European Offshore Wind Deployment Centre

Environmental Statement

Appendix 7.1: UXO Threat and Risk Assessment

A project part-funded by the European Union under the European Economic Plan for Recovery in the field of Energy

alpha ASSOCIATES

Unexploded Ordnance (UXO) Threat & Risk Assessment with Risk Mitigation Strategy

***Project*: Aberdeen Offshore Wind Farm**

***Client*: Vattenfall**

***Report Number*: P2219 TRA**

September 2010

Draft Version 1.0

Prepared by:	Gary Hubbard	29th September 2010
Reviewed by:	Lee Gooderham	29th September 2010
Released by:	Simon Cooke	29th September 2010

Contents

Contents iii

Appendices vi

Acronyms and Abbreviations vii

Executive Summary ix

1 Introduction 1

1.1 Overview 1

1.2 Background 1

2 Report Methodology 2

2.1 Structure 2

2.2 Sources of Information 3

2.3 Standards, Guidance and Best Practice 3

2.4 Joint Service Explosive Ordnance Disposal Operations Centre, UK 3

3 Proposed Intrusive Works 5

3.1 Marine Site Investigation 5

3.2 Marine Cable Installation 5

3.3 Turbine Installation 5

3.3.1 Foundations 5

3.3.2 Scour Protection Systems 6

4 Sources of UXO Contamination 7

4.1 General 7

4.2 British Military Activities and Firing Ranges 7

4.2.1 Civilian and Military Firing Ranges 7

4.2.2 Black Dog Firing Range 7

4.2.3 Munition / Explosives Disposal 8

4.3 Allied Sea Minefields 9

6.4.3 Mine Clearance 9

4.4 Aerial Bombing Campaign 10

4.4.1 Overview 10

4.4.2 Shipping Lanes, Sea Convoy Routes and Ports 10

4.4.3 Tip and Run 10

4.4.4 Defensive Anti Aircraft Artillery (AAA) 10

4.5 Shipwrecks / Downed Aircraft 11

5 Explosive Threat Items 12

5.1 General 12

5.2 Weapon Fill Materials 12

5.2.1 High Explosives (HE) 12

5.2.2 Low Explosives 12

5.2.3 Propellants 13

5.3 Artillery Projectiles 13

5.4 Torpedoes 14

5.5 Sea Mines 14

5.5.1 General 14

5.5.2 Fuzing 15

5.6 Depth Charges 15

5.7 German Air-Delivered Weapons 16

5.7.1 Iron Bombs 16

6 UXO Ground Penetration, Burial and Migration 18

6.1 General 18

6.2 Seabed Migration 18

6.3 Seabed Burial 18

6.4 Seabed Penetration 19

7 UXO Detonations 20

7.1 Initiation Scenarios 20

7.2 Detonation Variables 20
7.3 Underwater High Explosive Detonations 21
7.3.1 Underwater Detonation Hazards 21
7.3.2 Direct Effects of Ordnance Detonation 21
7.3.3 Effect of Explosive Shockwave and Gas Bubble on Supporting Vessels 21
8 UXO Risk Assessment Factors 23
8.1 Source – Pathway – Receptor 23
8.1.1 Source 23
8.1.2 Pathway 23
8.1.3 Receptors 23
9 Semi-Quantitative Risk Assessment 24
9.1 Overview 24
9.2 Risk Rating 24
9.3 Risk Rating Criteria 25
9.4 Definition of Consequence and Probability 25
9.4.1 Consequence 25
9.4.2 Consequences Specific to AOWF 26
9.4.3 Probability 27
9.4.4 Specific to the development of AOWF 27
10 Recommended Risk Mitigation 29
10.1 Overview 29
10.2 Quality Assurance / Quality Control .... Error! Bookmark not defined.
10.3 Marine Operations 29
10.3.1 Overview 29
10.3.2 UXO Probability Grading and Mitigation Options 29
11 Conclusions 31
11.1 Key Findings 31

Appendices

Appendix 01	Project Location
Appendix 02A	World War Two (WWII) Armament Ranges
Appendix 02B	Firing Ranges
Appendix 03	Munitions Disposal Areas
Appendix 04	WWII British Minefields
Appendix 05	“Munitions” related Shipwrecks
Appendix 06	Ordnance Characteristics
Appendix 07	Project Risk Assessment Tables
Appendix 08	Project UXO Probability Map

Acronyms and Abbreviations

ALARP	As Low As Reasonably Practicable
CIRIA	Construction Industry Research and Information Association
BD	Bomb Disposal
BDO	Bomb Disposal Officer
BMAPA	British Marine and Aggregate Producers Association
dGPS	Differential Global Positioning Systems
EO	Explosive Ordnance
EOD	Explosive Ordnance Disposal
ERW	Explosive Remnants of War
GIS	Geographical Information System
HE	High Explosive
HMX	High Molecular (mass) RDX
HSE	Health and Safety Executive
IB	Incendiary Bomb
JSEODOC	Joint Service Explosive Ordnance Disposal Operations Centre
KHz	Kilohertz
Kg	Kilogram
Km	Kilometre
lb	Pound (weight)
LSA	Land Service Ammunition
M	Metres
MCM	Mine Countermeasures
MDA	Mine Danger Area
MCA	Maritime and Coastguard Agency
MoD	Ministry of Defence
mm	Millimetres
NaREC	New and Renewable Energy Centre
NEQ	Net Explosive Quantity
NGR	National Grid Reference
Nm	Nautical Mile

RDX	Research Department (composition) ‘X’
ROV	Remotely Operated Vehicle
RN	Royal Navy
QA/QC	Quality Assurance/Quality Control
SAA	Small Arms Ammunition
SI	Site Investigation
SOP	Standard Operating Procedure
SSS	Side Scan Sonar
SQRA	Semi Quantitative Risk Assessment
TNT	Trinitrotoluene
UK	United Kingdom
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
WWI	World War One
WWII	World War Two

Executive Summary

Purpose

Items of Unexploded Ordnance (UXO) are regularly encountered within the North Sea and rarely become inert or lose their high explosives effectiveness with age. There is therefore, a potential risk that UXO could be encountered at the Aberdeen Offshore Wind Farm (AOWF). Vattenfall has commissioned 6 Alpha Associates Limited to conduct a detailed UXO desk based study for this wind farm development.

Aim and Objectives

The aim of this document is to address the initial stages of the UXO risk management process by providing a holistic overview of the UXO threats and risks for the marine component of the entire operation. In commissioning 6 Alpha as the project's UXO consultant, Vattenfall intends to:

- Discharge its duty of care to those involved in the development of the project site;
- Ensure that it takes appropriate "best practice" measures to manage all of the risks posed by the UXO threat;
- Protect the development itself from the risks of UXO blight and in doing so protect its investors, investment and reputation;
- Procure the most time efficient and cost effective means of managing and mitigating the UXO risk.

The report will cross reference and account for relevant statutory instruments vis-à-vis UXO risk (with which clients will have to comply), including Heath and Safety at Work legislation as well as the Corporate Manslaughter and Corporate Homicide Act of 2007 and common law liabilities. Additionally, and in particular, the report will explain how and why the Construction Design and Management (CDM) Regulations 2007 apply as does CIRIA's *UXO – A Guide for the Construction Industry*, (the latter providing the first UK "good practice guide", helping developers and the construction industry to deal with UXO).

The report will describe the potential for UXO encounter, the risks that may be posed as a result, as well as how those risks can be reduced to As Low As Reasonably Practicable (ALARP), at best value. In this way we anticipate that Vattenfall will be able to both satisfy and discharge their client's liabilities concerning corporate governance and UXO risk management through the provision of appropriate levels of project safety.

UXO Threat and Risk

The UXO threat is primarily the result of munitions and weaponry used on the Black Dog Range; although there is the background residual risk presented by UXBs and AAA projectiles from WWII. Other threat sources are recorded within the general region however given the nature of these operations and their location, 6 Alpha does not consider that this source will pose a significant threat to the project. The report will summarise this threat and will present a Semi Quantitative Risk Assessment (SQRA) concerning UXO and the effects that they may have upon personnel and the construction work that they are expected to undertake.

Conclusions and Recommendations

The report concludes that outside the Black Dog range template there is generally a low UXO risk to this project, which could be considered as the "background residual risk". 6 Alpha have therefore recommended that the following actions are required to address the UXO risk. This table should be read in conjunction with the "probability of UXO encounter map" at *Appendix 12*.

UXO Probability Rating	Grading	Action Required ahead of Intrusive Works	Associated Additional Costs Low → High
1-2	**Remote - Possible**	Areas defined as "background residual risk". Use, wherever possible, existing geophysical datasets for UXO risk reduction. Define smallest UXO threat items, interpret the datasets for contacts similar to UXO and avoid during future works. Brief all personnel involved in intrusive works and ensure reactive procedures/guidelines are in place. **6 Alpha Deliverable** - Client's must accept that this is not a 100% survey coverage for UXO, although if conducted by 6 Alpha the risk will be reduced to ALARP.	
3-4	**Likely - Very Likely**	There are three options for dealing with the risk in these areas: • **Option 1** - Relocate works to areas with a grading of 1 or 2; • **Option 2** – Conduct a UXO Specific Geophysical Survey and avoid targets. This survey should be designed to match the defined UXO threat and provide 100% coverage of specific threat area; • **Option 3** – If target avoidance not possible conduct either diver investigation or ROV inspection, which may discount the item or lead to UXO disposal. **6 Alpha Deliverable** - Once the UXO risk reduction actions have been successfully implemented and subject to our own QA/QC measures, 6 Alpha will sign-off the UXO risk as ALARP.	
5	**Almost Certain**	6 Alpha would strongly suggest avoiding these areas, and relocation work. As the costs associated reducing the risk to ALARP are likely to be considerable.	

1 Introduction

1.1 Overview

Vattenfall Wind Power Limited (Vattenfall) has commissioned 6 Alpha Associates Limited (6 Alpha) to conduct a detailed Unexploded Ordnance (UXO) desk based study for the Aberdeen Offshore Wind Farm (AOWF); the project's location is depicted at *Appendix 01*. The AOWF development zone is situated off the east coast of Scotland within the North Sea.

