date Drawn: 02 May 2017
Drawing Reference: JM5353_DTS_14
Drawing Version: 1.0

2.14 Probability of UXO Contamination

The UXO items we consider most likely to be *present* within the study area are shown in Table below. Note that this table shows the probable *encounter* of generic UXO types within the Study Area based on the evidence we have gathered about potential UXO sources.

It is important to recognise that the probability of *encounter* (i.e. a positive interaction with the UXO during a specific Project activity) will generally be less than the probability of items of that particular UXO type being *present* across the whole study area; given that the actual Project activity footprint will be significantly less than the total study area. Among other factors, the probability of *encounter* will depend on the Project activity being undertaken and the potential for burial.

Probability of Contamination Key	
1	Very Unlikely
2	Unlikely
3	Possible
4	Likely
5	Very Likely

	Probability of Contamination								
UXO Threat Item	**Lacanau (Landfall)**	**Main Route La Cantine (landfall)**	**Main Route North (La Cantine)**	**Le Grande Crohot Option Route (Landfall)**	**Canyon Head Bypass Coast South Option Route**	**Alternative Canyon Head Bypass Coast Option Route**	**HDD Canyon Crossing Route**	**Additional Route Spanish Waters**	**Spanish Landfall Site**
German Ground Mine	3	3	2	3	3	3	3	1	1
British Ground Mine	1	2	2	2	3	3	3	1	1
British and German WWI Mines	1	1	1	1	1	1	1	1	1
Artillery and Naval Projectiles	5	5	5	5	5	5	5	5	5
Small HE Bombs (250lb)	3	3	3	3	3	3	3	3	2

Probability of Contamination Key	
1	Very Unlikely
2	Unlikely
3	Possible
4	Likely
5	Very Likely

UXO Threat Item	Probability of Contamination								
	Lacanau (Landfall)	Main Route La Cantine (landfall)	Main Route North (La Cantine)	Le Grande Crohot Option Route (Landfall)	Canyon Head Bypass Coast South Option Route	Alternative Canyon Head Bypass Coast Option Route	HDD Canyon Crossing Route	Additional Route Spanish Waters	Spanish Landfall Site
Large HE Bombs (500lb and greater)	3	3	3	3	3	3	3	3	2
Depth Charges and Torpedoes	1	2	2	2	2	2	2	2	1
British and German WWII Buoyant Mines	1	3	3	3	3	2	2	2	1
Land Service Ammunition	1	3	3	3	2	1	1	1	2

Table 2.1 – Likelihood of UXO encounter along the Biscay Gulf Western HVDC Interconnector.

3 UXO and Interaction in the Natural Environment

3.1 Seabed Conditions

3.1.1 General Description

Along the route the surficial geology is predominantly SAND with occasional deposits of SILT and fine SAND interspersed with a hard substrate interpreted and SAND and GRAVEL. In addition BEDROCK outcrops and boulder fields are located at several sections along the route. “Dune-like” bedforms of fine to medium SAND 1 to 2 m thick overlying coarser sediment of SAND and GRAVEL occur across the Aquitaine shelf in French Waters. Smaller scale ripples are seen intermittently along most of the route.

The shallow geology typically comprises of unconsolidated SAND sediments that range from 0 to 20 m thickness although tending to be 1 m to 2 m in thickness over a large portion of the route. Underlying these is a denser SAND and GRAVEL unit that has been channelled along some sections. Two harder substrates nominated as Consolidated Sediment and BEDROCK are the other two lithological units that come within the top 5 m of seabed. In addition, there are boulder fields in the south of the canyon and a large rocky plateau at the Spanish landfall.

3.1.2 Seabed Mobility

Ordtek have been informed site specific seabed mobility studies are not planned until after the UXO survey. However, where the *MMT* report suggests that the sediment is mobile, we have used our experience of previous offshore projects and assumed that UXO may be buried to the maximum height of minor bedforms (megaripples/ripples). For larger sand waves, we have made a judgement based on previous experience of projects in the region to determine whether the bedform is likely to be mobile in the period under consideration (i.e. ~100 years). For example, sandy bedforms forced by tides and currents in relatively shallow coastal waters are generally mobile, whereas, it can be safely assumed that “relict” bedforms in deeper waters are not.

Similarly, we have no Project-specific data on the amount or likelihood of sediment deposition or erosion along the route; though we have been informed at the 3 French landfalls in the very nearshore area, the immerged beach is eroded up to 4m thickness during each significant storm. There are a number of open-source academic studies available and we have made use of some of these but we have found that these are not definitive and can be contradictory. Therefore, we have made what we consider reasonable assumptions based on our previous experience of other Projects in the Bay of Biscay and our general understanding of sediment transportation mechanisms and seabed morphology over time described in the studies mentioned.

3.2 UXO Burial

3.2.1 Overview

Over a period of several decades, the seabed level within an area can change due to the process of sediment accretion (also sometimes referred to as “deposition”) or erosion. It is an important factor that must be taken into consideration when determining the potential for UXO burial. The movement of sandy bedforms (ripples, mega-ripples, sand waves, etc.) also has the potential to bury (or expose) items of UXO over time and therefore the seabed sediment composition, morphology and mobility must also be considered. Bedforms in shallow water migrate and change shape due to forcing by tides and currents. Most active bedforms are those formed of sand, although where currents are strong, particularly in the nearshore, gravel can also be mobilised; this is particularly prevalent during high-energy storm events.

Within dynamic sediment conditions, UXO items are likely to become buried; the depth of burial at any one location is dependent on a number of variables that will be explored below. It should also be noted however that where seabed conditions are relatively stable (limited or no accretion or bedform movement) or where there is limited or no sand/gravel cover UXO burial is less likely and in some environments does not happen.

- **Initial impact** – within water depth <5m LAT
- **Liquefaction** – within shallow and nearshore sands/silts
- **Self-burial by scour, sinking and backfill** – within sands and silts,
- **Bedform migration** – within areas of sandwaves and mega ripples

Figure 3.1 below shows an example of how the combination of self-burial, sediment accretion and sand wave migration might lead to deeply buried UXO.

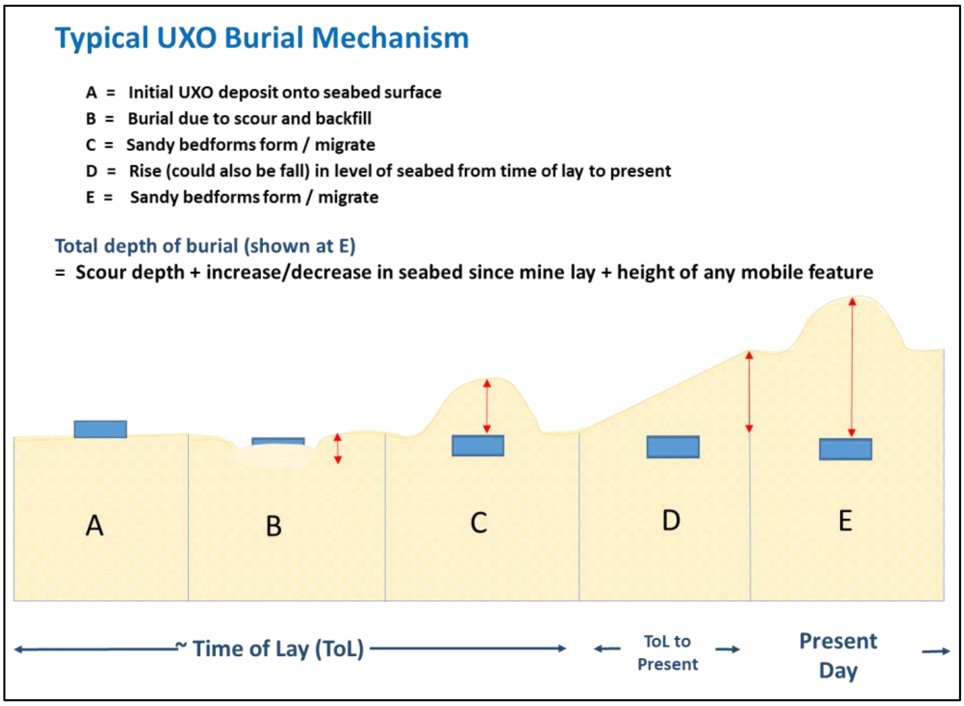


Figure 3.1 – Typical UXO burial mechanisms

3.2.2 Initial Impact Penetration

The first mechanism for UXO burial to consider is that due to initial impact, however this method is only applicable within water depths less then 5m LAT.

The depth an air-delivered bomb will penetrate to on land is well understood; there is ample empirical data from WWII on which to base a reasonably accurate estimate. However, determining how far an unexploded bomb will penetrate into the seabed is more problematic. As on land, it depends among other factors upon its speed of entry, which is a function of the height from which it is dropped, its weight and construction, its shape, the angle of entry, and the properties and underlying geology of the sediment. However, in the maritime environment, the bomb's kinetic energy is rapidly attenuated by the water it passes through and its trajectory underwater is altered from near perpendicular in the air to a much shallower angle of entry into the sediment.

To our knowledge, there is no comprehensive and proven data on which to base a reliable calculation regarding how far a bomb will penetrate into the seabed in various depths of water and in differing sediment conditions. However, experiments on Mk84 bombs in the USA show that the trajectory of a bomb falling into water at an angle of entry of ~90° is rapidly altered by the new medium, reaching near parallel to the seabed by a depth of around 5m (*Chu et al.*, 2010). For a period subsequently, the bomb orientates to fall tail first, but by now it can be assumed that most of the kinetic energy gained through its fall through the air has bled off and at whatever angle the bomb finally strikes the seabed, its burial due to impact will be minimal.

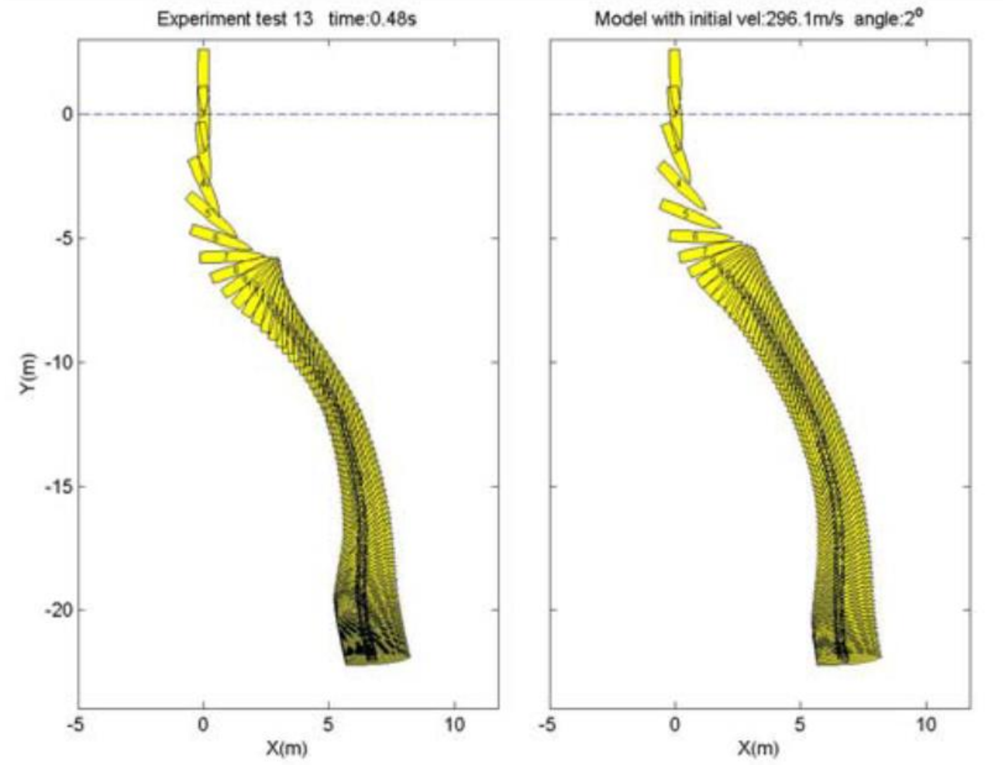


Figure 3.2 – Comparison between modelled and observed Mk84 bomb trajectories (Chu et al., 2010).

Thin-cased blast bombs and sea mines (when laid by air) were usually retarded by parachute and, unless they fell on particularly soft material, are very unlikely to penetrate into the seabed on initial impact.

Historical records and predictive tables devised during WWII are typically used to calculate the maximum bomb penetration depth for mitigation. While these are a valuable reference source, they should be treated with caution and interpreted accordingly:

- Typically bomb penetration tables and predictive models use homogenous geology types and strengths that are not always applicable to a site in question. This is a problem for sites where sediments in the historical reports consider a far softer material than the dense sands (<3m) and clays.
- The reference tables do not take into account the often complex layering of shallow sediments.

- Predictive theoretic maximum penetrations are cited as 1 UXB in 10,000 bombs reaching the deeper depths.
- These tables only display absolute figures and do not account for the statistical distribution of bombs with depth. In reality the vast majority of UXBs found are less than half of the maximum bomb penetration depth. This is demonstrated if we consider 213 individual UXB finds in “gravels” (on land) from WWII:
  - 53% of all UXBs from 50kg to 1,000kg were buried between 1m and 3.2m bgl.
  - 91% of all UXBs from 50kg to 1,000kg were buried to 6m bgl.
  - 9% of all UXBs from 50kg to 1,000kg were buried within 6m and 8.3 bgl.
- Considering water cover and saturated soils, even below <5m, water will have a retarding effect on a bomb.

Therefore there is the potential for bombs to be buried deeply within the nearshore and landfall environments.

3.2.3 Liquefaction

UXO burial due to liquefaction can occur on initial impact or in relatively shallow water due to wave motion. The phenomenon of liquefaction is most often observed in saturated, loose uncompacted silty sands and sandy soils. Loose sand has a tendency to compress when a load is applied; dense sands by contrast tend to expand in volume (i.e. dilate). If the sand is saturated, then water fills the gaps between sand grains ('pore spaces'). In response to the sand compressing, this water increases in pressure and attempts to flow out to zones of low pressure (usually upward towards the surface).

3.2.4 Self-Burial by Scour, Sinking and Backfill

The self-burial process by scour, sinking and backfill depends upon sediment grain size; as this becomes coarser, and approaches gravel size, seabed burial will reduce and instead a settling effect will occur working the UXO partially into the seabed. UXO self-burial on hard consolidated surfaces such as clay or chalk will not occur. Where the required conditions, sediment grain size and tidal flow, are met UXO burial by scour, sinking and backfill will occur.

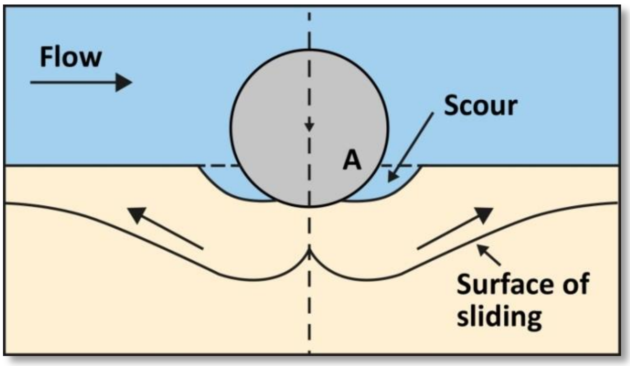


Figure 3.3 – Scour mechanism

When an item of UXO is situated on an unconsolidated sediment bed in the tidal flow, wave motion and currents of a marine environment, scour will develop in its immediate vicinity. The local change in the flow will generally cause an increase in the bed shear stress and in the turbulence level, resulting in an increased sediment transport close to the structure and thus leading to scour. After the onset of scour, the scour occurs in the form of tunnel erosion, which is followed by lee wake erosion. The scour depth approaches a steady state through a transitional period.

The type and transitional phase of the self-burial, before equilibrium is reached, will depend among other factors on the shape and weight of the UXO item and sediment grain size. However, the mechanism is essentially the same in all cases. There are three stages in this UXO/seabed interaction process: scour, sinking, and backfilling. As the process continues, the underlying bearing area reduces, placing an increasing load on the sediment. Eventually, the bearing capacity of the sediment is exceeded and it fails. The failure occurs by sliding in an outward direction. As the scour continues, this process is repeated, leading to the permanent sinking of the UXO. The process will stop only when the UXO sinks to such depths that it will be protected against scour. When the scour stops, the repeated failure of the bed will stop, and consequently the sinking of the sphere will come to an end (*Truelson* e*t al.,* 2005). In the final stage, the space between the UXO and the scour hole is gradually filled with sand, this is known as backfilling.

Within test conditions self-burial of a sphere in sand (0.18mm) has been seen to reach equilibrium at 0.5 x the diameter (*Truelson* e*t al.,* 2005). For a bomb shaped cylinder, it will vary on precise shape and circumstances but will be similar to the sphere, and around 0.6 x the diameter.

In finer sediment (silts and sands), self-burial is likely to be greater becoming closer to complete burial of the item (0.6<1 x UXO diameter), however where the sediment is coarser, or consists of gravel or pebbles, the maximum scour depth will be less; varying with the granularity from 0<0.6 x UXO diameter.

3.2.5 Bedforms and Accretion

UXO burial (and exposure) is also caused by the formation and migration of bedforms such as sand banks, sandwaves, ripples and mega ripples. The presence and size of these features are a function of grain size and seabed current orbital velocity.

The characteristics of the sediments and distribution of grain sizes, coupled with the wind, wave and current conditions dictate the characteristics that can cause sandwaves to occur. Sandwaves form because the sand grains have a roughness which creates turbulence as water flows over the surface. When the drag on a particle gives it an uplift force which exceeds its weight, it is transported along the seabed. Relatively slow flow speeds can achieve this effect for sand particles. Gravel, however, because it is heavier than the uplift force that is generated over its surface, tends to be more stable. This propensity to move in relation to grain size is illustrated in the *Hjulström* curve (Figure 5.4).

