BRIMSTONE

DETAILED UXO RISK ASSESSMENT

STAGE 2 DETAILED UXO RISK ASSESSMENT

Client:	JNP Group		
Project Ref:	JNPG133R		
Site Name:	83-89 Manor Way, Ruislip		
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EXECUTIVE SUMMARY

RESULT: Brimstone concludes that unexploded ordnance (UXO) poses a **LOW-MODERATE RISK** to the proposed works.

THE SITE: The Site is located in Ruislip, within the London Borough of Hillingdon, approximately 200m north-west of Ruislip Manor station. It predominantly comprises hardstanding, with a small garage structure present in the central extent.

The Site is bound on all sides by gardens associated with residential structures on Windmill Hill, Manor Way & Priory Close. The Site is also bound to the east by hardstanding and a further garage structure, and to the south by Manor Way itself.

Grid Reference: TQ 09929 87402 **What3Words:** areas.tools.slime

THE PROPOSED WORKS: Brimstone was not made aware of any upcoming site investigation (SI) works occurring on Site at the time of writing.

Client provided information states development works will comprise the construction of a three-storey building for five flats with hardstanding for a road/parking and shared green space. Associated depths of intrusions were not provided, and it is assumed that piling may be required.

UXO RISK ASSESSMENT:

German UXO:

- During WWII the Site was situated within the Urban District of Ruislip and Northwood, which sustained 38.4 bombs / 1,000 acres, a moderate bombing density, according to official Home Office statistics. Luftwaffe target photography identifies RAF Blenheim Crescent, a training centre approximately 1.4km south-west of the Site, as the closest primary bombing target in the region.
- Indeed, bomb census mapping records seven high explosive (HE) bombs and two unexploded oil bombs (UOXB) within an approximate 300m radius of the Site. No bomb strikes are recorded directly on Site, with the closest incident, an unexploded oil bomb plotted approximately 40m east of the Site. Three bomb sticks are recorded in the wider area, one of which, containing the two UXOBs, potentially straddles the south-eastern extent of the Site as it is aligned in a north-east / south-west direction. A local bomb map for Ruislip also records nine HE bombing incidents within the abovementioned radius, none of which are on / adjacent to the Site. This lack of bombing on Site or its immediate surrounds is also corroborated by available written records as the closest incident, an HE, is located approximately 150m south-west of the Site.
- A comparison between pre- & post-WWII OS mapping, as well as post-WWII aerial photography has not evidenced any immediately obvious bomb related damage, such as cratering or structural damage, on Site or within its immediate surrounds. It should be noted, the ground cover within the majority of the immediate surrounds, and partially within northern extent of the Site, may have presented visually unconducive conditions to such evidence, and as such evidence of a UXB strike in these locations may have gone unnoticed..
- Given the majority of the Site comprised hardstanding utilised as an access way for garages associated with the neighbouring residential structures, access levels to the Site are anticipated to have been intermittent. Furthermore, the adjacent structures did not sustain any damage throughout the conflict, therefore potentially providing an elevated level of access on Site, although to what extent cannot be confirmed. This somewhat increases the likelihood that evidence of an unexploded bomb strike would have been observed and dealt with at the time, although this would have depended on the individual landowner(s).

- However, any UXB strike to the hardstanding / garage structure on Site, as well as residential structures in the wider surrounds, would have caused incontrovertible evidence of its incidence as it passed the structures / hardstanding into the ground beneath. Contrastingly, a majority of the immediate surrounds to the north-east and north-west comprised open ground garden areas, within which a UXB strike could easily have gone unnoticed, leaving a small, easily obscured entry hole and coming to rest beneath the Site area via the J-curve (lateral offset) effect (See ***Section 6.3.2***).
- In conclusion, no bombing incidents or identifiable bomb related damage is recorded directly on / adjacent to the Site within available records / photography. However, one bomb stick flightpath, containing two unexploded oil bombs, potentially straddled the south-eastern extent of the Site, and the flightpath also intersected visually unconducive gardens adjacent to the Site. It is feasible, that an additional bomb (potential UXB) within this stick may have landed unnoticed and unrecorded within the open ground adjacent to the Site and potentially come to rest underneath the Site via the J-curve effect. Whilst this remains a possibility, no such evidence has been identified to suggest this occurred. As such, a **Low-Moderate** risk of encountering German UXBs has been assessed across the Site. A UXO safety Awareness Briefing is recommended prior to works commencing.

British / Allied UXO:

- No evidence of historic military activity within the Site boundary has been identified and it is highly unlikely any has occurred historically. Consequently, the risk from associated UXO is **Low**.
- 14 permanent HAA batteries were active within a range of the Site during WWII. LAA guns may have defended vulnerable points within the borough also. Luftwaffe activity was somewhat frequent and intense over the wider area and therefore these guns may have expended a notable quantity of ammunition. Consequently, it is possible that an unexploded AA shell may have struck the Site; although, no evidence of such an occurrence has been identified. Therefore, the risk is considered analogous to that of German UXBs, and a **Low-Moderate Risk** has been assessed across the Site.

Likelihood of UXO Remaining and UXO Encounter:

- The Site has not been subject to any significant post-conflict ground works, with a garage structure being constructed in the central extent of the Site, indicated by post-WWII OS mapping. General maintenance of the hardstanding & construction of the garage will have disturbed WWII-era soil to very shallow (<1m bgl) depths. No shallow (1-2m bgl) or deep (>2m bgl) excavations into WWII-era soil are anticipated to have occurred in the post-WWII period.
- The risk associated with (any) very shallow buried UXO has likely been partially mitigated across the entire Site. The risk associated with (any) shallow or deep buried UXO almost certainly remains unmitigated across the Site.
- Please note, the risk of a UXO encounter can be considered mitigated in the exact locations and down to the exact depths of any post-WWII intrusive works

RECOMMENDED RISK MITIGATION MEASURES: The measures detailed below are recommended to mitigate the risk to ALARP level.

Risk Mitigation Measure	Recommendation
UXO Safety Awareness Briefings	Prior to all intrusive works commencing.

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QUALITY POLICY

Brimstone Site Investigation Ltd, known as Brimstone, is committed to the delivery of unexploded ordnance (UXO) risk mitigation services, including safe removal and disposal of explosive ordnance, in the UK and overseas. Since our incorporation in 2016 it has been our goal to provide unsurpassed and unbiased UXO risk mitigation services. Brimstone is a client-centric organisation, with the aim to provide the client the services they need, to the agreed requirement, in accordance with national and international standards or standard operating procedures.

We are committed to providing a safe, cost-effective, and quality service, underpinned by our core values:

- **Integrity:** We are unwavering in our commitment to providing pristine, unbiased counsel and superior services. Our ethical compass guides every interaction, ensuring we maintain the highest standards of conduct in all our endeavours.
- **Professionalism:** We embody professionalism at every level, conducting our business with unparalleled excellence. Our commitment to quality guarantees top-tier service and a seamless experience for every client.
- **Knowledge:** We are devoted to perpetual growth, consistently expanding our expertise to stay at the forefront of industry innovation and strategy. Our thirst for knowledge ensures we are equipped to lead and succeed in an evolving marketplace.
- **Innovation:** We champion innovation, continuously advancing our services and processes. Our pursuit of inventive strategies and pioneering solutions ensures we not only meet but exceed the evolving needs of our clients and the industry.

We are committed to the applicable requirements of the ISO 9001:2015 standards. We set and review quality monitoring objectives using the plan, do, check, act cycle to measure the performance of our quality management system. Brimstone wholly endorses the ethos of 'continual improvement efforts' and allocates resources to meet this requirement.

This policy applies to the whole of the Brimstone services and involves all personnel including the managing director. All personnel are responsible for helping manage quality, seeking improvement through constant review, and by encouraging supplier and subcontractor involvement. We are committed to achieving customer satisfaction using quality procedures, which will be operated to meet or exceed the applicable requirements of ISO 9001.

Aaron Florence
Founder and Managing Director
Brimstone Site Investigation Ltd.

1 INTRODUCTION

1.1 Background

JNP Group (the Client) has commissioned Brimstone to carry out a Stage 2 Detailed Unexploded Ordnance Risk Assessment (DRA) of the proposed redevelopment works at the 83-89 Manor Way, Ruislip site (the Site).

