Ferry Pools

RSPB

Detailed Unexploded Ordnance (UXO) Threat and Risk Assessment with Risk Mitigation Strategy

Meeting the requirements of the United Kingdom's
Construction Industry Research and Information Association's
Unexploded Ordnance Risk Management Framework:
"Unexploded Ordnance (UXO) – A Guide for the Construction Industry" (C681)
and in compliance with the Construction (Design and Management) Regulations 2015

6 Alpha Associates Ltd

Project No.: 10853

27th October 2023

V1.0

Using This Report

This Detailed UXO Threat and Risk Assessment with Risk Mitigation Strategy is designed to inform the reader whether military related Unexploded Ordnance (UXO) is likely to pose a hazard at the Study Site and if so, calculate the level of risk generated by proposed or likely ground intrusive operations at the Site. The assessment is intended to meet with the requirement of Stages 2 and 3 of the *Health and Safety Executive* endorsed *CIRIA C681 UXO Risk Management Framework* – for which *6 Alpha* were the lead technical author.

There are two prospective outcomes of this report; either the risk level requires a Risk Mitigation Strategy (Stage 3 of the *CIRIA C681* framework) aimed at reducing UXO risks As Low As Reasonably Practicable (ALARP) in accordance with the Project's minimum legal responsibility; or that no further action is required. In the former instance *6 Alpha* will provide a Risk Mitigation Strategy consisting of proactive and/or reactive risk mitigation measures aimed at reducing the identified risks to ALARP.

Document Control

Version	Author(s)	Reviewed By	Recipient
1.0	Beth Skoulding	Ben Wilkinson	RSPB

6 Alpha Associates Limited

2A Woolpit Business Park

Woolpit, Bury St. Edmunds, Suffolk

IP30 9UP

Tel: +44(0) 203 371 3900

Web: www.6alpha.com

Executive Summary

Document Scope

6 Alpha Associates Limited (6 Alpha) has been commissioned by *RSPB* to provide a UXO Threat and Risk Assessment with Risk Mitigation Strategy, for the Site described as "RSPB Pagham Harbour, Ferry Field/Ferry Pool Complex". The Study Site is centred on *British National Grid Reference* 485354, 96369.

UXO Threat Assessment Summary

The output of *6 Alpha*'s UXO Threat Assessment is summarised at Table I:

UXO Threat Assessment Summary			
Threat Source		**Result**	**Comments**
	Was the Site or its vicinity considered a primary bombing target during WWII?	✔	*Luftwaffe* aerial photography identified the *Selsey Airfield* (located 875m to the south-east) as a primary bombing target.
	Was the Site or its vicinity bombed during WWII?	✔	1944 aerial photography shows two potential bomb craters 170m north-north-east and 205m north of the Study Site.
	Was the Site or its vicinity damaged by bombing during WWII?	✔	
	Has any *British* military activity been identified in the area?	✔	*RAF Selsey* was located 965m to the south-east of the Study Site.
	Has ordnance been manufactured and/or stored at the Site or its vicinity?	✘	Although military activity was recorded in the wider area, it is unlikely to have generated a UXO hazard at the Site given the distance from the Site that it occurred.
	Does UXO contamination pose a potential hazard at the Study Site?	✔	Given that bombing was recorded in the wider area, it is possible that UXO might be encountered.

Table I: UXO Threat Assessment Summary

UXO Threat Items

Given the evidence presented at Table I, *6 Alpha* consider it reasonably foreseeable that a UXO encounter could occur at this Site. The most probable UXO threat items are *German* HE bombs and IBs. *British* AAA projectiles may also pose a residual threat.

Potential UXO Burial Depth

Given the likely ground conditions at the Study Site, the average WWII bomb penetration depth has been calculated as 7m below WWII ground level at this Study Site. Although larger UXBs could be present below this depth (potentially up to 16m), they were deployed infrequently during WWII and are highly unlikely to be encountered.

UXO Risk Pathways

The Study Site has not undergone any post-WWII development and consists of undeveloped greenspace to date. Therefore, given the undeveloped nature of the Study Site, a UXO risk pathway could be generated by intrusive works at this Study Site.

UXO Risk Assessment

A Semi-Quantitative UXO Risk Assessment has been undertaken and the UXO risk rating is assessed to be:

MEDIUM

Such risks may pose harm to human health and damage any equipment involved in intrusive activities. Whilst the level of risk posed is relatively limited, the former risk to human health is intolerable. Therefore, such intolerable risks will require mitigating to ALARP, through the implementation of a risk mitigation strategy (see below, and Part III of the report).

Risk Mitigation Strategy

6 Alpha recommends that the UXO risk to the proposed intrusive works is reduced ALARP, through the implementation of both proactive and reactive UXO risk mitigation measures.

Recommended UXO Risk Mitigation Measures

There following risk mitigation measures summarised at Table II, are recommended as a minimum in order to reduce risks ALARP during intrusive works in **all previously undisturbed ground**.

UXO Risk Mitigation Measures Overview							
Proposed Intrusive Works		Emergency Response Plan	Safety and Awareness Briefings	On-Call EOD Engineer	UXO Watching Brief	Non-Intrusive UXO Survey	Intrusive UXO Survey
Open Works	Excavations	✔	✔	✔	✘	✘	✘
	Trenching	✔	✔	✔	✘	✘	✘
	Trenching	✔	✔	✔	✘	✘	✘
Blind Work	Fence Post Installation	✔	✔	✔	✘	✘	✘
Residual UXO Risk Rating		**ALARP**					

Table II: UXO Risk Mitigation Measures Overview

Recommended Next Steps

We recommend that the Client's next steps are focused upon phase four of the UXO Risk Management Framework namely, the detailed designs of the recommended proactive UXO risk mitigation measures as outlined above. The design ought to be finalised and the UXO risk mitigation measures are to be executed in advance of the GI and/or construction phases of work, in order to warrant and to evidence that UXO risks can be mitigated and reduced to ALARP.