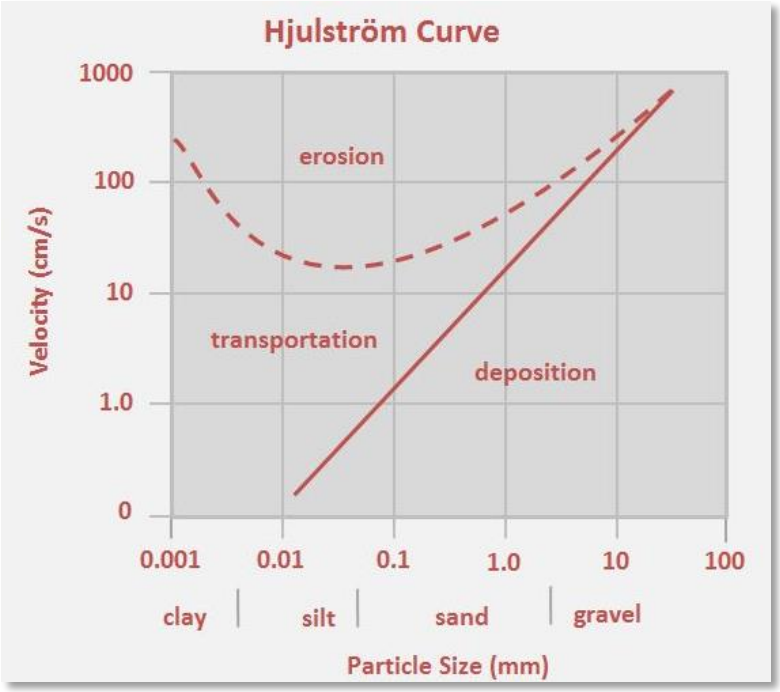


Figure 3.4 – Hjulström Curve

The graph is used to determine whether an area will erode, transport, or deposit sediment. The dotted line is the critical erosion velocity line: the minimum current velocity before the particles are eroded. The solid line shows the critical deposition velocity: the minimum current velocity before the particles are transported.

As a sediment bedform moves across the seabed, any UXO in its path will be alternatively buried and exposed. For very large formations, such as migrating dunes, the resulting motion and burial depth of UXO has the potential to be quite complex, depending on where the UXO originally falls; whether, for instance, it lands on the forward slope, crest or back slope of the feature. The UXO will tend to gravitate towards the base of a slope but not necessarily reach equilibrium at the deepest point. However, taking the worst case, it follows that the burial depth of the UXO will vary with the depth of any bedform that covers it.

When added to self-burial by scour, the resultant maximum UXO depth in the sediment will be the height of the feature plus the self-burial.

3.3 Burial Assessment Conclusions

Using the information seabed conditions (see *Appendix 1*) the conclusions on the potential for UXO burial are presented below:

- UXO may be completely buried in ripple and sand wave areas, up to the full height of the bedform, which could be several metres.
- In the highly dynamic sands, in the absence of bedforms, UXO is likely to be buried to ~2m.
- In areas of sand and gravelly sand areas where there are no bedforms, UXO is likely to be partially exposed; showing around 0.4 diameter above the sediment.
- In areas of gravel, burial due to scour will be substantially less than in sandy areas and may not have occurred.
- In areas of outcropping bedrock UXO will be exposed on the seafloor.

- Over the areas within the cable corridor where burial is likely to be negligible, depending on size and orientation, large items of UXO should be visible to SSS. However, these areas often coincide with concentrations of boulders, which will complicate SSS data analysis.
- Although the probability of encounter is considered very low, in the inter-tidal zone HE bombs could be deeply buried (up to ~3.5m for the most common bomb types; ~9m for the most common large bombs).

3.4 UXO Migration Conclusions

It is often a misconception that UXO movement is equal or similar to sediment migration, i.e. is caused by it. The probability of an item of UXO migrating along the seabed due to water flow (tidal stream/current) is a function, among others, of seabed composition, firmness and morphology (slopes, ripples, troughs, boulders etc.); the current strength, duration and persistence of direction; and the weight, shape (particularly of protrusions, such as lifting lugs) and orientation of the UXO.

The maximum tidal flow is < 0.5m/s at the level of the seabed. Given that most UXO is likely to be at least partially buried by scour, UXO migration due to this mechanism is considered very unlikely.

Some smooth, cylindrical types of UXO, such as ground mines and torpedo warheads, have been known to roll along the seabed when conditions are favourable; i.e. if the seabed is flat and without obstruction, if it is firm and if the current is strong enough and predominantly uni-directional. If the UXO is laid in shallow water, storm surges etc. can also produce the conditions necessary to move UXO from its original position. In view of the depth of water along the majority of the cable route, relatively low tidal flow and partial burial due to scour that will have occurred, it is very unlikely that these conditions will be met on this Project.

It is very common for fishing trawlers to encounter UXO; either knowingly by bringing it into the vessel in their nets or inadvertently by dragging an item for a distance along the seabed before it eventually falls free. In fact, 50% of finds reported to the OSPAR commission have been due to fishing activity. Anecdotally, fishermen that have recovered UXO in their nets have also been known to occasionally dump it back into the sea, often near a known wreck, rather than report the incident. *Ordtek* considers that this is the most likely vector for migration of UXO into the site, post mitigation and across the life of the wind farm.

Of note, in reality it is very difficult to quantify this migration mechanism within a risk assessment; mainly because finds are rarely recorded. Those that are, are not usually done so collectively as a coherent archive. The number of encounters and post-find disposal areas cannot therefore be measured with any accuracy. Moreover, unseen, inadvertent movement of UXO, i.e. dragged by a trawl for a distance and then released, is by its nature unquantifiable. Nonetheless, it is important to consider this migration factor as part of the baseline residual risk.

Many modern trawls do not penetrate the seabed; they are designed to ride over boulders and other debris. UXO already buried will not be moved by this process and it is very unlikely that even modern UXO deposited as the result of relatively recent ad hoc naval and air exercises in the area will be caused to move.

Ordtek has a raft of ground truth data and evidence to show that UXO remains at their relative position to support these opinions. This includes comparison of both pre-installation survey data and annual UXO/anomaly inspections.

4 UXO Risk Assessment (Baseline Pre-Mitigation)

4.1 General

The risk that UXO poses to a Project activity is the product of three key elements:

- The likelihood of encountering an item of ordnance.
- ***If*** that encounter happens, the likelihood of the UXO detonating.
- ***If*** the UXO detonates, the severity of the consequence to vulnerable receptors (people and equipment).

4.2 Likelihood of Encounter

4.2.1 General

Likelihood of encounter, the first element, is a function of the density of UXO items and the total area of intrusive engineering interaction of as a proportion of the total area of the site (to be accurate: by volume to the maximum intrusive depth). It is rarely possible to know precisely how many items of UXO are potentially present within the site boundary (if any) but we make a judgement call based on the results of our historical search, our experience and our knowledge of the types of project activities to be undertaken.

The factors to consider for the study area in relation to each other are:

- Likelihood of UXO burial
- Likely density of UXO by type
- Areas covered
- Project activities
    - Intrusive (deep)
    - Intrusive (shallow)
    - Non-intrusive

Drilling will intrude into the sediment well below the likely maximum burial depth of all types of EO and any of the UXO items articulated in Section 2 could be encountered during CPT/VC/BH operations.

4.3 Likelihood of UXO Detonation

4.3.1 Factors Affecting Likelihood of Detonation

The second element, *Likelihood of the UXO detonation*, we cannot know with any accuracy: most UXO that has been in the ground for a long time is relatively stable, even if subjected to unintended vigorous stimuli but, if the explosive ordnance is for any number of reasons particularly sensitive, or it is hit hard or crushed, it could detonate. However, the risk of detonation can be reduced by the adoption of certain mitigation measures, considered later in this report.

The factors, among others, that will affect the UXO's susceptibility to inadvertent detonation are:

- Condition and type of UXO
    - Sensitivity to impact (kinetic energy)
    - Sensitivity to crushing

    - Sensitivity to friction, heat, static electricity
    - Sensitivity to movement and vibration
        - Cocked strikers
        - Clockwork fuses re-starting
        - Highly sensitive metallic salts within fuse pockets etc.
    - Sensitivity to sympathetic detonation
        - Burial depth
        - Orientation
        - Proximity to donor charge / energy source (e.g. plough)
- Type of Interaction
    - Kinetic blow, crushing, vibration etc. as above

Before a weapon can detonate, a sequence of events must happen, called the Explosive Train (also known as the Firing Train), which starts with the removal of any safety measures and culminates in the detonation of the main charge of high explosive.

The accidental detonation of an item of UXO that has lain undisturbed on the seabed for several decades is a rare event, even when subjected to quite a heavy shock such as being struck by heavy equipment or dragged by a ship's anchor.

Most HE weapons have four principal components: a fuze (the part of the weapon that initiates function), a safety and arming mechanism/unit (often contained within the fuze), a detonator and a main charge. Additionally, most EO has a booster charge (also variously known as the primer or gaine) between the detonator and the main filling, to give the detonation shock wave from the initiating detonator sufficient energy to ensure the weapon's complete detonation.

The detonator is filled with a Primary Explosive, such as Lead Azide, which is extremely sensitive to stimuli such as impact, friction, heat or static electricity and a relatively small amount of energy is required for its initiation. The detonator's purpose is to trigger the primer and, subsequently, the larger main charge. This is made of much less sensitive Secondary Explosive and requires substantially more energy to be initiated but is relatively safe to store and transport. The safety and arming system ensures that the detonator and main charge remain separated and the firing chain broken until the weapon is clear of its carrier/launcher and is in a position to function as designed.

Although it may not actually be the case, when UXO is encountered, it must always be assumed that the explosive train is intact: that is, all safety measures have been removed and the detonator is in contact with the main charge.

Nevertheless, the main filling is inherently stable and such a detonation is a rare event, even when UXO has been subjected to robust handling, for example when a bomb is caught up in a dredger head or ship's anchor. Most UXO – particularly EO that has lain on the seabed for several decades – will have been the subject of significant corrosion to its casing and to any mechanical moving parts. It is extremely rare for UXO found on the seabed to function as intended; detonation will almost always be the result of unusual and vigorous kinetic stimuli.

4.3.2 Detonation Mechanisms during Geotechnical Activities

From the previous paragraphs it can be seen that for a detonation to occur, the UXO must be in a sensitive state and a certain set of conditions satisfied. It is evident from the many items of UXO that are recovered from building sites, farmers' fields, anchor flukes, fishing nets and dredger buckets every year that these conditions are hardly ever met and an accidental detonation is unusual.

The potential for UXO to be initiated if encountered during project operations will depend on its condition and the energy with which it is struck or moved, or if it is subjected to friction or excessive heat. The movement of vessels and implementation of non-intrusive surveys will not result in the initiation of ordnance through influence alone.

There are two main mechanisms that have the potential to cause unintended detonation of an item of UXO:

- Crushing of the casing, leading to the detonation of the EO's detonator (the main filling is unlikely to be initiated independently).
- A blow with sufficient energy by heavy equipment or, perhaps, a drill bit against a sensitive fuse pocket or exposed detonator.

In all but the most unusual circumstances, for a high order detonation initiated by the detonator to occur, the EO needs to have been armed; i.e. the detonator is in intimate contact with the primer and main charge.

The first mechanism is most likely to happen during the deployment of a seabed platform and the second during cone penetration and vibracoring. In these cases, encounter and interaction with the UXO must occur first, therefore the probability of the event is extremely low.

In theory, cone penetration and vibracoring could deliver a blow or friction with sufficient energy to the detonator of an item of UXO to cause it to detonate. However, employing a camera survey prior to the start of drilling will significantly reduce the chance of encountering a large item of UXO, such as a ground mine or large bomb. These are less likely to be completely buried than smaller items such as naval and artillery projectiles. Although not essential to deploy a drop-down camera ahead of geotechnical sampling for UXO risk mitigation, if the facility is available it will reduce the risk further. Moreover, given the complex surface geology in Spanish waters, it may not be fully possible to discriminate UXO from the rocky or boulder conditions. Therefore, the use of a camera on the rock corer is advised for UXO mitigation.

For detonation to occur with a buried item, the drill (VC) or rod (CPT) would have to encounter the casing of the UXO normal enough for it not to glance off/be pushed to one side and to be in exactly the right place; either to hit an external fuse pocket/fuse, which is in a sufficiently sensitive state for it to be caused detonate, or to break through the casing and strike the detonator.

It is also possible that the vibrations associated with rotary sonic coring could initiate the detonator without penetration of the casing; however although the propagation from a rock corer would be slightly higher than from VC through sediments, we consider the statistical probability of both events as extremely low.

4.4 Effects and Consequences of UXO Detonation

4.4.1 Overview

Severity of consequence of detonation, the third element of the risk calculation, is a multifaceted issue depending on a wide range of variables – sensitivity of receptor (e.g. robustness of the vessel/equipment) and protection (are deck crew below the water line, on deck, under hard cover etc.), range from UXO, type of weapon (casing, filling type, charge weight, orientation), depth of water, depth of burial, sediment/ground consistency etc. Quantifying the precise damage that may occur to a vessel or equipment from a specific item of UXO will depend on how its construction reacts to the shock and impulse generated. *Ordtek* can therefore only offer generic advice. The equipment manufacturer and naval architects are best placed to make this calculation.

4.4.2 Effects of Detonation Underwater

When an item of UXO detonates on the seabed underwater, several effects are generated, most of which are localised at the point of detonation; such as crater formation and movement of sediment and dispersal of nutrients and contaminants. Surface vessels and submarine equipment are also susceptible to the rapid expansion of gaseous products known as the “bubble pulse”; in this instance damage is caused by a water jet preceding the bubble and lifting and whiplash effect that can break the back of a ship. Once it reaches the surface, the energy of the bubble is dissipated in a plume of water and the detonation shock front rapidly attenuates at the water/air boundary. Fragmentation (that is shrapnel from the weapon casing and surrounding seabed materials) is also ejected but does not pose a significant hazard underwater for receptors more than ~10m away.

The effect that causes damage to structures and vessels is shock transmitted through the seabed and water column.

4.4.3 Shock

The principal effect that causes damage to vessels and structures in the far field is shock transmitted through the water column and the seabed (ground). The severity of consequence of UXO detonation will depend on many variables but principally the charge weight and its proximity to the receptor. In simple terms, the larger the UXO charge weight and the closer it is to any given structure, the more damage it may cause.

The shock wave from a detonation consists of an almost instantaneous rise in pressure to a peak pressure, followed by an exponential decay in pressure to the hydrostatic pressure. Initially, the velocity of the shock wave is proportional to the peak pressure but it rapidly settles down to the speed of sound in water, around 1,525 metres per second (m/s). In shallow, normally consolidated sediments and rock this can increase to ~1,800m/s. After detonation the shock wave will expand spherically outwards and will travel towards any particular receptor in a straight line – i.e. line of sight. Therefore, unless the wave is reflected, channelled or meets an intervening obstruction, for all practical purposes, the object will not be affected by the pressure wave if it is out of line of sight.

There is very little literature that covers the seismic damage to buried structures from a detonation of explosive ordnance underwater, situated on the seabed. Most studies deal with the effect of shock through the water column, which is reasonably understood and well-documented. The peak pressure and decay constant depends on the size of the explosive charge and the stand-off distance from the charge. The Peak Pressure (P_{max}) and Impulse (I) (momentum) experienced by a receptor (vulnerable structure) at distance R from a charge W can calculated using Coles’ equations, which for TNT are:

$$P_{max} = 52.4\,(W^{1/3}/R)^{1.13} \quad \text{MPa}$$

$$I = 5.75.\,W^{1/3}(W^{1/3}/R)^{0.89} \quad \text{MPa-ms}$$

Examples of calculated Peak Pressure values for various typical UXO at representative ranges are shown at in Section 6.5

4.4.4 Seismic Shock

The peak pressure experienced by a buried structure (e.g. a cable) will depend principally on the range from the UXO, the sediment type, whether the UXO is on the surface of the seabed, partially or wholly buried and the charge weight.

Quantifying the shock experienced by a buried receptor is difficult: there are a great many variables. Seismic shock propagation in earth media is a complex function of the dynamic constituent properties of the sediment, the explosive products and the geometry of the explosion. No single sediment index or combination of indices can adequately describe the process in a simple way for all cases. In particular, whether the sediment is unconsolidated or consolidated makes a significant difference to both the speed of propagation and attenuation rate of the seismic wave. The attenuation rate has been found to be greater in the latter (we have assumed that the cable is buried in unconsolidated sediment, in this case sand).

The optimum depth of water for maximum efficiency of energy transfer from the medium of water into the sediment is calculated as:

$$d=38.41*W^{2/11}$$

Some of the energy of detonation will also be expended in the formation of a crater and the ejection of seabed material from it and on detonation. Energy is lost across the boundary of the two mediums, water and sediment. Taking all these losses into consideration, energy transfer into the sediment from a detonation of a UXO item on the seabed is usually, at most, around 50%-60% of the initial energy generated by the detonation and therefore it is the distance of the receptor from the UXO through the water column that is the dominant consideration.

4.4.5 Shock Factor

The most widely used parameter for describing shock severity is the shock factor value. Normally applied to vessels, this value is a shock input severity parameter that is a function of charge weight and charge distance (stand-off from a receptor). A small explosive charge close to a receptor can give the same SF as a larger one further away, although the pressure characteristic and damage mechanism may be different. Shock damage to the hull area of a vessel can vary quite appreciably, depending on the charge size, orientation and proximity to the hull. If the charge is located directly or almost directly underneath and/or close to a vessel, the bubble collapse onto the ship's hull and the whipping caused by the bubble pulse will contribute to the damage.

In simple terms, the larger the UXO charge weight and the closer it is to any given structure, vessel, equipment or person, the more damage it may cause. A deep draft vessel is at more risk of damage than a shallow draft one operating in the same depth of water. A vessel is more at risk at Low Water than at High Water. The formula used to calculate the HSF is based on simple spherical spreading of the shock wave and is:

$$HSF = \frac{\sqrt{C}}{R}$$

where C is the charge weight equivalent in Kg of TNT and R is the distance to the nearest point of the receptor. When the charge is on the seabed and measured relative to the keel of a ship on the water's surface, the angle of incidence of the shock wave with respect to the vessel is also taken into account, the calculated value is referred to as the Keel Shock Factor (KSF) or sometimes "Q" or just the Shock Factor (SF).