Whilst 6 Alpha considers that only marine threat items within 500m of the study will impact on the operation, a much wider search area has been considered for this report to ensure all threats are considered.

Items of UXO are regularly encountered within the North Sea, as confirmed by the media and Royal Navy, and rarely become inert or lose effectiveness with age. Over time, trigger mechanisms (such as fuzes and gaines) can become more sensitive and therefore more prone to detonation. This applies equally to items that have been submersed in water and/or lodged within the seabed. It is possible that significant kinetic energy created by the intense impacts generated by marine engineering, such as cable trenching or site investigation boreholes, could cause an inadvertent detonation.

The aim of this document is to address the gaps in the previous BACTEC study, as identified in the Situation Report (ref. P2219 dated 16th August 2010) by providing a holistic overview of the UXO threats and risks for the entire marine operation. This includes employing background research and factual data, which has been provided by (client engaged) third parties, and upon which we have relied. To ensure a comprehensive and complete report there may be a certain element of duplication from the BACTEC desk study.

1.2 Background

In commissioning 6 Alpha as the project's UXO consultant, Vattenfall intends to:

- Discharge its duty of care to those involved in the development of the project site;
- Ensure that it takes appropriate "best practice" measures to manage all of the risks posed by the UXO threat;
- Protect the development itself from the risks of UXO blight and in doing so protect its investors, investment and reputation;
- Procure the most time efficient and cost effective means of managing and mitigating the UXO risk.

2 Report Methodology

2.1 Structure

This study consists of a desk-based collation and review of readily available documentation and records relating to the possibility of encountering UXO and/or dangerous Explosive Ordnance (EO) related paraphernalia, within the study area. Certain information obtained by 6 Alpha may be either classified or restricted material or, considered to be confidential to 6 Alpha. Therefore summaries of such information have been provided. Please note that our appraisal partly relies on the accuracy of the information contained in these and other third party documents consulted and that 6 Alpha will, in no circumstances, be held responsible for the accuracy of such third party information or data supplied.

In agreement with Vattenfall the following facets will be covered within this report:

- The entire scope of the proposed wind farm project work has been considered;
- The history of the region has been considered, incorporating data from the previous reports;
- Relevant modern military records have been researched and presented;
- Wartime activities have been researched and presented;
- The holistic UXO threat has been considered, including the types that could be encountered, the probabilities of encountering them as well as exposing their potential mechanisms and risks of detonation;
- An outline assessment of how UXO interacts with the natural environment and conditions is made;
- The risks regarding UXO have been assessed;
- A semi-quantitative risk assessment (SQRA) has been undertaken employing 6 Alpha's "Azimuth ©" proprietary risk model;
- The consequences of an inadvertent High Explosive (HE) detonation has been considered;
- Conclusions have been drawn;
- Recommendations, and an overview risk mitigation strategy has been presented.

2.2 Sources of Information

The sources of information consulted for this report include:

- Royal Navy (Northern Diving Unit), Scotland;
- The National Archives, Kew;
- Naval Historical Centre, Portsmouth;
- UK Hydrographic Office, Taunton;
- 6 Alpha's "Agility Database ©" which contains historic maps, aerial photographs and records;
- Development boundary supplied by Vattenfall.

2.3 Standards, Guidance and Best Practice

In producing this document 6 Alpha has consulted the most relevant published guidance and best practice. It should be noted that some of these sources may *prima facie*, not appear to be distinctively relevant to this project/study but, in the absence of specific guidance concerning the management of UXO for the offshore renewable industry, the following sources of guidance are considered most applicable:

- Construction Industry Research & Information Association (CIRIA) – UXO A Guide for the Construction Industry (reference number C681);
- Maritime and Coastguard Agency (MCA);
- British Marine Aggregate Producers Association (BMAPA);
- Health & Safety Executive (HSE).

2.4 Joint Service Explosive Ordnance Disposal Operations Centre, UK

According to Joint Service Explosive Ordnance Disposal Operations Centre (JSEODOC – collocated with one of the British Army's Bomb Disposal Regiments at Didcot, Oxfordshire), UXO discovered during wind farm related operations have presented a problem in the recent past. However, and as yet, there is no clear guidance as to what actions should be taken to mitigate the risk nor in what circumstances the Ministry of Defence (MoD) might respond. JSEODOC directed 6 Alpha to the BMAPA guidance employed for mitigating UXO risk during dredging operations, although this only partly address the UXO risk in a wind farm situation.

In summary the pertinent points gathered from the JSEODOC are:

- There is no legal obligation on the Royal Navy (RN) to respond to UXO incidents outside the UK's 12 nautical mile (Nm) limit;
- Each reported UXO find would be risk assessed on a case by case basis;
- The RN response will depend upon the perceived risk and their commitments to other operations;
- If commercial operations are active in an area where there is a "reasonably foreseeable" risk from UXO, then commercial Explosive Ordnance Disposal (EOD) consultancy and/or contracting support should be arranged. However, in terms of offshore cable laying and foundation installation especially, there is no clear indication as to which areas have "reasonably foreseeable" UXO risk. For dredging operations, by comparison, the level of UXO distribution over the seabed and thus the associated risk is much better clarified and delivered as part of the operating license.

3 Proposed Intrusive Works

3.1 Marine Site Investigation

As part of the project, as is good practice in all offshore renewable projects, geophysical and/or geotechnical work is undertaken. This type of work involves remote and direct sensing techniques that may carry increased risk with regard to UXO. Many systems use the reflection or refraction of energy sources to derive data that can be interpreted to provide a picture of the seabed. The typical energy sources employed are acoustic, pressure or "physical energy" sources that compress or penetrate the seabed. Whilst it is theoretically possible that some of these energy sources could be employed to initiate very sensitive marine explosive ordnance it is considered practically impossible to initiate WWII ordnance in this way; there is no evidence of historic UXO in the marine environment being initiated by conventional methods of marine geophysical survey.

3.2 Marine Cable Installation

The Client will install an export cable to the Scottish mainland; in addition there will be a number if interconnector cables between the turbines. Given empirical evidence it is conceivable that potential interaction with UXO may occur during the following operations:

- **Pre-Lay Grapnel Run (PLGR)** – This is used to prove that the route is clear of disused cables or scrap. It will involve towing a heavy grapnel iron(s) along the route;
- **Cable trenching** – This will follow the PLGR and is expected to be conducted by a variety of methodologies, which will be influenced primarily by water depths and seabed conditions.
- **Deployment of barge anchors** – In areas where the water depth is less than 10m a cable plough may be deployed from a moored cable-laying vessel, to install the cable. The anchor spread will be positioned using a tugboat.

3.3 Turbine Installation

3.3.1 Foundations

Although it has not been confirmed, the foundations for the wind turbine structures are likely to be monopiles. Other techniques and structures are sometimes utilised but for this report we will assume that monopiles will be used. Monopiles are made from welded tubular steel sections, which are driven vertically into the seabed. They are a friction pile system (employing the friction between pile wall and surrounding geology), which supports the weight of the tower and turbine. Indicative monopile dimensions are shown in Table 3.3.1:

Monopile Technical Specification	
Diameter	Up to 6m
Total Length	Up to 90m
Sea bed Penetration	Up to 45m
Steel Plate Thickness	Up to 100mm
Total Weight	200 to 900te

Table 3.3.1 - Typical Monopile Dimensions

Monopiles may be installed using the Drive-Drill-Drive method. The pile is allowed to sink under its own weight and it is then driven into the seabed using a hydraulic hammer. Upon first refusal a drill rig is lowered into the pile and a socket is drilled beneath the toe. Afterwards the pile is again driven into the socket until the required penetration is achieved.

If other foundation techniques are employed the key factor is the force used and the resultant kinetic energy that may initiate UXO. Most foundation techniques usual create this situation.

3.3.2 Scour Protection Systems

It is anticipated that wind turbines will employ anti scour protection system in the form of rock emplacement. This is generally emplaced after turbine installation works are complete. The type and extent of anti scour protection depends upon the soil and sea conditions and mast foundations employed; other types may be employed that will involve interaction and intrusion into the seabed.

4 Sources of UXO Contamination

4.1 General

6 Alpha have conduct detailed research for this project, and after analysing the datasets it is envisaged that there are five principle potential sources of UXO contamination in the region, namely:

- WWII Enemy Bombing;
- Allied Defensive Sea Minefield;
- Military Firing Ranges;
- Munitions related Shipwrecks;
- Munitions Disposal Areas.

However not all of these threats do not directly impact upon the project development zone. From the five sources only one military firing range encroaches within the AOWF boundary.

4.2 British Military Activities and Firing Ranges

4.2.1 Civilian and Military Firing Ranges

There are numerous firing range located along the east coast in the vicinity of AOWF, these are depicted at *Appendix 2A and 2B*. Table 4.2.1 lists the geographically relevant areas and specifies their usage. Of these four sites only Black Dog range has direct impact on the proposed works.

Range Number	Name	Facility
N/A	Black Dog	WWII Military Land Service Ammunition and Current Small Arms Range
N243	Aberdeen	Heavy and light guns used by vessels.
244	Girdleness	Anti-Aircraft Guns Heavy and Light
N/A	Drums Link	Civilian Small Arms Range

Table 4.2.1 – Firing Ranges in proximity of the project.

4.2.2 Black Dog Firing Range

This range has been operational from 1940 to present day. During this time a number of military weapons and munitions have been used on the site. The range by-laws state the range can be utilised for the following:

- Anti Aircraft Small Arms;
- Anti Tank Guns;
- Anti Tank Rifles;
- Machine Guns;
- Mortars;
- Grenades;
- Revolvers and Rifles.

The by-laws document also stipulates that no public interference within the range boundary area is permitted and that any item discovered within the sea danger area should be returned to the sea immediately.