1.2 Legislation

There are no regulations that specifically govern the UXO risk mitigation industry in the UK. However, there are two pieces of legislation that require consideration. It is industry best practice (and common sense) to frame your site in the context of UXO, and to put in place measures to protect people from risks. In 2009, CIRIA published Unexploded Ordnance (UXO) - A Guide for the Construction Industry C681. This publication, though not legally binding, provides the gold-standard framework to which UXO and construction companies operate.

1.2.1 Construction Design and Management Regulations (CDM) 2015

The regulations identify the client, the CDM coordinator, the designer, and the principal contractor as responsible parties. Under the regulations, responsible parties are held accountable for the way a construction project is managed and for the health and safety of workers. Responsible parties must:

- Provide an appropriate assessment of potential UXO risks, or ensure an assessment is completed by another party.
- Put in place appropriate risk mitigation measures if necessary.
- Supply all parties with information relevant to the risks.
- Ensure the preparation of an emergency response plan.

1.2.2 The Health and Safety at Work Act 1974

The Health and Safety at Work Act 1974 had a transformative impact on health and safety, saving thousands of lives since its enactment. Employers must consider their employees, workers not in their employment, and members of the public. The act places a duty on every employer 'as far as is reasonably practicable' to protect workers from risks. It also says that information must be provided about aspects of health and safety that affect their role.

1.3 Commercial Contractor and the Authorities

1.3.1 Commercial Contractors

If your site has been given a moderate or high-risk rating, then control measures will be recommended. The measures will be specific to the scope of works on site, usually in relation to the depth and extent of excavations, piling and similar activities. There are a range of different methods at Brimstone's disposal, including:

- Non-intrusive surveying (including drone surveying)
- Intrusive surveying
- Search and clear
- Watching brief
- Support to geotechnical investigations
- Target investigation
- Site-specific training packages
- Site safety briefings

Our UXO Engineers can assess suspicious items on site when they are found. This will avoid unnecessary site

evacuations. If our engineer(s) decide the item is UXO, they will coordinate with the authorities, manage disruptions, and advise on control measures, such as evacuations and a cordon.

1.3.2 UK Authorities

If Brimstone is not on site and a suspicious item is found, the local police must be immediately called on the non-emergency number. Police will visit the site. They will then inform the Joint Services Explosive Ordnance Disposal (JSEOD) office, which will coordinate the callout of an army or navy response team.

A precautionary cordon will initially be put into effect, with possible evacuation of homes and businesses, road and rail closures. The cordon may be extended following the advice from JSEOD's response team.

To manage their resources, JSEOD triages incidents. A consideration of the type, size and location of the UXO is made. If an incident is not given a high priority rating, a team may not be available for up to two days following the initial report.

The use of JSEOD is under the Military Aid to Civil Authorities (MACA) framework, therefore the budget and personnel is limited, and there are no statutory obligations made of the MOD. Often the MOD will recommend involvement of a commercial UXO contractor to manage the ongoing risk – this is especially true of former airfields and training areas where contact with land service ammunition can be frequent.

1.4 UXO Risk in the UK

Fortunately, to the best of our knowledge, there has not been a single post-war incident in the UK where a construction worker has been killed or injured because of an item of UXO exploding. There have been cases in mainland Europe where UXO had been struck and then exploded, killing workers. In 2019, a WWII general purpose bomb spontaneously detonated in a field north of Frankfurt, Germany.

However, the incident in Frankfurt is not comparable to the UK, due to the way different countries manufactured ordnance. Bombs made in different countries have different associated hazards. British WWII bombs, for example, have a fuzing system which uses chemicals which makes them very unsafe. Please see **APPENDIX 1** for recent examples of UK UXO incidents.

Between 2013 and 2016 JSEOD responded to 7,500 callouts. These callouts range from falsely identified objects, inert objects, small items of UXO and large WWII German unexploded bombs (UXBs). Each year the construction industry inadvertently unearths UXO; often this goes unreported. UXO contamination comes from three main sources:

- **Enemy action:** during WWI and WWII the air forces of Germany, and to a lesser extent Italy, bombed targets throughout the UK. The German navy bombarded several coastal targets in eastern England during WWI and then in WWII German long-range artillery on the French coast bombarded parts of Kent.
- **Allied military activity:** during WWI and WWII several Allied nations used the UK as a staging area for military action in the European Theatre; predominantly the US and Canada.
- **UK military activity:** domestic British Army, Royal Air Force (RAF) and Royal Navy (RN) training activities during peacetime and conflict as well as anti-aircraft gun and rocket batteries during WWI and WWII.

1.5 UXO Detonations

A detonation is a violent chemical reaction which creates a huge volume of gas. This reaction appears to happen instantaneously – the velocity of the shockwave moving is up to 9,000m per second. This chemical reaction is started using a small amount of very sensitive explosives called primary explosives. These types of explosives are highly sensitive to shock, friction, heat, and spark. As the explosive charge undergoes high order decomposition (detonation), the brisance, or shattering effect, causes the casing to splinter, projecting razor-sharp shrapnel across long distances.

The blast wave effect and the shrapnel effect can cause significant damage. Calculating safety distances is a

complex process. As a rule of thumb, in open ground, a 250kg explosive charge (as would be found inside a typical 500kg bomb) would require an omnidirectional safety distance of at least 1.6km.

Bombs work by amplifying the explosive charge from the sensitive primary explosive through to the main charge or fill of the item. This process is called an explosive train, if any link in that chain is broken, the item will fail to function as intended. This can be due to mechanical, electrical, or manufacturing tolerances or faults. Amongst other reasons, detonation of UXO could occur under the following circumstances:

- **UXO body impact:** A substantial impact onto the main body of a UXO; borehole rigs, piling rigs, jack hammers and mechanical excavator buckets.
- **Fuse impact:** Environmental conditions during decades of burial can result in the primary explosives located in the fuse pocket to crystallise and become shock sensitive. It would then take a relatively small impact or friction impact to cause the fuse to function and detonate the UXO.
- **Re-starting a timer:** A small proportion of German WWII bombs used clockwork fuses. In 2002, an Army EOD Engineer reported that the clockwork fuse in a UXB re-started. Decades of burial causes substantial corrosion in WWII German UXBs and therefore an incident such as this is extremely rare.

2 ASSESSMENT METHODOLOGY

2.1 Introduction

This assessment has been produced in accordance with the relevant CIRIA guidelines; *Unexploded Ordnance (UXO) - A Guide for the Construction Industry C681* (published in 2009). CIRIA C681 is a publication which originated from round table best practice discussions from industry leaders.

2.2 Source, Pathway, Receptor, Consequence Risk Model

The Source, Pathway, Receptor, Consequence (SPRC) risk model can be applied to buried UXO as follows:

- **Sources:** UK and Allied UXO sources include military firing ranges, bases, storage depots, munitions factories, anti-aircraft batteries, amongst others. There are many wartime causes of UXO contamination. The source for enemy contamination is overwhelmingly from WWII German air raids.
- **Pathways:** the pathway describes how the UXO reaches receptors. Usually, UXO is buried and therefore pathways can be any activity which involve breaking ground. Examples include ground investigation works, site enabling works and excavations.
- **Receptors:** receptors are the people, assets and infrastructure that can be adversely affected by UXO exposure. This includes site personnel, plant, equipment, buildings, the general public, and the environment.
- **Consequence:** the consequences of an inadvertent UXO detonation are catastrophic. They include injury and loss or life, as well as damage to property. Fortunately, the likelihood of UXO detonating is low, even when it is uncovered during works. However, another consequence to consider is delays to works, which itself can be a risk.

2.3 Assessment Structure

In accordance with CIRIA C681 this assessment addresses the following considerations in the appropriate order:

- The likelihood that the site was contaminated with UXO.
- The type of UXO that could have contaminated the site, and their associated hazards.
- The likelihood that UXO remains on the site.
- Theoretical bomb penetration depths.
- The likelihood that UXO will be uncovered during the proposed works.
- Risk rating and risk mapping (as appropriate).
- Risk mitigation recommendations.

2.4 Information Sources

To complete this risk assessment, Brimstone has gathered information from a wide range of sources. Brimstone's research team has completed detailed historical research, including access of original archived records. The list below is a general list of information sources that are consulted during the research process. For Site-specific sources consulted for this risk assessment, please refer to **APPENDIX 5**.

