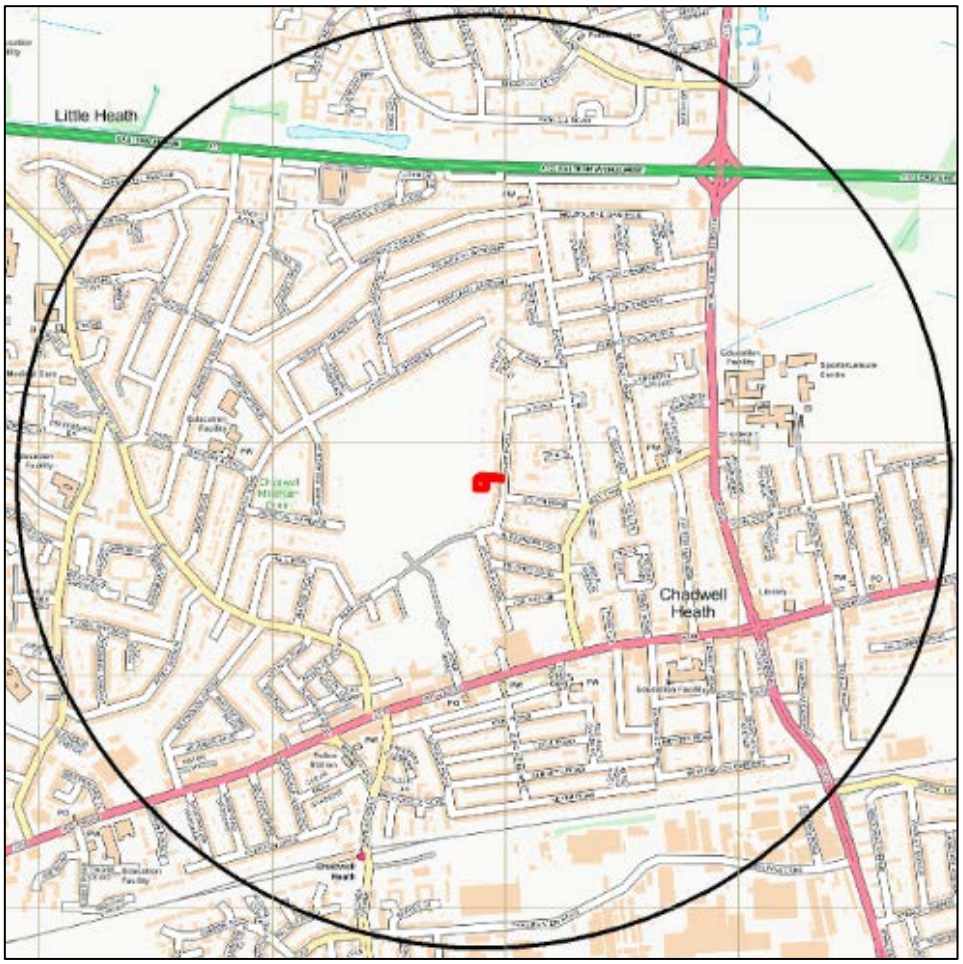
Detailed Unexploded Ordnance (UXO) Threat & Risk Assessment

Meeting the requirements of *CIRIA* C681 'Unexploded Ordnance (UXO) A guide for the Construction Industry' Risk Management Framework



PROJECT NUMBER	8584_8	**ORIGINATOR**	D. Barrett
VERSION NUMBER	1.0	**REVIEWED BY**	B. Wilkinson (23rd March 2021)
CLIENT	Arcadis	**RELEASED BY**	L. Gregory (24th March 2021)
STUDY SITE	West Road, RM6 6YA		
RATING	**MEDIUM** - This Study Site requires limited further action to reduce risk to ALARP during intrusive activities.		

alpha ASSOCIATES
special risks consultancy

6 Alpha Associates Limited, Unit 2A Woolpit Business Park, Bury St Edmunds, IP30 9UP, United Kingdom
T: +44 (0)2033 713 900 | W: www.6alpha.com

Contents

Contents 1
Acronyms and Abbreviations 2
EXECUTIVE SUMMARY 3
EXECUTIVE SUMMARY (…continued) 4
ASSESSMENT METHODOLOGY 5
STAGE ONE – STUDY SITE LOCATION AND DESCRIPTION 6
Proposed Works 6
Ground Conditions 6
STAGE TWO – REVIEW OF HISTORICAL DATASETS 8
STAGE THREE – DATA ANALYSIS 12
STAGE FOUR – RISK ASSESSMENT 13
Threat Items 13
Bomb Penetration Depth 13
UXO Risk Calculation Table 14
STAGE FIVE – RECOMMENDED RISK MITIGATION MEASURES 15
Report Figures 16

FIGURES

Figure One - Study Site Location
Figure Two - Study Site Boundary
Figure Three - Aerial Photography (2020)
Figure Four - Aerial Photography (1945)
Figure Five - WWII High Explosive Bomb Density
Figure Six - WWII Consolidated Bomb Strikes