Table of Contents

List of Appendices

Acronyms and Abbreviations

AAA	Anti-Aircraft Artillery	**NEQ**	Net Explosive Quantity
ALARP	As Low As Reasonably Practicable	**NGR**	National Grid Reference
ARP	Air Raid Precaution	**OS**	Ordnance Survey
AXO	Abandoned Explosive Ordnance	**PoW**	Prisoner of War
BDO	Bomb Disposal Officer	**RAF**	Royal Air Force
bgl	Below Ground Level	**RMS**	Risk Mitigation Strategy
BGS	British Geological Survey	**RN**	Royal Navy
BH	Borehole	**SAA**	Small Arms Ammunition
BPD	Bomb Penetration Depth	**SQRA**	Semi-Quantitative Risk Assessment
CIRIA	Construction Industry Research and Information Association	**TA**	Territorial Army
CS	County Series	**TARA**	Threat and Risk Assessment
EOD	Explosive Ordnance Disposal	**TNT**	Trinitrotoluene
HE	High Explosive	**UK**	United Kingdom
HSE	Health and Safety Executive	**UN**	United Nations
IB	Incendiary Bomb	**USAAF**	United States Army Air Force
kg	Kilogram	**UXB**	Unexploded Bomb
km	Kilometre	**UXO**	Unexploded Ordnance
LCC	London County Council	**V Weapons**	*Vergeltungswaffen* – Vengeance Weapons
LSA	Land Service Ammunition	**WWI**	World War One
m	Metre	**WWII**	World War Two

Part I: Introduction

1 Document Overview

1.1 Scope of Work

6 Alpha Associates Limited (6 Alpha) has been commissioned by *RSPB* to provide an Unexploded Ordnance (UXO) Threat and Risk Assessment with Risk Mitigation Strategy, for the Site described as "RSPB Pagham Harbour, Ferry Field/Ferry Pool Complex".

The Study Site is centred on *British National Grid* reference 485354, 96369 and is depicted at Appendices 1 and 2.

1.2 Study Site Location

The Study Site is situated on the outskirts of the *Town of Selsey* and totals an area of approximately 15ha. The Study Site itself predominantly consists of undeveloped greenspace, with *Ferry Pools* situated within the south-eastern sector of the Study Site.

Aerial photography of the Study Site is presented at Appendix 3.

1.3 Aims and Objectives

This document has the following aims and objectives:

1.3.1 Aims

The document aims to assess and evidence the nature and scope of the UXO risks to people, plant, equipment and/or the environment at this Study Site. In the event that an intolerable UXO risk is identified, a recommended UXO risk mitigation strategy will also be articulated.

1.3.2 Objectives

The document has the following objectives:

- To assess the nature and scope of potential UXO contamination at the Study Site;
- To assess whether any UXO contamination generated at the Site is likely to remain extant;
- To consider whether the proposed intrusive works will generate a viable UXO risk pathway;
- To identify those sensitive receptors likely to be impacted by an inadvertent UXO encounter during the proposed intrusive works;
- To assess the UXO risk to those sensitive risk receptors during intrusive works;
- To outline proportional risk mitigation measures that are consistent with a coherent overarching risk mitigation strategy, in order to effectively manage the UXO risk ALARP.

2 Introduction to UXO Risk Management

2.1 Definition of UXO

For the purposes of this risk assessment, *6 Alpha* have adopted the definition of UXO outlined in the undermentioned *CIRIA C681* guide, as follows:

"*Explosive ordnance that has been primed, fuzed, armed, or otherwise prepared for use and used in an armed conflict. It may have been fired, dropped, launched or projected and should have exploded but failed to do so…UXO also refers to explosive ordnance that has not been used during an armed conflict, that has been left behind or dumped by a party to an armed conflict, and which is no longer under control of the party that left it behind or dumped it...*"

2.2 Generic UXO Threats

There are multiple factors which may have contributed to the UXO contamination of a construction site in the *UK* but generally, UXO contamination is likely to result from the warfighting activity associated with WWI and WWII, the military occupation and use of land such as airfields, camps and training areas; and the manufacture of munitions to support the armed forces.

For example, *WWII Bomb Census* data from the *Ministry of Home Security* calculated that approximately 10% of bombs dropped on *Britain* during WWII failed to function as designed. If the bomb did not detonate when it was dropped, the force of impact enabled the Unexploded Bomb (UXB) to penetrate the ground. Whilst efforts were made to locate and render safe those UXBs that were observed entering the ground (or left behind clear evidence of having done so) during WWII, evidence of such UXBs was readily obscured by bomb damage debris, vegetation and a lack of footfall in some settings – thus, ensuring that an unquantifiable number of UXBs were left *in situ* below the surface of the ground.

Additionally, it has been estimated that at least 20% of the *UK's* land surface area has been used for military training activities or has otherwise been requisitioned for military use historically. Therefore, *British* Abandoned Explosive Ordnance (AXO), Land Service Ammunition (LSA), Small Arms Ammunition (SAA) and aerially delivered ordnance is also commonly encountered in areas that were formerly occupied by military forces (such as *Royal Air Force* (RAF) airfields, military camps and/or military training areas). Conventional and chemical munitions dumping was also prevalent in these periods with little consideration given to future safety implications. There was also widespread unrecorded dumping of LSA and SAA below the ground that was rarely recorded because the activity was often perceived to be inconsequential.

2.3 Generic UXO Risks

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

2.4 UXO Industry Best Practice

In the absence of specific legislation concerning the management of UXO risks during construction projects, the *UK*'s *Construction Industry Research and Information Association* (CIRIA) has published a best practice guide for the assessment and management of UXO risk in the construction industry (*CIRIA* document reference C681). The *CIRIA C681* guide has been judged and recognised by the *Health and Safety Executive* (HSE) as a minimum standard of good practice, that satisfies the law when applied in an appropriate manner.

6 Alpha were *CIRIA's* lead technical author for their *C681* publication and as such, are in a unique position to ensure that Client's manage UXO risk in a safe, cost-effective and time-efficient manner.

2.5 UXO Risk Management Strategic Framework

At Section 5 of *CIRIA's* C681 guide, a framework for the management of UXO risk is articulated and consists of four key stages. These correspond with the framework employed by *6 Alpha*, as presented at Table 1.

6 Alpha Risk Management Framework	UXO Risk Management Phase	CIRIA C681 Risk Management Framework	Delivered within Report? (✔/✘)
UXO Threat Assessment	**STAGE ONE**	Preliminary Risk Assessment	✔
UXO Risk Assessment	**STAGE TWO**	Detailed Risk Assessment	✔
Risk Mitigation Strategy	**STAGE THREE**	Risk Mitigation	✔
Implementation	**STAGE FOUR**	Implementation	✘

Table 1: 6 Alpha and CIRIA UXO Risk Management Frameworks

3 UXO Threat and Risk Assessment Methodology

3.1 Source – Pathway – Receptor Risk Model

The source-pathway-receptor model is a conceptual risk model employed by *6 Alpha* across all projects that informs how UXO risks are assessed. The model also helps to explain the link between the separate sections of this report and the UXO risk assessment at Section 7. The components of the model are as follows:

3.1.1 UXO Sources

The nature and scope of the UXO threat is summarised in the UXO threat assessment (at Section 4) and it forms the source element of the source-pathway-receptor model.