The range at present is assigned to the Army Training Estate (ATE) Scotland. The ranges usage currently is limited to three live firing areas, and a dry training area that may be used day or night. These ranges have been historically used for “Non-Mechanised” weapons systems.

4.2.3 Munition / Explosives Offshore Disposal

Post WWI and WWII, both chemical and conventional munitions were extensively dumped at sea, including in areas off the UK coast. The locations of some of these areas are well known as are the type and numbers of munitions deposited, but in other areas there are problems concerning accuracy of types and numbers dumped. This inaccuracy is incurred because of a combination of factors including; inadequate record keeping, the dumping of items outside designated official dumping areas; and, to an extent, the movement of munitions post dumping as the result of tidal flow.

There is an explosives/munitions disposal area to the south of the project development zone. This area is recorded as a “conventional munitions” disposal site, but is too far away to directly impact upon the project (the location is presented at *Appendix 03*).

4.3 Allied Sea Minefields

A naval mine is a self-contained explosive device placed in the water to destroy ships and/or submarines. They are weapons which are triggered by the approach of a ship. Naval mines can be used offensively, to hamper enemy shipping and lock it into it's harbour, or defensively, to protect Allied shipping and create "safe" zones. Some sources state that up to 70% of sea mines were not recovered after WWII. As a result of enemy sea mining activity, proposals were made in November 1939 to mine the North Sea. These proposals considered the likely effect on fishing as well as the requirement to provide mine-clear sea-channels for British, Dutch and Belgian shipping.

6.4.3 Mine Clearance

At the end of WWII there was a significant sea-mine clearance operation undertaken by both Allied and German Navies, who attempted to clear their respective minefields. This operation was undertaken by one of two methods:

- Using two minesweepers, a sweep-wire (with a serrated edge and an "otter" or "kite" to keep the sweep wire at the required depth), was laid into the water and both ends were attached to a winch at the stern of each ship. The sweep-wire was towed by both vessels over a mined area and, when connected to the "mooring stay" of a moored mine, the ships momentum would then force the stay to the serrated edge of the sweep wire, which cut it. The mine would then (usually), float to the surface for disposal.
- An alternative method was to use one ship only with the sweep wire attached to an oropesa float (to keep the sweep wire away from the ships), and the wire would then cut the mooring stay of the mine (as described above). The untethered mine would then (usually) float to the surface where it was then destroyed, often by rifle fire (however, on occasions the bullet only penetrated the outer casing of the mine, which allowed water to ingress and it would then sink and come to rest on the sea bed; an explosive hazard thus remained).

Historical Admiralty mapping confirmed that minefields that had been situated off the eastern coast were cleared post-War. Whether all those mines that were recorded as being laid, were *de facto* recovered during clearance, could not be confirmed (it should be noted that 100% clearance of minefields, even with today's technology, is not always achievable). The locations of the local mine lays can be seen at *Appendix 04*, they are over 18km away from the development zone and are not considered to present a direct threat to this project.

4.4 Aerial Bombing Campaign

4.4.1 Overview

Limited bombing occurred during WWI, as the main German threat in the marine environment were U-Boats. With the development of aircraft and air delivered weaponry, aerial bombardment became an important phase prior to any possible invasion during WWII. During the early stages of the war, Britain was continuously bombed between 1940 and 1943. Strategic targets along the coastlines of Britain included ports, docks, shipping lanes and power stations. Aberdeen was one such port that was regularly bombed as part of the German campaign.

4.4.2 Shipping Lanes, Sea Convoy Routes and Ports

The east coast ports of Scotland were important commercially and, as WWII progressed, they achieved strategic importance for the transport of coal, as well as for fishing (which was considered key to helping feed the UK's wartime population). A military lesson from WWI was implemented, which saw merchant ships gathered into convoys for protection. Notwithstanding the Royal Navy's attempts to afford such convoys protection, they were regularly attacked from the air. The Luftwaffe also dropped thousands of HE bombs on these convoys and regularly targeted other vessels as the opportunity arose.

Given that there is firm evidence that the vessel, SS Arcangel, was sunk by bombing close to the development boundary (*Appendix 05*), there is the risk that UXBs may remain on the seabed in this region.

4.4.3 Tip and Run

A significant number of air-to-air battles also occurred over this area, some of which resulted in numerous allied and enemy aircraft jettisoning all or part of their payloads i.e. *inter alia* medium and large capacity, UXBs (a tactic known as "Tip and Run"), either in an attempt to escape their pursuers, or to quickly offload weapons from damaged aircraft, before returning to base. Although records of these events are poor, the threat of encountering jettisoned munitions in the sea must be considered an unquantifiable risk, when assessing the background UXO threat for all areas in the North Sea.

4.4.4 Defensive Anti Aircraft Artillery (AAA)

There were two types of AAA battery deployed during WWII; heavy and light. These weapons were deployed on the ranges along the Scottish east coast, notably at Black Dog.

Heavy batteries were static and usually sited in the same position for the duration of the war. They deployed either 4.5 or 3.7 inch guns in groups of 2, 4, 6 or 8 guns per battery. Typically heavy battery was divided between two sites each with four guns and up to several miles apart. The 4.5 inch gun could fire a HE shell (weighing approximately 25kg and fitted with either a barometric or time fuze) 8 miles in 50 seconds. The 3.7 inch gun had a similar ceiling height but smaller calibre shell, again with barometric or time fuzes.

The light batteries were deployed with the 40mm Bofors gun. This weapon could fire up to 120 x 40mm HE shells per minute to approximately 6,000ft; the shells were designed to explode on impact with enemy aircraft. These batteries were not static and could be moved easily to new positions by truck when required.

If AAA shells failed to explode or strike an aircraft they would eventually fall back to land or sea, settling on the seabed in the latter case.

Naval and merchant vessels are commonly equipped with various types of deck guns to protect themselves against enemy air attack. If projectiles or AAA fire missed the target, then it could fall into the sea or over land and may still present a UXO hazard. Again records for this activity are poor and should be considered as a background residual risk.

4.5 Shipwrecks / Downed Aircraft

Shipwrecks in the region confirm that enemy aerial bombing occurred in the region. Although there are no military/munitions related wrecks are recorded within the actual development.

Both merchant and naval vessels that were sunk in WWII may have contained munitions. Empirical evidence has shown that munitions did spill from the ships as they sank and subsequently broke-up. Similarly, aircraft that were shot down or otherwise had to ditch into the sea, may have also contained munitions. In general, the risk of munitions contamination is somewhat less in the vicinity of wrecks as compared with munitions dump-sites because the munitions, in all probability, are most likely to remain enclosed and immobile within the body of the wrecks. However, it may be possible that some items may have been thrown clear of the vessel as it sank or they could become exposed as the wrecks gradually broke up.

5 Explosive Threat Items

5.1 General

Having established potential contamination sources, the following generic ordnance groups are considered likely to present a threat to the proposed development. Clearly, some varieties of UXO are likely to be more common within the project area than others. The table at *Appendix 06*, provides a schedule of dimensions and explosive quantities for the main threat items.

5.2 Weapon Fill Materials

5.2.1 High Explosives (HE)

A HE compound detonates at rates ranging from 1,000m to 9,000m per second, and may be subdivided into two explosives classes, differentiated by their respective sensitivity:

- **Primary Explosives** – are extremely sensitive to mechanical shock, friction and heat to which they will respond by burning rapidly or detonating. Examples include mercury fulminate and lead azide. This characteristic makes them unsuitable to use as base (i.e. main-fill) explosives in military ordnance. Sensitivity is an important consideration in selecting an explosive for a particular purpose, e.g. the explosive in an armour-piercing projectile must be relatively insensitive, or the shock of impact would cause it to detonate before it penetrated the target.
- **Secondary Explosives** – are relatively insensitive to shock, friction and heat. They may burn when exposed to heat in small-unconfined quantities, although the risk of detonation is always present (especially when they are confined and/or are burnt in bulk). Dynamite, TNT, RDX and HMX are classed as secondary high explosives, which are commonly used as, base explosives in military ordnance. PETN is the benchmark compound; those explosives that are more sensitive than PETN are classed as primary explosives.

5.2.2 Low Explosives

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

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

5.2.3 Propellants

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

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

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

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

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

5.3 Artillery Projectiles

Artillery projectiles may be classified and grouped as follows:

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

5.4 Torpedoes

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

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

Whilst it is possible that unexploded torpedoes might be encountered, it is anticipated that their potential discovery is likely to be less frequent than other naval weapons e.g. sea mines.

5.5 Sea Mines

5.5.1 General

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

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

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

5.5.2 Fuzing

Sea mines can be armed with more complex fuzing and initiation mechanisms, which fall into 3 main groups:

- **Hydrostatic Fuzing** – A valve that detects the difference in water pressure (i.e. generated by a passing vessel). Some sophisticated German WWII mines had this type of fuzing and were used in the North Sea;
- **Magnetic Fuzing** – A fuze that detects a displacement of the ambient magnetic field, normally by the introduction of a ferrous metal object (such as a passing vessel);
- **Sonar Fuzing** – Based upon a similar principle as radar, whereby any increased return of the underwater return signal to the sea mine, is interpreted as a potential target vessel and therefore the arming sequence is initiated.

The older generation of moored sea mines were, more commonly, designed to function upon contact with a ship or vessel. The externally mounted chemical horns (or spikes), consisted of a lead outer sheath, which contained two, separated, chemical ampoules. Upon contact, the external horn would crumple, thereby crushing the ampoules and allowing the chemicals to mix. The resultant mixture would immediately produce either an electrical charge or combustion, forming the basis for an explosive reaction and detonation of the bulk high explosive.

5.6 Depth Charges

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

Depth charges varied in size (from 55Kg to 300Kg) and consequently the mass of HE of explosive changed to suit the type of target being attacked. Towards the end of WWII the RN were using a “Mark X” depth charge, which contained 1000kg of explosives; they were fired from tubes mounted on the decks of war-ships.