Acronyms and Abbreviations

AA	Anti-Aircraft
AAA	Anti-Aircraft Ammunition
ALARP	As Low As Reasonably Practicable
AOD	Above Ordnance Datum
ARP	Air Raid Precaution
AXO	Abandoned Explosive Ordnance
BD	Bomb Disposal
BDO	Bomb Disposal Officer
bgl	Below Ground Level
BGS	British Geological Survey
BH	Borehole
BPD	Bomb Penetration Depth
CDP	Cast Driven Piles
CFA	Continuous Flight Auger
CIRIA	Construction Industry Research and Information Association
CPT	Cone Penetration Testing
CS	County Series
EO	Explosive Ordnance
EOC	Explosive Ordnance Clearance
EOD	Explosive Ordnance Disposal
GI	Ground Investigation
GIS	Geographic Information Systems
GL	Ground Level
GP	General Purpose
GPS	Global Positioning Systems
HAA	Heavy Anti-Aircraft
HE	High Explosive
HO	Home Office
HSE	Health and Safety Executive
IB	Incendiary Bomb
kg	Kilograms
km	Kilometres
LAA	Light Anti-Aircraft
LCC	London County Council
LE	Low Explosive
LSA	Land Service Ammunition
m	Metres
MoD	Ministry of Defence
mm	Millimetres
NEQ	Net Explosive Quantity
NFF	National Filling Factory
NGR	National Grid Reference
OD	Ordnance Datum
OS	Ordnance Survey
PM	Parachute Mine
PoW	Prisoner of War
RADAR	Radio Detection And Ranging
RAF	Royal Air Force
RN	Royal Navy
RNAS	Royal Naval Air Service
ROF	Royal Ordnance Factory
SAA	Small Arms Ammunition
TA	Territorial Army
TNT	Trinitrotoluene
UK	United Kingdom
UN	United Nations
USAAF	United States Army Air Force
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
V Weapons	*Vergeltungswaffen* – Vengeance Weapons
WD	War Department
WWI	World War One
WWII	World War Two

EXECUTIVE SUMMARY

Study Site

The Client has defined the Study Site as "West Road, RM6 6YA" and is centred on NGR 547953, 188415.

Risk Level

MEDIUM

Potential Threat Sources

The most probable UXO threat is posed by WWII *German* HE bombs, whilst IBs and *British* AAA projectiles (which were used to defend against *German* bombing raids) pose a residual threat.

Risk Pathway

Whilst there is a residual UXO risk within this Study Site, 6 Alpha do not believe there is a significant risk pathway to warrant on-site pro-active UXO risk mitigation measures.

Key Findings

During WWII, the Study Site was situated within *Dagenham Municipal Borough,* which recorded 18 HE bomb strikes per 100 hectares, a low level of bombing.

Luftwaffe aerial reconnaissance photography associated with the Study Site did not identify any primary bombing targets on-site or within 1,000m of it.

ARP records associated with the Study Site did not note any HE bomb strikes within it however, five were recorded in the wider area; 150m to the north, 210m to the north, 295m to the north-east, 310m to the south-east and 350m to the north-east. In addition, an AA shell was identified impacting 55m to the south-west.

LCC bomb damage mapping did not cover the Study Site. Nonetheless, an analysis of historical records identified bomb damage to *Blackbush Avenue* (320m to the west), *Woodlands Avenue* (465m to the south-east), the *Embassy Cinema* (640m to the south-west), *Birchdale Gardens* (730m to the south-west) *Whalebone House* (760m to the south-east), and *Chadwell Heath Station* (800m to the south-west). An analysis of 1945 aerial photography also identified an area of significant bomb damage on *Bennet Road* (540m to the south-east).

Pre-WWII mapping (1938) and aerial photography (1945) associated with the Study Site shows that the Study Site was located within a densely developed urban area during WWII, with the Study Site itself consisting of undeveloped ground. As a result, it is likely that footfall across the Site would have been relatively low throughout WWII.

Between 1945 and 1963 a structure had been built on-site, with an additional structure developed by 1999. Consequently, it is considered likely that any UXO within post-war disturbed and developed ground would potentially have been discovered and removed, however, the potential for deep buried UXO to be present within remaining areas of undisturbed ground is assessed to be extant.

Given that WWII bomb strikes were recorded in the wider area, the following risk mitigation measures are recommended as a minimum, in order to reduce risks ALARP, during intrusive works in all previously undisturbed ground i.e. that which has not previously been excavated, probed, drilled or otherwise intrusively disturbed since it was potentially contaminated with UXO.

EXECUTIVE SUMMARY (…continued)

Recommended Risk Mitigation Measures Overview

"Open" Intrusive Works

Engineering Methodology	UXO Emergency Response Plan	UXO Safety and Awareness Briefing	On-Call EODE	UXO Risk Rating (Post-Mitigation)
Excavations	✔	✔	✔	**ALARP**

"Blind" Intrusive Works

Engineering Methodology	UXO Emergency Response Plan	UXO Safety and Awareness Briefing	On-Call EODE	UXO Risk Rating (Post-Mitigation)
Boreholes	✔	✔	✔	**ALARP**
Window Sampling	✔	✔	✔	

A full and detailed guide to the recommended risk mitigation measures is presented at Section 5 of this report.

For further information, please contact *6 Alpha Associates*:

Website: http://www.6alpha.com

Telephone: +44 (0)2033 713 900

Email: enquiry@6alpha.com

ASSESSMENT METHODOLOGY

Approach

6 Alpha Associates is an independent, specialist risk management consultancy practice, which has assessed the risk of encountering UXO (as well as buried bulk high explosives) at this Study Site, by employing a process advocated for this purpose by *CIRIA*. The *CIRIA* guide for managing UXO risks in the construction industry (C681) not only represents best practice but has also been endorsed by the *HSE*. Any risk mitigation solution is recommended *only* because it delivers the Client a risk reduced to ALARP at best value.

UXO hazards can be identified through the investigation of local and national archives associated with the Study Site, *MoD* archives, local historical sources, historical mapping as well as contemporaneous aerial photography (if it is available). Hazards will have only been recorded if there is specific information that could reasonably place them within the boundaries of the Study Site. The amalgamation of information is then assessed to enable the researcher to provide relevant and accurate risk mitigation practices.

The assessment of UXO risk is a measure of *probability of encounter* and *consequence of encounter*; the former being a function of the identified hazard and proposed development methodology; the latter being a function of the type of hazard and the proximity of personnel (and/or other 'sensitive receptors', such as equipment) to the hazard, at the moment of encounter.