- The National Archives,
- Local archive centres,
- Ministry of Defence,
- The Council for British Archaeology,
- Groundsure mapping services,
- Historical aerial photography (Historic England, Britain from Above, NCAP),
- Google open-source mapping,
- The British Geological Survey,
- Open sources; published book, articles, web resources,
- Site-specific information supplied by the Client,
- Brimstone's library and historical database, and
- Brimstone's former armed forces employees.

2.5 As Low as Reasonably Practicable Principle

The ALARP (as low as reasonably practicable) principle corresponds to the actions that should be taken to reduce risks. The term 'ALARP' is in the Health and Safety at Work Act 1974, which says that risks must be controlled in a reasonable way.

Infinite time, effort and money could be spent trying to eliminate risk entirely. HSE uses the example that spending £1m to prevent five employees bruising their knees is disproportionate, whereas spending the same amount to prevent an explosion which could kill 150 people is proportionate.

Using this principle, Brimstone aims to reduce client costs by recommending strategies that are proportionate to the assessed risks, if any elevated risk is found at all.

2.6 Risk Tolerances

The Brimstone risk assessment process divides UXO risk into two tolerances:

- **Tolerable:** Low Risk and Low-Moderate Risk ratings are tolerable. Where the risk cannot be completely discounted, it may be a useful strategy to opt for a low-cost measure, such as a UXO safety briefing from a qualified UXO engineer.
- **Intolerable:** Moderate, Moderate-High, and High-Risk ratings are intolerable. Proactive risk mitigation measures should be put in place. Various strategies are at Brimstone's disposal to meet your project-specific needs.

2.7 Mapping/Imagery Accuracy Disclaimer

The information presented in any drawings, maps, or images has been compiled from a variety of sources, where possible, and is provided for general reference only. While Brimstone makes every effort to ensure the accuracy and completeness of this information, it may contain errors or omissions and should not be relied upon as definitive. Brimstone disclaims any liability for the misuse or misinterpretation of the information and makes no warranties or representations, express or implied, regarding its accuracy, completeness, or suitability for any particular purpose. Please contact Brimstone for further information regarding a map or image and further information can be provided where possible.

2.8 Reliance and Limitations

This report has been prepared using published information and information provided by the Client. Brimstone is not liable for any information which has become available following the publication of this report. No third-party liability or duty of care is extended. Any third-party using information contained in this assessment do so at their own risk.

3 THE PROJECT

3.1 The Site

The Site is located in Ruislip, within the London Borough of Hillingdon, approximately 200m north-west of Ruislip Manor station. It predominantly comprises hardstanding, with a small garage structure present in the central extent.

The Site is bound on all sides by gardens associated with residential structures on Windmill Hill, Manor Way & Priory Close. The Site is also bound to the east by hardstanding and a further garage structure, and to the south by Manor Way itself.

Grid Reference: TQ 09929 87402 **What3Words:** areas.tools.slime

FIGURE 1: Site Location Maps

3.2 The Proposed Works

Brimstone was not made aware of any upcoming site investigation (SI) works occurring on Site at the time of writing.

Client provided information states development works will comprise the construction of a three-storey building for five flats with hardstanding for a road/parking and shared green space. Associated depths of intrusions were not provided, and it is assumed that piling may be required.

FIGURE 2: Existing Site Plan

4 SITE HISTORY

4.1 Site Introduction

Site-specific history can be assessed by reviewing historical mapping, historical aerial photography and by carrying out additional Site-specific research where appropriate. Below are descriptions of a selection of records relevant to the Site:

4.2 Mapping

The below table describes the composition of the Site, structural changes in pre- and post-WWII Ordnance Survey (OS) editions, and relevant points of interest. All maps were retrieved from National Library Scotland (NLS) online database and the Landmark Promap OS database.

Period	Map Date	Map Scale	Review
Pre-WWI	1864	1:10,560	The Site comprised entirely undeveloped ground, potentially utilised agriculturally. The Site was bound on all sides by further undeveloped agricultural ground.
	1894	1:2,500	No significant changes have occurred on Site or in the immediate surrounds.
	1912	1:2,500	No significant changes have occurred on Site or in the majority of the immediate surrounds. Manor Way has been constructed adjacent to the south of the Site.
Pre-WWII	1935	1:2,500	**FIGURE 3:** No significant changes have occurred on Site. Multiple residential structures and their associated garden / yard areas have been constructed to the east / west of the Site, as well as in the wider study area.
Post-WWII	1960-1962	1:2,500	**FIGURE 3:** A small-scale garage-like structure has been constructed within the central extent of the Site. The remainder of the Site has not undergone any significant changes. Further residential structures have been constructed immediately south / west of the Site. Note, no structures within the immediate surrounds have been subject to clearance, and no ruins are recorded.

4.3 Photography/Aerial Photography

The below table describes the composition of the Site visible in post-WWII aerial photography, including areas of possible structural clearance, damage and other possible features of note. All photographs were retrieved from Historic England's (HE) Royal Air Force (RAF) Photography Archive.

Period	Photo Date	Review
Pre-WWII	May 1934	**FIGURE 4.1:** This oblique image, taken approximately five years before the start of WWII, displays the entirety of the Site and its immediate surrounds. The Site corroborates pre-WWII OS mapping, as it consists of entirely undeveloped ground. Furthermore, multiple residential structures and their associated gardens are adjacent to the east / west of the Site, and Manor Way is visible immediately south.

Post-WWII	**29th April 1947**	**FIGURE 4.2:** This vertical view photograph, taken approximately two years after the end of WWII, displays the entirety of the Site and its immediate surrounds. Note, the majority of the Site is now occupied by hardstanding, it is possible albeit unconfirmed that this redevelopment occurred prior / during WWII. No immediately obvious evidence of bomb related damage on Site or in the immediate surrounds such as cratering / ground disturbances or structural clearance.

4.4 Additional Site-Specific History

Some sites will have been occupied by landmarks or significant buildings historically and in such cases specific written histories including significant wartime details are occasionally available in the public domain. No such information was available.

5 UXO RISK - GERMAN BOMBING

5.1 WWI Bombing History

5.1.1 Britain during WWI

During World War I (WWI), an estimated 9,000 German bombs were dropped on London, Eastern England and South-Eastern England during some 51 Zeppelin airship raids and 52 fixed-wing aircraft raids. London suffered the worst of the bombing with an estimated 250 tonnes of HE and incendiary bombs recorded across the Capital, over half of which fell on the City of London district.

The WWI bombing campaign waged by Germany was on a far smaller scale than the WWII campaign, in terms of the number of raids, the weight of ordnance dropped during each attack and the size of the bombs used. When coupled with the fact that most WWI-bombed locations have since been redeveloped, German WWI UXB finds are extremely rare. Furthermore, most air raids took place during daylight hours and as it was the first time Britain had experienced strategic aerial bombardment, the raids often attracted public interest and even spectators, increasing the chances of any UXBs being reported.

5.1.2 Site Specific

A collection of written reports describing each air raid in the region was reviewed.[1] No evidence that Ruislip was targeted by enemy bombing during WWI was uncovered.

5.2 WWII Bombing History

5.2.1 London

In the summer and autumn of 1940, the Luftwaffe targeted the RAF's airfields and support network with the intention of achieving air supremacy prior to a planned amphibious invasion of south-east England. The resulting Battle of Britain campaign (July to October) resulted in many air raids across England, although these were mainly concentred in the south-east. During this period, a few small-scale raids affected the outer London boroughs.

In early September 1940, the Luftwaffe changed their tactics and commenced an indiscriminate carpet-bombing campaign against London. The resulting nine-month Blitz began on 7th September 1940 and ended on 12th May 1941 - the heaviest raid of the Blitz. The vast majority of the Luftwaffe units based in occupied Europe were then redeployed to the Russian front.

During 1943, a number of small-scale fighter bomber raids were carried out against the Capital, then in 1944, the Luftwaffe commenced Operation Steinboch. This campaign comprised 31 major raids against London and

[1] ttps://www.iancastlezeppelin.co.uk/

other southern England targets, executed by inexperienced Luftwaffe crews, between January and May. However, poor navigation and improved defences resulted in unsustainable Luftwaffe losses, many formations being broken up by the RAF over the Home Counties. The final large-scale Luftwaffe raid on the Capital took place during May 1944, with all air raids ceased by the end of June.

