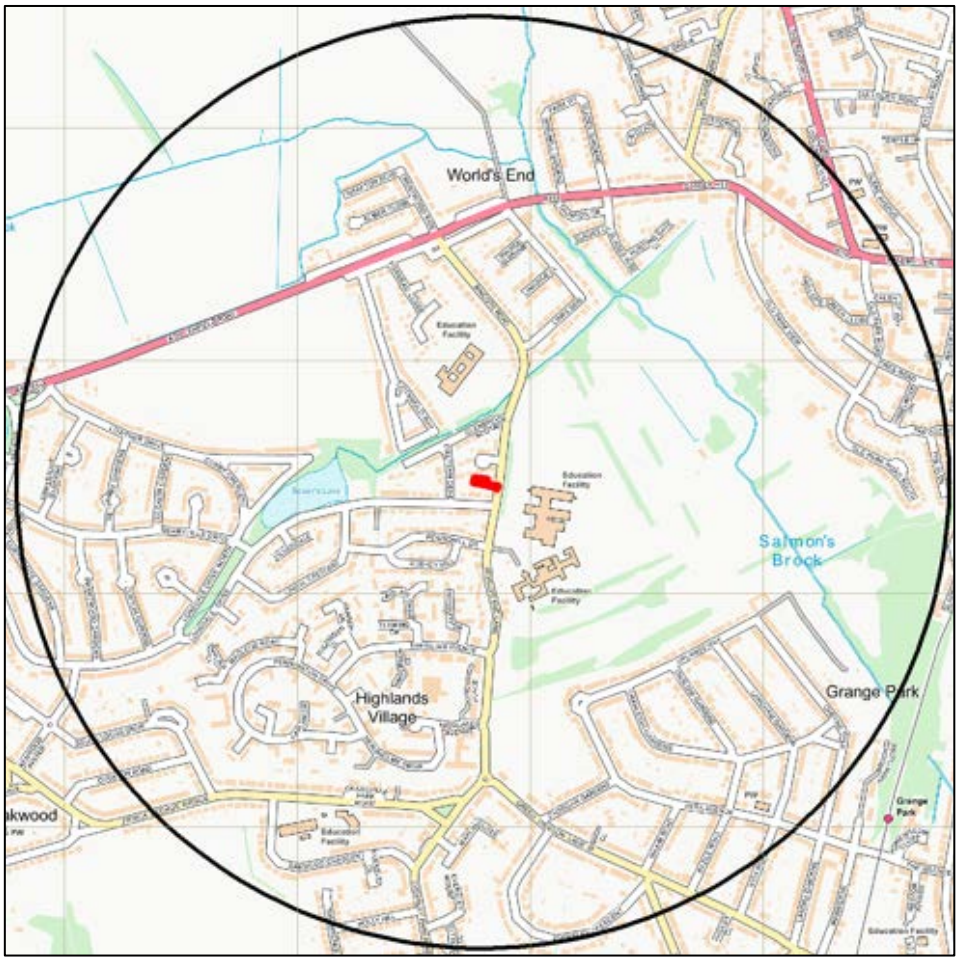
Detailed Unexploded Ordnance (UXO) Threat & Risk Assessment

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



PROJECT NUMBER	9424	**ORIGINATOR**	D. Barrett
PROJECT	Chiltern Dene	**REVIEWED BY**	B. Wilkinson
CLIENT	Arcadis	**RELEASED BY**	L. Gregory
VERSION	1.0	**DATE**	27th January 2022
UXO RISK RATING	**MEDIUM** - This Study Site requires limited further action to reduce risk to ALARP during intrusive activities.		

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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 "Chiltern Dene, London" and it is centred on NGR 530898, 196239.

Risk Level

MEDIUM

Potential Threat Sources

The most probable UXO threat is posed by WWII-era *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 that the proposed intrusive works will generate a significant risk pathway.

Key Findings

During WWII, the Study Site was situated within *Enfield Urban District,* which recorded seven HE bomb strikes per 100 hectares, a "very 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 vicinity of the Site; 40m to the north, 170m to the south, 175m to the south, 180m to the south and 185m to the south-west.