If UXO risks are identified, the methods of mitigation we have recommended are considered reasonably and sufficiently robust to reduce them to ALARP. We advocate the adoption of the legal ALARP principle because it is a key factor in efficiently and effectively ameliorating UXO risks. It also provides a ready means for assessing the Client's tolerability of UXO risk. In essence, the 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 consume disproportionate time, money and effort are considered *de minimis* and thus unnecessary. Because of this principle, UXB and UXO risks will rarely be reduced to zero (nor need they be).

Important Notes

Key source material is referenced within this document, whilst secondary/anecdotal information may be available upon request.

Although this report is up to date and accurate at the time of writing, our databases are continually being populated as and when additional information becomes available. Nonetheless, *6 Alpha* have exercised all reasonable care, skill and due diligence in providing this service and producing this report.

The assessment levels are based upon our professional opinion and have been supported by our interpretation of historical records and third-party data sources. Wherever possible, *6 Alpha* has sought to corroborate and to verify the accuracy of all data we have employed, but we are not accountable for any inherent errors that may be contained in third party data sets (e.g. *National Archive* or other library sources), and over which *6 Alpha* cannot exercise control.

STAGE ONE – STUDY SITE LOCATION AND DESCRIPTION

Study Site

The Client has defined the Study Site as "West Road, RM6 6YA". The Study Site is centred at NGR 547953, 188415 as presented at *Figures 1* and *2,* respectively.

Location Description

The Study Site is situated within *London Borough of Barking and Dagenham* and totals an area of 0.07 hectares (ha).

Furthermore, the Study Site is bounded by:

- North: Various residential structures and undeveloped ground*;*
- East: *West Road;*
- South: Various residential structures and undeveloped ground*;*
- West: Areas of hardstanding.

Aerial Photography (2020) (*Figure 3*)

Current aerial photography corroborates the information above and shows that the Study Site is situated within a densely developed urban area. The Study Site itself consists of two structures and areas of hardstanding.

Proposed Works

The Client has informed *6 Alpha* of the following proposed works:

"We are proposing to undertake a one-day, 3-4 window sample holes at each site by way of preliminary ground investigation to a maximum depth of 6m bgl with installations for groundwater and ground gas monitoring purposes."

Ground Conditions

It is important to establish the specific ground conditions in order to determine the maximum *German* UXB penetration depth as well as the potential for other types of munitions to be buried.

If the site investigations and/or construction methodologies change, and/or if a specific methodology is to be employed, and/or if the scope of work is focused upon a specific part of the Study Site, then *6 Alpha* are to be informed so that the prospective UXO risks and the associated risk mitigation methodology might be re-assessed. Certain ground conditions may also constrain certain types of UXO risk mitigative works e.g. magnetometer survey is adversely affected in mineralised and made ground.

It is important to establish the provenance of made ground, where this is recorded as being part of the ground make-up, 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 make appropriate recommendations aimed at reducing the risk to ALARP.

STAGE ONE – STUDY SITE LOCATION AND DESCRIPTION (…continued)

Ground Conditions

BGS borehole log "TQ48NE233 – Cranfield Golf Centre Chadwell Heath" (located 575m to the north-east of the Study Site sector), recorded the following strata:

Depth bgl (m)	Strata	Description
0.00m to 0.50m	Overburden	
0.50m to 5.00m	Sand/Gravel/Clay	Sands, gravel & clay
5.00m to 6.00m	Sand/Gravel/Clay	Sands, gravel & brown clay
6.00m to 18.00m	Clay	Grey clay
18.00m to 18.50m	Shingle	
18.50m to 22.00m	Clay	Grey clay
22.00m to 27.00m	Sand	Grey sands & shells
27.00m to 37.00m	Sand	Greens sands
37.00m to 42.00m	Sands	Grey & green sands
42.00m to 52.00m	Sands	Green sands
52.00m to 108.00m	Chalk	Chalk & flints

In addition, the *British Geological Survey* describes the general area as being comprised of *"London Clay Formation – Clay, Silt And Sand"*

STAGE TWO – REVIEW OF HISTORICAL DATASETS

Sources of Information Consulted

The following primary information sources have been used in order to establish the background UXO threat:

1. *6 Alpha*'s *Azimuth* Database;
2. *Home Office* WWII Bomb Census Maps;
3. WWII and post-WWII aerial photography;
4. Official Abandoned Bomb Register;
5. Information gathered from the *National Archives* at *Kew*;
6. Historic UXO information provided by *33 Engineer Regiment* (Explosive Ordnance Disposal) at *Carver Barracks, Wimbish*.

Potential Sources of UXO Contamination

In general, there are several activities that might contaminate a site with UXO, but the three most common ways are: legacy munitions from military training/exercises; deliberate or accidental dumping (AXO) and ordnance resulting from war fighting activities (also known as the Explosive Remnants of War (ERW)).

During WWII, the *Luftwaffe* undertook bombing campaigns all over the *UK*. The most common type of UXO discovered today is the aerially delivered high explosive (HE) bomb, which are comparatively thick-skinned and were dropped from *Luftwaffe* aircraft. If the bomb did not detonate when it was dropped, the force of impact enabled the UXO to penetrate the ground, often leaving behind it a UXB entry hole. These entry holes were not always apparent, and some went unreported, leaving the bomb buried and unrecorded. More rarely, additional forms of *German* UXO are occasionally discovered including *inter alia V1* and *V2* rockets, Incendiary Bombs (IBs), and Anti-personnel (AP) bomblets.

Although the *Luftwaffe* had designated primary bombing targets across the *UK*, their high-altitude night bombing was not accurate. As a result, thousands of buildings were damaged and civilian fatalities were common. Bombs were also jettisoned over opportunistic targets and residential areas were sometimes struck.