3.1.2 UXO Pathways

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

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

3.1.3 UXO Receptors

Receptors are defined as anything which might be adversely affected by the consequences of an inadvertent detonation of any UXO source through an identified pathway. The proximity, robustness, and sensitivity of such receptors is essential in determining their capacity to withstand such high explosive effects and defining what degree of UXO risk might be tolerated (if any).

3.2 Semi-Quantitative Risk Assessment Methodology

The assessment of UXO risk is a semi-quantitative measure of the probability of UXO encounter and initiation and the consequence of an inadvertent UXO initiation; the former being a function of the identified hazard and proposed development methodology and the latter being a function of the type of hazard and the proximity of personnel (and/or other sensitive receptors) to the hazard.

UXO risk is calculated using the following formula:

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

3.3 Information Sources

Significant archive research associated with the Study Site has been undertaken to corroborate and to highlight, any and all potential sources of UXO contamination as well as to assess their likelihood of encounter. For the production of this report, *6 Alpha* have reviewed information from the following sources:

- Information gathered from the *National Archives* at *Kew*, including but not limited to:
  - *Ministry of National Security WWII Bomb Census* statistics;
  - *Air Raid Precaution* (ARP) written records and associated bomb strike mapping;
  - Official WWII bomb damage mapping;
- *Ministry of Defence* (MoD) *Abandoned Bomb Register*;
- *Former 33 Engineer Regiment* (Explosive Ordnance Disposal) records at *Carver Barracks, Wimbish*;
- Post-WWII *RAF* aerial photography;
- *County Series* (CS) and *Ordnance Survey* (OS) mapping.

3.3.1 Azimuth© UXO Threat Database

The above list is not exhaustive, and *6 Alpha's Azimuth*© database has also been heavily drawn upon to deliver the UXO threat assessment element of this report. The *Azimuth*© database contains digitised historic charts, aerial photographs and other extensive analogue records from an exhaustive range of additional national, regional and global archives and/or data sets that have been digitised.

3.4 Constraints

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

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

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

Part II: UXO Threat & Risk Assessment

4 UXO Threat Assessment

4.1 WWII Aerial Bombing

The county of *West Sussex* was home to numerous targets that were of interest to the *Luftwaffe*, including its port installations and numerous airfields. As such, numerous areas across the county were bombed, especially around *Bognor Regis, Littlehampton,* and *Worthing* – though generally not to the same extent experienced in other areas of the country.

4.1.1 WWII HE Bomb Density

The Study Site was located within *Chichester Rural District,* as presented at Appendix 4. This region recorded one HE bomb strike per 100 hectares, a "very low" level of bombing. However, further **site-specific** data has been considered regarding the potential bombing of the Site during WWII.

4.1.2 WWII Luftwaffe Bombing Targets

Luftwaffe aerial reconnaissance photography did not identify the Study Site or its immediate vicinity as a primary bombing target. However, *Selsey Airfield* (located 875m to the south-east of the Study Site) was located in the wider area and was recorded a primary bombing target.

The locations of *Luftwaffe* bombing targets, in relation to the Study Site, are presented at Appendix 5.

4.1.3 WWII HE Bomb Strikes

During WWII, *ARP* wardens and other local officials compiled detailed logs of bomb strikes across their respective districts that were then often consolidated and mapped at the end of WWII; however, ARP bomb strike mapping associated with the Study Site was unavailable. Nonetheless, an analysis of written local records and supplementary research did not evidence any bombing at the Study Site itself, nor within a 1,000m radius of it. The closest documented bombing was within the centre of nearby *Selsey* – with the closest recorded bomb strike impacting on *Paddock Lane* (approximately 2.5km south of the Site). There are however, potential bomb craters visible on 1944 aerial photography (undermentioned at section 4.1.3) which may be indicative of unrecorded bombing in closer proximity to the Site. Given the Site's relatively rural setting, it would be implausible for further bombing to have gone unnoticed in the area. Furthermore, whilst IBs may have fallen within the Study Site, they were dropped in large clusters and accurate record keeping was often either non-existent or perfunctory.

In addition to IBs and HE bomb strikes, during the latter stage of WWII, when more conventional aerial bombardment of the *UK* had significantly declined, the main threat came from *V* type weapons. *V1* and *V2* rockets were thin-skinned, unmanned and inaccurate weapons and generally exploded upon

impact and thus, are less likely to pose a UXO threat. There is also no evidence to suggest that the Study Site (or its immediate vicinity) was subjected to rockets strikes during WWII.

4.1.4 WWII Bomb Damage

Official bomb damage mapping associated with the Study Site was not available. Nonetheless, an analysis of 1944 aerial photography has identified two potential bomb craters 175m to the north-north-east and 205m north of the Study Site, adjacent to *Selsey Road*. Whilst further supplementary research could not confirm that these were bomb craters, they may be indicative of potential bombing in closer proximity to the Study Site than the previous evidence allowed for.

The locations of these bomb craters are presented at Appendix 6.

4.1.5 UXB Entry Holes

The CS mapping prior to WWII (1938), in addition to 1944 aerial photography shows that the Study Site was located within a rural area, with the Study Site itself predominantly consisting of undeveloped greenspace, *Ferry Pools* and potentially soft marshy/muddy ground. Therefore, it is likely that the Study Site would not have been accessed frequently during WWII, and as such potential UXB entry holes may not have been observed or reported during WWII. This potential is elevated given that any evidence of UXB entry holes may not have been present for long in the potentially soft mud/marsh located across much of the Study Site during WWII.

4.2 *British* Military Activity

There is evidence to suggest that military activity has occurred at the Study Site and/or its immediate area previously, as detailed below:

4.2.1 Historic Military Activity

Royal Air Force (RAF) *Selsey* was officially located 965m to the south-east of the Study Site after undeveloped farmland was requisitioned in 1942. Construction of the airfield was completed by the 31st of *May* 1943, and *RAF Selsey* was subsequently designated as an *Advanced Landing Ground* (ALG) in time for the arrival of the *No. 65 (East India) Squadron*. Shortly after, *Selsey's ALG* underwent further development as the airfield prepared for *Operation Overlord* (colloquially known as *D-Day*). Developments were finalised by *April* 1944 of which saw the arrival of *No. 135 Wings* in addition to several other military squadrons. From the end of *August* 1944, military personnel and squadrons moved on from the *Selsey AGL*, consequently leaving it vacant. By *March* the following year, the land associated with the former airfield was decommissioned and reallocated as farmland, with its military features removed shortly after.