LCC bomb damage mapping did not cover the Study Site. Nonetheless, whilst an analysis of post-war mapping and further research of historical records did not identify evidence of bomb damage on-site, bomb damage was recorded at *Links Rise* (approximately 450m to the north-east of the Site) and *Langham Gardens* (605m to the south-east).

Pre-WWII mapping (1938) and aerial photography (1945) associated with the Study Site shows that it was located within a developing urban area during WWII, although the Study Site itself consisted of undeveloped ground. Therefore, it is likely that footfall within the Site would have been low. Consequently, it is possible that any UXBs impacting within the Site during WWII could have done so unobserved and otherwise unnoticed.

In the mid-to late 1960s, several structures had been built in the Site's western sector, with hardstanding visible across the Study Site by 1999 which may also have been installed post-WWII. 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 any remaining areas of undisturbed ground is assessed to be extant.

Given that WWII bombing was recorded in the vicinity, combined with the limited post-war development in some areas, 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 EOD Engineer	Non-Intrusive Magnetometer Survey	EODE Watching Brief	Intrusive Magnetometer Survey	UXO Risk Rating (Post-Mitigation)
Trial Pits	✔	✔	✔	✘	✘	✘	ALARP
Excavations	✔	✔	✔	✘	✘	✘	
Trenching	✔	✔	✔	✘	✘	✘	

"Blind" Intrusive Works

Engineering Methodology	UXO Emergency Response Plan	UXO Safety and Awareness Briefing	On-Call EOD Engineer	Non-Intrusive Magnetometer Survey	EODE Watching Brief	Intrusive Magnetometer Survey	UXO Risk Rating (Post-Mitigation)
Boreholes	✔	✔	✔	✘	✘	✘	ALARP
Window Sampling	✔	✔	✔	✘	✘	✘	
Piling	✔	✔	✔	✘	✘	✘	

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

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ASSESSMENT METHODOLOGY

Approach

6 Alpha Associates is an independent, specialist risk management consultancy practice, which has assessed the prospective UXO risk at this Study Site by employing a process advocated by *CIRIA*. The *CIRIA* guide for managing UXO risks in the construction industry (C681) not only represents industry best practice but has also been endorsed by the UK's *HSE*. *6 Alpha* were the lead technical author of the CIRIA C681 guide.

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 contemporary aerial photography (where it is available). Prospective 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 within a Semi-Quantitative Risk Assessment (as per industry best practice outlined in CIRIA C681) in order to form the basis of a proportional UXO risk mitigation strategy in circumstances where the SQRA evidences that further action is necessary in order to reduce the UXO risk at the Study Site.

The assessment of UXO risk is a 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', such as equipment) to the hazard. UXO risk is thus calculated using the following formula:

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

If intolerable UXO risks are identified, the methods of mitigation we have recommended are considered reasonable and sufficiently robust to reduce them to ALARP. We advocate the adoption of the ALARP legal 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

Although this report is up to date and accurate at the time of writing, *6 Alpha's* UXO threat databases are continually being populated and updated 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 also 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 "Chiltern Dene, London". The Study Site is centred at NGR 530898, 196239 as presented at *Figures 1* and *2,* respectively.

Location Description

The Study Site is situated within the *London Borough of Enfield* and totals an area of 0.05 hectares (ha).

Furthermore, the Study Site is bounded by:

- North: Residential structures*;*
- East: *Worlds End Lane;*
- South: Residential structures*;*
- West: *Chiltern Dene* and residential gardens.

Aerial Photography (2021) (*Figure 3*)

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

Proposed Works

The Client has not provided *6 Alpha* with specific details of the proposed development of the Study Site. As a result, *6 Alpha* will assume that a number of geotechnical investigative methodologies and/or construction methodologies may be undertaken.

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 "TQ39NW279 – Worlds End Lane Enfield BH7" (located 100m to the east of the Study Site), recorded the following strata:

Depth bgl (m)	Strata	Description
0.00m to 0.30m	Topsoil	
0.30m to 7.50m	Clay	Firm closely fissured brown to orange brown CLAY with occasional sand sized selenite crystals. Occasional blue grey greying along fissure planes. Fissures predominately sub horizontal and subvertical curviplanar smooth and irregular and tight
7.50m to 20.00m	Clay	Very stiff very closely fissured CLAY with occasional sand sized selenite crystals. Fissures predominantly sub horizon and subvertical, smooth, curviplanar and tight

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 "*Thames Group – Clay, Silt, Sand And Gravel*".