Between 1940 and 1944, there were a total of 71 major air raids on Greater London resulting in some 190,000 bombs being dropped, killing over 29,000. In total some 50,000 tonnes of HE bombs and 110,000 tonnes of incendiary bombs (mainly of the 1kg type) were dropped during the Blitz over Britain. The army BDUs successfully dealt with approximately 40,000 UXBs during the war.

Immediately following the final air raids on London, the Luftwaffe launched the V Weapons campaign, commencing in June 1944. The V1 (Flying Bomb or Doodlebug) and later the V2 (Long Range Rocket) were launched from occupied Europe. 2,419 of the former and 517 of the latter were recorded in the London Civil Defence region.

Both carried a large 1,000kg HE warhead and were constructed of thin sheet steel, rather than the thick steel used on the Luftwaffe's free fall bombs. V Weapons were designed to detonate on the surface (like parachute mines), as opposed to free fall bombs which were designed to have some penetration ability through multi-storey buildings.

Consequently, any V Weapons which failed to detonate broke up on impact, resulting in an easily identifiable debris field. Although there is a negligible risk from unexploded V Weapons on land today, they caused widespread destruction throughout London and therefore, at V Weapon impact sites, the assessment of pre-1944 UXB risk can be hampered.

5.2.2 Site Specific

The Site is located approximately 22km north-west of the Luftwaffe's primary aiming point for indiscriminate air raids in the region, the City of London. Therefore, in terms of individual targets, their proximity is more relevant than in other parts of the country/city because the study area experienced fewer large-scale raids indiscriminate raids than the City.

Luftwaffe target records highlight the nearest target to the Site as RAF Blenheim Crescent, a training centre approximately 1.4km south-west of the Site. Railway infrastructure, approximately 175m south of the Site, may have been identified as a target of opportunity.

5.2.3 Bombing Decoy Sites

In mid-1940 bombing decoys were introduced. The decoys used either:

- A system of lighting to simulate an urban area or a military airfield's runway,
- Deliberately started fires to simulate a previously bombed target,
- Dummy buildings and vehicles to simulate a military facility.

792 static decoy sites were built at 593 locations in Britain. They were estimated to have drawn at least 5% of the total weight of bombs away from their intended targets. No decoys were operational within a significant radius of the Site during WWII. The closest was approximately 10.9km to the south-west.

5.3 WWII Bombing Records

5.3.1 Introduction

The bomb census recorded the location and type of bomb strikes to help with intelligence gathering and planning. It was compiled using information recorded by ARP wardens. These records were gathered by the Ministry of Home Security to calculate bombing density within administrative areas.

The bomb census was unreliable in the early stages of the war, though by 1941 procedures had been standardised. The quality of the census records also depended on where in the UK the records were produced. Some records are held at the National Archives and some are held at local borough archives.

Relevant records held at the National Archives; London Metropolitan Archives & Hillingdon Archive were obtained for this risk assessment.

5.3.2 Bombing Density Statistics

The table below records the Ministry of Home Security's bombing density calculation for the Urban District of Ruislip & Northwood. It gives a breakdown of the types of large German bombs reported and is understood to not include UXBs.

Admin Area	Ruislip & Northwood
Area Acreage	6,593
High Explosive Bombs (all types/weights)	228
High Explosive Parachute Mines	4
Flam (Oil) Bombs	20
40kg Phosphorus Incendiary Bombs (IBs)	1
40kg 'Fire Pot' IBs	0
V1 Flying Bomb	4
V2 Long Range Rocket	1
Total (excluding V-Weapons and 1kg / 2kg IBs)	253
Bombs Per 1,000 Acres	**38.4**

1kg / 2kg incendiary bombs and 2kg anti-personnel (AP) bombs were often too numerous to record accurately and therefore are not included in the above figures. The latter were not dropped on London. Small IBs were however dropped in vast numbers (>100,000) over the capital.

5.3.3 Bomb Census Maps

Brimstone has reviewed a collection of original consolidated and weekly bomb census maps for the wider study area. These small-scale maps cover the entire bombing campaign and record all types of bomb. Relevant maps are displayed at **FIGURE 5**.

- Approximately nine x 'iron' bombs and two unexploded oil bombs (UXOB) are plotted within a 300m radius of the Site. The closest of these, an UXOB, is located approximately 40m east of the Site. The weekly maps, presented at **FIGURE 5.2**, identify two bomb sticks within the same radius; neither of which intersect the Site, although one potentially straddles the south-eastern border of the Site.
- No day-time air raids affected the study area.
- No 1kg / 2kg IB showers are plotted within 300m of the Site. Note, no weekly plot maps are available for the 7th September to 7th October 1940 period and therefore it is not known whether IB showers affected the Site during this month.

5.3.4 Ruislip Bomb Map

Brimstone has reviewed an original bomb plot map for Ruislip held by Hillingdon Archives. This map appears to be comprehensive of the entire bombing campaign, covering raids from September 1940 to June 1944, and records HE bombs, IBs, V1 flying bombs and V2 long range rockets. A relevant section of this map is displayed at **FIGURE 6**.

- Nine HE bombs are recorded within an approximate 300m radius of the Site.
- No bombing incidents are recorded on Site; the closest HE is recorded approximately 120m north-east of the Site.
- No V1 / V2 bombs are recorded within an approximate 1km radius of the Site, the closest, a V1, was recorded approximately 1.4km south of the Site.

5.3.5 Middlesex County Council War Damage Map

Brimstone has reviewed an original war damage map covering the study area. The map was produced by the Engineer and Surveyors Department of the Middlesex County Council and was updated throughout the bombing campaign. The severity of damage is divided into three categories: Category 3 – indicates damage with uncertainty on whether repairs are possible, or demolition may be necessary. Category 2 – some repairs possible, could become Category 1, and Category 1 – total damage. Note, minor damage to structures was not recorded within this source. A section of the map covering the study area is displayed at **FIGURE 7.**

- No structures adjacent to the Site are recorded to have sustained a category of damage.
- The closest structure recorded as sustaining damage was situated approximately 150m north-west of the Site (Category 3 damage).
- As this source only records damage to structures and the Site itself comprised undeveloped ground, any potential significant damage occurring on Site would not be recorded in this source.

5.3.6 MCC Log Book of Air Raid Incidents

Brimstone has reviewed a collection of written records reporting locations of bomb strikes and resulting damage in the Urban District of Ruislip & Northwood. The entries recorded the date, time, location and type of ordnance utilised. Entries within an approximate 1km radius of the Site have been transcribed below. It should be noted, multiple entries did not provide a specific enough location to accurately determine the distance from the Site, and only provided street names. As such, these entries have been plotted at their closest possible point in relation to the Site although they may have occurred further away.

Date & time	Location *(relative to the Site)*	Type of bomb	Number of bombs
8th September 1940, 22:54	South Drive, Ruislip *(Approx. 490m west)*	UXB	1
24th September 1940, 13:40	Eastcote Road *(Approx. 355m north)*	HE	1
11th January 1941, 21:36	Lime Grove *(Approx. 845m east)*	HE	1

28th February 1941, 20:45	Corner of High Street & Midcroft *(Approx. 665m west)*	HE	1
	Eastcote Road & Ridgeway *(Approx. 460m north)*	HE	1
28th February 1941, 21:22	Croft Court in Brickwall Lane *(Approx. 385m south-west)*	HE	1
	King College Road *(Approx. 400m north)*	HE	1
	Windmill Way *(Approx. 200m west)*	HE	1
	Pembroke Road *(Approx. 150m south-west)*	HE	1
28th February 1941, 21:54	Croft Gardens & Manor Close *(Approx. 450m west)*	HE	1
1st March 1941	Eastcote Road *(Approx. 355m north)*	UXB	1
23rd February 1944	Brickwall Lane *(Approx. 300m south-west)*	UXAA	1

5.3.7 Ruislip & Northwood Air Raid Damage Report

Brimstone has reviewed an air raid damage report from Hillingdon Archive covering Ruislip. This report, covering raids from 1940-1945, includes information such as bomb strikes, dates, locations and damage. As per above, multiple entries did not provide a specific enough location to accurately determine the distance from the Site but have been included for indicative purposes. Entries within an approximate 1km radius of the Site have been transcribed below.