In this case,

$$KSF = \frac{\sqrt{C}}{R} \cdot \frac{(\text{Sin}\,\Theta + 1)}{2}$$

In the hypothetical case that a receptor on the seabed (such as a cable or pipeline), rather than a vessel, is subject to the effects of a HE detonation, Sin ϴ will tend to zero and, in theory, the SF received by the cable will be =

$$\frac{\sqrt{C}}{2R}$$

However, we have found no experimental or wartime empirical data to support this assumption and it should be applied with great caution.

The table 4.1, which shows typical vessel damage symptoms for SF values, is taken from the US Navy Salvage Engineer's handbook. The representative damage shown can only be indicative and must be treated with a great deal of caution: the construction of civilian vessels varies considerably and, in deeper water, the bubble pulse must also be taken into account. The SF values, which were originally calculated in imperial values, have been converted by *Ordtek* to metric.

SF (√kg/m)	Typical Damage
<0.22	Minor damage (defects to fuses, destruction of light bulbs/luminescent tubes and the like.
0.22 to 0.33	Damage to piping with leaks, possibly individual pipe ruptures, damage to fuses, lamps, electronic failures and the like.
0.33 to 0.44	Increase in the above described damage symptoms, piping ruptures and misalignment of machinery on its base likely.
>0.44	Serious damage to ship, general machinery damage
>1.1	Typically total loss of ship.

Table 4.1 – Shock factors with typical damage symptoms (taken from US Navy Salvage Engineers' Handbook, converted by Ordtek for kg/m)

4.4.6 Representative Hull Shock Factor at Varying Water Depths

The table below shows typical representative calculations for various UXO for Hull Shock Factor and possible damage for a vessel at varying water depths from the detonation where the UXO is situated on the surface of the seabed.

UXO Type	~NEQ	Water Depth					
		15m	30m	50m	70m	100m	130m
LMB (GC)	700kg	0.84	0.42	0.25	0.18	0.13	0.10
Torpedo	300kg	0.52	0.26	0.16	0.11	0.08	0.06
1000kg Bomb	500kg	0.67	0.34	0.20	0.14	0.10	0.08
250kg Bomb	120kg	0.33	0.17	0.10	0.07	0.05	0.04
250lb Bomb	55kg	0.22	0.11	0.07	0.05	0.03	0.03
100lb Bomb	25kg	0.15	0.08	0.05	0.03	0.02	0.02
5in Shell	5Kg	0.07	0.03	0.02	0.01	0.01	0.01

Table 4.2 – Representative calculations for Hull Shock Factor at varying depths of water

The calculations above have shown what the effects might be to vessels should UXO detonate. However, while this is based upon a quantifiable approach, there are some assumptions and variables that have been made (and does not consider effects on equipment on the seabed). Therefore, while the calculation suggests “minor damage” would occur in some scenarios, in accordance with the ALARP principle it is not considered tolerable to accept a potential hazardous scenario if it could be reasonably avoided.

4.4.7 Effects above Water

Underwater, the blast effect is relatively short range and decays rapidly. After detonation, the shock wave will expand spherically outwards and will travel towards any particular receptor in a straight line – i.e. line of sight. Therefore, unless the wave is reflected, channelled or meets an intervening obstruction, for all practical purposes, the receptor will not be affected by the pressure wave if it is out of line of sight. This is also true for the shrapnel that will be simultaneously ejected outwards with very high kinetic energy from heavier cased items.

In air, fragmentation (shrapnel), together with secondary products such as gravel etc., can be thrown considerable distances. Typically this is 1-2 km or more for medium sized bombs and projectiles. Isolated heavy fragments such as fusing components, lugs and baseplates etc. of large bombs and mines have the potential to travel in excess of 3km. For UXO underwater, the kinetic energy the fragmenting case receives from the HE charge is attenuated by the water and the distance it will be thrown once it reaches the surface is proportional to the depth underwater. As described earlier, fragmentation can generally be ignored for all but the largest UXO in water depths > 10 m.

Both blast and shrapnel will be mitigated substantially if the UXO is buried (for the purpose of entering safety tables, “buried” means covered by >2.5 x the EO length. However, the seismic shock created can cause significant damage to unprotected and vulnerable subsurface infrastructure such as pipelines. As a rule, cables are much less vulnerable. On land, a 500kg SC bomb, detonating fully buried (i.e. deeper than 2.5 times its length) will cause a crater of approximately 13.7m (45ft) x 3.7m (12ft). Underwater, the dynamic forces are more complicated but the land figures can be used to give a reasonable approximation of likely crater size (while factoring in the optimum depth calculation for maximum energy transfer).

It follows that exposed soft-skin equipment and personnel are likely to suffer injury or damage from items of UXO that detonate close to or on the surface. The larger the NEQ of the UXO, the greater the severity of the consequence. Personnel under solid cover will also be less likely to be injured than those caught in the open.

4.5 Semi-Quantitative Risk Assessment

4.5.1 Important Considerations

The UXO risk calculation table is located at Appendix 2. *Ordtek* sees the purpose of the risk calculation table at the pre-mitigation stage of the risk management process mainly to produce a relative order of merit that will inform the Risk Mitigation Strategy.

In assessing the UXO risk to offshore projects, *Ordtek* uses a SQRA process widely considered as best practice in the offshore industry and in line with the Construction Industry Research and Information Association (CIRIA) guidance (Reference A).

We have shown that the risk that UXO poses to any particular Project activity is the product of three key elements:

- The probability of encountering an item of ordnance;
- *If* that encounter happens, the probability of the UXO detonating; and
- *If* the UXO detonates, the severity of the consequence to vulnerable receptors (people, marine life, vessels and equipment) and company reputation.

UXO risk is generally considered a low probability but very high consequence event and it is the latter factor that usually dictates the overarching risk score. The potential consequence of a UXO detonation is by far the dominant factor in the calculation.

Consequences apply to the specific equipment, vessel or personnel and in the circumstances that may lead to detonation for a particular activity. The SQRA calculation may therefore produce resultant similar risk levels for dissimilar activities that could appear counter-intuitive. For example, although the probability of encounter may be greater for one type of UXO over another, the likelihood of detonation for a particular activity may be less. The values assigned to each factor in the risk calculation are subjective and based on many variables, which themselves are difficult or impossible to quantify. Moreover the data for a statistical analysis is not available. **The risk calculation results must be treated with caution and an understanding of their origin.**

The risk factor values assigned in the *Ordtek* SQRA are determined by our UXO specialist experts and are consequently subjective and open to different interpretation. The values assigned cannot be absolute or based upon statistical data (for example, of previous occurrences) because the data is not generally available and there are a great many permutations of the factors involved. A wholly statistical analysis is not possible and a "pseudo" statistical analysis should be treated with caution.

Scoring probability requires a qualitative and informed judgement to be made based upon the limited facts available. It is rarely possible (almost never when dealing with UXO in the offshore environment) to present a purely quantitative and statistically accurate measure of UXO probability factors, simply because the base data is largely qualitative i.e. it is drawn from a variety of different historical and environmental sources. The UXO specialist provides a professionally informed judgement based upon empirical, qualitative and anecdotal evidence employed in a consistent approach. Nevertheless, despite its limitations, our view is that the risk assessment matrix as currently used is suitable for adequately assessing and grading Health and Safety risk, which is generally mandated by legislation as well as individual company policy. It is also a robust tool for assessing Project risk tolerability. In the risk calculation tables at Appendix 2, for risk assessment purposes, a number of generic ordnance classifications have been grouped. This is justifiable as the probability of encounter, potential for initiation and NEQ are sufficiently similar.

Unless otherwise stated, the consequence (hazard severity) level shown is for the typical vessel or equipment used for a particular development stage. The tables also contain a separate section that shows the likely consequence of UXO detonation to exposed personnel. This section will always assume the worst case scenario.

It is also important to note that the severity of consequence figures in the tables are predicated on the assumption that there is a reasonable degree of separation (water) between the UXO and receptor on detonation. The figure, therefore, primarily considers the effect of a detonation on vessels afloat and embarked personnel. The exception to this is the calculation for Jack-Up barge operations, where detonation of a relatively small NEQ UXO has the potential to initiate collapse of a spud leg, resulting in the vessel capsizing *(note, we have no trials data to support this view but we consider it prudent to take a cautious approach)*.

Equipment in direct contact or immediately adjacent to the detonation may receive substantial, or even catastrophic, damage from even a small item of UXO (e.g. 3.7in projectile). However, (apart from jack-up) we consider this a Project risk, while the tables are predominantly concerned with presenting H&S risk.

4.5.2 Risk Assessment Matrix

"Hazard" is a source of potential harm or a situation with the potential to harm or damage. For the purposes of this report the hazard will be termed as "UXO". This is an overarching term which may include all munitions and/or explosive items that have been dumped, fired or unfired.

"Risk" is the calculation of two principal elements:

(1) The likelihood that a hazard may occur (= probability of encountering UXO x probability of detonation);

(2) The consequence (severity) of the hazardous event.

Ordtek uses the following matrix to quantify the risk, each generic UXO hazard is assessed for severity and likelihood of occurrence. This model is generally considered best practice for assessing risk in the marine environment, although it has been modified where required to ensure it is UXO centric.

Likelihood of Occurrence (Encounter *and* Detonation)		Hazard Severity				
		1 = Negligible Negligible injury or impact on equipment with no lost work	**2 = Slight** Minor injury or damage requiring treatment or repair	**3 = Moderate** Injury leading to lost time incident and moderate damage to equipment	**4 = High** Involving single death and serious damage to equipment	**5 = Very High** Multiple deaths and/or sunk vessel, equipment totally destroyed beyond repair
	1 = Very Unlikely A freak combination of factors would be required for a UXO initiation to result	**1 = L**	**2 = L**	**3 = L**	**4 = L/M**	**5 = L/M**
	2 = Unlikely A rare combination of factors would be required for a UXO initiation to result	**2 = L**	**4 = L**	**6 = L/M**	**8 = M**	**10 = M/H**
	3 = Possible Could happen if sensitive UXO exists but otherwise unlikely to occur	**3 = L**	**6 = L/M**	**9 = M**	**12 = M/H**	**15 = H**
	4 = Likely Not certain to happen but sensitive UXO may exist and density may be above average resulting in an accident	**4 = L/M**	**8 = M**	**12 = M/H**	**16 = H**	**20 = H**
	5 = Very Likely Almost inevitable that an UXO initiation would result due to the type and density of UXO	**5 = L/M**	**10 = M/H**	**15 = H**	**20 = H**	**25 = H**

Table 4.3 - UXO Risk Assessment Matrix

4.5.3 Risk Assessment Results

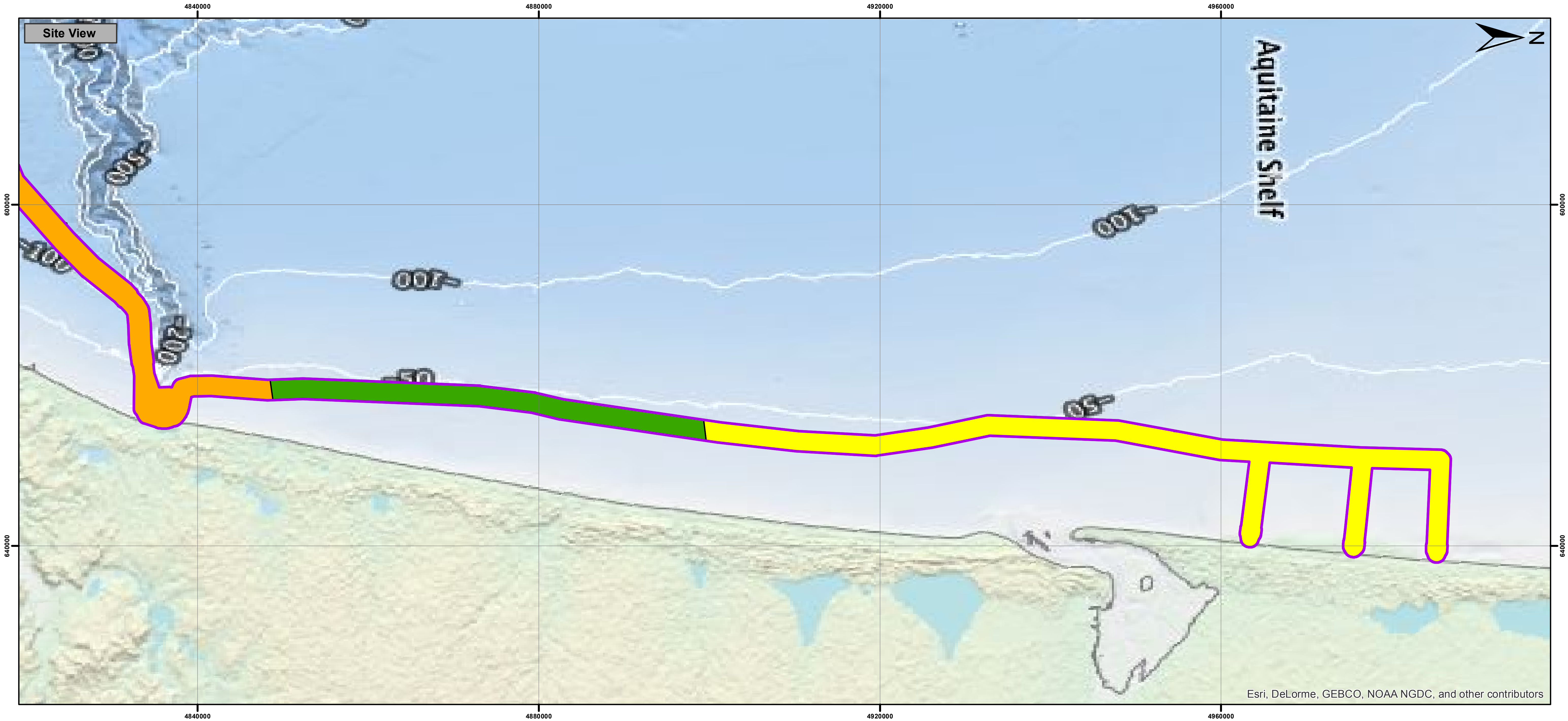
In can be seen from a Health & Safety risk assessment perspective that in general the risk to the geotechnical operation is Low to Moderate.

The geotechnical equipment footprint is very small as a proportion of the volume of the site as a whole, therefore, depending on the assessed likely density of UXO, the probability of encounter with an item of UXO will usually also be very low. It follows that the likelihood of an inadvertent UXO detonation will be even less. Even though there is a consistent background threat along the entire route for artillery projectiles the risk they present to the geotechnical campaign is very low.

However there are some sections of the route where the risk are elevated due to the level of military activity. To show relative ranking and further resolution of risk areas along the route *Ordtek* have presented charts with the following scaling:

- Low
- Low-Moderate
- Moderate

When using these charts it should be noted that this is a combined UXO risk (i.e. an accumulation of threat items).



Legend for Site View

Biscay Gulf Interconnector Risk Assessment Corridor

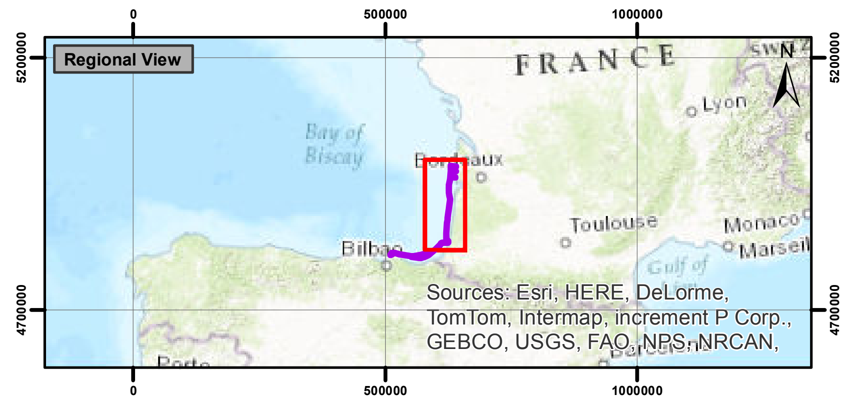
UXO Risk

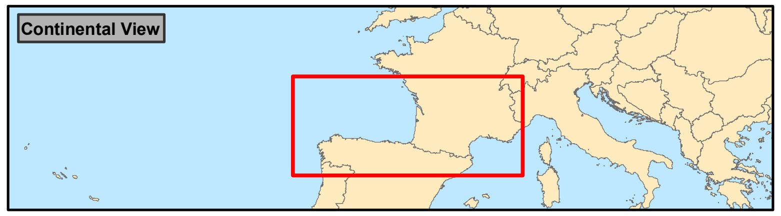
- Low
- Low - Moderate
- Moderate

Horizontal Scale(s)

Kilometers: 0, 10, 20, 40

Nautical Miles: 0, 5, 10, 20





Consultant	Client	Drawing Title	User Notes
ORDTEK	inelfe	**Biscay Gulf Interconnector UXO Risk Map**	Note 01 - Biscay Gulf Interconnector Risk Assessment Corridor dervied from INELFE file "Survey areas 2016.kmz". For the purposes of charting, the Risk Assessment Corridor includes an additional 1km either side of the INELFE survey corridor. Note 02 - Two possible alternative Spanish landfall HDD options have also been considered, as defined by REE "HDD option3 UXO risk assessment area.kmz" and "HDD option 5 UXO risk assessment area.kmz".