STAGE TWO – REVIEW OF HISTORICAL DATASETS

Sources of Information Consulted

The following information sources have been employed in order to establish the nature and scope of the 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 - Overview

In general, there are several activities that might have contaminated 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* and although the *Luftwaffe* had designated primary bombing targets across the *UK*, their high-altitude night bombing was not accurate. There was also a period of indiscriminate bombing of civilian and industrial areas alike in *British* cities in an attempt to cripple the morale of the *British* people. As a result, thousands of buildings were damaged across industrial and residential areas and civilian fatalities were common. Bombs were also jettisoned over opportunistic targets and more rural locations were also attacked in this manner.

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 most common type of UXO discovered today in the *UK* 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. *British* AXO/LSA/SAA is also commonly encountered in areas that were formerly occupied by military forces (such as RAF airfields, military camps and/or military training areas). More rarely, additional forms of *German* UXO are occasionally discovered including *inter alia* Incendiary Bombs (IBs), and Anti-personnel (AP) bomblets and fragments of *V1* and *V2* rockets.

"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 during WWII 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;
- *British* decoy sites were also constructed to deliberately cause incorrect targeting. For obvious reasons, such sites were often built in remote and uninhabited areas – few historical records concerning these sites are available.

WWII Bombing of *London*

As the capital of the *UK*, *London* became the most important symbolic and strategic target for the *Luftwaffe* during WWII. The most intensive period of bombing over *London* occurred in the nine months between October 1940 and May 1941 - known as *The Blitz*. During this period, the *Luftwaffe* had a variety of strategic goals they hoped to achieve with the bombing of *London.*

In total, 18,000 tonnes of bombs were dropped on *London* between 1940 and 1945. Many residential, commercial, and industrial buildings sustained large scale damage, with up to 43,000 civilians killed as a result of *Luftwaffe* bombing in *London*. Even those not directly impacted by the bombing often had gas, electricity and water supplies cut-off following damage to either the installations themselves or to the supply infrastructure.

WWII HE Bomb Density (*Figure 4*)

The Study Site was located within *Enfield Urban District,* which recorded seven HE bombs per 100 hectares, a "very 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 targets 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 5*)

During WWII, ARP wardens compiled detailed logs of bomb strikes across their respective districts. ARP records associated with the Study Site did not note any HE bomb strikes within it. Nonetheless, five were recorded in the vicinity of the Site; 40m to the north, 170m to the south, 175m to the south, 180m to the south and 185m to the south-west. 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. Nonetheless, analysis of high-level bomb strike mapping noted IB strikes impacting approximately 665m to the north-north-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 of June 1944, with the first recorded *V2* strike on *London* on the 8th of September 1944. *V1* and *V2* rockets were thin-skinned, unmanned and inaccurate weapons. One *V1* rocket strike was identified impacting approximately 580m to the west-north-west.

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, whilst an analysis of post-war mapping and further research of historical records did not identify evidence of bomb damage on-site, bomb damage was recorded at *Links Rise* (approximately 450m to the north-east of the Site) and *Langham Gardens* (605m to the south-east).

Abandoned Bombs

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

Records of WWII UXB Disposal Tasks

Civil defence records did not identify any UXB disposal tasks within *Enfield Urban District* from 1940-45 within 1,000m of the Study Site. However, it is known that these records are incomplete, some having been destroyed by *Luftwaffe* action during WWII.

Military Activity

Whilst no military activity was identified on-site, it was documented in the wider area. For example, an Anti-Aircraft Artillery (AAA) Battery and associated camp were located 815m to the north of the Site, which further research indicated it was comprised of four 4.5" naval guns and was used operationally to defend the area against air raids during WWII.

Nonetheless, there is no evidence to suggest that the Study Site has previously been occupied by military personnel. Therefore, it is considered unlikely that munitions were previously stored, located and/or fired from this Study Site during WWII.