5.7 German Air-Delivered Weapons

5.7.1 Iron Bombs

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

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

- **General Purpose** – Designed, as the name suggests, to attack a variety of targets and normally contain an explosive content of approximately 50% of the overall mass of the bomb.
- **Armour Piercing** – Designed to create a mechanically driven entry point in the target prior to detonation, in order to maximise the consequent blast and fragmentation effect. Bunker busting systems, anti-shipping, anti-armoured fighting vehicle and counter-tunnel systems are good examples of the tactical deployment of armour piercing bombs. In general, only 30% of the overall mass contains HE with the remaining 70% made up of steel (in order to maximise penetration and any subsequent fragmentation effect). Armour piercing bombs are always fitted with tail-fuzes.
- **Anti-Submarine** – As the name suggests, primarily designed to attack known underwater targets. These types of bombs are always equipped with a tail fitted hydrostatic fuse and 85 – 90% of the overall mass consists of HE.
- **Incendiary** – These are normally constructed of a thin metal casing containing a thermite (manganese/aluminium) compound. Generally, once the compound is

exposed to oxygen, an instantaneous combustion takes place with the heat generated reaching in excess of 800°C. These bombs were often targeted against high concentrations of industry, general urban development and shipping.

- **Fragmentation** – Fragmentation bombs are normally deployed to maximise the secondary effects of an explosion. The bomb is generally constructed from thick (sometimes segmented), steel, designed to for maximum fragmentation effect. Fragmentation bombs are generally deployed against "soft" unprotected targets.

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

6 UXO Ground Penetration, Burial and Migration

6.1 General

When assessing the potential for ordnance ground penetration it is essential not to rely solely on either an empirical, statistical and arithmetical formula. Experience has shown that a realistic penetration depth is best estimated by considering a blend of the above approaches supplemented by accounts of Explosive Ordnance Disposal Tasks (and thus empirical evidence) in the area.

6.2 Seabed Migration

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

After prolonged exposure to saline water and the action of sea, some munitions can break-up or be otherwise rendered ineffective as high explosive devices; others are still discovered (today), in excellent condition. Additionally, munitions tend to gather in seabed depressions (they roll in, but tidal action often has insufficient momentum to roll them out again). In some areas of the North Sea high concentrations of UXO may gather in such natural seabed "sinks".

6.3 Seabed Burial

Empirical evidence has shown that it is possible for UXO that initially lie on the seabed, to become subsequently buried within the "offshore" environment. This occurs especially where substantial tidal and environmental factors impact seabed conditions e.g. when there are high sedimentation rates, and thus UXO movement (into a seabed depression), and subsequent concealment. Storms and/or exceptional tidal flows could significantly alter the topography of the seabed, and although items of UXO are usually very dense, if they are not moved (and they might during strong tidal flows), they may be concealed easily with the sequential passing of tides and associated sediment movement/deposition.

On this project the highest rates of sedimentation is expected to be close to the shore; accordingly it is possible that munitions may have become buried, over time in that region. Clearly, smaller munitions are more likely to buried (such as AAA or projectiles rather than the larger items of UXO (such as sea mines and iron bombs). When establishing the options for UXO risk mitigation it is important to ascertain the level of potential sediment cover in areas of proposed works.

6.4 Seabed Penetration

The presence of a body of water will have a considerable affect on the conventional and expected penetration depth (into the seabed) for air dropped bombs. Bombs behave uniquely as they enter a body of water and their velocity is reduced significantly before the bomb comes into contact and penetrates the seabed. As a guideline and subject to specific UXO and geotechnical factors the maximum penetration of a 500kg bomb is unlikely to exceed 1m below seabed level, when more than 10m of water is present at the time the munition was delivered).

7 UXO Detonations

7.1 Initiation Scenarios

In ‘normal’ conditions at sea, UXO does not usually spontaneously explode. Ordinarily, high explosive requires the input of a significant amount of energy to create the conditions for detonation to occur. Although the British Geological Society seismological records suggest that there were 47 spontaneous detonations of dumped munitions in the Beauforts Dyke dumping grounds, between 1992 and 2004. However it is possible that these were the result of munitions deteriorating in the salt-water environment (which is in itself unlikely) and/or becoming more sensitive to shock with age (which is more likely).

Notwithstanding this, in the event of UXO discovery within the construction environment, there are a number of potential initiation mechanisms; they are:

- Direct impact onto the main body of the munition e.g. from the PLGR, jack up barge leg or cable trench;
- Friction impact, initiating the (more sensitive) fuze explosive caused by a number of construction related activities (for example impact from an excavator bucket, piling, or trenching equipment);
- Over pressure caused by piling that may initiate a hydrostatic fuzed munition (where applicable).

During the 1980’s British Royal Navy clearance divers were informed, by technical experts from North Atlantic Treaty Organisation (NATO), that WWII-era munitions, which relied on a capacitor in the firing system, would not retain enough electrical charge to function as designed. Therefore very old items, which rely on magnetic or acoustic fuzing to initiate, are not considered a threat, although direct impact to these items may generate enough kinetic energy to initiate the item.

7.2 Detonation Variables

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

- The size of the item and its Net Explosive Quantity (NEQ).
- The proximity of the item to vulnerable equipment (and/or other structures).
- The type of explosive and/or fill (e.g. high explosive, incendiary, or specialist).
- Location of the item which may be:

- Floating on the body of water (buoyant mines only);
- On the seabed;
- On the surface;
- Partially buried;
- Totally buried.

- The construction and structural strength of any vessel, equipments or structures near the site of an explosion.

7.3 Underwater High Explosive Detonations

7.3.1 Underwater Detonation Hazards

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

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

7.3.2 Direct Effects of Ordnance Detonation

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

7.3.3 Effect of Explosive Shockwave and Gas Bubble on Supporting Vessels

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

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

8 UXO Risk Assessment Factors

8.1 Source – Pathway – Receptor

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

8.1.1 Source

6 Alpha has considered that the threat is primarily the result of munitions and weaponry used on the Black Dog firing range, although there is always the potential background residual risk from both UXBs and AAA shells from WWII.

8.1.2 Pathway

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

- Geotechnical investigation;
- PLGR;
- Marine cable trenching;
- Laying barge anchors;
- Monopile Installation.

8.1.3 Receptors

Sensitive receptors on this site would include:

- Site Investigation Crews.
- Construction Workers/Engineers.
- High-value Equipment.
- Ships/vessels
- Third party shipping/vessels in the immediate vicinity – Note extended safety distances for detonations underwater apply (for reasons we have articulated above).
- Infrastructure and people located along the coastline (close enough to be harmed UXO if was inadvertently detonated).

9 Semi-Quantitative Risk Assessment

9.1 Overview

In undertaking a series of Semi-Quantitative Risk Assessments (SQRA) across the project, we have employed the technical data associated with the items presented within this report and the proposed operation. The following sections transparently outlines the methodology and calculations used in conduction the SQRA for the project. Risk assessment tables are presented at *Appendix 07*.

9.2 Risk Rating

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

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

Table 9.2 – Risk Matrix

9.3 Risk Rating Criteria

It is important that the numerical values assigned to the potential probability and impact of a risk match the risk tolerance of the Client. Table 9.3 outlines the risk rating rationale that has been applied in this analysis:

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

Table 9.3 – Risk Tolerability Table

The risk levels are used to determine the level of mitigation required to reduce the risk to conform to the ALARP principle. In producing the strategy the risk levels are benchmarked against the various degrees of tolerability (shown in Table 9.3 above), to determine what degree of risk is considered acceptable.

9.4 Definition of Consequence and Probability

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

9.4.1 Consequence

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

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

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

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

9.4.2 Consequences Specific to AOWF

The detonation consequence assessment assigns a site-specific consequence level to any potential UXO that may be encountered at the site. This is achieved by combining the UXO impact distance from sensitive receptors, the Net Explosive Quantity (NEQ) of the item and, where applicable, the average water depth range (assumed here to be in the region of 10-15m). A rating system for assigning impact levels has been derived based on the expected effects of a detonation event on each of the receptors identified in the project consequence matrix is presented at Table 9.4.2. The expected impacts are ranked from 1 (no significant effect) to 5 (major widespread effects / catastrophic).

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

Table 9.4.2 – Consequence Matrix

9.4.3 Probability

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

9.4.4 Probability Specific to the development of AOWF

Based on past experience, the probability levels presented at *Table 9.4.4*, have been used in building the overall risk ratings for this specific project:

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

Table 9.4.4 – Probability Matrix

6 Alpha have collated, reviewed and analysed the historical data and conducted an assessment based on the criteria in Table 9.4.4 to produce a chart that demonstrates “probability of UXO encounter” on the project (*Appendix 08*).

This map is not a risk map *per se* because it does not incorporate the activities that might be associated with such an “encounter” nor the likely consequences. However this map is an important tool in the risk management process as it displays areas that require UXO risk mitigation and others which should be avoided.

10 Recommended Risk Mitigation

10.1 Overview

In view of the UXO risk in this region and the proposed engineering works, 6 Alpha has designed the following mitigation strategy to reduce the risk to a level that conforms with the Health & Safety Executive's ALARP principle. This strategy has been developed in order to fully address the UXO risk across the entire development site, whilst working within critical operational and time limitations.

6 Alpha believes that avoidance of potential risk items is the key to successful UXO risk management in this environment. By adhering to robust procedures and operational guidelines the impact to the ongoing development can be significantly reduced. 6 Alpha recommend that the time window between any proactive mitigation works and the proposed works is minimised (within reasonable operational constraints).

It should be noted that the risk from UXO could never be considered 'zero' in the offshore environment, as there is always the potential for UXO migration through natural sedimentation transportation or the recorded deposition of munitions through war, training or disposal.

10.2 Marine Operations

10.2.1 Overview

Prior to undertaking any intrusive work, the "higher UXO threat areas" as displayed at *Appendix 08* should be avoided. In particular 6 Alpha would draw Vattenfall's attention to the Black Dog firing range. If the client does not want to avoid this area, as it is a viable development area, then 6 Alpha would recommend that any intrusive works are mitigated accordingly.