Date & time	Location *(relative to the Site)*	Type & No. of bomb	Comments
08/09/1940 22:54	118 Evelyn Avenue *(Approx. 570m north)*	UXHE x 1	n/a
28/02/1941 20:10	Brickwall Lane *(Approx. 300m south-west)*	HE x 15	Five people killed, four seriously injured & 27 homes destroyed or require demolition
	Glenalla Road *(Approx. 160m west)*		
	Pembroke Road *(Approx. 150m south-west)*		
	Manor Close *(Approx. 290m west)*		
	Eastcote Road *(Approx. 355m north)*		

5.3.8 Register of Unexploded Bombs and Shells

Brimstone has reviewed a collection of written records from Hillingdon Archives which identifies unexploded bombs and shells found within Hillingdon. No evidence has been found from this source to suggest any UXBs were found on Site or in the surrounding area.

5.3.9 V Weapons

Brimstone has reviewed a collection of original consolidated V1 Bomb Plot Maps, as well as a contemporary plot map of V2 Rocket incidents, produced using collections of original written incident reports.

No V1 or V2 strikes are plotted within or adjacent to the Site boundary. The closest V1 strike (29th / 30th June 1944) is plotted approximately 1.3km to the south and the closest V2 strike occurred 3.75km to the north-east.

Neither of these incidents occurred in close proximity to the Site. Furthermore, several blocks of buildings that survived the conflict intact will have shielded the Site from the 1,000kg HE blast. Therefore, these incidents are insignificant.

5.3.10 Abandoned Bomb Register

Due to the overstretched bomb disposal units during WWII, many bombs were intentionally left undisturbed. UXBs were triaged based on where they were and how big they were. If they didn't pose a significant risk, they were 'abandoned'. The locations of these bombs were recorded on the abandoned bomb register.

The abandoned bomb register is a public record document held at the Parliamentary Archives of the House of Commons, from which Brimstone has obtained a copy. The register should not be relied on for completeness or accuracy. The closest abandoned bomb is recorded approximately 7.3km south-west of the Site.

5.3.11 Secondary Source / Anecdotal Evidence

A search of online resources, as well as a review of local history publications was carried out with the intention of locating any eyewitness accounts of local bombing incidents. However, no such evidence was found.

5.4 Likelihood of UXB Contamination

Where detailed bombing records exist, it is possible to predict whether any UXBs could be found on a site. This likelihood is discussed in the following table:

Density of Bombing	
Number of Air Raids in the Vicinity:	A comparison of the bombing incident records confirms that at least three air raids affected the study area (approx. 300m).
Intensity of these Air Raids:	Bombs dropped locally may have been part of small or medium scale bombing raids, the majority of which are anticipated to have been carried out at night.
Bomb Strike Positions	
Closest Bomb Strikes	HE bombs: 120m north-east. 1kg / 2kg IBs: n/a
Alignment of recorded Bomb Strikes:	Three bomb sticks have been identified in the surrounding area; one of which potentially straddles the south-eastern border of the Site in a southernly / northernly trajectory, comprising two unexploded oil bombs. The remaining bomb sticks are located approximately 265m west / 285m north-west of the Site and therefore too far removed to be of concern. Therefore, there may have been at least one occasion during which a UXB (unobserved and unplotted) could have been released over and landed within the Site boundary.
Bomb Failure Rate	
Evidence to suggest that the generally accepted failure rate of 10% differs in the vicinity of the Site:	None.
UXBs recorded in close proximity to the Site:	Closest plotted UXB strike to the Site is approximately 40m east.

5.5 Likelihood of Subsequent UXB Detection

A range of circumstances determine whether a UXB strike location would have been identified, during and after the war. This is discussed in the following table. This includes level of access to the Site during WWII, bomb damage, as well as the ground cover during WWII. This is discussed in the following tables.

Historic Access
A UXB falling on a site which was frequently accessed would have had a better chance of being found. ARP Wardens actively searched for UXBs in heavily bombed residential areas. The importance of a site or nearby buildings and infrastructure was also a factor. Many industrial facilities had fire watchers tasked with extinguishing incendiary bombs and reporting UXBs.
As most air raids in the immediate vicinity occurred during the hours of darkness, there is a greater probability that any UXB strike to the Site could have occurred unobserved as residents/employees were inside. Furthermore, no evidence of fire watchers providing night-time observation in the vicinity was found. These factors decrease the likelihood that any UXB fall would have been witnessed and reported. Although the Site was anticipated to be hardstanding during WWII, it was likely utilised as an access way to the garages on Site that were likely associated with the surrounding residential structures. As such, the Site would likely have experienced intermittent access at best; although, this would have depended on the residents. It is conceivable therefore that any UXB dropped within these areas could have fallen unnoticed. It should be noted, the residential structures adjacent to the south, west & east of the Site, as well as Manor Way, likely provided a degree of monitor / observation, but to what extent cannot be confirmed. Furthermore, these structures were undamaged throughout the conflict, increasing the likelihood that would have provided a degree of access to the Site.

Bomb Damage
As the bombing campaign continued, damaged areas became vulnerable to unreported UXBs. Bomb site wreckage or soil disturbance at a bomb crater could obscure evidence of a subsequent UXB strike.
No immediately obvious evidence of bomb damage, such as cratering or ground disturbances are visible on Site within post-WWII aerial photography. Furthermore, all structures adjacent to the Site do not appear to evidence any signs of significant bomb damage i.e. tiling repairs / structural clearance. It is possible that they sustained general blast damage which is not visible in available photography.

Ground Cover Type
A UXB which falls on open field could easily go unnoticed, whereas a UXB dropped on a hard-surfaced car park would have been easily observed.
Due to the limitations of available aerial photography, it has not been possible to accurately determine the exact nature of the ground cover during WWII. However, had the hardstanding across the majority of the Site within post-WWII aerial photography been present during WWII, any such UXB strike to would have caused incontrovertible evidence of its incidence as it passed into the ground beneath. The same can be said for the majority of neighbouring structures and road to the south, where (assuming no cratering) a HE UXB entry hole would have been persistent and easily recognisable. Grassy areas may have present on Site during WWII (thought to be unlikely), and such ground cover may have presented conditions unconducive to the visual detection of UXBs i.e. overgrown and unmaintained vegetation. Visual evidence of a UXB strike, such as a small entry hole, could have become obscured within such conditions. Indeed, the smallest German HE bomb (50kg), also the most commonly deployed over Britian during WWII, was just 20cm in diameter; a UXB strike could therefore leave a small, easily obscured entry hole within such conditions.

6 WWII GERMAN BOMBS

6.1 Bombs Dropped on the UK

Nazi Germany used different types of ordnance against the UK for different effects. Some types were designed to cause fires, others for their destructive blast effect and other for their penetration capability. Each type of ordnance was fitted with at least one fuze. For some bombs multiple fuzes were used. Many different types of fuzes were available for use – each with its own set of associated hazards.

Data sheets on those bombs most likely to be encountered today are included at **APPENDIX 2**.

- **HE bombs – moderate NEQ (net explosive quantity):** the most common types of HE bombs dropped were the SC (general purpose - GP) and SD (semi-armour piercing - SAP) series of bombs. The NEQ is between 30-50%. SAP bombs are engineered to attack light fortifications, whereas GP bombs are used in a mixed destructive blast and anti-personnel fragmentation role. 70% of bombs dropped on the UK were the 50kg type.
- **HE bombs – high NEQ:** blast bombs and parachute mines have bodies made of thin steel, allowing for larger HE charges. These were designed to detonate above ground, maximising the blast effect. Parachute mines were weapons slowed by parachutes and designed to detonate without penetrating the ground. Although, in some marshland areas, partially buried parachute mines have been observed. Consequently, it is highly unlikely that any unexploded blast bombs remain buried in the UK today.
- **HE bombs – low NEQ:** The PC series were armour piercing bombs used against heavy fortifications and reinforced bunkers. They were not commonly used over the UK.
- **Small incendiary bombs:** The 1kg and 2kg incendiaries were the most dropped bomb. Up to 620 x 1kg incendiaries could be packed into the largest container unit, which opened at a pre-determined height scattering its payload over a wide area. These small bombs could fully penetrate soft ground due to their small diameter. Variants of the 1kg and 2kg incendiary bombs contained a small HE charge designed for an anti-personnel role, and to increase its incendiary effect.
- **Large incendiary bombs - Thick skinned:** The C50 has a thick body and contained a mixture of incendiary liquids and white phosphorus. Another version of the C50 had a white phosphorus fill. The C50 'firepot' contained thermite incendiary containers (aka firepots) and a small HE charge.
- **Large incendiary bombs - Thin skinned:** The Flam 250 and Flam 500 models had thin steel bodies designed to break up on impact, spreading their oil-incendiary mixture, which was ignited by a small HE charge. Consequently, it is highly unlikely that any unexploded Flam bombs remain buried in the UK today. Their unreliability meant withdrawal from frontline use by January 1941.
- **Submunitions:** The SD2 'butterfly' bomb was a 2kg submunition dropped on several British cities and towns. It contained a 225gram HE charge. SD2s had no ground penetration ability so the vast majority were recovered at the time. However, SD2s are still found across Britain today.
- **V1 flying bombs and V2 rockets:** In the final year of WWII Germany began using pilotless weapons against England. Both V Weapons had 1,000kg HE warheads. Due to their light-body construction, they had no penetration ability, and any impact left a noticeable debris field. As such, there is negligible risk from unexploded V Weapons today.