THE BRITISH ASSESSMENT BUREAU ISO9001

WGS 1984 UTM zone 30N
Projection: Transverse Mercator
Datum: WGS 1984
false easting: 500,000.0000
false northing: 0.0000
central meridian: -3.0000
scale factor: 0.9996
latitude of origin: 0.0000
Units: Meter

Drawn by: AP
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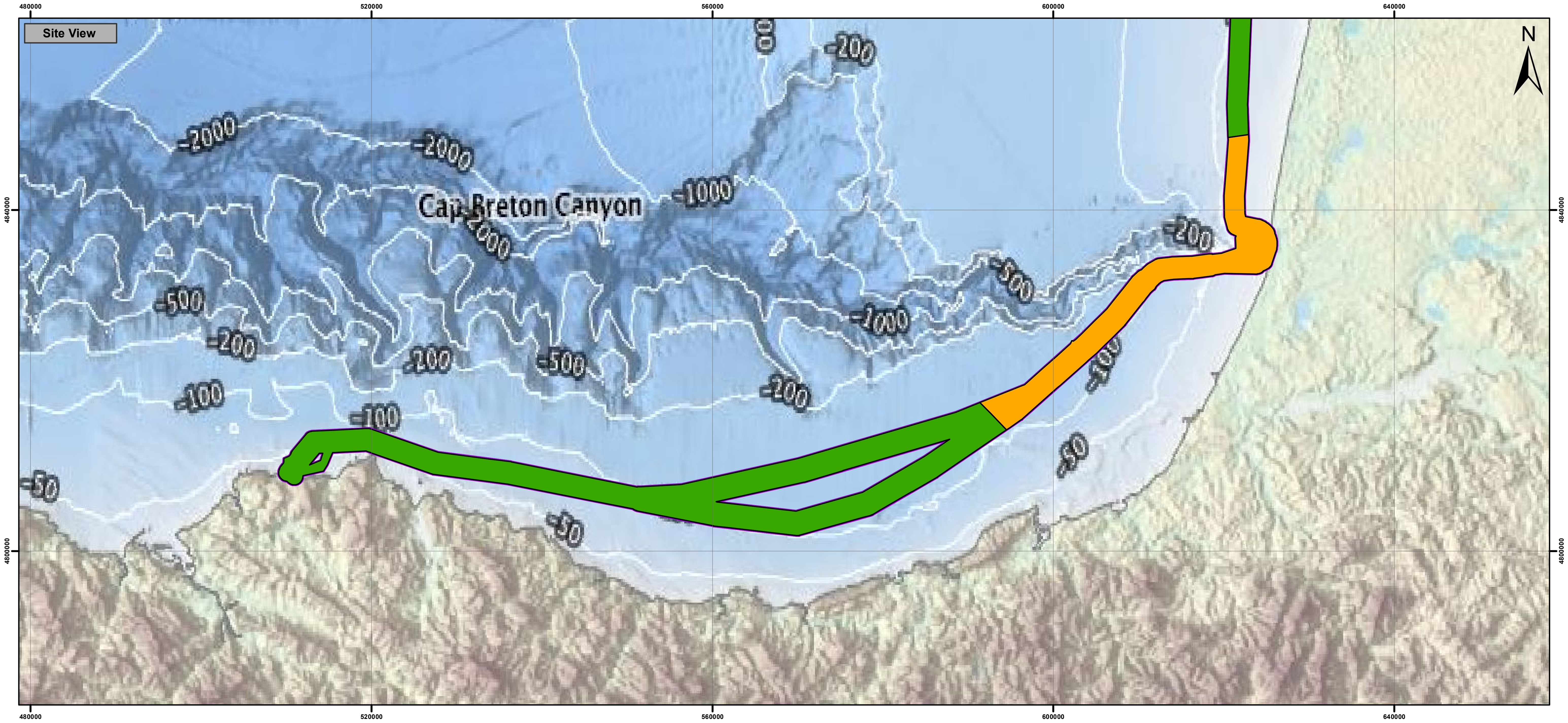
JM5353 - Bay of Biscay

Date Drawn: 24 May 2017
Drawing Reference: JM5353_DTS_15
Drawing Version: 1.1



Legend for Site View

Biscay Gulf Interconnector Risk Assessment Corridor

UXO Risk

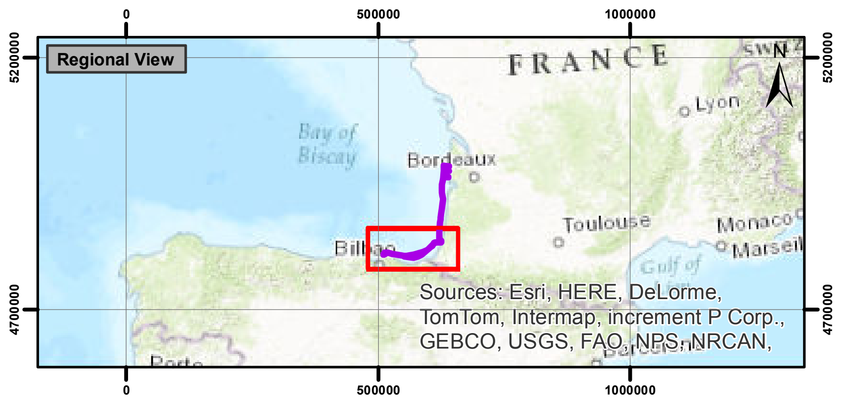
Low

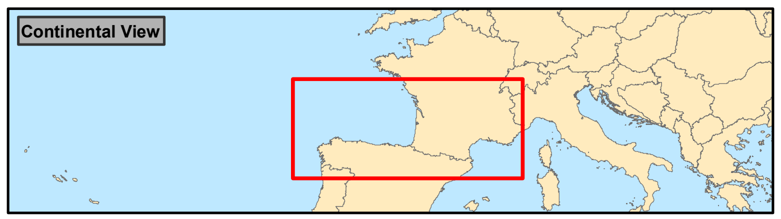
Moderate

Horizontal Scale(s)

Kilometers: 0, 10, 20, 40

Nautical Miles: 0, 5, 10, 20





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WGS 1984 UTM zone 30N
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Date Drawn: 26 May 2017
Drawing Reference: JM5353_DTS_16
Drawing Version: 1.1

5 UXO Risk Mitigation Strategy

5.1 Risk Tolerance

Although both European and French law clearly lays out the obligations on various parties and general preventative principles, the absolute level of risk that is acceptable (if any) is not defined; it is expressed as a relative value.

Certainly in most practical situations in the maritime environment, the level of risk can statistically never be "zero". The number of hazard items in a typical offshore development area are never known; the limitations of current survey equipment technology mean that the probability of detection can never be "1"; and therefore the probability of encounter cannot be zero. Similarly, the sensitivity and stability of any UXO present is not known and, therefore the probability of detonation cannot be zero. Finally, if development activities are to take place, people and equipment will necessarily be put in "harm's way". There will always be a residual level of risk. The level will depend on the mitigation measures put in place.

Risk tolerance is not defined in legislation, but in France the GAMAB principle (Globalement Au Moins Aussi Bon – "globally at least as good") assumes that there is already an "acceptable" solution and requires that any new solution shall in total be at least as good. The expression "in total" is important here, because it gives room for trade-offs: an individual aspect of the safety system may indeed be worsened if it is overcompensated for by an improvement elsewhere.

GAMAB is closely related to the ALARP principle. Many European regulatory authorities, including the UK Health & Safety Executive (HSE), require that operational risks should be within acceptable limits and As Low as Reasonably Practicable (ALARP); this is also the case with UXO. Determining that UXO risks have been reduced to ALARP involves an assessment of the UXO risk to be avoided, an assessment of the effort (in terms of money and time) involved in taking control measures to avoid or mitigate that risk and a comparison of the two facets. The graph at *Figure 2.1* demonstrates how ALARP is measured. The principle of ALARP is commonly applied across most of the European offshore renewables industry.

In *Ordtek's* view, there is very little difference, if any, between the practical application of GAMAB and ALARP for an offshore development.

To demonstrate that risks are ALARP, one must show that enough has been done to reduce risks. In cases where the risks are well-defined, it is sufficient to show that recognised "good practices" have been implemented. In more complex situations, i.e. where the industry or technology is new, to demonstrate risks are ALARP, it is necessary to show that all reasonably practicable risk reduction measures have been implemented and that all other measures that could be implemented are shown to be unjustified. Risk criteria may be defined by national regulations, corporate guidance and well-established industry standards.

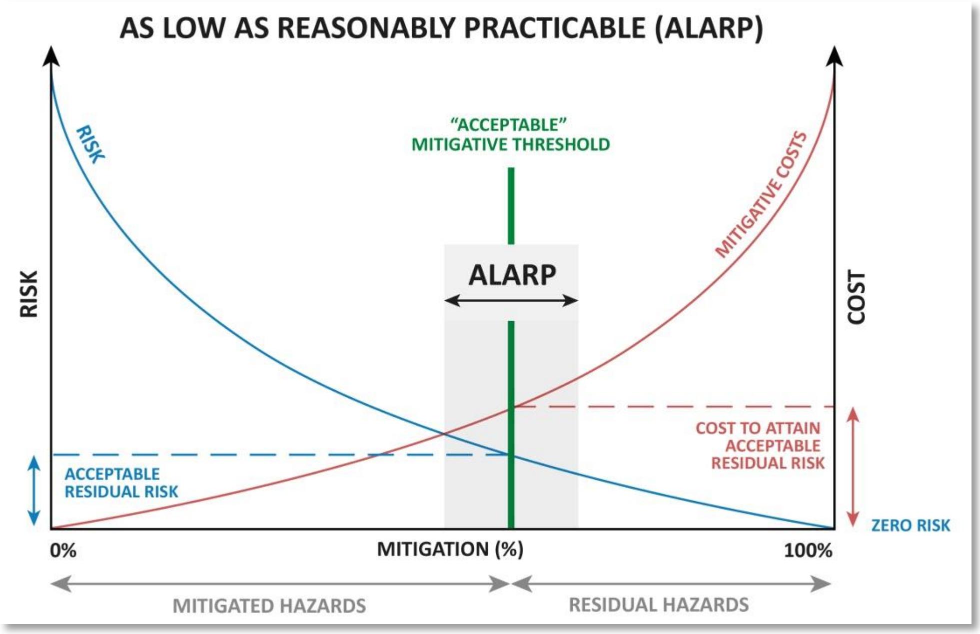


Figure 5.1 - Determining risk are ALARP by measuring Cost versus Effort

With GAMAB there is no requirement to achieve "Zero" risk and, in fact, there is no legal onus on the developer to achieve a level of UXO risk that is "as low as reasonably practicable". The only stipulated requirement is that as a total "system", the risk is no worse than on other developments. Logically, applying industry best practice and experience derived from French and European offshore projects will ensure that the UXO risk is "at least as good" as on other similar developments and GAMAB will be achieved.

It therefore follows that by achieving ALARP, the de facto industry norm, GAMAB should also be satisfied. The criticism often levelled at ALARP, and its weakness, is that the level of risk at which ALARP is reached and therefore, the amount of residual risk that is tolerable, is subjective. However, at *Biscay Gulf Western*, *Ordtek's* view is that as long as the ALARP level of UXO risk chosen is such that the total risk across the site in no greater than that at other comparable sites (in other words by following current best practice), the GAMAB principle will always be achieved.

As we noted earlier, the inadvertent detonation of an item of UXO is generally acknowledged as being a very low probability, high consequence event. Therefore the developer, if they judge it acceptable, may forego the potentially high costs of additional survey, contact investigation etc. in favour of risking the costs of the consequences of a detonation, in the knowledge that such a detonation is highly unlikely to occur. Particularly if the project costs incurred may be unreasonable in comparison.

From the risk assessment tables at Appendix 2, *Ordtek* then uses the following risk tolerability thresholds to determine the level of mitigation required.

Action	Risk	Category
Nominal risk. Control measures MUST be maintained and monitored.	1 – 5	Low - Tolerable
Some risk. Any control measures MUST be maintained and monitored and on-going actions completed.	6 – 10	Medium - Partly Tolerable
Significant risk. MUST NOT BE ALLOWED. Risk **MUST** be reduced. Any control measures **MUST** be maintained and monitored.	11 – 25	High - Intolerable

Table 5.1 - UXO Risk Tolerability

5.2 Risk Tolerance at Biscay Gulf Western HVDV Interconnector

Given the effort, cost and impracticality of trying to detect and investigate the number of geophysical survey anomalies likely to result from specifying a small UXO item (such as an artillery projectile), coupled with the very low risk to personnel above water (which can be satisfactorily mitigated procedurally), ***Ordtek* considers that the ALARP standard for H&S risk will be fully met by applying the smallest threat item threshold set out in Section 5.5.2**, assuming that our recommended risk management strategy is fully adopted.

As shown, *project risk tolerance*, however, also depends on other criteria. A key decision in determining the smallest item that should be specified for sign-off is whether the risk from UXO items *smaller* than the chosen threshold detonating is acceptable; bearing in mind that even though the consequence may be relatively high, the probability of the "event" is likely to be extremely low.

5.3 Strategy Objectives

In designing a mitigation strategy, *Ordtek* has the following objectives, to:

- Ensure it is technically robust within the bounds of available technology.
- Ensure it was in line with best practice in the offshore industry.
- Reduce the risks to ALARP.
- Take account of the potential for buried UXO.
- Provide a solution that has a reasonable weather tolerance.
- Is pragmatic and provides best value for the client.

5.4 Target Avoidance

Based on the mitigation strategy, an appropriate safety distance will be applied to potential UXO targets. The typical exclusion zone radius of 10m is commonly applied within the offshore renewables industry for relative low energy activities such as cable ploughing. The 10m refers to the proximity of the cable installation device rather than the as laid cable position and is based on the following:

- 5m "avoidance distance" – an arbitrary distance, based on the judgements and experience of an EOD expert, at which the probability of inadvertent detonation of an unknown item of UXO by the envisage project activity is negligible.
- ± 2.5m navigational error during the geophysical survey.*
- ± 2.5m positional error tolerance in the picking of geophysical anomalies during survey data analysis.

10m radius, therefore, is a distance at which typical activities can be conducted safely without "disturbing" potential, as yet unconfirmed, UXO. The 10m exclusion zone has generally become an industry standard exclusion zone for "cable installation", but it does not necessarily consider all project specific elements that make up that distance. The calculation of an exclusion zone for high energy activities, with the potential to cause sympathetic detonation of an item of UXO, such as percussive piling, is more complex. These distances are calculated according to the prevailing circumstances. Exclusion zones should be applied consistently across the route regardless of the water depth. The basis of the avoidance principle is to ensure that the item is not disturbed therefore the depth of water does not sufficiently influence the decision making.

5.5 Project Specific Mitigation Strategy for the Geotechnical Campaign

5.5.1 All Areas

To conform to best practice, geotechnical contractors should also adopt the following UXO risk management and mitigation actions:

- Obtain the ALARP sign-off certificate for geotechnical investigations. Input geophysical contacts to be avoided into the on-board navigation system.
- Obtain the ALARP sign-off certificate for each installable asset. Input geophysical contacts to be avoided into the on-board navigation system.
- Establish the location of known wreck sites. *Ordtek* suggests that non-military related wrecks are avoided in accordance to the developer's standard protocol.
- Ensure the Project team are aware of their internal UXO policy, including key support numbers.
- Hold a copy of this risk assessment on-site/on-board the vessel.
- Brief all personnel on the potential UXO risk.
- Hold a UXO specialist on-call in the event of a suspect item being discovered unexpectedly.

The contractor's/vessel emergency response plan (ERP) should identify management responsibilities in respect of reporting potential UXO items, marking of objects, dealing with potential UXO brought onto the vessel inadvertently, securing the area, ensuring the safety of personnel and informing the UXO specialist, whether embarked offshore or on-call ashore.

Management staff and supervisors, for all phases of development, will be required to attend the normal Explosive Ordnance Safety and Awareness Briefing, in addition to a separate expanded briefing detailing actions to be taken in the event that an item of ordnance or suspicious objects encountered. Key staff should be nominated as part of the vessel/site health and safety protocol with specific responsibility for the implementation and maintenance of the site Explosive Ordnance Site Safety Instructions.

All involved personnel will be required to attend a site safety induction briefing; this will be provided by an appropriately trained person. This formal briefing should include a section on Explosive Ordnance Safety and Awareness and will apply during all work that interacts with the seabed throughout the life of the Project. The briefing will be supported by photographs of the range of ordnance that is considered likely to be encountered. The visual material will depict the ordnance in a 'typical' state (e.g. rusting and covered in concretion). A record will be maintained of all personnel who attend the briefing and subsequent update briefings. At the discretion of the principal contractor, all personnel should attend a periodic update briefing, particularly during the seabed engineering phases of the Project.

5.5.2 Low-Moderate and Moderate Risk Areas (for geotechnical activities only)

To attain the ALARP criteria, a UXO-specified magnetometer survey should be undertaken to locate, identify, and avoid large NEQ items of UXO, while the smaller UXO may be dealt with by physical and procedural mitigative measures adopted during the geotechnical campaign.

Any magnetometer geophysical anomalies which are classified as "potential UXO" but are not definitively confirmed as such, can be avoided by a suitably safe distance, making the assumption that the item remains stable and will not be disturbed. In accordance with the ALARP principle, the installation could then proceed with a *de minimis* risk of encountering UXO. However the safety exclusion zones around the geophysical contacts must be respected. Unless these contacts are investigated and confirmed as not UXO related, they should be considered a potential hazard.

It is recommended magnetometer survey is collected in the following areas designated **low-moderate** and **moderate** risk:

UXO Risk Zone	Description	Percentage of Route
Low-Moderate	From French Landfalls to southern edge of area designated "Submerged Munitions and Obstructions" located at coordinates **[625204.84, 4899333.13 and 627670.16, 4899608.32]**.	31%
Low	From submerged munitions area, coordinates **[625204.84, 4899333.13 and 627670.16, 4899608.32]** to minefield FD39 at **[620498.42, 4848502.28 and 622888.97, 4848837.09]**.	13%
Moderate	From near to minefield FD39, coordinates **[620498.42, 4848502.28 and 622888.97, 4848837.09]** to westernmost edge of German coastal convoy route at **[591387.15, 4817455.63 and 594511.74, 4814245.65].**	17%
Low	From convoy route, coordinates **[591387.15, 4817455.63 and 594511.74, 4814245.65]** to Spanish landfall.	39%

Table 5.2 – UXO Risk Zone Demarcation

Based on the assumed methodologies to be deployed for the installation no geotechnical exploratory activity should interact with the seabed within 10m of a geophysical contact that is potentially UXO.