Furthermore, numerous *Royal Navy* decoy sites were constructed across the county of *West Sussex* during WWII as part of *Operation Fortitude South* in preparation for the invasion of *Normandy.* The

decoy sites were additionally intended to deflect *Luftwaffe* bombing from *Portsmouth*. The *Pagham Harbour* decoy site (located 980m to the east of the Study Site) was subsequently commissioned by the *RAF* as a part of these preparations, functioning as a Mobile 'QL' (MQL) Site.

Whilst extensive military activity has been evidenced in the wider area during WWII, there is no evidence that it would likely have resulted in the storing or firing of munitions at or in the Study Site.

4.3 Previous UXO Encounters

An analysis of historic records did not identify any UXO encounters within the vicinity of the Study Site, as follows:

4.3.1 Abandoned Bombs

The Abandoned Bomb register was compiled from wartime records and was published in the form of a written answer to the *House of Commons* in 1996. The list initially only covered abandoned bombs in *London* but has since been released for the rest of the UK.

An examination of the *MoD*'s official abandoned bomb records has not identified any abandoned bombs on-site nor within 1,000m.

4.3.2 UXO Disposal Tasks

An examination of pertinent historical records associated with the Study Site has not identified any UXO disposal tasks on-site nor within 1,000m.

4.4 UXO Threat Summary

Given the evidence presented above, *6 Alpha* consider it reasonably foreseeable that a UXO encounter could occur at this Site. The most probable UXO threat items are *German* HE bombs and IBs. *British* AAA projectiles may also pose a residual threat as they were likely fired in defence of the local area during WWII bombing raids.

5 UXO Burial Depths

5.1 Overview

It is important to establish the likely burial depth for threat spectrum UXO at the Study Site. The potential penetration depth of an UXB was dependent on a number of factors including but not restricted to those prior to striking the ground (e.g. velocity and orientation of the UXB), which in turn will be influenced on factors such as the release altitude from the aircraft and encounters with infrastructure during its fall; those encountered at the point of impact (i.e. was the impact on concrete, grass, water etc.) and finally, the below ground level conditions (e.g. infrastructure/services, basements, foundations, and geology).

Accordingly, the ground conditions at the Study Site must be understood in order to determine the average and maximum *German* UXB penetration depths, as well as the potential for other types of munitions to be buried. The provenance of made ground must also be considered in order to accurately determine the ground levels at the time when UXO contamination may have occurred (so as to accurately determine the average/maximum bomb penetration depths) and subsequently to inform any further recommendations.

5.1.1 Ground Conditions

BGS borehole log "*SZ89NW4 – SIDLESHAM WATER TREATMENT WORKS 3*" (located 435m to the south-west of the Study Site), recorded the following strata:

Depth bgl (m)	Strata	Description
0.00m to 2.50m	**Clay**	Firm orange brown silty sandy to very sandy Clay.
2.50m to 4.25m	**Sand**	Dense light grey brown silty Sand.
4.25m to 7.00m	**Silt**	Medium dense light grey brown clayey sandy Silt.
7.00m to 10.00m	**Sand**	Dense grey brown slightly clayey very silty Sand.
10.00m to 12.50m	**Clay**	Stiff dark brown fissured slightly sandy silty Clay.

Table 2: Ground Conditions Summary

In addition, an analysis of *BGS* mapping associated with the Study Site suggests that the Site is likely to be underlain by a bedrock of "*Wittering Formation – Sand, Silt and Clay*".

5.2 UXB Burial Depths

Based on the ground conditions described above, the average BPD for a 250kg *German* HE bomb is assessed to be approximately 7m bgl, with the maximum BPD considered to be approximately 15m bgl.

Although it is possible that the *Luftwaffe* deployed larger bombs in the area, an analysis of WWII bomb census data clearly evidences that their deployment was infrequent. Therefore, to use such larger bombs for BPD calculations **are not justifiable under the ALARP principle and thus, CIRIA C681 guidance**.

WWII *German* bombs have a greater penetration depth when compared to IBs and AAA projectiles, which are unlikely to be encountered at depths greater than 1m bgl.

5.2.1 The J-Curve Effect

As a UXB penetrated the ground, it's velocity naturally slowed where it either came to an abrupt stop (e.g., against foundations) or would continue along a route of least resistance – which often resulted in a curving of the trajectory back towards the surface. This is known as the "J Curve" effect and often resulted in a considerable horizontal off-set from the point of entry. This explains why UXBs have been discovered against or under the foundations of buildings which were present during WWII, or many meters from their entry holes. A diagrammatical representation of the "J Curve" effect is presented at Figure 1.

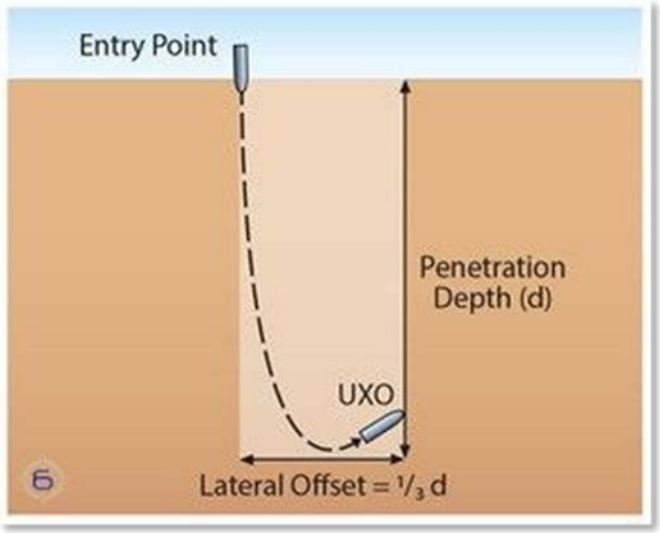


Figure 1: The "J Curve" Effect

6 UXO Risk Pathways

6.1 Overview

In order to assess whether a viable UXO risk pathway might exist at the Study Site, potential UXO contamination sources must be assessed (and have been at Section 5 of the report) and the likely depth of UXO contamination ought to be established (as per Section 6 of the report). Additionally, the Site's construction history ought to be considered to assess whether any previous intrusive works will have encountered and removed any UXO contamination present at the Site.