10.2.2 UXO Probability Grading and Mitigation Options

6 Alpha have recommended that the following actions are required to address the UXO risk. This table should be read in conjunction with the "probability of UXO encounter map" at *Appendix 08*.

UXO Probability Rating	Grading	Action Required ahead of Intrusive Works	Associated Additional Costs Low High
1-2	**Remote - Possible**	Areas defined as “background residual risk”. Use, wherever possible, existing geophysical datasets for UXO risk reduction. Define smallest UXO threat items, interpret the datasets for contacts similar to UXO and avoid during future works. Brief all personnel involved in intrusive works and ensure reactive procedures/guidelines are in place. **6 Alpha Deliverable** - Client’s must accept that this is not a 100% survey coverage for UXO, although if conducted by 6 Alpha the risk will be reduced to ALARP.	
3-4	**Likely - Very Likely**	There are three options for dealing with the risk in these areas: • **Option 1** - Relocate works to areas with a grading of 1 or 2; • **Option 2** – Conduct a UXO Specific Geophysical Survey and avoid targets. This survey should be designed to match the defined UXO threat and provide 100% coverage of specific threat area; • **Option 3** – If target avoidance not possible conduct either diver investigation or ROV inspection, which may discount the item or lead to UXO disposal. **6 Alpha Deliverable** - Once the UXO risk reduction actions have been successfully implemented and subject to our own QA/QC measures, 6 Alpha will sign-off the UXO risk as ALARP.	
5	**Almost Certain**	6 Alpha would strongly suggest avoiding these areas, and relocation work. As the costs associated reducing the risk to ALARP are likely to be considerable.	

Table 10.3.2 – Risk Mitigation Options

11 Conclusions

11.1 Key Findings

In terms of UXO threat, this report has demonstrate that the UXO threat is primarily the result of munitions and weaponry used on the Black Dog Range; although there is the background residual risk presented by UXBs and AAA projectiles from WWII. Other threat sources are recorded within the general region however given the nature of these operations and their location 6 Alpha does not consider that this source will pose a significant threat to the project. This has been reflected in the SQRA tables presented at *Appendix 11*.

It is conceivable that live HE items would have been fired out to sea (from land based weapons platforms) at the Black Dog range and a proportion of UXO could still be present in the area today. Therefore it would be prudent to avoid this area for all future intrusive works.

Due to the relatively slow tidal movement within the North Sea, tides are likely to have a minimal short-term effect on seabed munitions movement. The maximum penetration of a 500kg bomb along this route, is not likely to exceed 1.0m below seabed level. It is conceivable that, if present, any bombs, mines, torpedoes and parachute mines would be on or just below the seabed.

Where detonation occurs underwater, potential damage may result from direct fragmentation as well as the pulsing gas bubble and its resultant shock wave. The main consequence depending upon water depth is likely to include injury to personnel and damage to installation vessels, and associated support vessels and equipment. Given typical water depths seen in the area, assumed to be between 10-15m (TBC), a reasonable and practical working assumption is that any UXO which has a charge weight of 40kg or greater, is capable of causing significant damage.

As many of the sea mines and bombs that may be encountered have a NEQ of around 100kg or greater, the effect of them detonating (even on the seabed), is likely to be catastrophic, and remain extremely serious in the deeper waters.

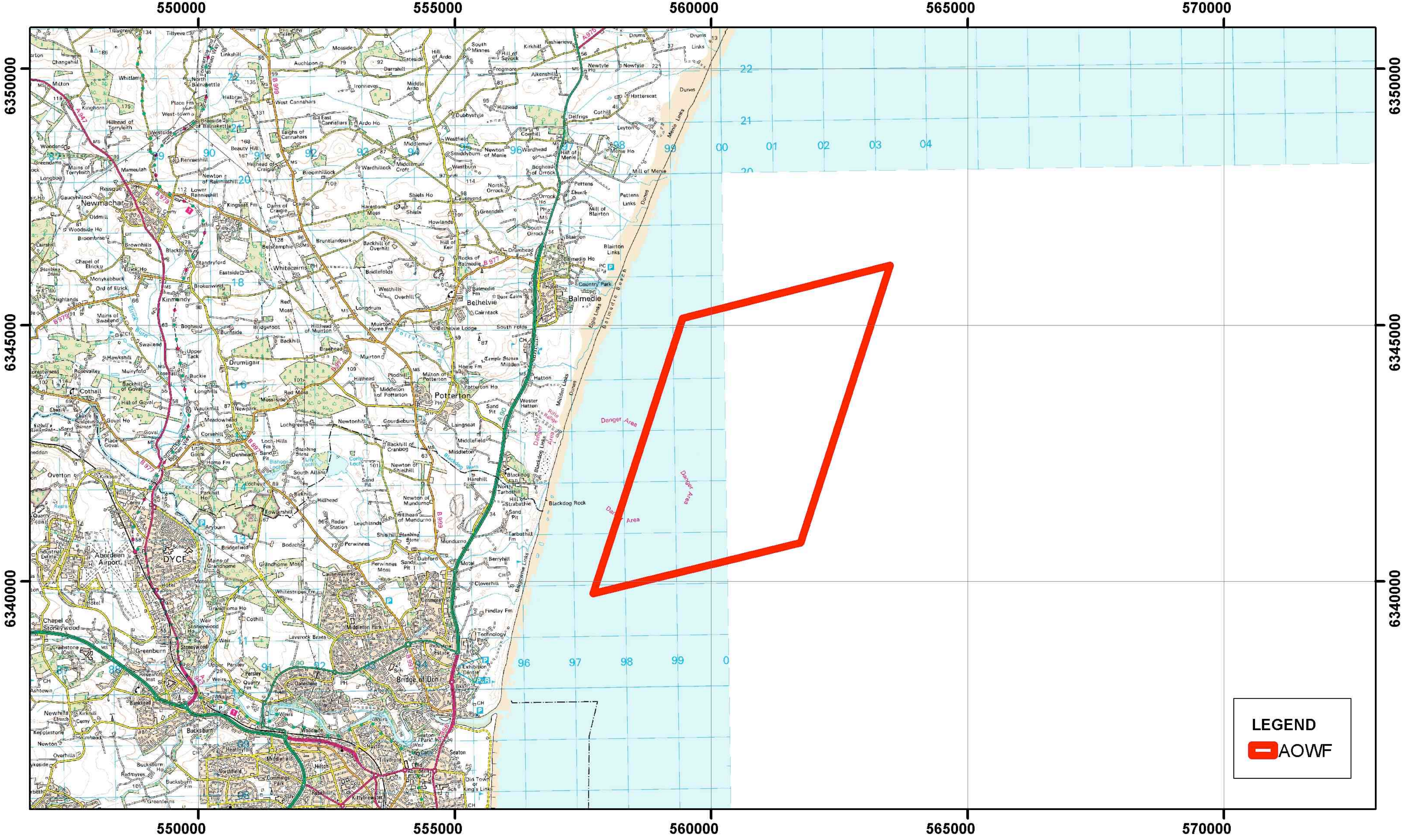
Appendices

Appendix 01

Project Location

Aberdeen Offshore Wind Farm
Project Location

Appendix 01



6 Alpha Associates Ltd.
Quatro House
Frimley Road
Camberley
Surrey GU16 7ER
United Kingdom
www.6alpha.com
0203 371 3900

0 0.5 1 2 Nautical Miles

Scale @ A4: 1:150,000
Revision: 001

N

Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please forward to 6 Alpha. Development zone (in GIS format) obtained from Vattenfall.