The choice of the smallest hazard item that needs to be mitigated for ALARP sign-off is determined, *inter alia*, by the prevailing environment (including likely UXO burial) and the ability to detect the item using available geophysical techniques. It is necessary to weigh up the perceived significance of the hazard to specified Project activities against what is "reasonably practicable" in terms of effort to detect it.

Accordingly, *Ordtek* considers that the smallest threat items for ALARP sign-off is the **British 250lb (114kg) GP Bomb.** This has been chosen as the smallest threat item due to the number of busy coastal convoy routes running adjacent to the study area. In addition to this, German U-boat bases along the French Atlantic coast were heavily attacked by Allied bombers and the RAF delivered massive raids, with many aircraft taking part. Raids of up to 437 aircraft are documented.

Depending on the variant, the 250lb GP is cylindrical/tear-drop in shape, made of cast steel with a wall thickness of 0.6in (1.5cm). The body length is ~28in (71cm). The body diameter is ~10.2in (26cm) and the filling consists of 110lb (50kg) of TNT or Amatol. The 250lb MC dimensions are the same, except the body wall thickness is only 0.3in (0.75cm) and the charge weight is greater at ~120lbs (55kg) of Amatol or Pentolite.

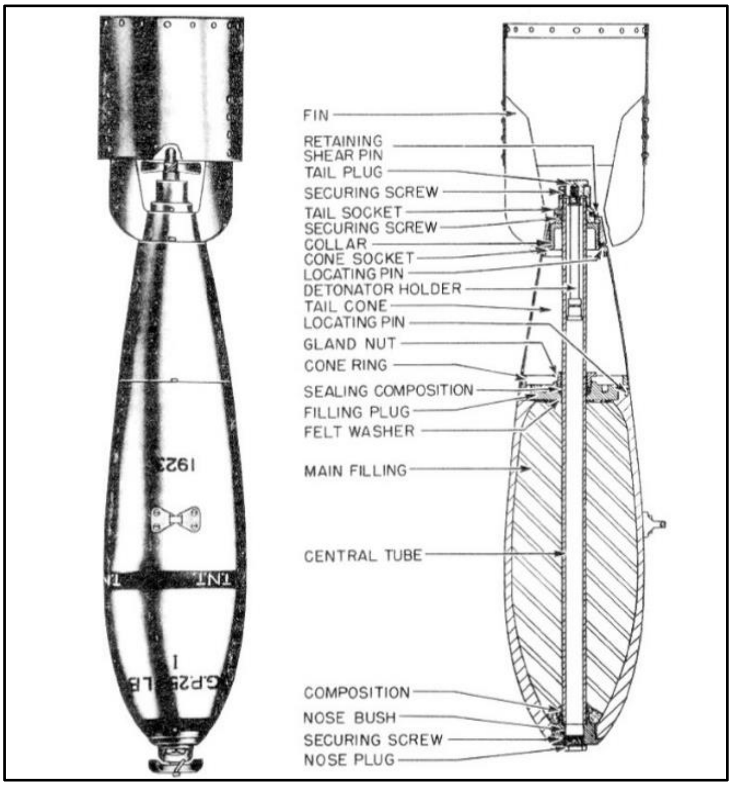


Figure 5.1 – British 250lb GP Bomb: Smallest UXO item for ALARP sign off.

For geophysical survey specification purposes it should be planned to detect these items to a reasonable maximum depth of 2m below bed level. However if this is not possible within the limits of the equipment *Ordtek* will consider the detection capability and the potential for burial within the assessment of the data during the ALARP sign-off process.

Assuming these items can be successfully detected and identified within the geophysical datasets, larger objects will also be detectable. While the possibility of finding smaller items of UXO in the *Biscay Gulf Western* project area cannot be discounted, the risk posed by them is considered low and can be sufficiently mitigated by implementing suitable reactive and procedural measures.

To ensure detection of this item within the planned geophysical survey, discussions on detection and operational survey parameters have taken place between *INELFE, MMT* (survey contractor) and *Ordtek*.

5.5.3 Low Risk Areas (for geotechnical activities only)

For a geotechnical campaign existing *MMT* SSS and MBES data will be of sufficient quality to mitigate the UXO risk in “Low Risk Areas”. While the existing magnetometry line spacing may not be adequate to cover the full corridor, the option exists to align any CPT/VC onto existing magnetometry survey lines. While aligning CPT/VC onto magnetometer survey lines would help reduce the risk further, in *Ordtek*’s opinion it is not required given that reactive and procedural measures will be used throughout the project to reduce the H&S UXO risk to ALARP.

As with the Low-Moderate and Moderate Risk Areas, when assessing the existing SSS and MBES data a 250lb item should be the smallest threat item and any anomalies profiling similar or larger should be avoided by 10m.

Appendix 1

Seabed Conditions

Main Route (La Cantine Landing) (MR)

KP Start	W.D. (m)	KP End	W.D. (m)	Bathymetry and Morphological Features Depths Relative to Lowest Astronomical Tide (LAT)	Shallow Geology Features (N.B. Lithology described below yet to be confirmed by geotechnical data)	Sediment Cover Depth
-0.138	-28.5	0.542	-2.9	Establish beach system, vegetated KP -0.138 to KP 0, KP 0 to KP 0.542, Sand dune system progresses into SAND beach	Surficial SAND	assumed <1m
0.542	-2.9	1.06	5	Intertidal zone, relatively steep slope	Surficial SAND	assumed <1m
1.06	5	20.035	34	Relatively steep dipping from 5.0 m to 11.5 m at KP 1.250. Dipping with reduced gradient to 23.5 m at KP 4.000 and 32.5 m at KP 12.500 Very gently dipping to 34.0 m at KP 20.035	Medium to Coarse SAND up to 2 m below sea floor (BSF) over SAND and GRAVEL until KP 1.950. SAND and GRAVEL over SAND >5 m BSF. SILT and SAND to within 5 m of seabed between KP 11.820 and KP 11.950, KP 12.340 and KP 13.280, and KP 14.237 and KP 14.398. SAND and GRAVEL over SAND >5 m persists until KP 20.050	5m
20.035	34	35.567	34	Gently undulating seabed between 30 m and 34 m. Few depressions, rough patches and ridges. Occasional scars. Seabed flattening at around KP 31	SAND and GRAVEL over SAND overlain with 1 to 2 m of fine to medium SAND together extending >5 m BSF until KP 24.550. SAND and GRAVEL over SAND with occasional deposit of fine to medium SAND <1 m thick, together extending >5 m BSF.	2m
35.567	34	40.223	40	Seabed gently dipping with increasing KP then levelling off at 40 m between KP 39.000 and KP 40.220	SAND and GRAVEL over SAND >5 m BSF. Occasionally overlain by deposits of fine to medium SAND 1 to 2 m BSF from around KP 36.30 until KP 39.407. SAND and GRAVEL >5 m to KP 40.223	2m
40.223	40	43.097	43	Very gently dipping seabed.	Intermittent cover of fine to medium SAND veneer up to 2 m BSF over SAND and GRAVEL to >5 m BSF.	2m
43.097	43	46.112	46.2	Seabed slope steepens slightly and levels off at 45m around KP 44.40	Continuous cover of fine to medium SAND veneer up to 2 m BSF over SAND and GRAVEL to >5 m BSF	2m
46.112	46.5	54.237	51	Irregular seabed with shallow ridge features up to 1.5 m high between KP 46.10 and KP 47.65. Continues gently dipping to 50 m then gently undulates between around 50 and 51 m.	SAND and GRAVEL up to 2 m BSF over SAND together extending >5 m BSF. Occasional patches of fine to medium SAND up to 1 m thick.	2m
54.237	51	143.286	41	Predominantly at 50 m (except for the ridges of SAND described in adjacent box) until KP 57.0. Gently shoaling levelling off at KP 67.30 at 42 m.	SAND and GRAVEL extends along this section and appears to be at least 5 m BSF. Overlying Large ribbons of fine to medium SAND, 1 m to 2 m , cross the route at the following locations: Between KPs 54.267 and 54.745	2m
143.286	41	150.477	38	At KP 143.285 a ridge of SAND decreases the depth to 39.5 m and very gently shoals again, levelling off at 39 m by KP 144.75. From here it continues level until KP 147.00 gently shoaling again to 38.0 m at KP 150.480	A SAND unit, up to 1.5 m thick overlying SAND and GRAVEL and CS to >5m BSF. The SAND thickens to 4 m BSF by KP 144.69 and then thins to between 1 to 2 m between KP 147.59 and 148.50. The SAND and GRAVEL thins and eventually pinches out at KP 148.605 where the CS underlies the SAND unit to >5 m BSF SAND and GRAVEL appears again between the SAND and CS from KP 149.665	2m
150.477	38	155.509	3.5	The relatively flat and featureless seabed continues to shoal with an increased slope until KP 154.30 where the seabed continues its upward trend, but becomes rough. It reaches the top of the slope at a depth of just 3.5 m at KP 154.70. It continues shallow at around 3 m until KP 155.50, at the edge of the canyon.	SAND increases in thickness from 2 m to 4 m BSF overlying SAND and GRAVEL unit at KP 151.65 and it increasingly thins to 1.5 m BSF at KP 152.60 where it then sub-ducts a SAND and GRAVEL unit. Both continue up the slope and across the shallow section that terminates at the edge of the canyon at KP 155.50. The underlying CS comes to within 5m of the seabed between KP 150.477 and KP 152.30	4m
155.509	3.5	155.8	3.5	Steep sided canyon slopes down to 14 m and back up to 3.5 m	SAND and GRAVEL, SBP data not very easily acquired in steep sided canyon, so depth of units not established.	N/A
155.8	3.5	156.45	6	Rough seabed	SAND and GRAVEL >5 m BSF.	5m
156.45	6	156.75	4	Steep sided canyon slopes down to 14 m and back up to 4.0 m	SAND and GRAVEL, SBP data not very easily acquired in steep sided canyon, so depth of units not established.	N/A

KP Start	W.D. (m)	KP End	W.D. (m)	Bathymetry and Morphological Features Depths Relative to Lowest Astronomical Tide (LAT)	Shallow Geology Features (N.B. Lithology described below yet to be confirmed by geotechnical data)	Sediment Cover Depth
156.75	4	168.7791	90	Relatively flat and featureless seabed slopes down with reasonable gradient to 90 m.	SAND and GRAVEL over SAND, with top unit thinning and SAND outcropping at KP 159.615. SAND unit in excess of 5 m until KP 165.380 where BEDROCK comes to within 5 m of seabed surface at KP 166.269 and within 2 m at KP 167.579 and outcrops at KP 168.75 for approximately 100 m.	5m
168.791	90	182.547	123.7	The seabed continues to slope down at same gradient until a depth of 119 m where it levels off and continues gently undulating between 119 m and 120 m until KP 181.50 when it slopes down to 124 m at KP 182.75.	SAND thickens over the bedrock to >2 m then thins to less than 1 m at KP 170.858 and continues to overlie a highly eroded BEDROCK surface 1 to 2 m BSF until KP 179.487 where the overburden thins to <1 m. SAND veneer continues until KP 182.547 where the BEDROCK outcrops for 25 m.	2m
182.547	123.7	188.883	129	The seabed very gently shoals to 121 m at KP 185.80. The seabed gently dips slightly undulating until it levels off at 129 m, at KP 188.20. It remains level until KP 189.00 where it starts to gently shoal.	SAND over highly eroded BEDROCK surface 1 to 2 m thick until KP 184.60 where the subsurface BEDROCK slopes down and the overburden of SAND and SILT/SAND thickens to 4 to 5 m BSF.	5m
188.883	129	192.282	128.5	Seabed shoals gently to 123 m at KP 191.10 then slopes down gently to 128.5 m at KP 192.25.	SAND and SAND/SILT over highly eroded BEDROCK >5 m until KP 189.85 where BEDROCK comes to within 2 m of seabed and again at KP 190.00. BEDROCK then slopes down beyond 5 m BSF then back up to outcrop at KP 192.25.	5m
192.282	128.5	192.454	125.5	Rough seabed, relatively steep rock outcrops at depths between 128.5 m and 125.5 m.	BEDROCK outcrop with some SAND overburden.	assumed <1m
192.454	125.5	199.49	123	Seabed very gently slopes down to 128.5 m then levels off at KP 193.758 before shoaling again until KP 198.145 reaching depth of 117 m. Then seabed slopes down again reaching depth 123 m at KP 199.490.	SAND over BEDROCK 1 to 2 m thick. SAND and SILT and SAND overburden thickens from KP 194.698, becoming >5 m BSF at KP 195.295 with 2 m of SAND over 3+ m of SILT/SAND at KP 195.400. SAND unit thins to <2 m between KP 198.55 and KP 199.50.	5m
199.49	123	205.408	122.2	Seabed gently shoals to 115 m at KP 201.25, then slopes down levelling off at 121.2 m at KP 201.20. The seabed remains level for 1000 m then shoals, becoming undulating at KP 202.40 until KP 205.40 at a depth of 122 m	SAND over SILT/SAND >5 m thick. BEDROCK comes to within 5 m of seabed at KP 203.25 and continues to close the seabed until almost outcropping KP 204.8. SAND overburden then thickens to 3 m before rapidly thinning as BEDROCK outcrops at KP 205.40	5m
205.408	122.2	206.324	118	Very rough seabed. Highly undulating between 122.2 m and 113.8 m.	Outcropping BEDROCK.	N/A
206.324	118	211.769	120.1	Seabed gently dips levelling off at 122.4 m by KP 208.00, then shoaling to 116.8 m at KP 210.286. The seabed slopes down gently to reach 120.1 m at KP 211.50	SAND overburden gradually thickens to 4 m BSF at KP 207.478 then reduces to 2 m over BEDROCK between KP 208.60 and KP 209.10. SAND unit gradually thickens to >5m BSF at KP 209.910 and thins briefly again to 3 m BSF at KP 210.950 where it overlies BEDROCK.	4m
211.769	120.1	213.689	117.5	Seabed continues at a level of 120.1 m until KP 212.25 and then gently shoals again, levelling off at 117.5 m at KP 213.50, continuing level for 200 m.	SAND overburden thickens to 5 m by KP 211.805 and then thins to 2 m at KP 212.555. BEDROCK remains within 2 to 3 m of seabed until KP 213.00 when it slopes back down again. SAND and SILT/SAND thickens to >5 m BSF by KP 213.25. A BEDROCK peak comes to within 3.5 m of seabed at KP 213.694	5m
213.689	117.5	218.972	116	Seabed remains virtually level at 117.5 m until KP 217.00 where it starts very gently shoaling until reaching bedrock at a depth of 116.0 m at KP 218.95	SAND and SILT/SAND >5 m BSF continues to KP 216.145 where it starts to thin becoming 2.5 m thick at KP 216.50 and then thickening again to >5 m by KP 217.100. BEDROCK very quickly comes to the seabed surface from KP 218.855, outcropping at KP 218.972.	5m
218.972	116	219.262	113.5	Rough seabed between KP 218.972 and KP 219.262, ranging from 116.0 m to 113.5 m	Outcropping BEDROCK	N/A

KP Start	W.D. (m)	KP End	W.D. (m)	Bathymetry and Morphological Features Depths Relative to Lowest Astronomical Tide (LAT)	Shallow Geology Features (N.B. Lithology described below yet to be confirmed by geotechnical data)	Sediment Cover Depth
219.3	113.5	226.1	111	Seabed gently shoaling to depth of 109.6 m at KP 222.5. Then very gently sloping down 1 m by KP 223.50 and remaining at this depth until KP 225.00 where it very gently slopes down to 111.0 m at KP 226.10	SAND overburden increasing in thickness from 2 m to >5 m BSF by KP 220.353. BEDROCK very quickly comes to within 4 m of seabed at KP 222.936 and remains between 3 to 4 m until dropping down below 5 m at KP 224.00 and continuing as such.	5m
226.1	111	229.25	108	Seabed very gently shoals to depth of 108 m at KP 229.25	SAND remains >5 m thick until rock comes to within 4 m of seabed between KP 227.65 and KP 227.87. SAND thickens again to >5 m until the BEDROCK starts sloping up to within 2 m of seabed at KP 229.25.	5m
229.25	108	238.5	102.1	Seabed continues gently shoaling to 105 m at KP 231.60. It levels off before gently shoaling again at KP 233.25. It reaches a depth of 102.1 at KP 236.55 and then very gently undulates 1 m to KP 238.50	SAND overburden remains between 1 to 2 m BSF over highly eroded bedrock, then starts to thicken to >5 m by KP 232.490. The BEDROCK comes to within 5 m of seabed at KP 232.75 and continues upwards until coming within 2 m of seabed at KP 233.910. SAND remains at between 1 to 2 m BSF over highly eroded bedrock until KP 237.395 where it starts to thicken again, becoming 4 to 5 m up to KP 238.500	5m
238.5	102.1	239.776	96	The seabed shoals to a depth of 95.5 m at KP 239.20 then continues irregularly undulating +/-1 m until KP 239.776 where the seabed becomes very rough.	SAND thins to <1 m at KP 238.778 then thickens to reach >5 m BSF at KP 239.00 and then quickly reduces until KP 239.105 where the BEDROCK outcrops for 100 m. SAND thickens to >2 m BSF over the highly eroded BEDROCK that eventually outcrops at KP 239.776	5m
239.776	96	243.24	90.5	Very rough seabed irregularly undulating between 96 m and between 85 m	Outcropping BEDROCK	N/A
243.24	90.5	245.59	94.5	The seabed slopes down to 95.8 m at KP 244.10 then undulates +/-2 m until KP 245.64 to a depth of 94.5 m	SAND thickens gradually to between 2 to 3 m BSF by KP 243.70. SAND remains 2 -3 m thick until BEDROCK outcrops between KP 244.644 and 244.691. SAND continues with very irregular thickness between 0.5 m and 3 m BSF to KP 245.590.	3m
245.59	94.5	251.92	91	The seabed shoals irregularly to a depth of 85.5 m at KP 246.67. It then irregularly dips again to 93.4 m at KP 248.50. It continues very irregularly shoaling to KP 250.52 and slopes down to an escarpment feature at KP 251.92. The top of this feature is at depth of 89 m and it drops 3 m to 91.2 m	SAND increases >2 m BSF then thins until BEDROCK outcrops again at KP 248.76. BEDROCK continues at seabed surface until KP 251.92.	2m
251.92	91	257.96	83.2	The seabed continues smoothly level at 91.2 m until KP 253.03 where it becomes rough and gently shoals 2 m by KP 254.73. It then very gently shoals to 83.2 m at KP 257.960	SAND overburden thickens to 5 m by KP 252.35 then reduces to 2.5 m BSF by KP 253.55. It varies in thickness between 2 to 4 m over highly eroded bedrock until KP 257.960	5m
257.96	83.2	261.82	75.2	Steep shoaling seabed until KP 258.11 reaching depth of 72.2 m. Very rough undulating seabed +/-2 m until KP 259.30. Then irregularly dipping to 77.4 m at KP 261.330 m and back up to 75.2 m at KP 261.82	Outcropping BEDROCK. SAND and GRAVEL deposits 1 to 2 m BSF over highly eroded bedrock between KP 259.30 and KP 259.95. Then again between KP 261.13 and KP 261.33. The BEDROCK continues to outcrop until KP 261.82.	2m
261.82	75.2	272.695	58	Seabed gently shoaling until KP 269.55 to a depth of 46.5 m. It then dips to 52.3 m at KP 270.85 and then continues almost level to KP 271.87 where it dips again, reaching 58 m at KP 272.82	SAND increasing in thickness to 4 m BSF by KP 252.83. It remains this thick except between KP 263.00 and KP 263.50 where BEDROCK comes to within 2 m of seabed. SAND thickens to >5 m at KP 267.20 and continues >5 m until KP 271.50 where BEDROCK comes to within 1.5m of the seabed at KP 271.090. BEDROCK continues to be within 5 m of seabed until KP 271.720. SAND irregularly thins from 5 m at KP 272.274 until BEDROCK outcrops at KP 272.690.	5m
272.695	58	276.23	72.2	Very rough seabed trending deeper until KP 276.23 reaching a depth of 72.2 m	Outcropping BEDROCK	N/A