6.2 Study Site Construction History

From an analysis of CS and OS mapping, together with aerial photography, the following site history can be deduced:

Year	Development History
1938 CS Map	The Study Site was situated within a rural area and predominantly consisted of undeveloped greenspace, though *Ferry Pools* were situated within the south-eastern sector of the Study Site.
1961 OS Map	Changes were not recorded at the Study Site.
1976 OS Map	Changes were not recorded at the Study Site.
1985 Aerial Photography	Changes were not recorded at the Study Site.
2001 Aerial Photography	Changes were not recorded at the Study Site.
2011 Aerial Photography	Changes were not recorded at the Study Site.
2023 OS Map	Changes were not recorded at the Study Site.

Table 3: Study Site Development History

As per Table 3, it is apparent that the Study Site has not undergone any post-WWII development and the Site itself remains as undeveloped greenspace to date. Whilst it is considered likely that any UXO contamination within ground that has been disturbed since WWII would likely have been discovered

and removed, given the undeveloped nature of the Study Site it is possible that an unplanned UXO encounter may occur.

6.3 Proposed Works

An outline of the proposed intrusive works is also presented in order to evidence the potential UXO risk pathways that may be generated, should such work encounter those threat spectrum UXO that have been identified in Section 5.

A general overview of the scope of works for the project has been communicated to *6 Alpha* and consists of:

- *"Groundworks to create wetland features – excavating a 200m footdrain (1m deep, 3m wide, 215m long); creation of scrape and pools (up to 500mm deep);*
- *Installation of water control structures – solar pump and drop-board sluices;*
- *Installation of 1900m predator exclusion fence with vehicle gate, overhand and excavated trench to bury wire mesh to min 600mm. Fence posts will be going in all around the orange-marked fence line, up to 1.1m in depth, strainers up to 1.5m."*

Consequently, it is apparent that the proposed works could theoretically generate a UXO risk pathway in ground that has not been previously disturbed (including any ground below post-WWII intrusive work) to a depth of 7m bgl.

If the planned methods are changed, then the risk assessment is to be reviewed and updated if necessary.

7 UXO Risk Assessment

7.1 Threat Items

The most probable sources of UXO risk at this Study Site are German HE bombs, whilst IBs and British AAA projectiles pose a residual threat. The consequences of initiating German HE bombs are generally more severe than initiating IBs or AAA projectiles, and thus they pose the greatest prospective risk to intrusive works.

7.2 Risk Pathways

Given the nature and scope of the prospective UXO hazard at the Study Site, all types of aggressive intrusive activities into previously undisturbed ground (including ground below any post-WWII redevelopment) to a depth of 7m bgl may generate a viable risk pathway.

7.3 Risk Receptors

The likely risk receptors include:

- Site personnel;
- Plant and equipment;
- Third-party infrastructure (utilities/services) and buildings;
- The natural environment.

Consequences of UXO initiation include:

- Injuries and/or fatalities to personnel;
- Damage to plant and equipment, nearby buildings and infrastructure;
- Rupture and damage underground utilities/services and the natural environment.

Consequences of an unexpected and unplanned UXO discovery include:

- Incurring delays and additional costs through the expenditure of additional risk mitigation resources and EOD clearance;
- Disruption to local community;
- Negative publicity.

7.4 Semi-Quantitative Risk Assessment

A semi-quantitative risk assessment has been undertaken and the results are presented at Table 4.

Activity	UXO Threat Item	Probability (SH+EM=P)	Consequence (D+PSR=C)	Risk (PxC=R)
Excavations	Aerial Bombs	1+2=3	3+3=6	**3x6=18**
	AAA Projectiles	1+2=3	3+1=4	**3x4=12**
Trenching	Aerial Bombs	1+2=3	3+3=6	**3x6=18**
	AAA Projectiles	1+2=3	3+1=4	**3x4=12**
Fence Post Installation	Aerial Bombs	1+3=4	3+2=5	**4x5=20**
	AAA Projectiles	1+3=4	3+1=4	**4x4=16**

Table 4: UXO SQRA Results

7.4.1 SQRA Conclusions

The SRQA has determined that the proposed intrusive works may generate, as a reasonable worst-case scenario, a ***MEDIUM*** level of risk at the Study Site. Such risks may pose harm to human health and damage any equipment involved in intrusive activities. Whilst the level of risk to site personnel is relatively limited, it is intolerable and will require mitigating in accordance with the ALARP risk reduction principle, as per Part III of this report.

Part III: UXO Risk Mitigation Strategy

8 UXO Risk Mitigation Strategy

8.1 Strategic Overview

As per *CIRIA* C681 guidance, *6 Alpha* recommended that the identified UXO risks are reduced ALARP. Crucially, the ALARP principle states that if the cost of reducing a risk significantly outweighs the benefit, then the risk may be considered tolerable. This does not mean that there is never a requirement for UXO risk mitigation, but that any mitigation must demonstrate that it is beneficial. Any additional mitigation that delivers diminishing benefits and that consumes disproportionate time, money and effort are considered *de minimis* and thus unnecessary. Because of this principle, UXO risks will rarely be reduced to zero (nor need they be).

Consequently, a limited suite of reactive UXO risk mitigation measures ought to be implemented ahead of proposed intrusive operations at the Study Site in order to reduce the identified UXO risks to ALARP.

8.2 Proactive UXO Risk Mitigation Measures

The level of risk to the proposed works at this Study Site does not warrant the implementation of proactive UXO risk mitigation measures in the form of a geophysical UXO survey or UXO Watching Brief. The implementation of such measures at this Site would be beyond what is required under the ALARP risk reduction principle.

8.3 Reactive UXO Risk Mitigation Measures

The following reactive risk mitigation measures should be undertaken for all activities in all areas:

8.3.1 Operational UXO Emergency Response Plan

Appropriate site management documentation should be held on-site to guide and plan for the actions which should be undertaken in the event of a suspected or real UXO discovery (this plan can be supplied by *6 Alpha*).

8.3.2 UXO Safety and Awareness Briefings

The briefings are essential when there is a possibility of explosive ordnance encounter and are a vital part of the general safety requirement. All personnel working on the Site should receive a briefing on the following:

- The identification of threat spectrum UXO;
- What actions they should take to keep people and equipment away from such a hazard and to alert site management.

Information concerning the nature of the UXO threat should also be held in the site office and displayed for general information on noticeboards - both for reference and as a reminder for ground workers.

The safety awareness briefing is an essential part of the *Health & Safety Plan* for the site and helps to evidence conformity with the appropriate health and safety standards and legislation.