WWII Site Use (*Figure 6*)

The CS mapping prior to WWII (1938) and 1945 aerial photography shows that the Study Site was located within a developing urban area during WWII, although the Study Site itself consisted of undeveloped ground. Therefore, it is likely that footfall within the Site would have been low. Consequently, it is possible that any UXBs impacting within the Site during WWII could have done so unobserved and otherwise unnoticed.

Post-WWII UXO Encounters

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

Sources of UXO Contamination

Given the historic military activity documented at the Study Site, the most likely source of UXO contamination is *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).

Post-WWII Study Site Development

Generally, the probability of encountering UXO in ground that has been disturbed since it may have been contaminated with UXO is considered to be remote (up to the depth below ground level previously disturbed by any intrusive works). Therefore, an understanding of the Study Site's previous development history is crucial when assessing the likelihood that UXO might be encountered at the Study Site.

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
1897 CS Map	The Study Site was located in an undeveloped rural area. The Study Site did not consist of any structures.
1920 CS Map	Changes were not recorded at the Study Site.
1938 CS Map	Changes were not recorded at the Study Site.
1945 Aerial Photography	Changes were not recorded at the Study Site.
1960 OS Map	Changes were not recorded at the Study Site.
1969 OS Map	Structures had been built in the western sector of the Site.
1975 OS Map	Changes were not recorded at the Study Site.
1999 Aerial Photography	Hardstanding was visible across the Study Site.
2010 Aerial Photography	Changes were not recorded at the Study Site.
2022 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.	

STAGE THREE – DATA ANALYSIS

Variable	Result	Comment
Was the area considered to be a primary bombing target during WWII?	✗	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 185m of the Site, the closest being 40m to the north.
Did the Study Site or the immediate area experience bomb damage?	✓	Further research identified bomb damage 450m to the north-east of the Site.
Would munitions have been manufactured, stored and/or fired from the Study Site previously?	✗	There is no evidence to suggest munitions were located or fired from this Study Site.
Was the ground undeveloped during WWII?	✓	The Study Site consisted of undeveloped ground during WWII
Would the footfall have been high in the area?	✗	Given the lack of development on-site, it is likely that footfall would have been low.
Would a UXB entry hole have been observed during WWII?	✗	Given that footfall would have been low, it is unlikely a UXB entry hole would have been observed at the time.
Has UXO been encountered previously at the Study Site?	✗	There have been no documented UXO encounters within 1,000m.
Have previous intrusive works 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. The potential for a UXO encounter in areas of undisturbed ground remains extant.
Are proposed intrusive works likely to extend into previously undisturbed ground?	✓	Areas of the Study Site have remained undeveloped since WWII and therefore the 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 WWII bomb strikes were recorded in close proximity, it is considered possible for an unplanned encounter with UXO to occur.
Does the probability of a UXO encounter vary across the Study Site?	✓	The probability of encountering UXO within post-war disturbed and developed ground is considered to be remote. However, the probability of a UXO encounter 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 generally 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 within clays 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

Although there is a residual UXO risk within this Study Site, *6 Alpha* do not believe that the proposed intrusive works will generate a significant risk pathway. 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 ground intrusive 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 intrusive 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. UXO risk is determined by calculating the probability of encountering and initiating UXO and the consequences of an inadvertent UXO detonation.

UXO Risk Calculation Table – All Areas				
Activity	**UXO Threat Items**	**Probability (SH+EM=P)**	**Consequence (D+PSR=C)**	**UXO Risk (PxC=R)**
Trial Pits	HE Bombs	1+2=3	3+3=6	3x6=18
	AAA Projectiles	1+2=3	3+1=4	3x4=12
	IBs	1+2=3	3+1=4	3x4=12
Window Sampling	HE Bombs	1+3=4	3+2=5	4x5=20
	AAA Projectiles	1+3=4	3+1=4	4x4=16
	IBs	1+3=4	3+1=4	4x4=16
Boreholes	HE Bombs	1+3=4	3+2=5	4x5=20
	AAA Projectiles	1+3=4	3+1=4	4x4=16
	IBs	1+3=4	3+1=4	4x4=16
Excavations	HE Bombs	1+2=3	3+3=6	3x6=18
	AAA Projectiles	1+2=3	3+1=4	3x4=12
	IBs	1+2=3	3+1=4	3x4=12
Trenching	HE Bombs	1+2=3	3+3=6	3x6=18
	AAA Projectiles	1+2=3	3+1=4	3x4=12
	IBs	1+2=3	3+1=4	3x4=12
Piling	HE Bombs	1+3=4	3+2=5	4x5=20
	AAA Projectiles	1+3=4	3+1=4	4x4=16
	IBs	1+3=4	3+1=4	4x4=16
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 and piling 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 partially 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