As the threat of invasion lingered over *Britain* during WWII, defensive actions were undertaken. The *British* and *Allied Forces* requisitioned large areas of land for military training and bomb storage (including HE bombs, naval shells, artillery and tank projectiles, explosives, LSA and SAA). Thousands of tonnes of these munitions were used for the *Allied Forces* weapon testing and military training alone. It has been estimated that at least 20 per cent of the *UK*'s land has been used for military training at some point.

The best practice guide for dealing with your UXO risks on land (CIRIA publication C681) suggests that approximately 10 per cent of all munitions deployed failed to function as designed. ERW are therefore, still commonly encountered, especially whist undertaking construction and civil engineering groundwork.

Furthermore, in exceptional circumstances, UXO is discovered unexpectedly and without apparent rational explanation. There are several ways this might occur:

- When *Luftwaffe* aircraft wished to swiftly escape e.g. from an aerial attack, they would jettison some or all of their bombs and flee. This is commonly referred to as *tip and run* and it has resulted in bombs being found in unexpected locations;
- Transportation of aggregate containing munitions to an area that was previously free of UXO, usually related to construction activities employing material dredged from a contaminated offshore borrow site;
- Poor precision during targeting (due to high altitude night bombing and/or poor visibility) resulted in bombs landing off target, but within the surrounding area;
- *British* decoy sites were also constructed to deliberately cause incorrect targeting. For obvious reasons, such sites were often built in remote and uninhabited areas.

Study Site Development History

From an analysis of the CS and OS historical mapping associated with the Study Site, the following history can be deduced:

Year	Analysis
1898 CS Map	The Study Site was located in a developing rural area. The Study Site did not consist of any structures.
1921 CS Map	Changes were not recorded at the Study Site.
1938 CS Map	Changes were not recorded at the Study Site.
1948 OS Map	Changes were not recorded at the Study Site.
1951 OS Map	Changes were not recorded at the Study Site.
1963 OS Map	A structure was built in the western section.
1977 OS Map	Changes were not recorded at the Study Site.
1999 Aerial Photography	An additional structure was noted in the western section, and hardstanding had been laid across the Study Site.
2010 Aerial Photography	Changes were not recorded at the Study Site.
2021 OS Map	Changes were not recorded at the Study Site.

The Study Site history assessment is our best interpretation of the data available at the time of writing. Given that yearly revisions of neither CS and OS mapping, nor aerial photography, are available for analysis, there are gaps between the mapping revisions.

Consequently, it should not be assumed that any new structures and/or features that are labelled on a map revision were constructed, developed, installed or demolished in the exact year that the mapping illustrates the change. It is possible – and indeed likely – that the exact date of development occurred somewhere between the two closest mapping revisions. Specifically, this may be particularly relevant where there is a gap between pre and post-WWII mapping, as it may not be clear whether structures were present during WWII or if they were constructed in the post-WWII period.

WWII Site Use (*Figure 4*)

The CS mapping prior to WWII (1938) and 1945 aerial photography shows that the Study Site was located within a densely developed urban area during WWII, with the Study Site itself consisting of undeveloped ground. As a result, it is likely that footfall across the Site would have been relatively low throughout WWII.

WWII Bombing of *London*

The most intensive period of bombing over *London* was the nine months between October 1940 and May 1941, known as 'The Blitz'. During this period the *Luftwaffe* attempted to overwhelm *Britain's* air defences, destroy key military and industrial facilities, as well as logistical capabilities, prior to invasion.

A total of 18,000 tons of bombs were dropped on *London* between 1940 and 1945. Many residential, commercial and industrial buildings were targeted during air raids and sustained large scale damage. Public services were also affected, with gas, electricity and water supplies often cut-off following damage to either the installations themselves or to the supply infrastructure. In addition, thousands of civilians were killed and injured, and many were forced to evacuate as their homes were destroyed.

WWII HE Bomb Density (*Figure 5*)

The Study Site was located within *Dagenham Municipal Borough,* which recorded 18 HE bombs per 100 hectares, a low level of bombing.

WWII Luftwaffe Bombing Targets

Prior to WWII, the *Luftwaffe* conducted numerous aerial photographic reconnaissance missions over *Britain*, recording key military, industrial and commercial facilities for attack, in the event of war. In addition, logistics infrastructure and public services, such as railways, canals, power stations, reservoirs, water and gas works were also considered viable bombing targets.

Luftwaffe aerial reconnaissance photography associated with the Study Site did not identify any primary bombing targets on-site or within 1,000m of it.

WWII HE Bomb Strikes (*Figure 6*)

During WWII, ARP wardens compiled detailed logs of bomb strikes across their respective districts. However, ARP records associated with the Study Site did not note any HE bomb strikes within it. Nonetheless, five were recorded in the wider area; 150m to the north, 210m to the north, 295m to the north-east, 310m to the south-east and 350m to the north-east.

Furthermore, whilst IBs may have fallen within the Study Site, they fell in such large numbers that accurate record keeping was either non-existent or perfunctory therefore, their prospective presence cannot be either corroborated or discounted. Nonetheless, further research of official bomb strike mapping identified IB strikes 585m to the east-south-east. In addition, five parachute mines were identified; 570m to the south-east, 715m to the east-south-east, 740m to the east-south-east, 865m to the north-east and 925m to the east-south-east. Finally, four AA shells were noted impacting 55m to the south-west, 180m to the south-west, 205m to the north-east and 355m to the south-east.

In addition to IBs and HE bomb strikes, during the latter part of the war when aerial bombing had significantly declined, the main threat came from *V* type weapons. The first recorded *V1* strike on *London* was on the 13th June 1944, with the first recorded *V2* strike on *London* on the 8th September 1944. *V1* and *V2* rockets were thin-skinned, unmanned and inaccurate weapons. Two *V1* rocket strikes were recorded landing 415m to the north-north-east and 830m to the south-east with one *V2* rocket strike impacting 475m to the south-east.