KP Start	W.D. (m)	KP End	W.D. (m)	Bathymetry and Morphological Features Depths Relative to Lowest Astronomical Tide (LAT)	Shallow Geology Features (N.B. Lithology described below yet to be confirmed by geotechnical data)	Sediment Cover Depth
276.23	72.2	278.857	77.4	Seabed undulates +/-2 m until KP 278.000 then gently dips to 77 m at KP 278.500 and remains level until KP 278.850 where it becomes rough terrain and generally shoals.	SAND and GRAVEL deposit thickens to >5 m by KP 276.53 and becomes SAND >5 m BSF by KP 277.330 SAND unit thins until BEDROCK outcrops at KP 278.857	5m
278.857	77.4	281.186	66	Very rough generally shoaling seabed until rock peak at KP 280.75 at a depth of 62.1 m. Seabed levels off at 66 m and starts shoaling again from KP 281.18.	Outcropping BEDROCK until KP 285.75 when SAND and SAND/GRAVEL deposit up to 3 m BSF overlies irregularly eroded BEDROCK until KP 281.18.	3m
281.186	66	283.77	20	Very rough generally shoaling seabed until KP 283.770 water depth 20 m	Outcropping BEDROCK with isolated SAND deposits 2 to 3 m BSF between KP 282.52 and KP 282.55, and KP 282.74 and KP 283.770	3m

Appendix 2

Risk Assessment Results

Geotechnical Activity (Based on the offshore and nearshore scope	Generic Ordnance Category	Likelihood of Occurrence (Encounter *and* Detonation)	Severity of Consequence	Result	Likelihood of Occurrence (Encounter *and* Detonation)	Severity of Consequence	Result	Likelihood of Occurrence (Encounter *and* Detonation)	Severity of Consequence	Result
		Main Route (La Cantine)			Main Route La Cantine (Landfall)			Lacanau (Landfall)		
Geotechnical Investigation from DP vessel with no leg or anchor placement (Manta 200 CPT)	**German Ground Mines**	2	5	10	2	5	10	2	5	10
	British Ground Mines	1	5	5	1	5	5	1	5	5
	British & German WWI mines	1	3	3	1	3	3	1	3	3
	Artillery and Naval Projectiles	2	2	4	2	2	4	2	2	4
	HE Bombs	3	4	12	3	4	12	3	4	12
	Depth Charges and Torpedoes	2	3	6	2	3	6	2	3	6
	British & German WWII Buoyant Mines	2	3	6	2	3	6	2	3	6
	LSA	1	3	3	1	3	3	1	3	3
Geotechnical Investigation from DP vessel with no leg or anchor placement (Neptune 5000 CPT)	**German Ground Mines**	2	5	10	2	5	10	2	5	10
	British Ground Mines	1	5	5	1	5	5	1	5	5
	British & German WWI mines	1	3	3	1	3	3	1	3	3
	Artillery and Naval Projectiles	2	2	4	2	2	4	2	2	4
	HE Bombs	3	4	12	3	4	12	3	4	12
	Depth Charges and Torpedoes	2	3	6	2	3	6	2	3	6
	British & German WWII Buoyant Mines	2	3	6	2	3	6	2	3	6
	LSA	1	3	3	1	3	3	1	3	3
Geotechnical Investigation from DP vessel with no leg or anchor placement (VKG-6 3/6m Vibracore)	**German Ground Mines**	2	5	10	2	5	10	2	5	10
	British Ground Mines	1	5	5	1	5	5	1	5	5
	British & German WWI mines	1	3	3	1	3	3	1	3	3
	Artillery and Naval Projectiles	2	2	4	2	2	4	2	2	4
	HE Bombs	3	4	12	3	4	12	3	4	12
	Depth Charges and Torpedoes	2	3	6	2	3	6	2	3	6
	British & German WWII Buoyant Mines	2	3	6	2	3	6	2	3	6
	LSA	1	3	3	1	3	3	1	3	3

Geotechnical Activity (Based on the offshore and nearshore scope	Generic Ordnance Category	Likelihood of Occurrence (Encounter *and* Detonation)	Severity of Consequence	Result	Likelihood of Occurrence (Encounter *and* Detonation)	Severity of Consequence	Result	Likelihood of Occurrence (Encounter *and* Detonation)	Severity of Consequence	Result
		Main Route (La Cantine)			Main Route La Cantine (Landfall)			Lacanau (Landfall)		
Geotechnical Investigation from DP vessel with no leg or anchor placement (Rock-corer Minidrill MDS-6000)	**German Ground Mines**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	British Ground Mines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	British & German WWI mines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Artillery and Naval Projectiles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	HE Bombs	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Depth Charges and Torpedoes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	British & German WWII Buoyant Mines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	LSA	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Unprotected Personnel (considering activities that may potentially recover small items above the water surface – detonation on or very close to the surface; detonation <10m)	**German Ground Mines**	1	5	5	1	5	5	1	5	5
	British Ground Mines	1	5	5	1	5	5	1	5	5
	British & German WWI mines	1	4	4	1	4	4	1	4	4
	Artillery and Naval Projectiles	1	3	3	1	3	3	1	3	3
	HE Bombs	1	4	4	1	4	4	1	4	4
	Depth Charges and Torpedoes	1	5	5	1	5	5	1	5	5
	British & German WWII Buoyant Mines	1	5	5	1	5	6	1	5	5
	LSA	1	3	3	1	3	3	1	3	3

Geotechnical Activity (Based on the offshore and nearshore scope	Generic Ordnance Category	Likelihood of Occurrence (Encounter *and* Detonation)	Severity of Consequence	Result	Likelihood of Occurrence (Encounter *and* Detonation)	Severity of Consequence	Result	Likelihood of Occurrence (Encounter *and* Detonation)	Severity of Consequence	Result
		Le Grande Crohot Option Route (Landfall)			Canyon Head Bypass Coast Option Route			Alternative Canyon Head Bypass Coast Option Route		
Geotechnical Investigation from DP vessel with no leg or anchor placement (Manta 200 CPT)	**German Ground Mines**	1	5	5	1	5	5	1	5	5
	British Ground Mines	1	5	5	2	5	10	2	5	10
	British & German WWI mines	1	2	2	1	2	2	1	2	2
	Artillery and Naval Projectiles	2	2	4	2	2	4	2	2	4
	HE Bombs	3	4	12	3	4	12	3	4	12
	Depth Charges and Torpedoes	2	3	6	2	3	6	2	3	6
	British & German WWII Buoyant Mines	2	3	6	2	3	6	2	3	6
	LSA	1	1	1	1	1	1	1	1	1
Geotechnical Investigation from DP vessel with no leg or anchor placement (Neptune 5000 CPT)	**German Ground Mines**	1	5	5	1	5	5	1	5	5
	British Ground Mines	1	5	5	2	5	10	2	5	10
	British & German WWI mines	1	2	2	1	2	2	1	2	2
	Artillery and Naval Projectiles	2	2	4	2	2	4	2	2	4
	HE Bombs	3	4	12	3	4	12	3	4	12
	Depth Charges and Torpedoes	2	3	6	2	3	6	2	3	6
	British & German WWII Buoyant Mines	2	3	6	2	3	6	2	3	6
	LSA	1	1	1	1	1	1	1	1	1
Geotechnical Investigation from DP vessel with no leg or anchor placement (VKG-6 3/6m Vibracore)	**German Ground Mines**	1	5	5	1	5	5	1	5	5
	British Ground Mines	1	5	5	2	5	10	2	5	10
	British & German WWI mines	1	2	2	1	2	2	1	2	2
	Artillery and Naval Projectiles	2	2	4	2	2	4	2	2	4
	HE Bombs	3	4	12	3	4	12	3	4	12
	Depth Charges and Torpedoes	2	3	6	2	3	6	2	3	6
	British & German WWII Buoyant Mines	2	3	6	2	3	6	2	3	6
	LSA	1	1	1	1	1	1	1	1	1

Geotechnical Activity (Based on the offshore and nearshore scope	Generic Ordnance Category	Likelihood of Occurrence (Encounter *and* Detonation)	Severity of Consequence	Result	Likelihood of Occurrence (Encounter *and* Detonation)	Severity of Consequence	Result	Likelihood of Occurrence (Encounter *and* Detonation)	Severity of Consequence	Result
		Le Grande Crohot Option Route (Landfall)			Canyon Head Bypass Coast Option Route			Alternative Canyon Head Bypass Coast Option Route		
Geotechnical Investigation from DP vessel with no leg or anchor placement (Rock-corer Minidrill MDS-6000)	**German Ground Mines**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	British Ground Mines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	British & German WWI mines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Artillery and Naval Projectiles	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	HE Bombs	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Depth Charges and Torpedoes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	British & German WWII Buoyant Mines	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	LSA	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Unprotected Personnel (considering activities that may potentially recover small items above the water surface – detonation on or very close to the surface; detonation <10m)	**German Ground Mines**	1	5	5	1	5	5	1	5	5
	British Ground Mines	1	5	5	1	5	5	1	5	5
	British & German WWI mines	1	4	4	1	4	4	1	4	4
	Artillery and Naval Projectiles	1	3	3	1	3	3	1	3	3
	HE Bombs	1	4	4	1	4	4	1	4	4
	Depth Charges and Torpedoes	1	5	5	1	5	5	1	5	5
	British & German WWII Buoyant Mines	1	5	5	1	5	6	1	5	5
	LSA	1	3	3	1	3	3	1	3	3

Geotechnical Activity (Based on the offshore and nearshore scope	Generic Ordnance Category	Likelihood of Occurrence (Encounter *and* Detonation)	Severity of Consequence	Result	Likelihood of Occurrence (Encounter *and* Detonation)	Severity of Consequence	Result	Likelihood of Occurrence (Encounter *and* Detonation)	Severity of Consequence	Result
		HDD Canyon Crossing Route			Additional Route Spanish Waters			Spanish Landfall Sites		
Geotechnical Investigation from DP vessel with no leg or anchor placement (Manta 200 CPT)	**German Ground Mines**	2	5	10	1	5	5	1	5	5
	British Ground Mines	2	5	10	1	5	5	1	5	5
	British & German WWI mines	1	2	2	1	2	2	1	2	2
	Artillery and Naval Projectiles	2	2	4	2	2	4	2	2	4
	HE Bombs	3	4	12	1	4	4	1	4	4
	Depth Charges and Torpedoes	2	3	6	2	3	6	2	3	6
	British & German WWII Buoyant Mines	2	3	6	2	3	6	1	3	3
	LSA	1	1	1	1	1	1	1	1	1
Geotechnical Investigation from DP vessel with no leg or anchor placement (Neptune 5000 CPT)	**German Ground Mines**	2	5	10	1	5	5	1	5	5
	British Ground Mines	2	5	10	1	5	5	1	5	5
	British & German WWI mines	1	2	2	1	2	2	1	2	2
	Artillery and Naval Projectiles	2	2	4	2	2	4	2	2	4
	HE Bombs	3	4	12	1	4	4	1	4	4
	Depth Charges and Torpedoes	2	3	6	2	3	6	2	3	6
	British & German WWII Buoyant Mines	2	3	6	2	3	6	1	3	3
	LSA	1	1	1	1	1	1	1	1	1
Geotechnical Investigation from DP vessel with no leg or anchor placement (VKG-6 3/6m Vibracore)	**German Ground Mines**	2	5	10	1	5	5	1	5	5
	British Ground Mines	2	5	10	1	5	5	1	5	5
	British & German WWI mines	1	2	2	1	2	2	1	2	2
	Artillery and Naval Projectiles	2	2	4	2	2	4	2	2	4
	HE Bombs	3	4	12	1	4	4	1	4	4
	Depth Charges and Torpedoes	2	3	6	2	3	6	2	3	6
	British & German WWII Buoyant Mines	2	3	6	2	3	6	1	3	3
	LSA	1	1	1	1	1	1	1	1	1

Geotechnical Activity (Based on the offshore and nearshore scope	Generic Ordnance Category	Likelihood of Occurrence (Encounter *and* Detonation)	Severity of Consequence	Result	Likelihood of Occurrence (Encounter *and* Detonation)	Severity of Consequence	Result	Likelihood of Occurrence (Encounter *and* Detonation)	Severity of Consequence	Result
		HDD Canyon Crossing Route			Additional Route Spanish Waters			Spanish Landfall Sites		
Geotechnical Investigation from DP vessel with no leg or anchor placement (Rock-corer Minidrill MDS-6000)	**German Ground Mines**	N/A	N/A	N/A	1	5	5	1	5	5
	British Ground Mines	N/A	N/A	N/A	1	5	5	1	5	5
	British & German WWI mines	N/A	N/A	N/A	1	2	2	1	2	2
	Artillery and Naval Projectiles	N/A	N/A	N/A	2	2	4	2	2	4
	HE Bombs	N/A	N/A	N/A	1	4	4	1	4	4
	Depth Charges and Torpedoes	N/A	N/A	N/A	2	3	6	2	3	6
	British & German WWII Buoyant Mines	N/A	N/A	N/A	2	3	6	2	3	6
	LSA	N/A	N/A	N/A	1	1	1	1	1	1
Unprotected Personnel (considering activities that may potentially recover small items above the water surface – detonation on or very close to the surface; detonation <10m)	**German Ground Mines**	1	5	5	1	5	5	1	5	5
	British Ground Mines	1	5	5	1	5	5	1	5	5
	British & German WWI mines	1	4	4	1	4	4	1	4	4
	Artillery and Naval Projectiles	1	3	3	1	3	3	1	3	3
	HE Bombs	1	4	4	1	4	4	1	4	4
	Depth Charges and Torpedoes	1	5	5	1	5	5	1	5	5
	British & German WWII Buoyant Mines	1	5	5	1	5	6	1	5	5
	LSA	1	3	3	1	3	3	1	3	3

Annex A

Supplementary Notes on UXO Types

SUPPLEMENTARY NOTES ON UNEXPLODED ORDNANCE TYPES

High Explosive Bombs and Rockets

The charge weight (commonly referred to as the NEQ - Net Explosive Quantity) of a bomb depends on its purpose. Bombs intended to cause damage principally by blast are relatively thin cased and contain around 75% by weight of HE. Those that are designed to fragment and cause damage to thin-skinned buildings, people and equipment through shrapnel have thicker casings and around 30% HE. “General Purpose” (GP) and “Medium Capacity” (MC) bombs have a charge weight of around 50% of the total weight of the weapon. The German designations for these types of bombs were SB, SD and SC respectively. For example an SC-250 would be a general purpose “Minenbombe” weighing 250kg, with an NEQ of around 125kg of HE. An SD-500 would be a fragmentation “Splitterbombe” weighing 500kg and with a charge weight of around 150kg, depending on the variant.
Allied bombs dropped from medium/heavy bombers could vary from 50lb (~25kg) to 4000lb (~1800kg) or more but, predominantly, the majority were likely to be British General Purpose (GP) or US Medium Capacity (MC) bombs in the order of 100lb-1000lb (~50kg - ~450kg). These are more likely to be present on the inter-tidal zone or the inner Wash.

Bombs employed by the Germans varied from 50kg to 4000kg. However, less than 4% of all bombs dropped on Britain in WWII were of the larger variety; the majority were 500kg or less, with 50kg and 70kg bombs predominating (around 80%). The German HE bombs most likely to be encountered on this project therefore are medium capacity, ranging from the SC 50kg to SC 500kg.

High Capacity Blast Bombs (up to 80% explosives) and “Parachute” mines were also used. When laid by air, these German sea mines were usually fitted with bomb fuses that would function either on impact or with a delay, if they fell on land and did not receive the hydrostatic pressure required to disarm the bomb fuse and activate the mine influence sensors and firing circuits.