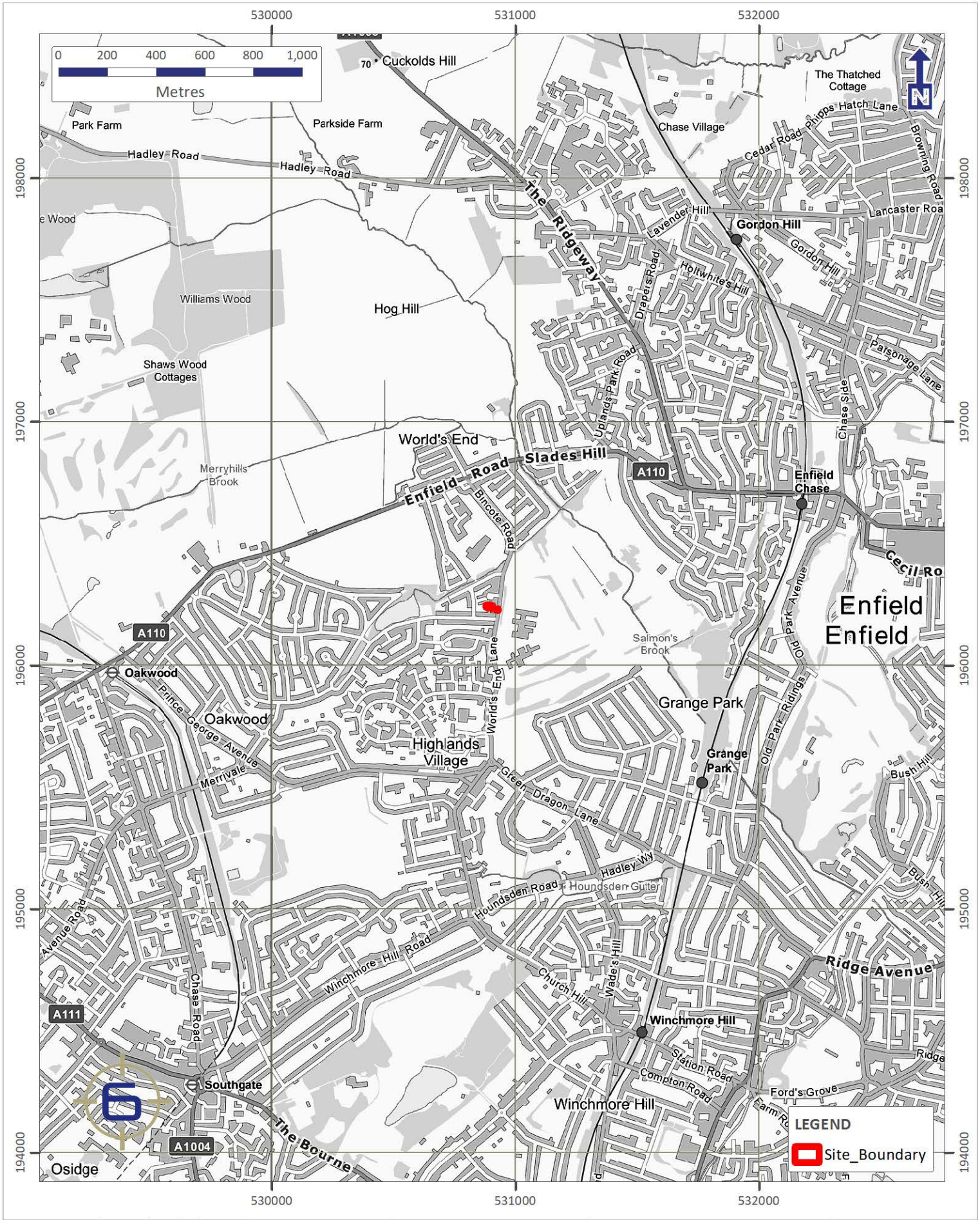
Figure One - Study Site Location

BRITISH NATIONAL GRID

CHILTERN DENE, LONDON

Site Location

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9424	1	LH	LG	25 January 2022