Projection System: UTM 30N
Datum: WGS84
Spheriod: WGS84

Project Number: P2219

Drawn By: Gary Hubbard

Checked by: Lee Gooderham

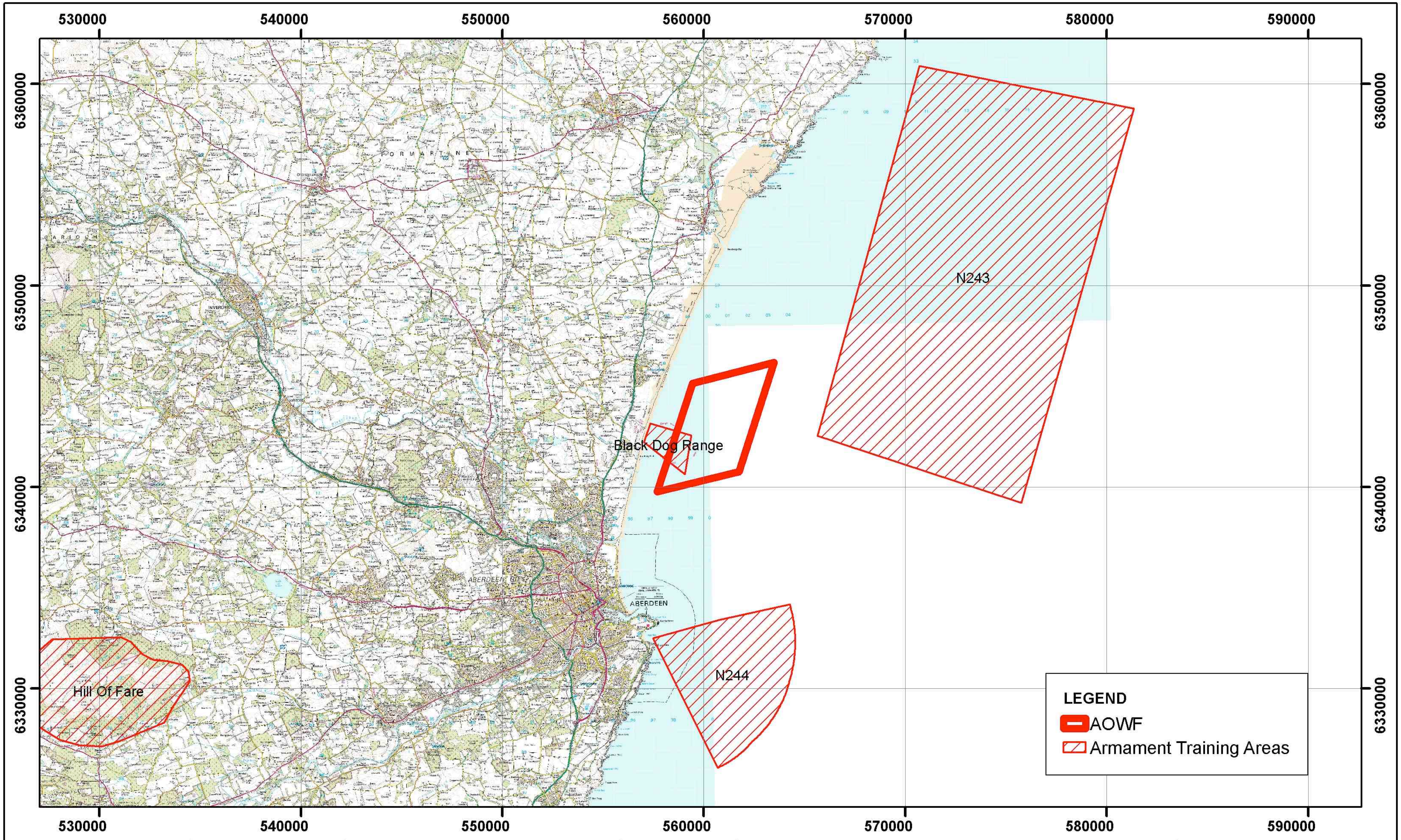
Date: 28th September 2010

Appendix 02

Military Training Areas and Firing Ranges

Aberdeen Offshore Wind Farm
WWII Armament Ranges

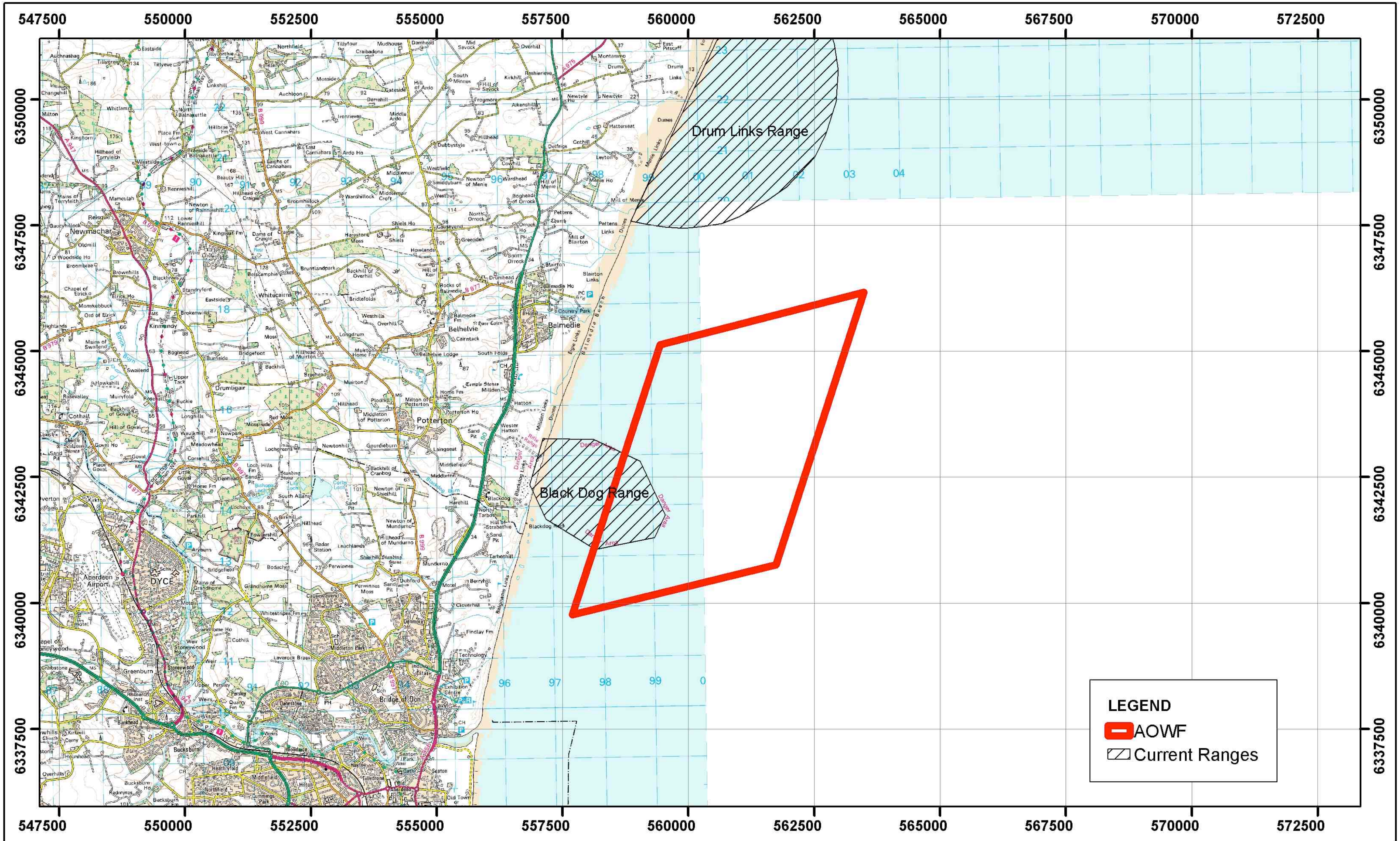
Appendix 02A



alpha ASSOCIATES special risks consultancy	6 Alpha Associates Ltd. Quatro House Frimley Road Camberley Surrey GU16 7ER United Kingdom www.6alpha.com 0203 371 3900	0 0.5 1 2 3 4 5 Nautical Miles Scale @ A4: 1:250,000 Revision: 001	N	Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please forward to 6 Alpha. Development zone (in GIS format) obtained from Vattenfall. Projection System: UTM 30N Datum: WGS84 Spheriod: WGS84	Project Number: P2219 Drawn By: Gary Hubbard Checked by: Lee Gooderham Date: 26th September 2010

Aberdeen Offshore Wind Farm
Drums Link And Black Dog Ranges

Appendix 02B



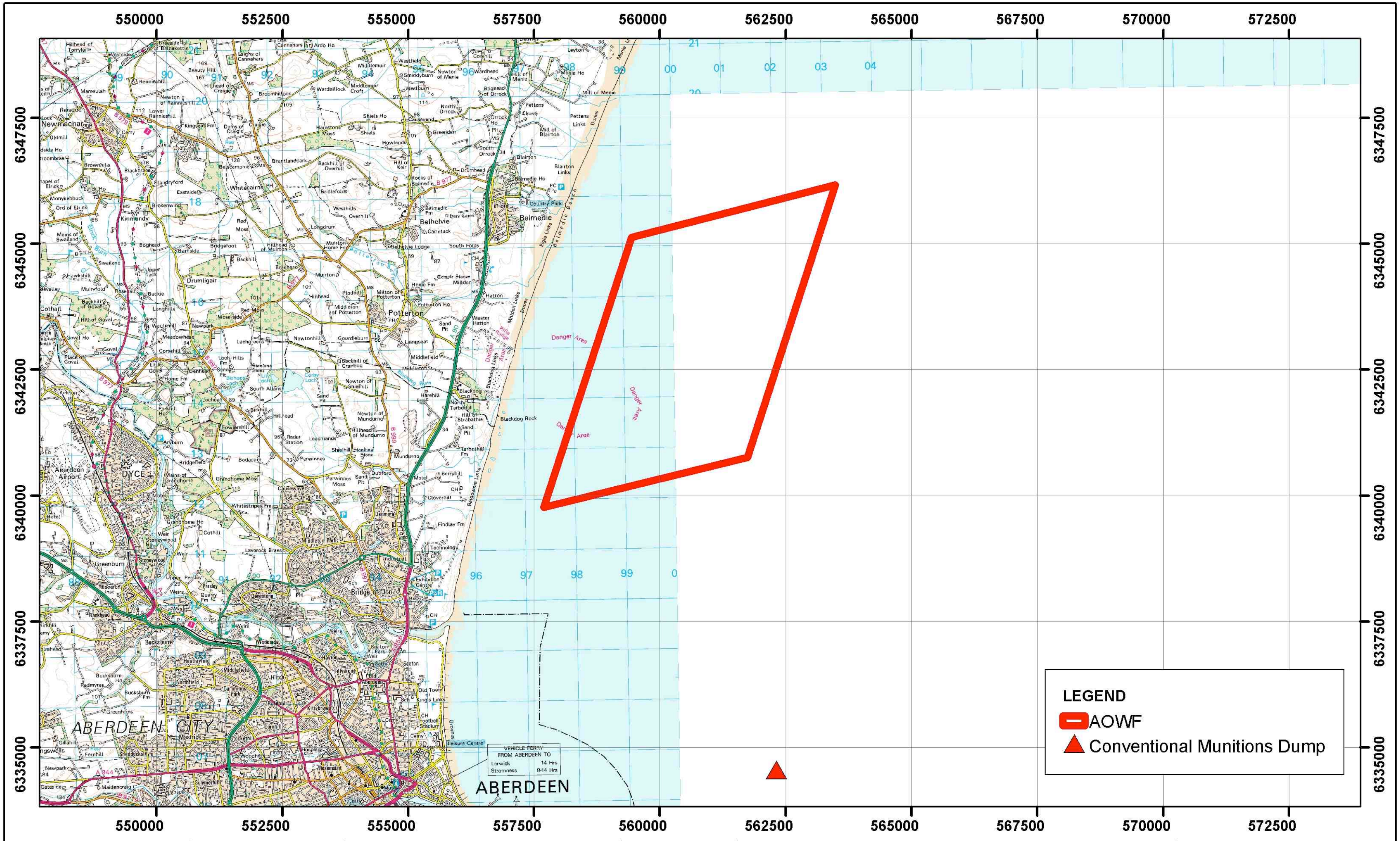
6 alpha ASSOCIATES special risks consultancy	6 Alpha Associates Ltd. Quatro House Frimley Road Camberley Surrey GU16 7ER United Kingdom www.6alpha.com 0203 371 3900	0 0.25 0.5 1 1.5 2 Nautical Miles Scale @ A4: 1:100,000 Revision: 001	N	Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please forward to 6 Alpha. Development zone (in GIS format) obtained from Vattenfall. Projection System: UTM 30N Datum: WGS84 Spheriod: WGS84	Project Number: P2219 Drawn By: Gary Hubbard Checked by: Lee Gooderham Date: 27th September 2010