6.2 Bomb Failures

Records from September 1940 to July 1941 show that an average of 84 UXBs were dropped on civilian targets each day. Around 8% of these were time delay bombs – designed to strike the ground and start a predetermined countdown which could last days.

There is a generally accepted 10% failure rate for WWII German HE bombs. This is estimated from records gathered by bomb disposal units. These statistics do not account for UXBs that went by unnoticed.

Failures can happen for different reasons, including:

- Equipment or human error in arming the bombs before release,
- Failure of a mechanism within the fuze (out of tolerance),
- Jettisoning payloads if the bomber was under attack or crashing, or
- Partially functioned bombs (e.g. cracks in the cast TNT).

6.3 Bomb Ground Penetration

6.3.1 Introduction

Using data gathered during WWII by the Ministry of Home Security, estimations can be made about how deep a bomb is likely to penetrate the ground. Over one thousand incidents were reported by the bomb disposal units to support this research. Further tests were carried out, dropping bombs of different sizes into chalk and measuring the depths they reached. This research is held at the National Archives. The estimates are:

Bomb weight (kg)	Ground Type (m)									
	Sand		Gravel		Chalk		Clay		Sandstone	
	Average	Max.	Average	Max.	Average	Max.	Average	Max.	Average	Max.
50	2.8	7.8	2.8	7.8	3.5	7.7	4.0	9.1	2.7	6.0
250	4.8	13.7	4.8	13.7	6.0	13.1	6.8	15.8	4.6	10.4
500	6.0	17.3	6.0	17.3	7.6	16.4	8.7	19.8	5.8	13.1
1,000	7.6	21.9	7.6	21.9	9.6	20.7	10.9	24.9	7.3	16.5

Different layers of geology affect penetration depths. For example, 1m of made ground, then 1m of gravel before reaching clay – as is many areas of London – is not easily calculated from the data above.

When calculating how deep a bomb could have reached, we must make three assumptions:

- **Impact velocity:** German bombing raids were carried out at altitudes in excess of 5,000m. The velocity of impact is roughly 313ms^{-1} (not accounting for resistance). It is the same velocity regardless of mass.
- **Impact angle:** strike angles of 10 to 15 degrees to the vertical. It must be assumed that the bomb was stable at the moment of ground penetration.
- **Bomb design:** Some larger German bombs were occasionally fitted with 'kopfrings' - a metal ring, triangular in cross section, fitted around the nose of the bomb to help prevent penetration. It must be assumed that no 'kopfrings' were fitted.

6.3.2 The J-Curve Effect

During WWII, Bomb Disposal Units (BDUs) reported that most buried UXBs were found horizontal or upturned. This observation confirmed the 'J-curve effect'. As an HE bomb penetrates the ground, slightly offset from the vertical, its passage underground creates a 'J' shape.

This is relevant because the J-curve effect results in a horizontal offset between the buried UXB and its point of entry. This distance is estimated to be one third of the theoretical penetration depth. A low altitude attack, meaning a low impact angle, could produce an even greater offset, of up to 15m.

6.3.3 Site Specific Geology

BGS Mapping	**Superficial Deposits:** No information available.	**Bedrock Deposits:** Lambeth Group-Clay, silt and sand.
SI Data	No recent SI data was provided by the Client. However, local BGS borehole logs were available. The closest BGS SI through the same mapped geology as the Site is located approximately 2.2km east of the Site (BGS ID: 581688). This SI (April 1981) encountered the following ground conditions: - 0.2m of concrete - 0.7m of clay, and firm brown sand - 1.5m of silty & sandy clay - 2.5m of firm to stiff clay - 4.0m of fissured firm to stiff clay - 5.0m of slightly silty clay	

6.3.4 Site Specific Maximum Bomb Penetration Depth

During WWII, the Luftwaffe dropped many different types of HE bomb. The SC (general purpose) series was by far the most numerous and of this series, the SC 500 model (weighing 500kg) was the largest of the most commonly deployed and therefore this will be used as the benchmark weapon for the Site-specific bomb penetration depth calculations.

In order to calculate the most likely maximum depth to which a bomb would penetrate, Brimstone has taken the average of the average and maximum figures for the predominant Site-specific geology (clay) in the table above. This gives a likely maximum bomb penetration depth of 14.25m below WWII ground level for a 500kg bomb. However, it should be noted that the consulted borehole was a significant distance removed from the Site. Therefore, the provided calculation cannot be considered Site-specific and has been provided for indicative purposes only.

Note, the Ministry of Home Security data indicates that the maximum bomb penetration depth could be down to 19.8m for a 500kg bomb, or 24.9m for a 1,000kg bomb; however, in line with the ALARP principle, it is not considered to be a likely scenario that a bomb would penetrate so deeply. Furthermore, while evidence indicates that a 1800kg HE bomb could penetrate to over 30m, these types of bombs were not dropped frequently. For example, War Office statistics confirm that between October 1940 and May 1941 the majority of HE UXBs (>90%) were either 50kg or 250kg, with the 500kg bombs making up most of the remaining 10%.

7 UXO RISK - BRITISH/ALLIED ACTIVITY

7.1 Introduction

The table below lists potential sources of UXO (excluding enemy action). Those which are potentially relevant to the Site are discussed in the subsequent section(s).

Potential UXO Source	Potentially Significant
Army or RAF training areas / ranges	×
Military bases and other installations	×
Munitions and explosives factories	×
Military storage depots	×
Defensive fortifications	×
Wartime site requisitions	×
WWII defensive mining (landmines)	×
WWII Home Guard activity	×
Wartime anti-aircraft fire	✓

7.2 Potential Sources of UXO

7.2.1 Introduction

Research has not located any evidence of significant British or Allied army, RAF or Royal Navy activity specifically on Site and none is likely to have occurred historically. The only likely potential source of British UXO contamination is therefore WWII AA artillery fire.

7.2.2 WWII Anti-Aircraft Fire

Anti-Aircraft (AA) Command was a British Army command established in 1939 to defend the UK during the anticipated German bombing campaign. It controlled the Territorial Army AA artillery and searchlight units. From 1940 to 1945 BDUs dealt with 7,000 unexploded AA shells in Britain. There were three main types of AA battery used for home defence (see below). Data sheets on these AA defences are included at **APPENDIX 3**.

- **Heavy Anti-Aircraft (HAA):** large-calibre guns (3.7" and 4.5") for engaging high-altitude bomber formations. Hundreds of permanent batteries were constructed in and around major cities and military bases during the 1930s. Some 2,000 of these guns were available during the Blitz. Each gun could fire between 10 and 20 rounds per minute and consequently HAA batteries could expend large quantities of shells during each engagement.

  British time fuses were poorly manufactured during WWII, and this led to high failure rate for HAA shells, up to 30%. Unexploded HAA shells had the potential to land up to 27km from their battery, although more typically landed within a 15km radius.

- **Light Anti-Aircraft (LAA):** smaller calibre guns for engaging dive bombers and low altitude intruders. As such, they were mostly used to defend specific industrial and military targets which were subject to precision bomber attack. LAA guns were either .303" calibre machine guns or 20mm and 40mm calibre cannon. The latter were fitted with simply impact fuses and small incendiary or HE bursting charges.

  The 40mm Bofors gun could fire 120 x HE shells / minute to a ceiling of 1,800m. Each shell was designed

to self-destruct if it didn't strike an aircraft, however, inevitably some failed and fell back to earth.