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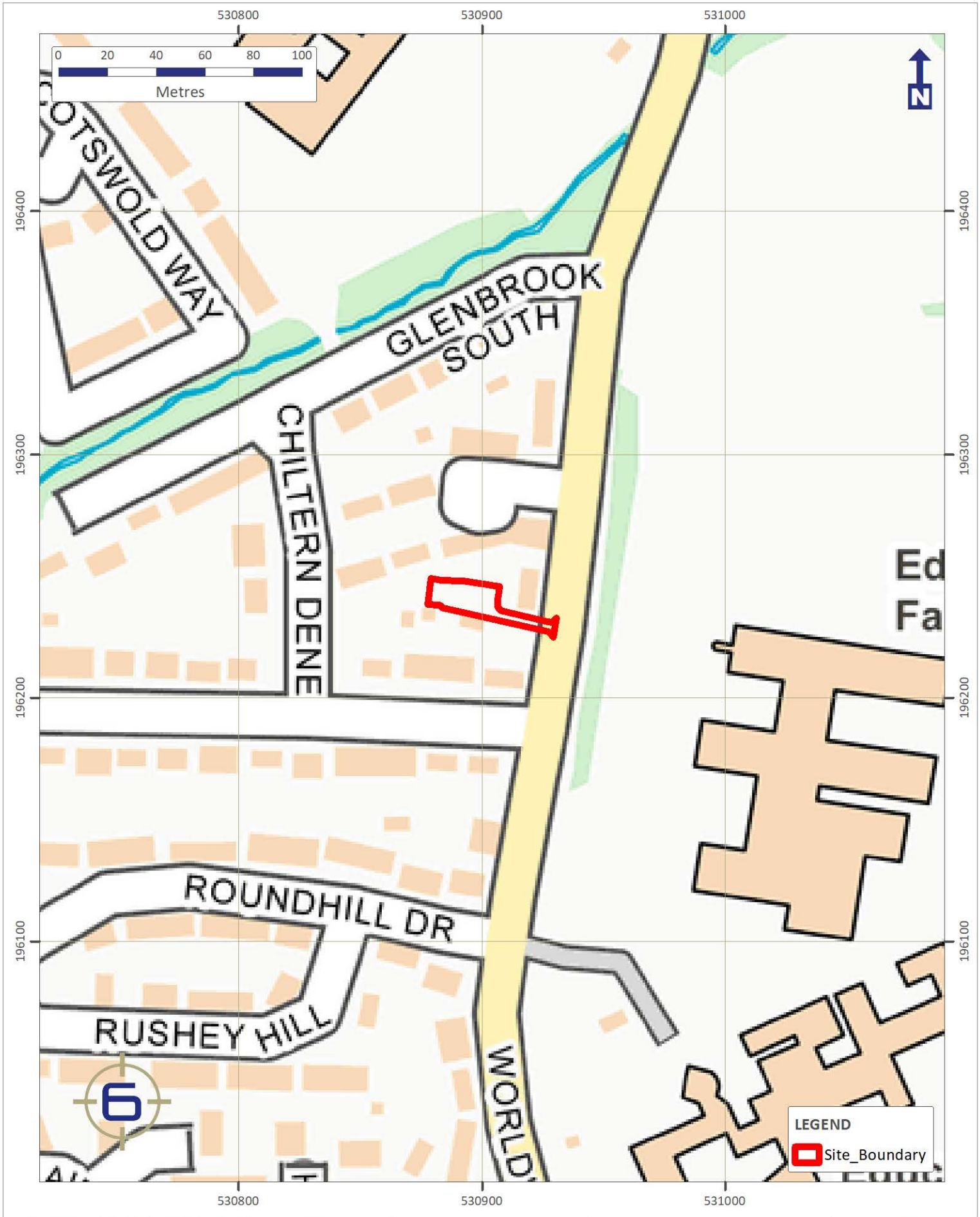
Figure Two - Study Site Boundary