Appendix 03

Munitions/Explosives Disposal Area

Aberdeen Offshore Wind Farm
Explosives / Munitions Disposal Area

Appendix 03



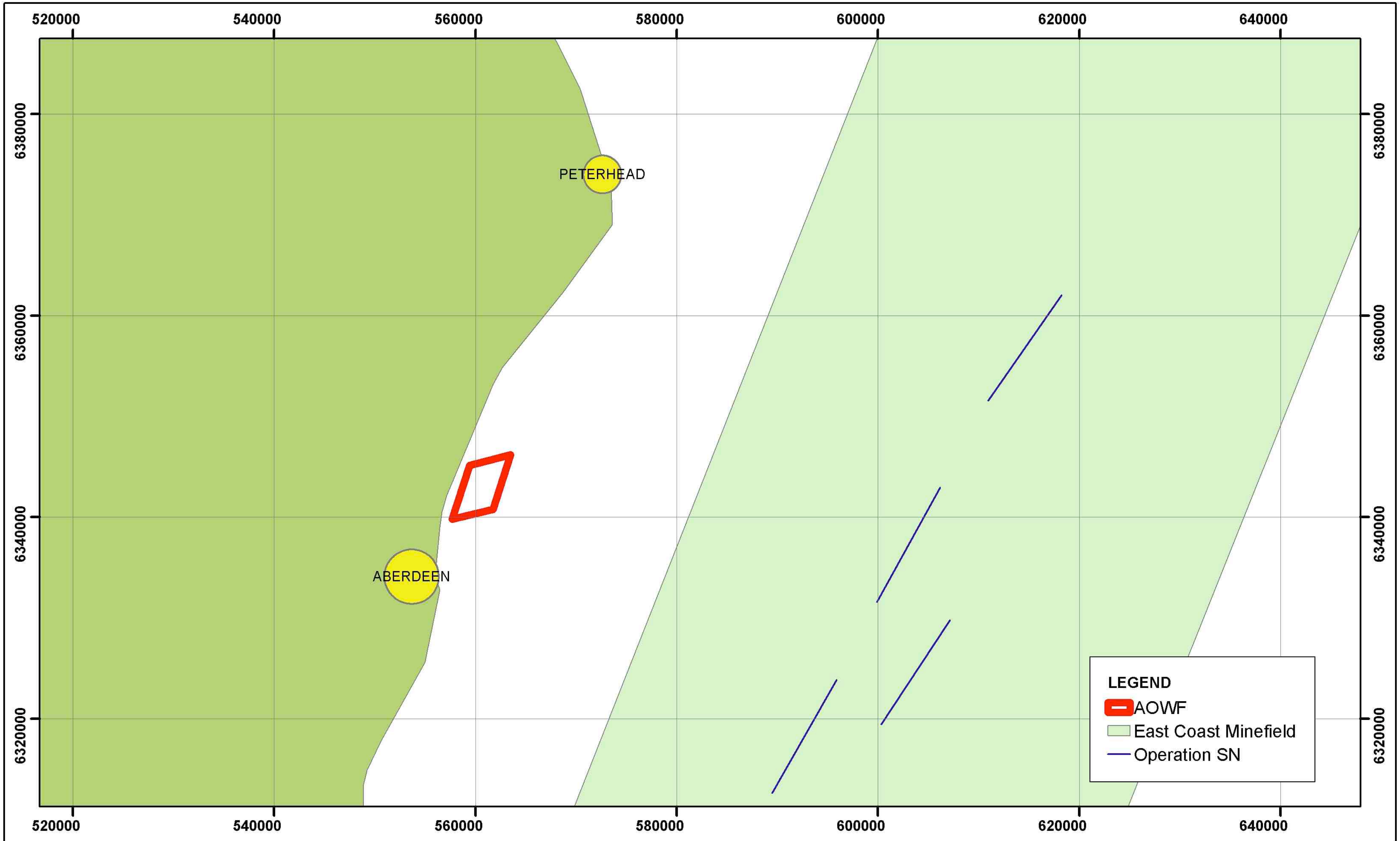
alpha ASSOCIATES special risks consultancy	6 Alpha Associates Ltd. Quatro House Frimley Road Camberley Surrey GU16 7ER United Kingdom www.6alpha.com 0203 371 3900	0 0.25 0.5 1 1.5 2 Nautical Miles Scale @ A4: 1:100,000 Revision: 001	N	Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please forward to 6 Alpha. Development zone (in GIS format) obtained from Vattenfall. Projection System: UTM 30N Datum: WGS84 Spheriod: WGS84	Project Number: P2219 Drawn By: Gary Hubbard Checked by: Lee Gooderham Date: 28th September 2010

Appendix 04

British Minefields

Aberdeen Offshore Wind Farm
WWII British Mine Fields and Mine Lays

Appendix 04



0 1 2 4 6 8 Nautical Miles

Scale @ A4: 1:500,000
Revision: 001

N

6 Alpha Associates Ltd.
Quatro House
Frimley Road
Camberley
Surrey GU16 7ER
United Kingdom
www.6alpha.com
0203 371 3900

Projection System: UTM 30N
Datum: WGS84
Spheriod: WGS84

Project Number: P2219

Drawn By: Gary Hubbard

Checked by: Lee Gooderham

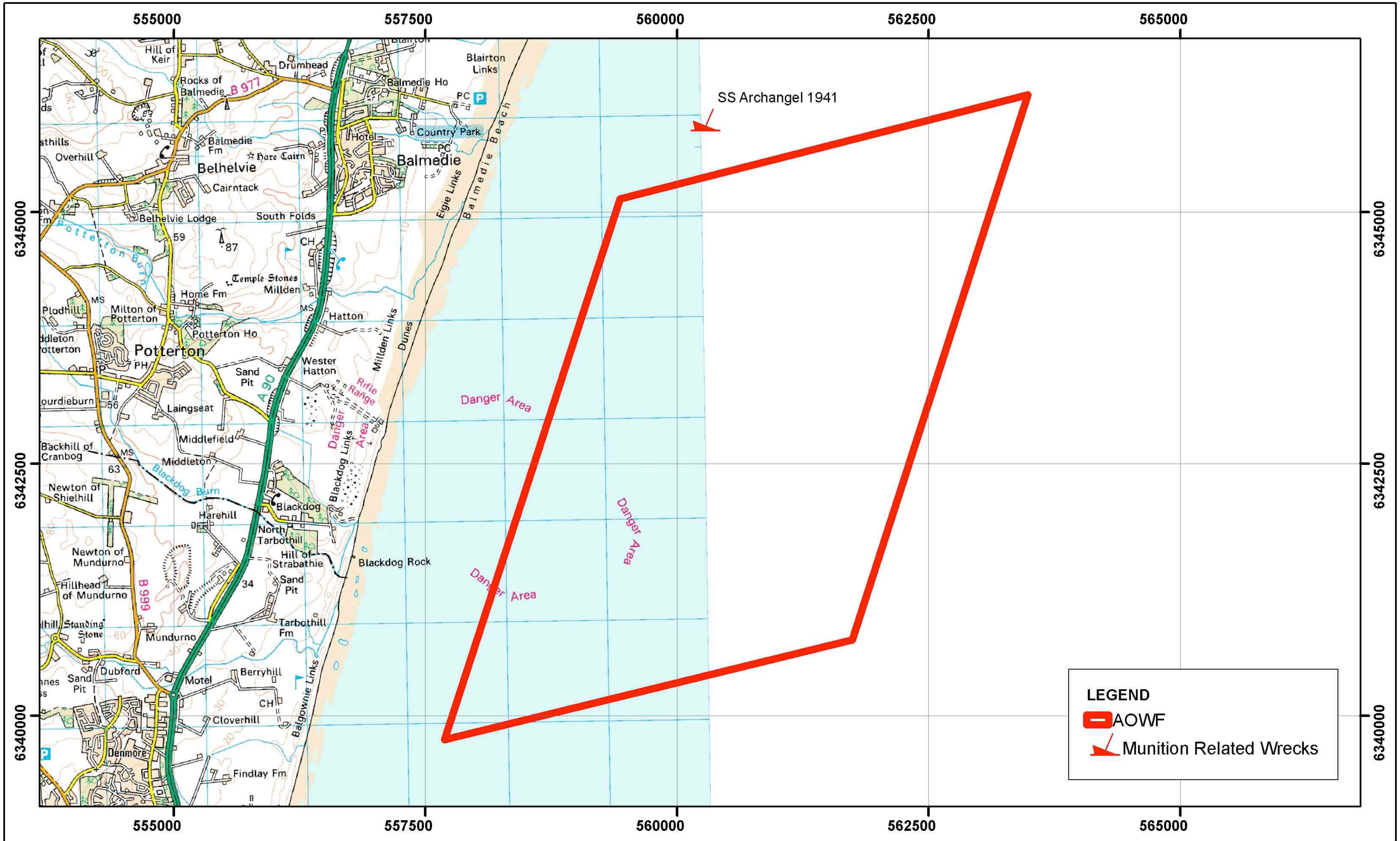
Date: 28th September 2010

Appendix 05

Munitions Related Shipwrecks

Aberdeen Offshore Wind Farm
Munition Related Shipwrecks

Appendix 05



6 Alpha Associates Ltd.
Quatro House
Frimley Road
Camberley
Surrey GU16 7ER
United Kingdom
www.6alpha.com
0203 371 3900

0 0.1 0.2 0.4 0.6 0.8 1 Nautical Miles

Scale @ A4: 1:50,000
Revision: 001

Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please forward to 6 Alpha. Development zone (in GIS format) obtained from Vattenfall.