- **Z (Rocket) Batteries**: a Z-Battery comprised a grid formation of 64 rocket projectors which fired 2" and later 3" Unrotated Projectile (UP) rockets to a maximum altitude of 5,800m; a ground range of some 9,000m. They were deployed in cities all around the UK from 1941 and proved to be an effective addition to the existing AA guns.

  The rockets measured 0.9m (2") and 1.8m (3") in length with four stabilising fins at the base and were fitted with 3.5kg or 8.2kg HE warheads. The larger warhead had an effective airborne blast radius of up to 20m. Some variants deployed a form of aerial mine described as a "small yellow bomb" which was designed to detach from the rocket at height and descend on a parachute with the objective of becoming snagged on target aircraft and then detonating.

Unlike bombs which were designed to strike the ground, AA projectiles and rockets were designed to function in the air. Due to their shape, and centre of gravity they would often not strike the ground nose first. This coupled with the lower mass of AA UXO resulted in shallower ground penetration depths, compared to UXBs. Although, in very soft conditions, unexploded AA projectiles have been found deeper than 1.5m bgl.

14 permanent HAA batteries were active within range of the Site during WWII. LAA guns may have defended vulnerable points within the borough. Luftwaffe activity was somewhat frequent and intense over the wider area and therefore these guns may have expended a notable quantity of ammunition. Consequently, there is an elevated likelihood of unexploded AA shells striking the Site. However, any such UXO is unlikely to have penetrated the ground on Site unseen.

8 UXO RISK MITIGATING CIRCUMSTANCES

8.1 Introduction

Works on a UXO contaminated site could result in the partial or complete removal of UXO risk. Construction or earthworks may have uncovered any UXO contamination, which would then have been reported and removed by the authorities. A site may have been subject to an explosive ordnance clearance (EOC) task conducted by the armed forces. EOC tasks involve surveying, subsequent target investigation and removal of UXO. Although the effectiveness of historic EOC tasks will have often been unsatisfactory.

8.2 Explosive Ordnance Clearance Tasks

The division of EOC tasks has been complex throughout British military history. It used to be the case that anything under the water level would be dealt with by navy units, and anything on land would be dealt with by army units. In recent years, RAF Explosive Ordnance Disposal (EOD) capability has been discontinued, and now only the Royal Navy and the British Army have EOD units. In the army, the Royal Logistics Corps and Royal Engineer EOD units have been amalgamated to form 29 EOD & Search Group. Often taskings are assigned to either the naval or army elements based on where in the country the threat is and the nature of the threat.

Brimstone has access to a database of historic EOC tasks. This database is only complete up until the early 2000s and therefore does not include recent EOC tasks. No such database for the RAF and Royal Navy EOD units is easily accessible. A search of this database has not resulted in any Army EOC tasks in the vicinity of the Site.

UXO encounters on civilian land are often reported in the media and therefore a web search of local media outlets was also carried out. One such incident occurred on 5th February 2014, in which an unspecified German WWII bomb was discovered at Ruislip Lido, approximately 1.8km north-west of the Site. The device was later safely detonated in a controlled explosion.[2] However, this incident is considered too far removed to be of concern regarding potential UXO contamination on Site.

[2] https://www.mylondon.news/news/local-news/video-explosion-site-ww2-bomb-6675189

8.3 Ground Works

The Site has not been subject to any significant post-conflict ground works, with a garage structure being constructed in the central extent of the Site, indicated by post-WWII OS mapping. General maintenance of the hardstanding & construction of the garage will have disturbed WWII-era soil to very shallow (<1m bgl) depths. No shallow (1-2m bgl) or deep (>2m bgl) excavations into WWII-era soil are anticipated to have occurred in the post-WWII period.

8.4 Deductions

The risk associated with (any) very shallow buried UXO has likely been partially mitigated across the entire Site. The risk associated with (any) shallow or deep buried UXO almost certainly remains unmitigated across the Site.

Please note, the risk of a UXO encounter can be considered mitigated in the exact locations and down to the exact depths of any post-WWII intrusive works.

9 CONCLUSION

9.1 Accuracy of Historical Records

Occasionally, the accuracy of some historical records can prove to be poor when compared with other sources of information. One significant consequence of this can be the possibility of unrecorded German bomb strikes in the study area. No such inconsistencies were noted within the records consulted for this report.

9.2 The Risk of UXO Contamination on Site

9.2.1 Key Findings – German UXO Risk

- During WWII the Site was situated within the Urban District of Ruislip and Northwood, which sustained 38.4 bombs / 1,000 acres, a moderate bombing density, according to official Home Office statistics. Luftwaffe target photography identifies RAF Blenheim Crescent, a training centre approximately 1.4km south-west of the Site, as the closest primary bombing target in the region.
- Indeed, bomb census mapping records seven high explosive bombs and two unexploded oil bombs within an approximate 300m radius of the Site. No bomb strikes are recorded directly on Site, with the closest incident, an unexploded Oil Bomb (UXOB) plotted approximately 40m east of the Site. Three bomb sticks are recorded in the wider area, one of which, containing the two UXOBs, potentially straddles the south-eastern extent of the Site as it is aligned in a north-east / south-west direction. A local bomb map for Ruislip also records nine HE bombing incidents within the abovementioned radius, none of which are on / adjacent to the Site. This lack of bombing on Site or its immediate surrounds is also corroborated by available written records as the closest incident, an HE, is located approximately 150m south-west of the Site.
- A comparison between pre- & post-WWII OS mapping, as well as post-WWII aerial photography has not evidenced any immediately obvious bomb related damage, such as cratering or structural damage, on Site or within its immediate surrounds. It should be noted, the ground cover within the majority of the immediate surrounds, and partially within northern extent of the Site, may have presented visually unconducive conditions to such evidence, and as such evidence of a UXB strike in these locations may have gone unnoticed..

- Given the majority of the Site comprised hardstanding utilised as an access way for garages associated with the neighbouring residential structures, access levels to the Site are anticipated to have been intermittent. Furthermore, the adjacent structures did not sustain any damage throughout the conflict, therefore potentially providing an elevated level of access on Site, although to what extent cannot be confirmed. This somewhat increases the likelihood that evidence of an unexploded bomb strike would have been observed and dealt with at the time, although this would have depended on the individual landowner(s).
- However, any UXB strike to the hardstanding / garage structure on Site, as well as residential structures in the wider surrounds, would have caused incontrovertible evidence of its incidence as it passed the structures / hardstanding into the ground beneath. Contrastingly, a majority of the immediate surrounds to the north-east and north-west comprised open ground garden areas, within which a UXB strike could easily have gone unnoticed, leaving a small, easily obscured entry hole and coming to rest beneath the Site area via the J-curve (lateral offset) effect (See ***Section 6.3.2***).
- In conclusion, no bombing incidents or identifiable bomb related damage is recorded directly on / adjacent to the Site within available records / photography. However, one bomb stick flightpath, containing two unexploded oil bombs, potentially straddled the south-eastern extent of the Site, and the flightpath also intersected visually unconducive gardens adjacent to the Site. It is feasible, that an additional bomb (potential UXB) within this stick may have landed unnoticed and unrecorded within the open ground adjacent to the Site and potentially come to rest underneath the Site via the J-curve effect. Whilst this remains a possibility, no such evidence has been identified to suggest this occurred. As such, a **Low-Moderate** risk of encountering German UXBs has been assessed across the Site. A UXO safety Awareness Briefing is recommended prior to works commencing.

9.2.2 Key Findings - British UXO Risk

- No evidence of historic military activity within the Site boundary has been identified and it is highly unlikely any has occurred historically. Consequently, the risk from associated UXO is **Low**.
- 14 permanent HAA batteries were active within a range of the Site during WWII. LAA guns may have defended vulnerable points within the borough also. Luftwaffe activity was somewhat frequent and intense over the wider area and therefore these guns may have expended a notable quantity of ammunition. Consequently, it is possible that an unexploded AA shell may have struck the Site; although, no evidence of such an occurrence has been identified. Therefore, the risk is considered analogous to that of German UXBs, and a **Low-Moderate Risk** has been assessed across the Site.

9.3 Site-Specific UXO Hazards

Different types of UXO pose differing types of hazard, depending on their structural design, Net Explosive Quantity (NEQ), fill type and likely contamination depth. The table below lists the main types of UXO most often encountered on urban UK sites and their relative hazard levels.