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 which were encountered such as infrastructure e.g. services, basements, foundations, and geology e.g. made ground, clay, sand, etc. Further, as the UXB penetrated the ground, it's velocity naturally slowed where, it either came to an abrupt stop e.g. against foundations or would continue for 10's of feet 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 is often the reason why UXBs have been discovered against or under the foundations of buildings, which were present during WWII, or many meters from the point of impact.

WWII Bomb Damage

LCC bomb damage mapping did not cover the Study Site. Nonetheless, an analysis of historical records identified bomb damage to *Blackbush Avenue* (320m to the west), *Woodlands Avenue* (465m to the south-east), the *Embassy Cinema* (640m to the south-west), *Birchdale Gardens* (730m to the south-west) *Whalebone House* (760m to the south-east), and *Chadwell Heath Station* (800m to the south-west). An analysis of 1945 aerial photography also identified an area of significant bomb damage on *Bennet Road* (540m to the south-east).

Abandoned Bombs

An examination of the official abandoned bomb records did not identify any abandoned bombs on-site, nor within 1,000m of the Study Site boundary.

Records of WWII UXB Disposal Tasks

An examination of the civil defence records listing UXBs dealt with in the *Borough of Barking and Dagenham* from 1940-45 has identified the following task within the Study Site's vicinity:

- One UXB was removed from *Gardens backing on East Road, Chadwell Heath* (situated 160m to the east at its closest point) on the 20th September 1940;

In addition, an analysis of ARP mapping associated with the Study Site identified five UXB encounters within 1,000m of the Study Site during WWII; 525m to the north, 645m to the south-east, 665m to the east-north-east, 860m to the south-south-west and 945m to the south-south-west.

Furthermore, six unexploded AA shells (UXAA) were also recorded; 355m to the south, 500m to the east-north-east, 560m to the north-east, 575m to the north-east, 695m to the south-east and 770m to the south-east.

Records of Post-WWII UXB Disposal Tasks

An examination of the post-WWII BDO tasks associated with the area has not identified any BDO operations within the Study Site itself, nor within 1,000m of its boundary.

Military Activity

Two Pillboxes were identified; 440m to the east and 750m to the west-north-west. However, given the distance between these military installations and the Study Site, it is considered highly unlikely that munitions were stored, located and/or fired from this Study Site during WWII or that military training would have taken place.

Sources of UXO Contamination

The most likely source of UXO contamination is from *German* aerially delivered ordnance, which ranges from small IBs through to large HE bombs (the latter forms the principal threat). Additional residual contamination may be present from *British* AAA projectiles (which were used to defend the UK against *German* bombing raids).

STAGE THREE – DATA ANALYSIS		
Variable	**Result**	**Comment**
Was the area considered to be a primary bombing target?	✗	No primary targets were identified within 1,000m.
Was the Study Site or the immediate area bombed during WWII?	✓	ARP records identified five HE bomb strikes within 350m, the closest being 150m to the north. An AA shell was also identified 55m to the south-west.
Did the Study Site or the immediate area experience bomb damage?	✓	Bomb damage was identified as close as 320m to the west.
Was the ground undeveloped during WWII?	✓	The Study Site consisted of undeveloped ground.
Would the footfall have been high in the area?	✗	Given the lack of development on-site, it is likely that footfall would have been fairly low.
Would a UXB entry hole have been observed during WWII?	✗	Given that footfall would have been low, it is unlikely that a UXB entry hole would have been observed and dealt with at the time.
Have military personnel ever occupied the Study Site?	✗	No military facilities were identified on-site or in the immediate vicinity of the Study Site.
Would munitions have been manufactured, stored and/or fired from the Study Site?	✗	There is no evidence to suggest munitions were located or fired from this Study Site.
Would previous intrusive works have removed the potential for UXO to be present?	✗	The Study Site has been subjected to varying levels of redevelopment; therefore, it is likely that any UXO within post-war disturbed and developed ground would potentially have been discovered and removed, whilst the surrounding areas remain extant.
Are proposed intrusive works likely to extend into previously undisturbed ground?	✓	Some areas of the Study Site have remained undeveloped since WWII and therefore some proposed works may extend into previously undisturbed ground.
Is there potential for an unplanned encounter with UXO to occur during proposed intrusive works?	✓	Given that bombing was recorded in the wider area, combined with the limited post-war redevelopment of certain areas of the Study Site, it is considered possible for an unplanned encounter with UXO to occur.
Does the probability of UXO vary across the Study Site?	✓	The probability of discovering UXO within post-war disturbed and developed ground is considered to be remote, however, the probability of UXO discovery within all previously undisturbed areas of the Study Site is extant.

N.B. The ✓ / ✗ symbology is intended to act only as a succinct visual indicator as to whether the data analysis has returned a positive (i.e. ✓) or negative (✗) answer to each question concerning the potential for UXO contamination at the Study Site.

STAGE FOUR – RISK ASSESSMENT

Threat Items

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

Bomb Penetration Depth

Considering the ground conditions (highlighted in Stage 1), the average BPD for a 250kg *German* HE bomb is assessed to be approximately 7m bgl, with the maximum BPD considered to be approximately 16m bgl. Although it is possible that the *Luftwaffe* deployed larger bombs in the area, their deployment was infrequent, and to use such larger (or the largest) bombs for BPD calculations are not justifiable on either technical or risk management grounds.

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. However, due to the "J Curve" and the potential for structures to impede the penetration into the ground, HE bombs have been discovered at much shallower depths than the average.

Risk Pathway

Whilst there is a residual UXO risk within this Study Site, 6 Alpha do not believe there is a significant risk pathway to warrant on-site pro-active UXO risk mitigation measures. Whilst not all UXO encountered aggressively will initiate upon contact, such a discovery could lead to serious impact on the project especially in terms of critical injury to personnel, damage to equipment and project delay.