8.3.3 On-Call EOD Engineer

An on-call EOD Engineer will be able to identify and/or advise on the appropriate course of action in the event of any suspicious and/or real UXO finds and should be implemented at this Site to mitigate the residual UXO risk associated with the proposed works. *6 Alpha* offer three tiers of immediate telephone and/or email response.

8.4 ALARP Safety Sign Off Certification

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

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

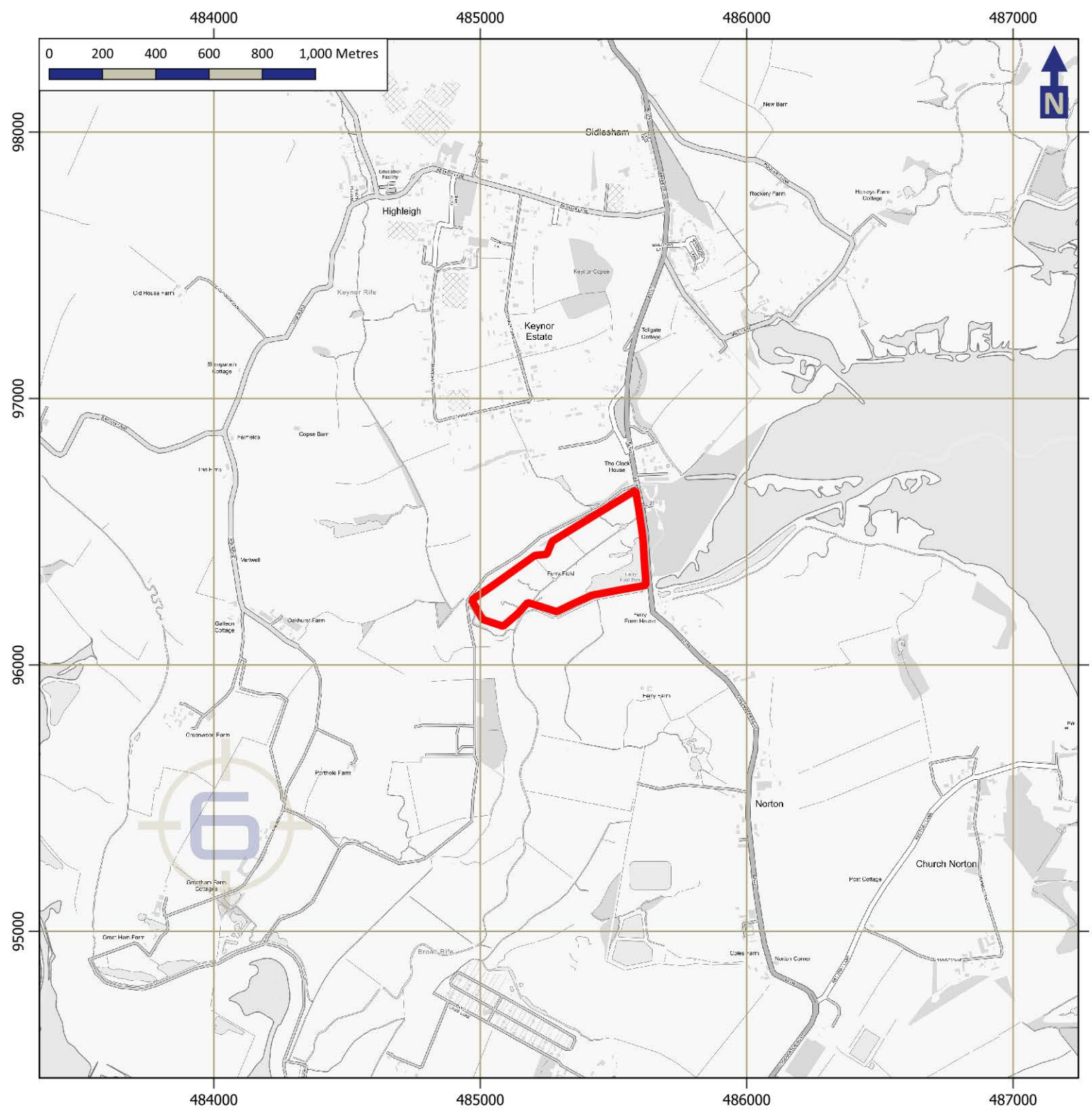
In accordance with best practice therefore, *6 Alpha* ALARP safety sign-off certification does not imply that any site is free from UXO, rather, that the necessary and appropriate UXO risk mitigation measures have been appropriately applied to evidence that UXO risks have been reduced ALARP.

8.5 Recommended Next Steps

We recommend that the Client's next steps are focused upon phase four of the UXO Risk Management Framework namely, the detailed designs of the recommended proactive UXO risk mitigation measures as outlined above. The specifications are to be delivered and the UXO risk mitigation measures are to be executed in advance of the GI and construction phases of work, in order to warrant and to evidence that UXO risks can be mitigated and reduced to ALARP.