German bombs are readily identified by the shape of the tail (if still fitted) and, particularly, by their transverse fusing. Both British and German bombs could be fitted with several kinds of fuses, including singly or in combination: impact, long delay and anti-disturbance. However, any anti-disturbance fuse that relied on a power source is now highly unlikely to function. Moreover, the majority of mechanical fuses or pistols will have been subject to significant corrosion and are also unlikely to function as designed. Nevertheless, some could be in an extremely sensitive state.

A typical rocket was the RP-3. These 3 inch rockets had a 60lb (27 kg) warhead in the HE variant.

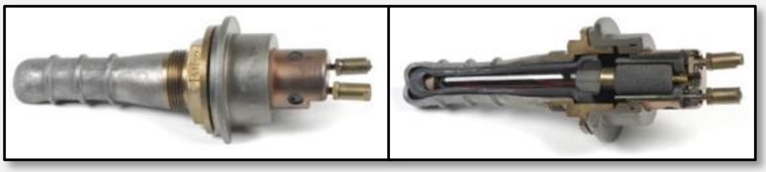
German (R) and British (L) HE bombs as UXO (note typical absence of tail)

Sea Mines

Mines are generally classified by their position in the water and their method of firing (actuation).

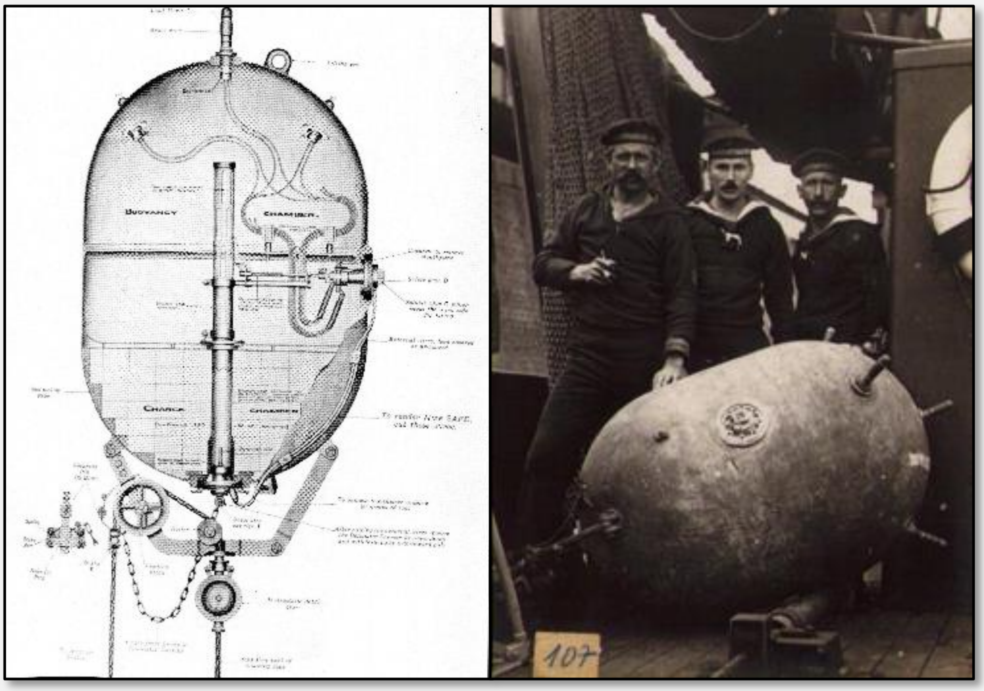
Buoyant Mines

The first and the most commonly employed in WWI, but also extensively deployed in WWII, is the buoyant mine, which is designed either to float just below the surface, tethered to the seabed by a mooring wire and sinker (anchor), or to drift with the ocean currents. Buoyant mines consist of a spherical or ovoid casing with a charge weight of typically 40kg - 250kg of HE, taking up approximately a third of their volume. They are most commonly actuated by contact with the target, using either mechanical switch horns to close a battery-powered firing circuit or "Herz" horns. The latter are also known as "Chemical Horns". A Herz horn consists of a soft lead or copper sheath enclosing a glass phial of acid at the base of which is a dry battery cell. On contact with a target vessel, the glass phial breaks, releasing the acid to act as the battery cell's electrolyte, which then provides power to the mine's detonator. The increased danger a Herz horn presents over a switch horn is that it does not rely on a battery, which will discharge over time, but can provide power to the detonator indefinitely.



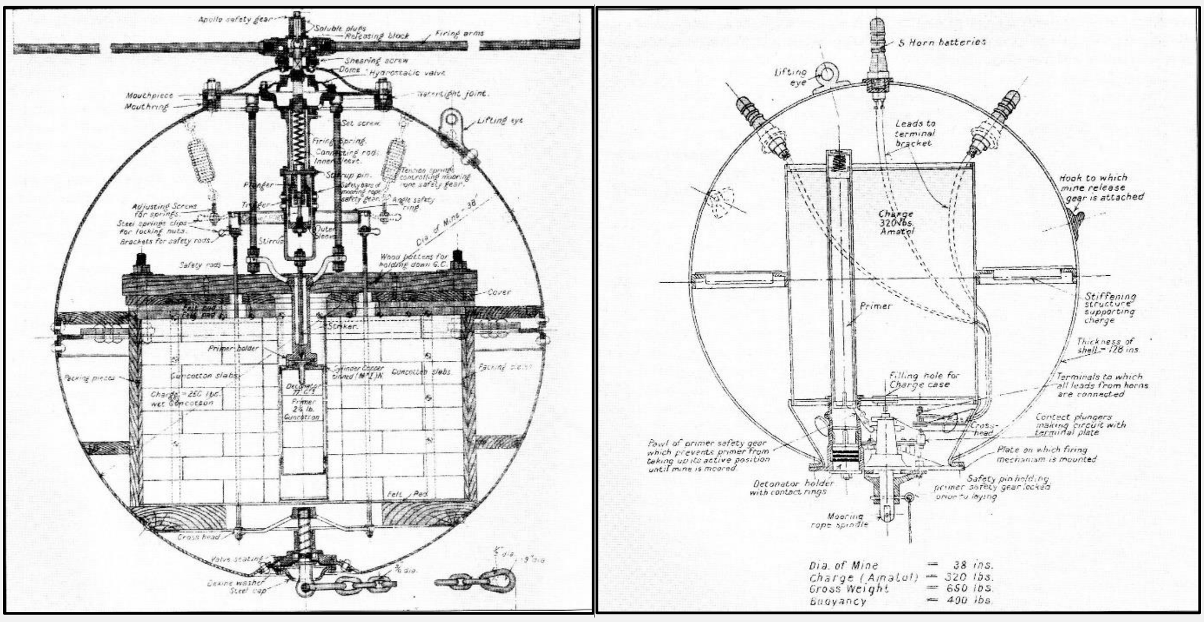
Herz (Chemical) Horn

Other variants of moored mines, but used in much less numbers, were the Antenna Mine, an anti-submarine contact mine that used the current generated by two dissimilar metals rubbing together to fire, and the Magnetic mine, an "influence" mine that was actuated by the small electro-magnetic current generated when a target vessel's moving magnetic field cut the mine's internal coiled rod sensor.

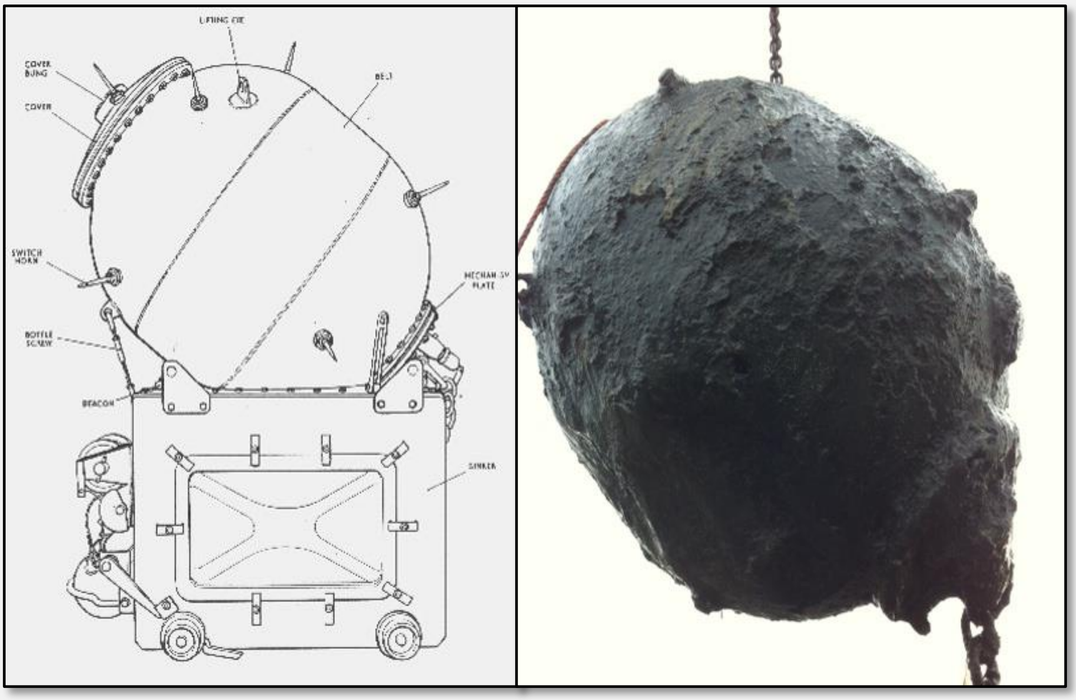


German WWI Type II "Egg" Mine

Mines specifically designed to drift mines are not particularly effective as an anti-ship weapon – their value lays in the fear and disruption they cause – and they were not often employed. However, hundreds of thousands of moored mines were laid during the two world wars. A moored mine frequently became a drifting mine when its cable parted due to the wear and tear of wave motion. In accordance with the Hague Convention of 1907, mines breaking free from their moorings are required to self-neutralise but, in reality, either by design or malfunction, early mines often remained active. They continued to be a danger to shipping and to civilians, if swept ashore. Most eventually sank, often a considerable distance from where they were originally laid. Consequently, estimating the risks posed in any particular area by the mines laid either defensively or offensively during the two world wars is exceptionally difficult. So many were laid that a general assumption is that buoyant mines could be present in any area off the coast of Northern Europe.



British WWI "Naval Spherical" (L) and "H2" (R) buoyant mines



British WWII Buoyant mine in typical condition as found today

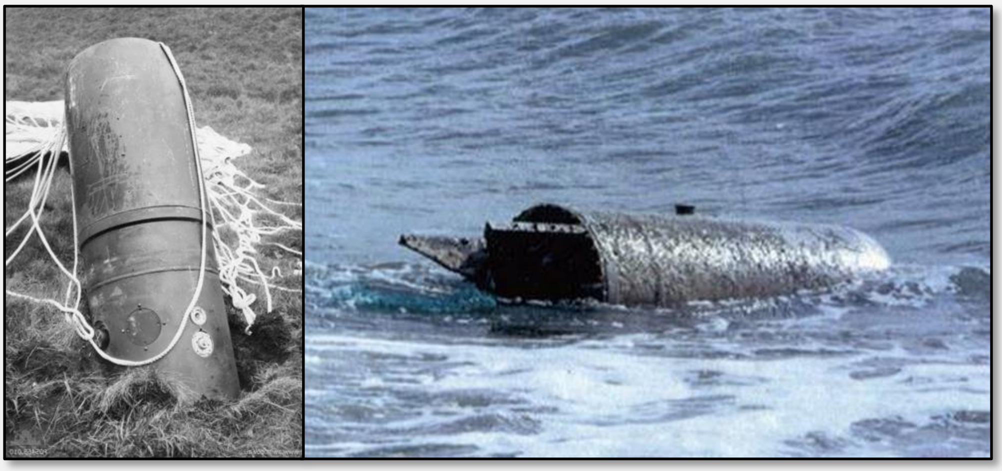
Other variants of moored mines, but used in much less numbers, were the Antenna Mine, an anti-submarine contact mine that used the current generated by two dissimilar metals rubbing together to fire, and the Magnetic mine, an “influence” mine that was actuated by the small electro-magnetic current generated when a target vessel’s moving magnetic field cut the mine’s internal coiled rod sensor or influenced the dip needle mechanism as, for example, in the German aluminium SMA (GO) buoyant mine shown below.

Ground Mines

Although they were in existence towards the end of WWI, ground mines were neither very effective nor common at that time. However, from 1939 onwards, both British and German influence ground mine technology advanced rapidly.

The influence Ground Mine, as its name suggests, is designed to lay on the seabed. It can be laid by surface vessel, submarine or aircraft and it is most commonly cylindrical in shape. It has a single or a combination of magnetic, acoustic and pressure sensors to detect the influence “signature” of passing target vessels. To be close enough to create sufficient damage to its target, a ground mine must be laid in relatively shallow water; generally not more than 70m but more usually around 30m or less. For the same reason, and because the mine does not have to float, the size of the main charge is considerably bigger than in a buoyant mine, typically 300kg - 750kg. Both Germany and Britain had versions that could be fitted with direct impact bomb fuses in addition to magnetic and acoustic firing circuits. Later in WWII, the German's developed the “Oyster” mine; this had a pressure sensor that was either fitted in combination with an acoustic or magnetic sensor circuit.

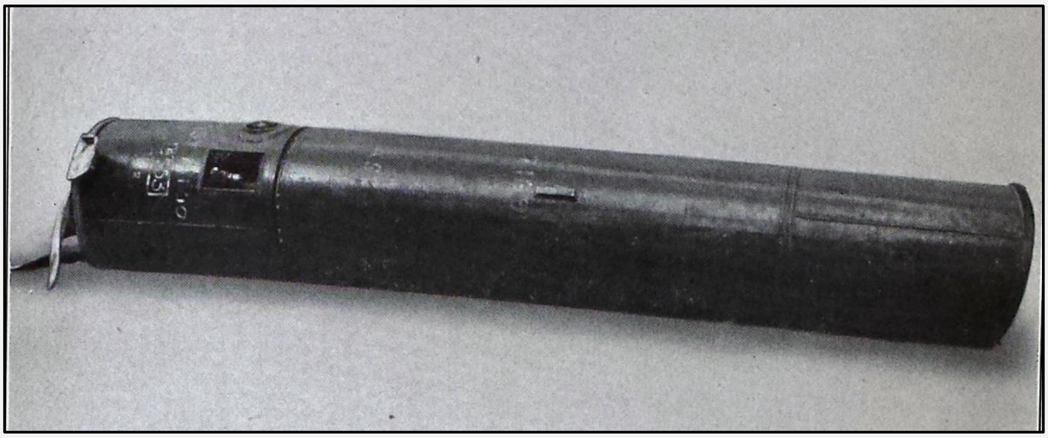
WWII German ground mines were made of aluminium with reliable *Rheinmetal* fuses and superbly engineered and consequently are frequently found in excellent condition after decades in the water. These German air dropped “parachute” mines are likely to be found intact and could probably function as designed if sufficient battery power was available. However, their batteries will now have discharged. Many variants were fitted with booby traps and anti-disturbance devices; some of these relied on battery power, some employed mechanical inertia designed to operate on impact, some had clockwork delay mechanisms and others relied on human intervention; all could be in a very sensitive condition and could function if disturbed.



German WWII GC (LMB) mine used both as sea mine and blast bomb

The LMB mine casing is made of aluminium and its ferrous content depends on the sensors fitted but is commonly limited to the dip needle sensor arrangement, which contains magnets, and a few other small ferrous components, mainly within the mechanism section. The BM1000 casing is made of manganese steel and presents a very low magnetic target. The ferrous content of a BM1000 is similar to that of a LMB mine. The

LMB casing is 1.74m long (without any additional fittings) and has a diameter of 0.66m. The overall weight is 988kg (NEQ is 698kg Hexanite). The BM1000 casing is 1.52m long and the diameter 0.66m. The overall weight is 986kg (NEQ is 727kg Hexanite).



British AMIII ground mine

British ground mine casings were generally made of steel and subject to corrosion over time unless they became buried in hypoxic sediment. The mines relied on batteries to power sensors and firing circuit; these will now be discharged and the mine will not function as designed. Charge weights were between 227kg-499kg, except for two specialist mines that had much smaller net explosive quantities (NEQs) of 45kg and 91kg. The British continued to develop ground mines throughout WWII, starting with A Mks I-IV in the early years, finally progressing to the A Mk IX by 1945. The AMks I-IV, which outwardly looked very similar, were the most common mine used by the British for offensive operations.

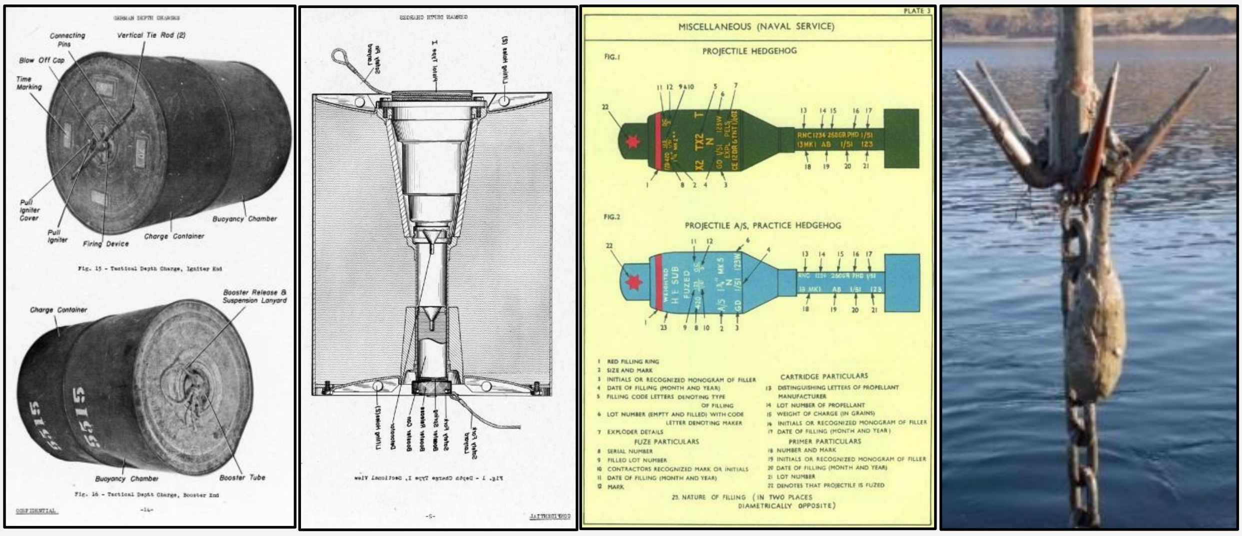
Naval and Artillery Projectiles

Most projectiles encountered in the study area likely to be relatively small calibre shells with an NEQ in the region of 2kg-5kg but larger WWI projectiles could be encountered and these have a slightly larger NEQ – up to 25kg of Picric acid based explosives, such as Shellite. Over time this explosive filling can react with the metal of the shell casing and create sensitive crystals of metal picrates, such as iron picrate. These are extremely sensitive, particularly if they are allowed to dry out and could easily be caused to detonate with sufficient power to initiate the main bursting charge. However, on balance, the risk they pose to Project activities is small. The hazard may reduce when the shells become corroded enough to admit seawater as these materials are water soluble.