Prospective Consequences

Consequences of UXO initiation include:

1. Fatally injure personnel;
2. Severe damage to plant and equipment;
3. Deliver blast and fragmentation damage to nearby buildings;
4. Rupture and damage underground utilities/services.

Consequences of UXO discovery include:

1. Delay to the project and blight;
2. Disruption to local community/infrastructure;
3. The expenditure of additional risk mitigation resources and EOD clearance;
4. Incurring additional time and cost.

UXO RISK CALCULATION

Site Activities

Although there is some variation in the probability of encountering and initiating items of UXO when conducting different types of intrusive activities, a number of investigative and construction methodologies have been described for analysis at this Study Site. The consequences of initiating UXO vary greatly, depending upon, *inter alia* the mass of HE in the UXO and how aggressively it might be encountered. For this reason, *6 Alpha* has conducted separate risk rating calculations for each investigative and construction methodology that might be employed.

Risk Rating Calculation

6 Alpha's Semi-Quantitative Risk Assessment assesses and rates the risks posed by the most probable threat items when conducting a number of different activities on the site. Risk Rating is determined by calculating the probability of encountering UXO and the consequences of initiating it.

UXO Risk Calculation Table – All Areas				
Activity	**Threat Item**	**Probability (SH+EM=P)**	**Consequence (D+PSR=C)**	**Risk Rating (PXC=RR)**
Window Sampling	HE Bombs	1+3=4	3+2=5	4x5=20
	AAA Projectiles	2+3=5	3+1=4	5x4=20
	IBs	1+3=4	3+1=4	4x4=16
Boreholes	HE Bombs	1+3=4	3+2=5	4x5=20
	AAA Projectiles	2+3=5	3+1=4	5x4=20
	IBs	1+3=4	3+1=4	4x4=16
Excavations	HE Bombs	1+2=3	3+3=6	3x6=18
	AAA Projectiles	2+2=4	3+1=4	4x4=16
	IBs	1+2=3	3+1=4	3x4=12
Abbreviations – Site History (SH), Engineering Methodology (EM), Probability (P), Depth (D), Consequence (C), Proximity to Sensitive Receptors (PSR) and Risk Rating (RR).				

STAGE FIVE – RECOMMENDED RISK MITIGATION MEASURES

Do the ground conditions support a geophysical UXO survey?

Non-Intrusive Methods of Mitigation – Magnetometer results may be affected by ferro-magnetic contamination due to previous construction activities and made ground within the Study Site.

Intrusive Methods of Mitigation – Intrusive magnetometry may be effective on this Study Site, prior to boreholing especially. However, any ferrous metal/red brick contamination in made ground/old foundations may affect the detection capability of the UXB survey equipment, as it passes through the contaminated layer especially. Nonetheless, beyond the contaminated strata such a survey should prove effective.

Mitigation Measures to Reduce Risk to 'ALARP'

Activity	Risk Mitigation Measures	Final Risk Rating
All Activities in All Areas	**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*); **2. UXO Safety & 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 identification of a UXB, 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 UXB threat should be held in the site office and displayed for general information on notice boards, 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 principles laid down in the *CDM* regulations 2015 (this brief can be delivered directly, or in some cases remotely, by *6 Alpha*). **3. On-Call 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. *6 Alpha* offer three tiers of immediate telephone and/or email response.	**ALARP**

This assessment has been conducted based on the information provided by the Client, should the proposed works change then *6 Alpha* should be re-engaged to refine this risk assessment

Report Figures

Figure One - Study Site Location

BRITISH NATIONAL GRID

WEST ROAD, RM6 6YA

Site Location

BOMB SEARCH
WWW.6ALPHA.COM



PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE			
8584_8	1	CC	LG	18 March 2021	Contains Ordnance Survey data © Crown copyright and database right 2017	Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please notify 6 Alpha.	alpha ASSOCIATES