Projection System: UTM 30N
Datum: WGS84
Spheriod: WGS84

Project Number: P2219

Drawn By: Gary Hubbard

Checked by: Lee Gooderham

Date: 28th September 2010

Appendix 06

Ordnance Characteristics

WWII Sea Mines				
Ordnance Variant	**Shape**	**Width**	**Length**	**Charge Weight**
German Contact Mine. Code EMA/EMB British Designation: GU	Ovoid	EMA: 1600m EMB: ~1400mm	EMA: 800m EMB: 900mm	EMA: 220kg EMB: 150kg
German Contact Mine. Code BMC British Designation: GM	Cylindrical with hemispherical top and bottom	660mm	1000mm	50kg
German Contact Mine. Code EMC British Designation: GY	Spherical	1120m diameter	1120mm diameter	300kg
German Contact Mine. Code KMA British Designation: GJ	Spherical	380mm diameter	380mm diameter	12kg
German Influence Mine. Code KMA British Designation: GA/GD	Cylindrical with hemispherical nose and rear parachute housing	660mm diameter	1800mm	300kg
German Influence Mine. Code LMF British Designation: GT	Cylindrical, finned	530mm diameter	2700m	230kg
German Influence Mine. Type LMB British Designation: GB/GC	Cylindrical with hemispherical nose and rear parachute housing	660m diameter	Up to 3200mm	700kg
German Influence Mine. Type GMB British Designation: GN & GS	Cylindrical with hemispherical ends	GN: 530mm diameter GS: 530mm diameter	GN: 3100mm GS: 2300mm	GN: 900kg GS: 420 to 560kg
German "Mine-bomb". Type BM1000 British Designation: GG	Cylindrical	660mm diameter	~2000mm long depending on tail unit	725kg
British Contact Mine Mk XIV & XV	Ovoid	1016mm diameter	1016mm diameter	145kg or 295kg
British Contact Mine. Mk XVII	Ovoid	1016mm diameter	1016 diameter	145kg
British Contact Mine. Mk XIX & XIXS	Spherical	790mm diameter	790mm diameter	45kg

WWII High Explosive Bombs				
Ordnance Variant	**Bomb Shape**	**Dimensions**	**Body Diameter**	**Charge Weight**
German SC 50	Cylindrical	1090 x 280mm	200mm	25kg
German SC 250	Cylindrical	1640 x 512mm	368mm	125-130kg
German SC 500	Cylindrical	1957 x 640mm	470mm	250-260kg
German SC 1000	Cylindrical	2580 x 654mm	654mm	530-590kg
German SC 1800	Cylindrical	3500 x 670mm	670mm	1000kg
German SC 2500	Cylindrical	3895 x 829mm	829mm	1700kg

Appendix 07

Project Risk Assessment Tables

Risk Assessment Table notes (applicable to all segments):

1. Risk level is prior to risk mitigation actions for that specific operation but in operational order i.e. previous action may have reduced cumulative risk level;
2. Values for both probability and consequence to be found in main report;
3. Risk mitigation measures are cumulative and assumes that previous stage has been undertaken;

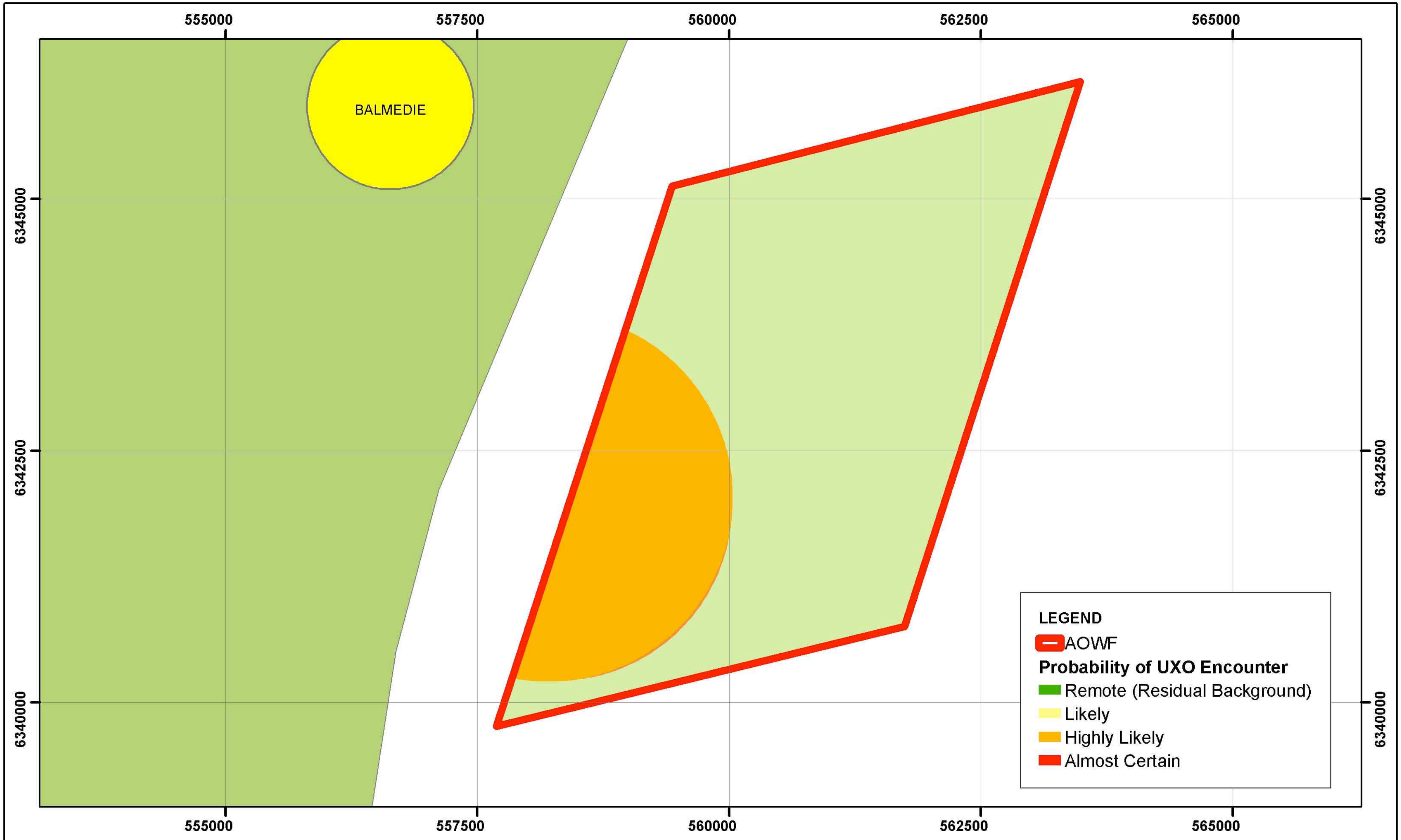
Aberdeen Offshore Wind Farm						
Phase	**Activity**	**Ordnance Variant**	**Probability of Encounter**	**Consequence of Initiation**	**Risk Level (Note 1)**	**Risk Mitigation Actions to lower risk to ALARP**
Site Investigation	Geophysical/Grab Samples Survey	Allied Sea Mines/Torpedoes	1	2	2	Ensure geophysical survey array does not encounter seabed. For trawl survey and grab samples ensure specific UXO guidelines are implemented.
		Air-delivered Bombs	1	2	2	
		Artillery Projectiles	2	1	2	
		Axis Influence Mines	1	2	2	
	Geotechnical Investigation	Allied Sea Mines/Torpedoes	1	4	4	Avoid Black Dog Range Template. “Standard” geophysical survey and target avoidance.
		Air-delivered Bombs	1	4	4	
		Artillery Projectiles	4	1	4	
		Axis Influence Mines	1	4	4	
Cable Installation	PLGR seabed operations	Allied Sea Mines/Torpedoes	1	3	3	Avoid Black Dog Range Template. “Standard” geophysical survey and target avoidance.
		Air-delivered Bombs	1	3	3	
		Artillery Projectiles	4	1	4	
		Axis Influence Mines	1	3	3	
	PLGR equipment recovery to vessel	Allied Sea Mines/Torpedoes	1	5	5	Safety procedures to be followed in the event of item recovery.
		Air-delivered Bombs	1	5	5	
		Artillery Projectiles	3	3	9	
		Axis Influence Mines	1	5	5	
	Barge Anchor Deployment	Allied Sea Mines/Torpedoes	1	3	3	Avoid Black Dog Range Template. “Standard” geophysical survey and target avoidance.
		Air-delivered Bombs	1	3	3	
		Artillery Projectiles	4	1	4	
		Axis Influence Mines	1	3	3	
	Trenching seabed operations	Allied Sea Mines/Torpedoes	1	4	4	No further action
		Air-delivered Bombs	1	4	4	
		Artillery Projectiles	4	1	4	
		Axis Influence Mines	1	4	4	
Turbine Installation	Foundation Installation	Allied Sea Mines/Torpedoes	1	4	4	“Avoid Black Dog Range Template. “Standard” geophysical survey and target avoidance.
		Air Delivered Bombs	1	4	4	
		Artillery Projectiles	4	1	4	
		Axis Influence Mines	1	4	4	

Appendix 08

UXO Probability Map

Aberdeen Offshore Wind Farm
Probability of UXO Encounter

Appendix 08



alpha ASSOCIATES special risks consultancy	6 Alpha Associates Ltd. Quatro House Frimley Road Camberley Surrey GU16 7ER United Kingdom www.6alpha.com 0203 371 3900	0 0.1 0.2 0.4 0.6 0.8 1 Nautical Miles Scale @ A4: 1:50,000 Revision: 001	N	Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please forward to 6 Alpha. Development zone (in GIS format) obtained from Vattenfall. Projection System: UTM 30N Datum: WGS84 Spheriod: WGS84

Project Number: P2219

Drawn By: Gary Hubbard

Checked by: Lee Gooderham

Date: 28th September 2010