BRITISH NATIONAL GRID

CHILTERN DENE, LONDON

Site Boundary

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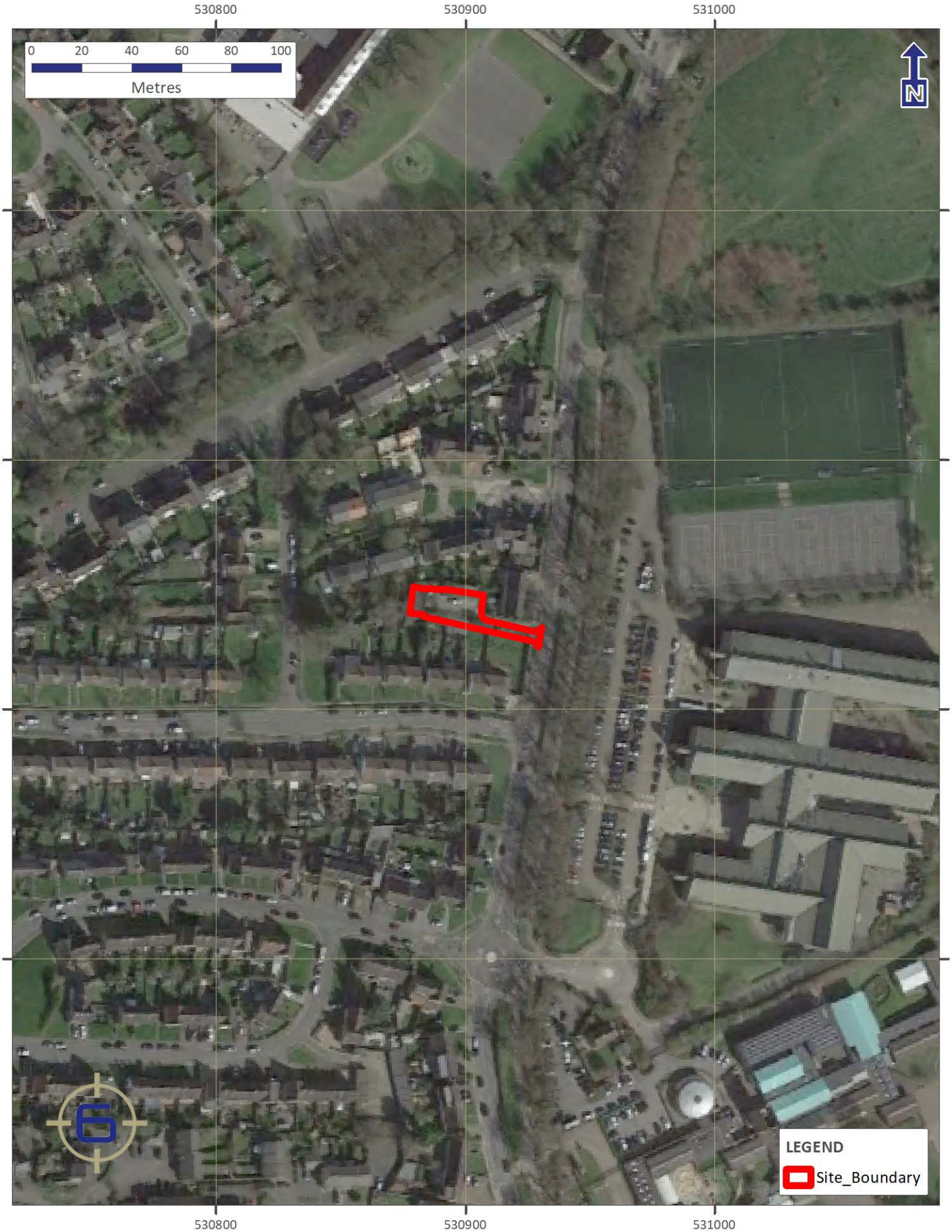
Figure Three - Aerial Photography (2021)

BRITISH NATIONAL GRID

CHILTERN DENE, LONDON

Aerial Photography (2021)

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9424	3	LH	LG	25 January 2022	Map data: Google	Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please notify 6 Alpha.