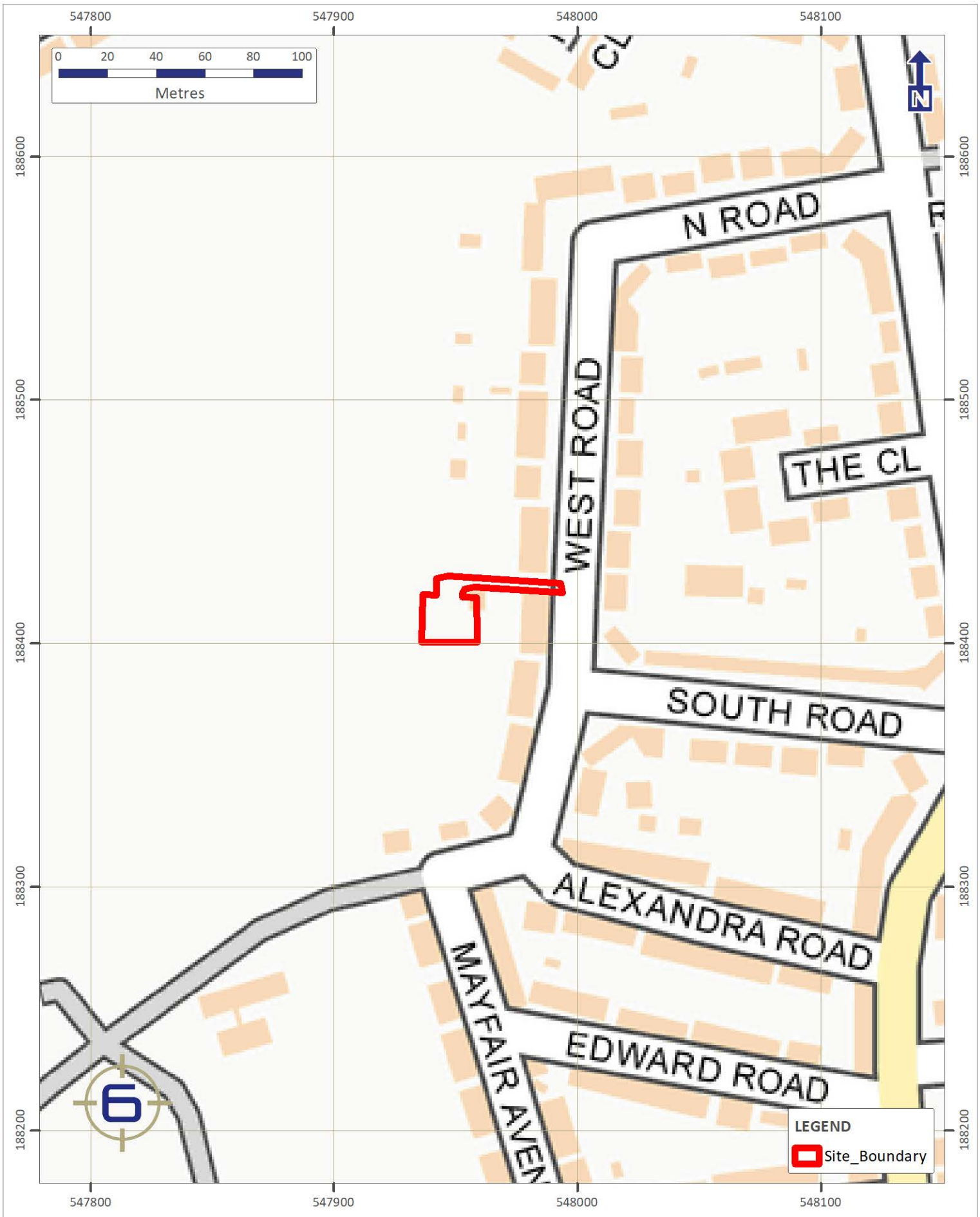
Figure Two - Study Site Boundary

BRITISH NATIONAL GRID

WEST ROAD, RM6 6YA

Site Boundary

BOMB SEARCH
WWW.6ALPHA.COM



PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE		
8584_8	2	CC	LG	18 March 2021	Contains Ordnance Survey data © Crown copyright and database right 2017	Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please notify 6 Alpha.

alpha ASSOCIATES

Figure Three - Aerial Photography (2020)

BRITISH NATIONAL GRID

WEST ROAD, RM6 6YA

Aerial Photography (2020)

BOMB SEARCH
WWW.6ALPHA.COM



PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE		
8584_8	3	CC	LG	18 March 2021	Map data: Google	Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please notify 6 Alpha.

alpha ASSOCIATES

Figure Four - Aerial Photography (1945)

BRITISH NATIONAL GRID

WEST ROAD, RM6 6YA

Aerial Photography (1945)

BOMB SEARCH
WWW.6ALPHA.COM



PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE		
8584_8	4	CC	LG	18 March 2021	Map data: Google, The GeoInformation Group	Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please notify 6 Alpha.

alpha ASSOCIATES

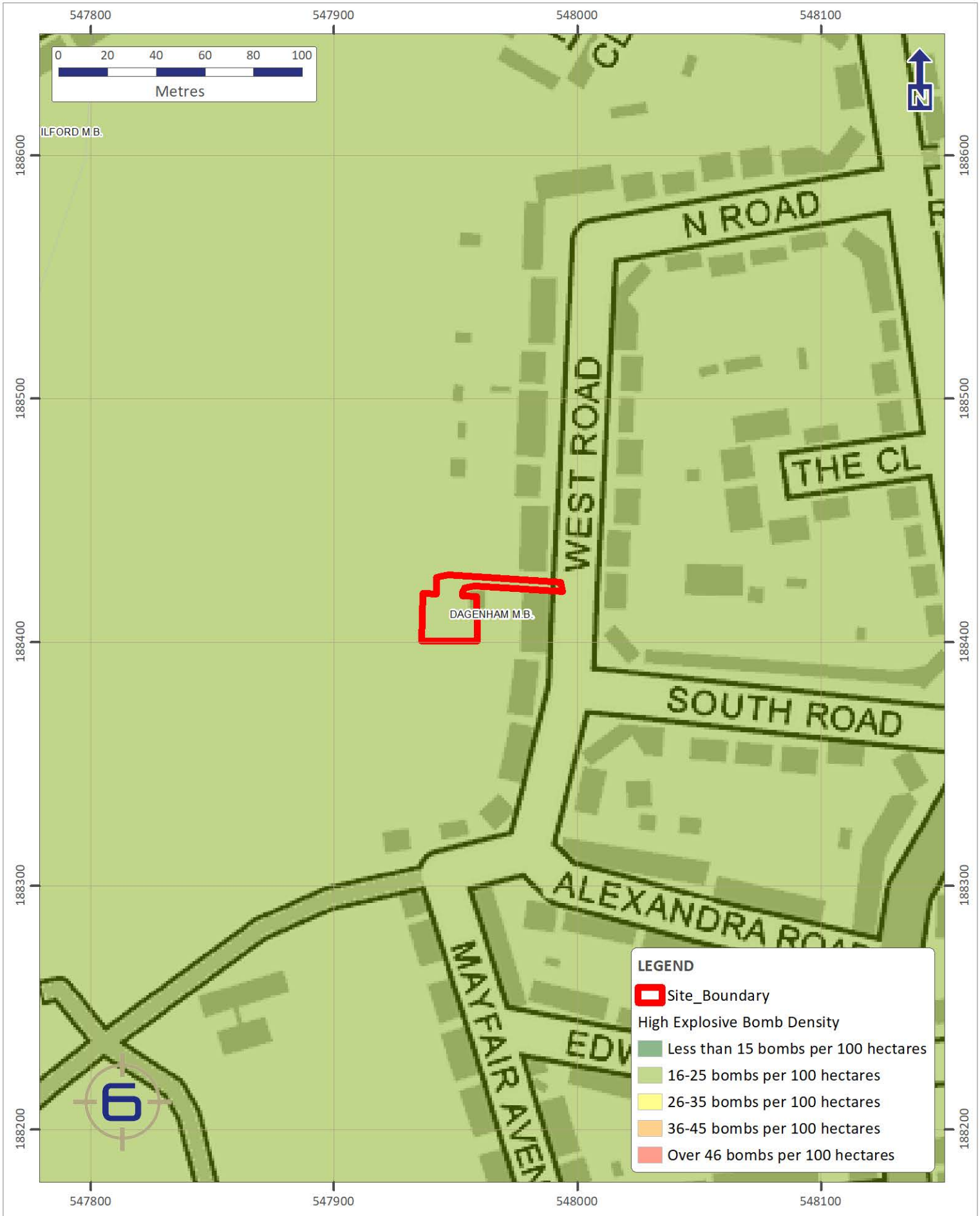
Figure Five - WWII High Explosive Bomb Density