An artillery projectile in typical condition on the seabed

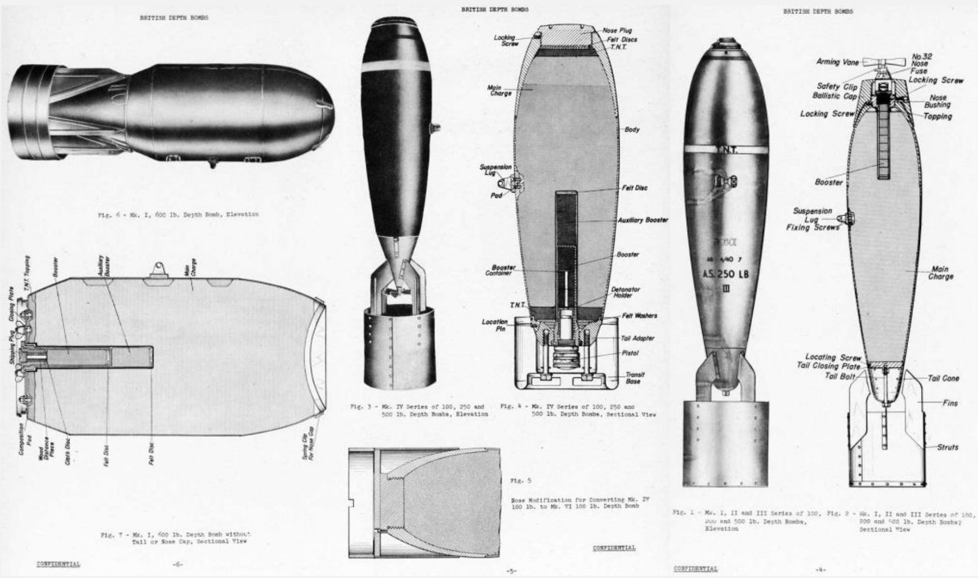
Depth Charges/Depth Bombs

A number of different types of depth charges and depth bombs could have been used to attack submarines, with an NEQ in the range of 50kg-200kg. They would have been caused to detonate by a hydrostatic pistol releasing a cocked striker or perhaps an impact bomb fuse with a delay.



Examples of German Depth Charge (L) and British Anti-Submarine "Hedgehog"

As anti-submarine "blast" weapons, all are thin-cased and consequently subject to severe corrosion in the intervening years, unless deeply buried in hypoxic sediment. Consequently, the firing mechanism is highly unlikely to operate as designed. Nevertheless, the firing train will very probably be complete (i.e. the detonator is in intimate contact with the primer and main charge) and this type of EO could present a significant UXO risk, given the relatively large NEQ. A depth charge could still detonate, for example, if crushed by the leg of a jack-up barge.



British Anti-Submarine Depth Bombs: L-R Mk I 600lb, Mk IV Series, Mk I-III Series

Torpedoes

Any torpedoes present within study area are likely to be of the “wet heater” or “burner cycle” types. During both WWI and WWII, the Germans developed torpedoes of the “wet heater” type; steam driven, with kerosene as fuel and compressed air providing oxygen for combustion. Warheads of around 250kg were detonated by means of a direct impact or magnetic fuse. WWI torpedo fusing was often unreliable and it is quite possible that attacks took place, unrecorded, when the torpedo failed to function and sank to the seabed. German WWII warheads were filled with 280kg of Hexanite and were generally much more reliable. In WWII, the Germans also developed an effective series of battery-driven torpedoes with similar sized warheads.

The standard British airborne torpedo for World War II was the 18-inch, a 450 mm-diameter design that progressed through several Marks through the war. It had an explosive charge of 388 lb (176 kg) of TNT. Later, more powerful versions had a 247kg Torpex warhead. As well as submarines, most ships of any size were fitted with torpedo launchers. The main British 21in heavyweight torpedo in use during WWII was the “improved” Mk VIII. It was used on ships, submarines and motor torpedo boats from 1927 and was the first British burner-cycle design torpedo. Depending on the variant, the warhead consisted of 325kg – 365kg Torpex.

Typical examples of heavyweight (21in/53cm) torpedoes

Annex B

Explosive Ordnance Technical Data

EXPLOSIVE ORDNANCE TECHNICAL DATA

MILITARY DESIGNATION	NATIONALITY	SHAPE	TYPE	FEATURES	NEQ	DIMENSIONS
			MINES			
GD (LMA)	German	Cylindrical	Ground Influence	Air Dropped with parachute/ also Surface Vessel	300kg	Diameter 66cm Length 2.0m (depending on configuration)
GC (LMB)	German	Cylindrical	Ground Influence	Air Dropped with parachute/ also Surface Vessel	700kg	Diameter 66cm Length 3.0m (depending on configuration)
GG (BM1000)	German	Cylindrical	Ground Influence	Air Dropped with parachute/ also Surface Vessel	730kg	Diameter 66cm Length 3.2m (depending on configuration)
TMC (GN)	German	Cylindrical	Ground Influence	Laid by submarine	907kg	Diameter 53.3cm Length 3.36m
EMA and EMB (GU)	German	Ovoid	Moored Contact	Equipped with five Hz Horns. Deployed with base mooring unit. Surface or submarine laid.	163kg or 220kg	Both had similar casing 1.17 m long x 0.863 m in diameter
EMC (GY, GV*)	German	Spherical	Moored Contact	Equipped with seven Hz Horns. Deployed with base mooring unit. Surface laid.	300kg	1.2 m in diameter
EMF (GO)	German	Spherical	Moored Influence	Magnetic influence mine, particularly sensitive in rough sea.	340kg	1.16 m in diameter 1.42m length
UMA (GZ)	German	Spherical	Moored Contact	Five Hz and three switch horns.	30kg	0.81 m in diameter
UMB (GR)	German	Spherical	Moored Contact	Improved moored contact mine with five Hz and three switch horns.	41kg	0.84 m in diameter
A Mk 1 – 4	British	Cylindrical	Ground Influence	Air Dropped with parachute	340-352kg	Diameter 45 cm Length 2.87 m

MILITARY DESIGNATION	NATIONALITY	SHAPE	TYPE	FEATURES	NEQ	DIMENSIONS
A Mk 5	British	Cylindrical	Ground Influence	Air Dropped with parachute	284-306kg	Diameter 40 cm Length 2.057 m
A Mk 6	British	Cylindrical	Ground Influence	Air Dropped with parachute	431kg	Diameter 49.4 cm Length 2.565 m
A Mk 7	British	Cylindrical	Ground Influence	Air Dropped with parachute	281kg	Diameter 42.6 cm Length 2.108 m
A Mk 8	British	Cylindrical	Ground Influence	Air Dropped with parachute	89kg	Diameter 34.3 cm Length 1.448 m
A Mk 9	British	Cylindrical	Ground Influence	Air Dropped with parachute	499kg	Diameter 9.4 cm Length 2.59 m
Naval Spherical Mk III (Service)	British	Spherical	Moored Impact Inertia	Unreliable mine used in the early years of WWI	113kg (wet gun cotton)	~0.8 m diameter
H2	British	Spherical	Moored Contact	5 Herz horns	320lbs (145kg) Amatol	0.97m diameter
Mk XIV	British	Ovoid	Moored Contact	Equipped with 11 mainly Hertz Horns. Used in both WWI and WII.	145kg or 227kg	1.02 m in diameter
Mk XV	British	Ovoid	Moored Contact	Equipped with 11 mainly Hertz Horns. Used in both WWI and WWII.	145kg or 227kg	1.02 m in diameter
Mk XVII	British	Ovoid	Moored Contact	Equipped with 11 switch Horns. Used in WWII.	145kg	1.02 m in diameter
TORPEDOES						
G7a Naval Torpedo (multiple combinations of warhead and fusing)	German	Cylindrical	Impact or Magnetic	Some fitted with Whiskers, Wet Heater propulsion	235kg-295kg	21 inch diameter (533 mm) Length 7.162 m

MILITARY DESIGNATION	NATIONALITY	SHAPE	TYPE	FEATURES	NEQ	DIMENSIONS
G7e	German	Cylindrical	Impact or Magnetic	Electric	280kg	21 inch diameter (533 mm) Length 7.186 m
Luftwaffe Torpedo (F5)	German	Cylindrical	Impact or Magnetic	Wet Heater	200kg	45 cm diameter Length 4.8 m – 5.16 m
Torpedo Mk VIII	British	Cylindrical	Impact or Magnetic	Air/Steam powered	340kg or 365kg	21 inch (533 mm) diameter Length 6.579 m
Torpedo Mk XII	British	Cylindrical	Impact	Air/steam powered	176kg	45 cm diameter Length 4.95 m
DEPTH CHARGES						
DC Type I	German	Cylindrical	Hydrostatic Pistol (cocked striker)	Preset depth set by hand. 5 pistol types	136kg	44.5 cm diameter Length 57.0cm
Mk7 Series	British	Cylindrical	Hydrostatic Pistol (cocked striker)	Preset depth set by hand. 3 versions, depending on depth range	147kg	44.4 cm diameter Length 70.2cm
Mk11	British	Cylindrical	Hydrostatic Pistol (cocked striker)	Dropped by aircraft. Length with tail 1.39m	82kg	27.9 cm diameter Length 94.4cm
BOMBS						
250lb GP Bomb	British	Streamlined sides with ogival nose	Impact/delay	Tail or Nose pistol or fuse	95kg, 100kg, 105kg	Diameter 26 cm Body Length 0.72 m
500lb MC Bomb	British	Parallel sides with ogival nose	Impact/delay	Tail or Nose pistol or fuse	95kg, 100kg, 105kg	Diameter 32.7cm Body Length 1.041 m
1000lb MC Bomb	British	Parallel sides with ogival nose	Impact/delay	Tail or Nose pistol or fuse	215kg, 226kg, 238kg	Diameter 45 cm Body Length 1.33 m

MILITARY DESIGNATION	NATIONALITY	SHAPE	TYPE	FEATURES	NEQ	DIMENSIONS
12000lb HC bomb	British	Parallel sides with convex nose	Impact/ Delay	3 nose pistols, sectional construction (each section ~1.23m	5425 kg	Diameter 0.97m Body Length 3.7m
500lb MC	US	Parallel sides with ogival nose	Impact/delay	Tail or Nose pistol or fuse	126kg	Diameter 0.36 m Body length 1.2 m
1000lb MC	US	Parallel sides with ogival nose	Impact/delay	Tail or Nose pistol or fuse	260kg	Diameter 0.48 m Body length 1.37 m
2000lb MC	US	Parallel sides with ogival nose	Impact/delay	Tail or Nose pistol or fuse	525kg	Diameter 59.2 cm Body Length 1.824 m
50kg SC	German	Parallel sides with ogival nose	Impact/delay	Transverse fusing	25kg	Diameter 0.20m Body length ~0.67 m
250kg SC	German	Parallel sides with ogival nose	Impact/delay	Transverse fusing	130kg/145kg	Diameter 0.368 m Body length 1.2 m
500kg SC	German	Parallel sides with ogival nose	Impact/delay	Transverse fusing	220kg	Diameter 0.46 m Body length 1.45 m

Annex C

Potential Detonation Mechanisms for Explosive Ordnance Items

ORDTEK

POTENTIAL DETONATION MECHANISMS FOR EXPLOSIVE ORDNANCE ITEMS

Air Dropped Bombs

Statistics compiled after the war showed that approximately 8.5% of the bombs dropped failed to explode. Subsequent Home Office analysis came up with figure of between 9%-11%. The reasons for failure were several, the main ones were:

Not armed correctly on release from the aircraft

- Deliberately dropped "safe" (if being jettisoned)
- Failure/jamming of a clockwork delay mechanism
- Impact fuse malfunction on striking the ground
- Failure of the detonator or gaine (booster)

Today, in the marine environment, pistols and fuses are likely to be corroded and unlikely to function as intended, although they may be in a sensitive state through the exudation of sensitive salts (this is much less likely underwater than on land). However, a blow with sufficient kinetic energy directly onto a fuse or fuse pocket could be enough to detonate the EO. Small bombs could be lifted inadvertently in the flukes of an anchor; this is unlikely in itself to cause the UXO to detonate but if allowed to dry out, it may become much more sensitive to knocks and friction. Most bombs are relatively thick-cased and therefore not easy to crush; they are more likely to be pushed further into the sediment or moved aside.

Incendiary bombs containing phosphorous pose a particular danger in certain scenarios. If exposed to the air, phosphorous will spontaneously ignite and, while not detonating, will burn fiercely, thereby presenting a threat to exposed personnel and inflammable equipment.

Buoyant Mines

Today, if encountered both WWI and WWII buoyant mines will be found situated on the seabed, often partially buried in the sediment. The mine casings will be heavily corroded. Chemical (Hertz) horns may still be capable of functioning but internal wiring and firing mechanisms are unlikely to be effective. Switch horn mines require power from an internal battery and these will no longer function. The explosive filling is likely to be stable if undisturbed but the mine may still detonate if appropriate criteria are met. If wiring is intact on Hertz horn variants, crushing or deforming the horn could trigger the mine. Charge weights are between 145 - 227kg.

British Ground Mines

WWII British ground mines were made of steel. If encountered, they could be partially or completely buried. Significant corrosion to the casing may have taken place, depending on the depth of burial. Internal batteries, required to power internal influence sensors and the firing mechanism, will have discharged. These mines will not function as intended but have a large charge weight (300kg - 450kg) that could still detonate if the right conditions are met. The detonator is placed in line with the booster by hydrostatic pressure. Once the correct depth of water is reached the detonator is locked into place and cannot easily be withdrawn. It is not possible to see on a cursory external visual inspection (e.g. by diver or ROV) whether the mine is armed or not. It must be assumed that the mine is fully armed and the firing train is complete.

German Ground Mines

WWII German ground mines were very well engineered, with casings of corrosion-resistant aluminium or manganese steel and fuses made by Rheinmetal. They are very liable to be found intact and in excellent condition. The mines could still function as designed if sufficient battery power was available. However, the batteries will have discharged. Many variants were fitted with booby traps and anti-disturbance devices. Charge weights are likely to be in the region of 700kg of HE. Common German ground mine variants, GC & GD, are relatively thin-cased and therefore susceptible to crushing.

Projectiles

HE Naval and artillery projectiles typically will be around 5kg NEQ, but less than 50kg, and consequently present minimal threat to vessels and equipment. Any fusing will be corroded and unlikely to function as designed. However, as relatively small items, they could become wedged in the flukes of an anchor and be brought to the surface, presenting a blast and fragmentation hazard to exposed deck-hands. WWI projectiles were filled with Picric Acid, and derivatives that could be in an extremely sensitive state, particularly if allowed to dry out.

Torpedoes and Depth Charges

As with most UXO, torpedo warheads are liable to be stable if undisturbed but remain a potential hazard, particularly if after launch from the torpedo tube, safety détentes have been removed and the firing train is complete; that is, the detonator is married to the booster and main charge within the warhead. Any depth charges encountered, unless they have been completely buried in hypoxic sediment, are likely to be severely corroded and decomposed to the point of presenting minimal hazard. The firing mechanism is highly unlikely to operate as designed. Nevertheless, the firing train will very probably be complete (i.e. the detonator is in intimate contact with the primer and main charge) and this type of EO could present a significant UXO risk, given the relatively large NEQ. A depth charge could still detonate, for example, if crushed by the leg of a jack-up barge or a vessel grounding.

Land Service Ammunition

A mortar relies on a striker hitting a detonator for detonation to occur. If a mortar failed to function as designed, it is possible that the striker may already be in contact with the detonator and that only a slight increase in pressure would be required for initiation. Similarly, a grenade striker may either be in contact with the detonator or still be retained by a spring under tension and therefore shock may cause it to function. In addition to HE, these items of LSA may be filled with "pyrotechnics" which come in a variety of flares and smoke generating compounds and can include magnesium, thermite and phosphorus.

Small Arms Ammunition

Small arms ammunition (SAA), even if it functioned, is not contained within a barrel and consequently detonation would only result in local overpressure and very minor fragmentation from the cartridge case. SAA cartridges are frequently discovered in military practice areas. These are likely to have been dropped inadvertently during training or deliberately discarded by soldiers. Although technically explosive ordnance, they pose little risk unless they are caused to function by a deliberate act. Moreover it is illegal for an unlicensed person to be in possession of SAA, therefore all finds no matter how minor should be reported in accordance to the appropriate procedure.

Practice Munitions

Most modern practice munitions are painted light blue and/or have fluorescent orange markings. Older practice weapons were often painted white. Generally these are inert but may have small smoke and flash components, which could present a small hazard to personnel close by if these have not been expended. Many practice bombs are readily distinguished as "practice" by their shape and size. However, most practice ordnance items use the same casings, filled with inert material, as the HE versions. Older practice ordnance that has been immersed in sea water for some time will not easily be distinguished from the live, HE-filled, version, even by an EOD expert. If encountered, usually these items will have to be treated as if live.