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Figure Four - WWII High Explosive Bomb Density

BRITISH NATIONAL GRID

CHILTERN DENE, LONDON

WWII High Explosive Bomb Density

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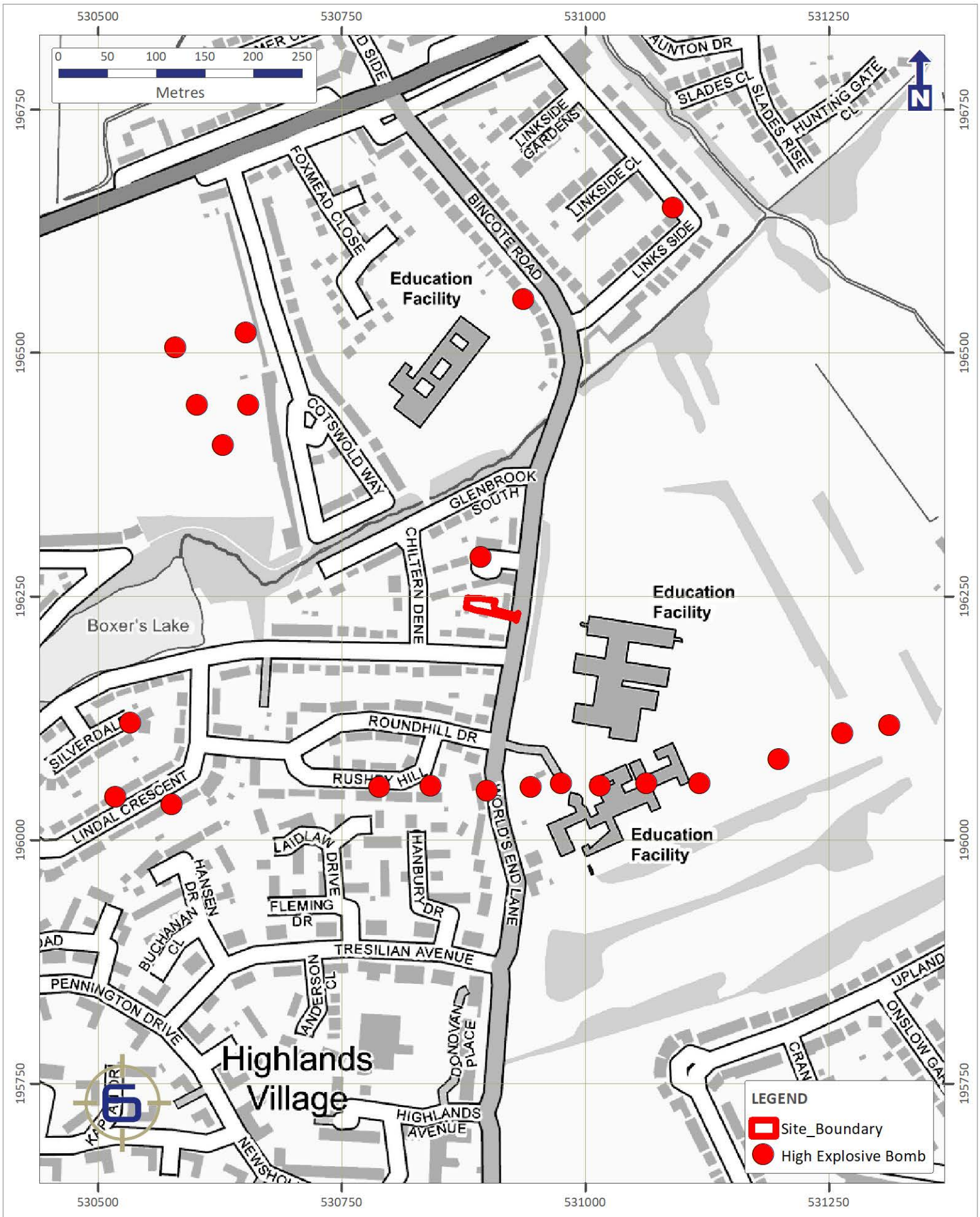
Figure Five - WWII High Explosive Bomb Strikes

BRITISH NATIONAL GRID

CHILTERN DENE, LONDON

WWII High Explosive Bomb Strikes

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Figure Six – Aerial Photography (1945)

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CHILTERN DENE, LONDON

Aerial Photography (1945)

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9424	6	LH	LG	25 January 2022	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