BRITISH NATIONAL GRID

WEST ROAD, RM6 6YA

WWII High Explosive Bomb Density

BOMB SEARCH
WWW.6ALPHA.COM



PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE
8584_8	5	CC	LG	18 March 2021

Contains Ordnance Survey data © Crown copyright and database right 2017

Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please notify 6 Alpha.

alpha ASSOCIATES

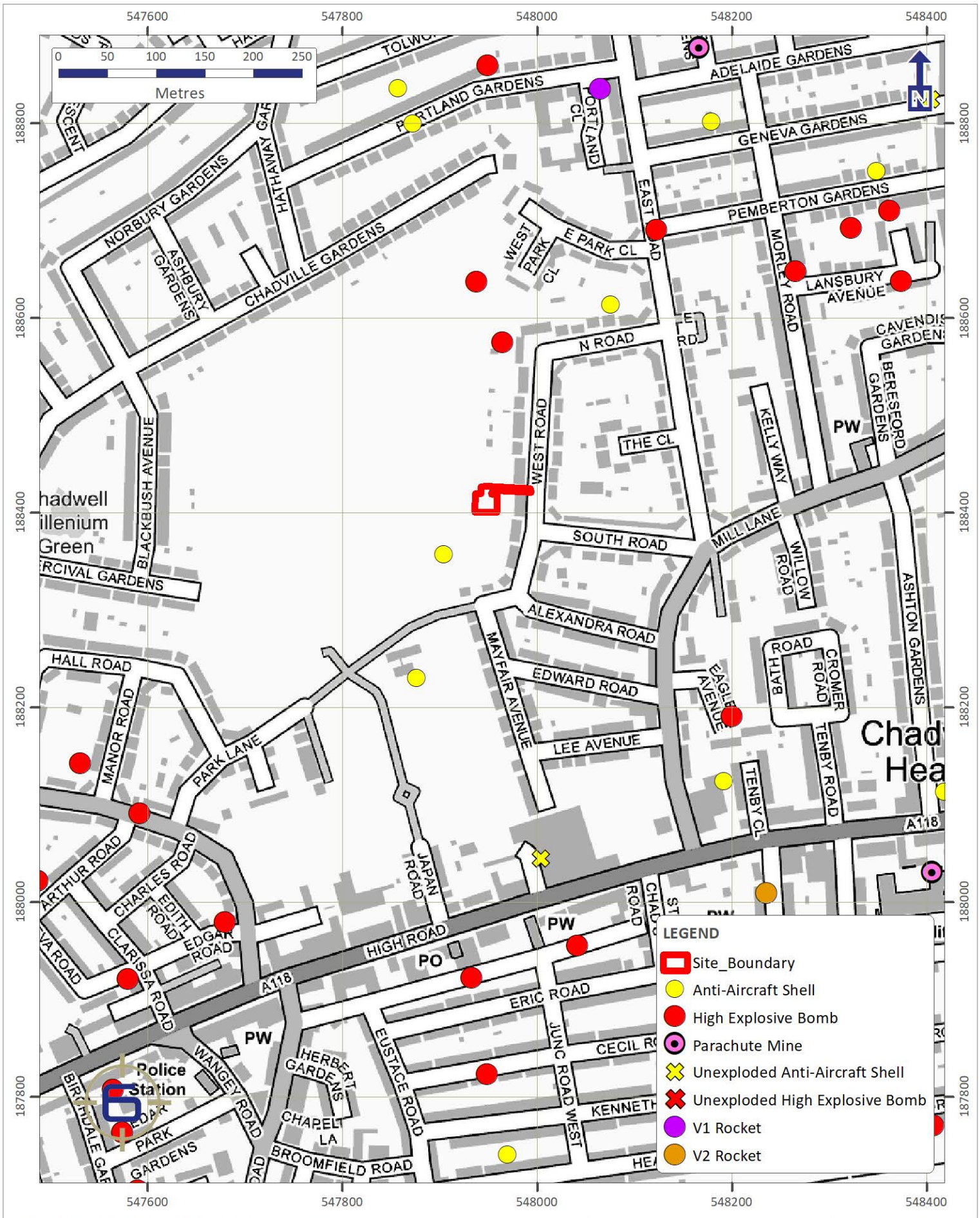
Figure Six - WWII Consolidated Bomb Strikes

BRITISH NATIONAL GRID

WEST ROAD, RM6 6YA

WWII Consolidated Bomb Strikes

BOMB SEARCH
WWW.6ALPHA.COM



PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE
8584_8	6	CC	LG	18 March 2021

Contains Ordnance Survey data © Crown copyright and database right 2017

Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please notify 6 Alpha.

alpha ASSOCIATES