Appendices

Appendix 1 – Site Location



Site Location

BOMB SEARCH

LEGEND

Site Boundary

British National Grid

Address

RSPB Pagham Harbour, Ferry Field/Ferry Pool Complex

PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE
10853	1	LG	BW	18/10/2023

alpha ASSOCIATES
special risks consultancy

W W W . 6 A L P H A . C O M
E: ENQUIRY@6ALPHA.COM | T: +44 (0)203 371 3900

Site Boundary

BOMB SEARCH

LEGEND

Site Boundary

British National Grid

Address

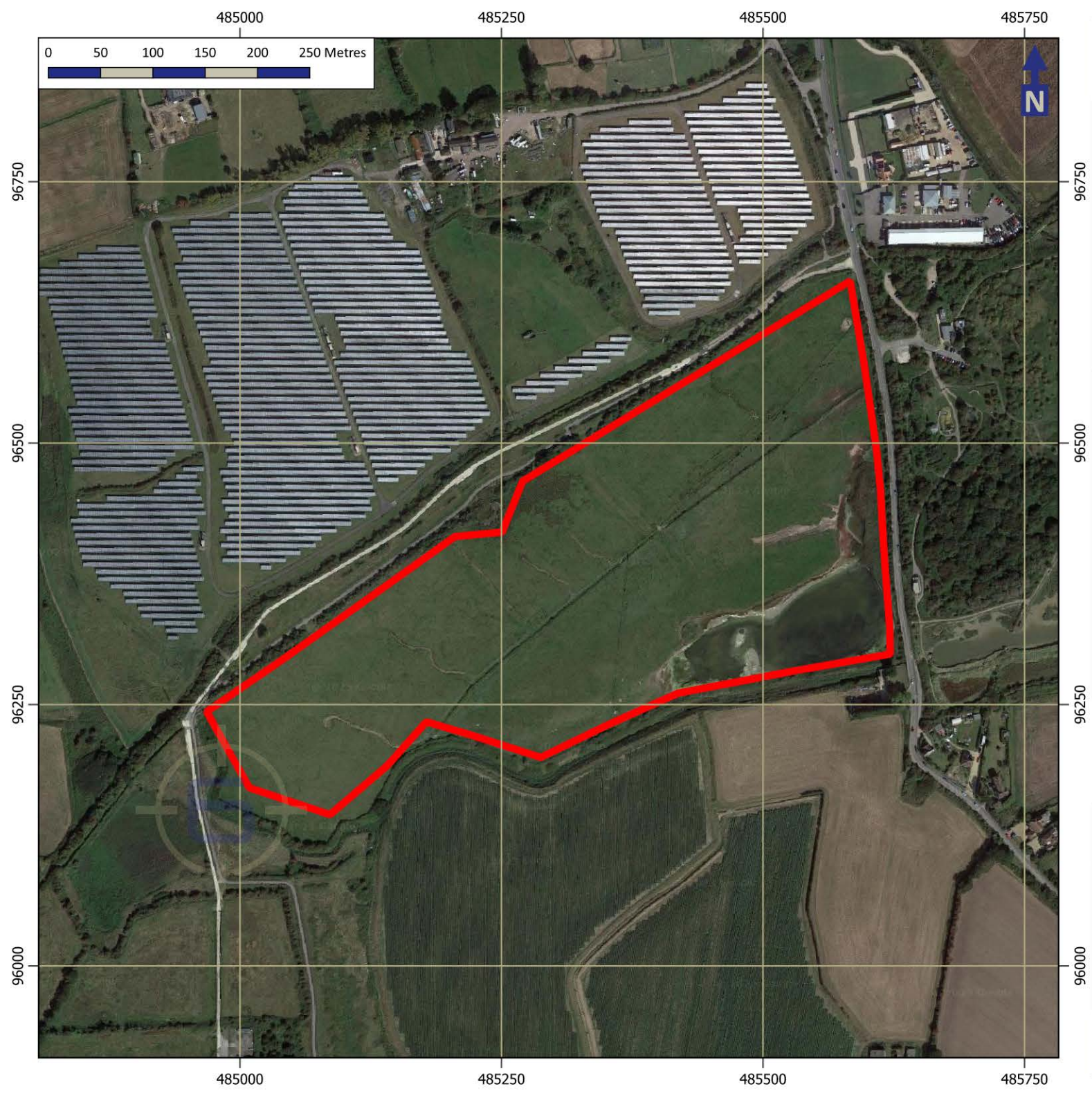
RSPB Pagham Harbour, Ferry Field/Ferry Pool Complex

PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE
10853	2	LG	BW	18/10/2023

alpha ASSOCIATES
special risks consultancy

W W W . 6 A L P H A . C O M
E: ENQUIRY@6ALPHA.COM | T: +44 (0)203 371 3900

Appendix 3 – Modern Aerial Photography



Modern Aerial Photography

BOMB SEARCH

LEGEND

Site Boundary

British National Grid

Address

RSPB Pagham Harbour, Ferry Field/Ferry Pool Complex

PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE
10853	3	LG	BW	18/10/2023

6 alpha ASSOCIATES
special risks consultancy

Map data: Google, The GeoInformation Group, Infoterra Ltd, Bluesky, Getmapping plc

W W W . 6 A L P H A . C O M
E: ENQUIRY@6ALPHA.COM | T: +44 (0)203 371 3900

Appendix 4 – WWII High Explosive Bomb Density

WWII High Explosive Bomb Density

BOMB SEARCH

LEGEND

Site Boundary

High Explosive Bomb Density

- Less than 15 bombs per 100 hectares
- 16-25 bombs per 100 hectares
- 26-35 bombs per 100 hectares
- 36-45 bombs per 100 hectares
- Over 46 bombs per 100 hectares

British National Grid

Address

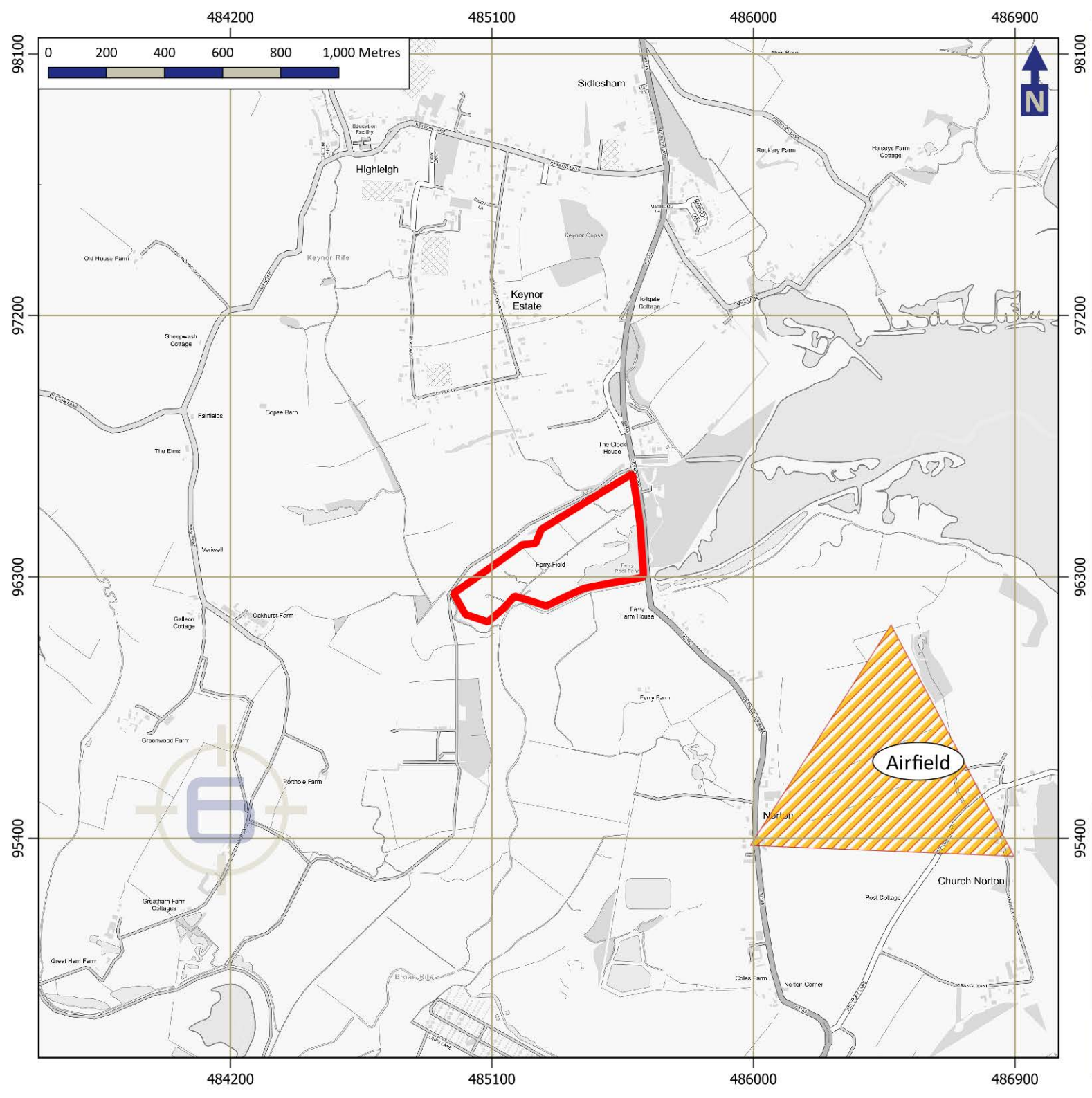
RSPB Pagham Harbour, Ferry Field/Ferry Pool Complex

PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE
10853	4	LG	BW	18/10/2023

alpha ASSOCIATES
special risks consultancy

W W W . 6 A L P H A . C O M
E: ENQUIRY@6ALPHA.COM | T: +44 (0)203 371 3900

Appendix 5 – WWII Luftwaffe Bombing Targets



WWII Luftwaffe Bombing Targets

BOMB SEARCH

LEGEND

- Site Boundary
- Luftwaffe Target

British National Grid

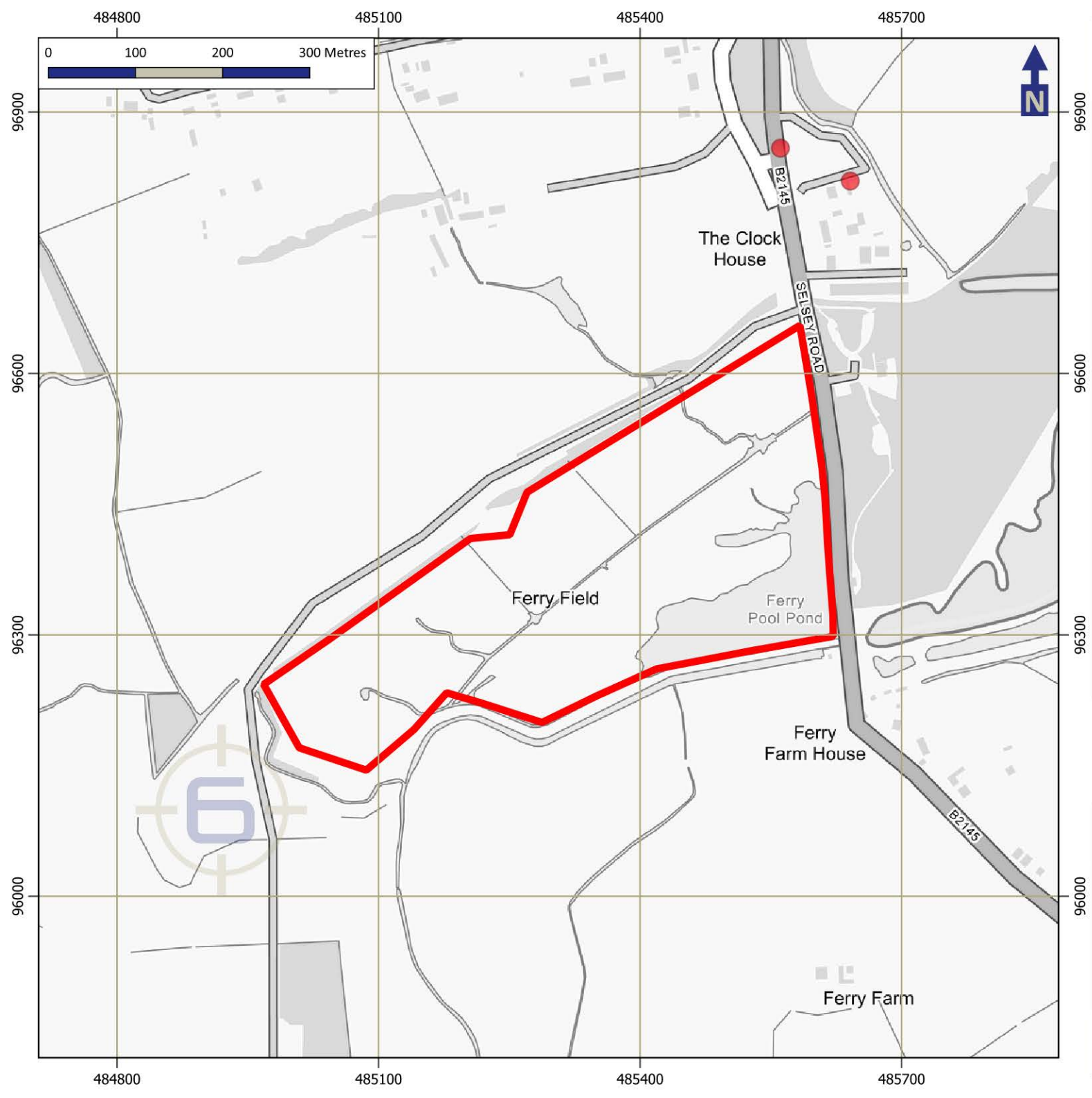
Address

RSPB Pagham Harbour, Ferry Field/Ferry Pool Complex

PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE
10853	5	LG	BW	18/10/2023

alpha ASSOCIATES
special risks consultancy

W W W . 6 A L P H A . C O M
E: ENQUIRY@6ALPHA.COM | T: +44 (0)203 371 3900



Potential Bomb Craters

BOMB SEARCH

LEGEND

- Site Boundary
- Potential_Bomb_Craters

British National Grid

Address

RSPB Pagham Harbour, Ferry Field/Ferry Pool Complex

PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE
10853	LG	BW	BW	26/10/2023

alpha ASSOCIATES
special risks consultancy

W W W . 6 A L P H A . C O M
E: ENQUIRY@6ALPHA.COM | T: +44 (0)203 371 3900