UXO Type	NEQ (NEQ Range)	Likely Burial Depth	Hazard Posed
WWII German General Purpose HE Bombs	25kg - 220kg (most commonly deployed bomb weights)	Deep burial (>2m)	**HIGH**
WWII British Heavy Anti-Aircraft Shells (HAA Shells)	1.1kg - 1.7kg	Shallow burial (1-2m)	**MODERATE-HIGH**
WWII British Land Service Ammunition (LSA)	<2kg	Shallow burial (1-2m)	

WWII German 2kg Incendiary / HE Bombs (IBs)	680g incendiary hazard + ~500g explosive hazard	Shallow burial (1-2m)	
WWII German 1kg IBs	680g (incendiary, not explosive hazard)	Shallow burial (1-2m)	**MODERATE**
WWII British Light Anti-Aircraft Shells (LAA Shells)	4g - 70g	Very shallow burial (<1m)	**LOW-MODERATE**
Small Arms Ammunition (SAA)	<1g	Very shallow burial (<1m)	**LOW**
Inert/Practice Item	0g	Very shallow burial (<1m)	

9.4 The Likelihood of UXO Encounter

9.4.1 Introduction

This report assesses the risk of UXO in relation to the proposed works, not simply the risk that UXO remains buried on Site. The likelihood of UXO encounter during intrusive ground works will vary depending on the type of UXO and the type of construction methods employed during the project. With increased soil disturbance i.e. more excavations, the likelihood of encountering UXO increases.

Within an area of elevated UXO contamination likelihood, the sub-surface volume of potential UXO contamination will comprise the natural soil / geology in between WWII ground level and the maximum bomb penetration depth. Therefore, any intrusions into this layer will be at risk of UXO encounter.

Any post-WWII fill material deposited on a site is unlikely to be contaminated with UXO and therefore the risk of encountering UXO on such a site could vary with depth.

In the wake of the initial nine-month Blitz, many cities and towns were left with vast quantities of bomb site rubble that required removal and relocation. This material was put to use for in a variety of ways, for example >750,000 tons of London's rubble was used to build runways for new RAF and USAAF airfields and much of Liverpool's rubble was used to create and maintain sea / flood defences throughout Merseyside.

It is quite possible that unexploded British AA projectiles and German 1kg incendiaries were overlooked during removal, resulting in UXO contaminated fill material ending up on otherwise low UXO risk sites, possibly many miles from any high bombing density areas.

9.4.2 German UXBs

Although most German UXBs came to rest several metres below WWII ground level, these weapons can be found at any level between just below WWII ground level and the maximum bomb penetration depth. There are a number of reasons why these heavy bombs might be found at surprisingly shallow depths.

- **Tip and run:** When enemy aircraft had to take evasive action to escape RAF fighter intercepts or AA defences, they often dropped their bomb loads from a reduced height, potentially resulting in extreme J-curve effect.
- **Deflection:** the shape of German bomb nose sections meant they were susceptible to deflection when striking surface or shallow sub-surface obstacles, occasionally resulting in shallow burial or even UXBs skidding across hardstanding.
- **Aircraft Crash Site:** if an aircraft was unable to dump its bomb load before impacting the ground, due to mechanical fault, any externally fitted bombs could have become buried on impact.

German 1kg / 2kg incendiaries were cylindrical and approximately 50mm in diameter. They had tail sections, and so landed nose first. Within soft ground this could result in full penetration of the bomb below the surface. Such UXBs are usually found close to the surface.

9.4.3 British / Allied UXO

The nature of British/Allied military activity involving LSA and SAA and the smaller size of these munitions (in relation to German HE bombs) indicates that any resulting UXO contamination on a site will be limited to shallow depths, usually within 1.5m of the surface, notwithstanding added material to raise the ground level.

Domestic military LSA and SAA contamination will either be the result of expending blinds (dud ammunition) which bury into the ground on impact or munitions purposefully buried, for a number of reasons. Either way, these types of UXO are all found at shallow depth.

9.4.4 Deductions

A slightly elevated likelihood of UXO contamination (German) and likelihood of that UXO remaining up to the present day has been identified across the entire Site. While proposed works are therefore considered to be exposed to a UXO encounter, the risk of such an encounter occurring is not significantly elevated, and no proactive risk mitigation measures are considered necessary.

10 OVERALL RISK RATING

Ratings for the likelihood of UXO contaminating the Site, remaining within the Site up to the present day and being encountered during the proposed works, inform the overall risk rating. Please refer to the UXO hazard table presented in ***Section 9.3*** for a breakdown of the most common hazards and their associated risk. The colour of each respective type of hazard indicates the associated risk, as defined within the aforementioned table. The UXO risk to the proposed works has been assessed as **Low-Moderate.**

Risk Table					
Risk Zone	**UXO Type (Hazard)**	**Likelihood of UXO Contamination**	**Likelihood of UXO Remaining**	**Likelihood of UXO Encounter**	**Overall Risk Rating**
Low-Moderate Risk	**WWII German GP HE Bombs**	Low-Moderate	Moderate-High	Moderate	**LOW-MODERATE**
	HAA Shells	Low-Moderate	Moderate	Moderate-High	
	LSA	Low	n/a		
	German 2kg IBs	Low	n/a		**LOW**
	German 1kg IBs	Low	n/a		
	LAA Shells	Low	n/a		
	SAA	Low	n/a		

11 RISK MITIGATION RECOMMENDATIONS

Brimstone has not identified an elevated UXO risk to the proposed works. The measures detailed below are recommended to mitigate the risk to ALARP level.

Risk Mitigation Measure	Recommendation
UXO Safety Awareness Briefings: To all personnel conducting intrusive works on Site. An essential part of the Health & Safety Plan for a site. Conforms to the requirements of CDM2015.	Prior to all intrusive works commencing.

FIGURES: 1 - 7

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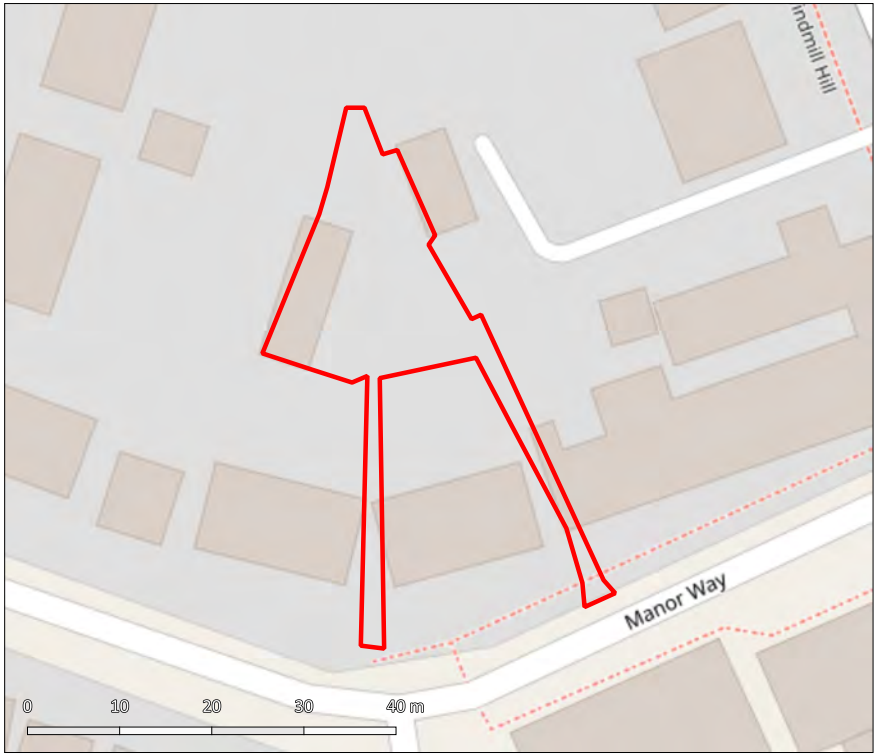

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DRA-26-1994

Project: 83-89 Manor Way, Ruislip

Client: JNP Group

Source: OpenStreetMap, Google Earth

Legend:

- Site boundary
- Site location

Notes:

Site Location

FIGURE: 1

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Location Plan

Scale 1:1250

ng Site Layout

Scale 1:500

Proposed Site Layout

Scale 1:500

BRIMSTONE

DRA-26-1994

Project: 83-89 Manor Way, Ruislip

Client: JNP Group

Source: JNP Group

Legend:

Site boundary

Notes:

Exisiting Site Plan

FIGURE: 2

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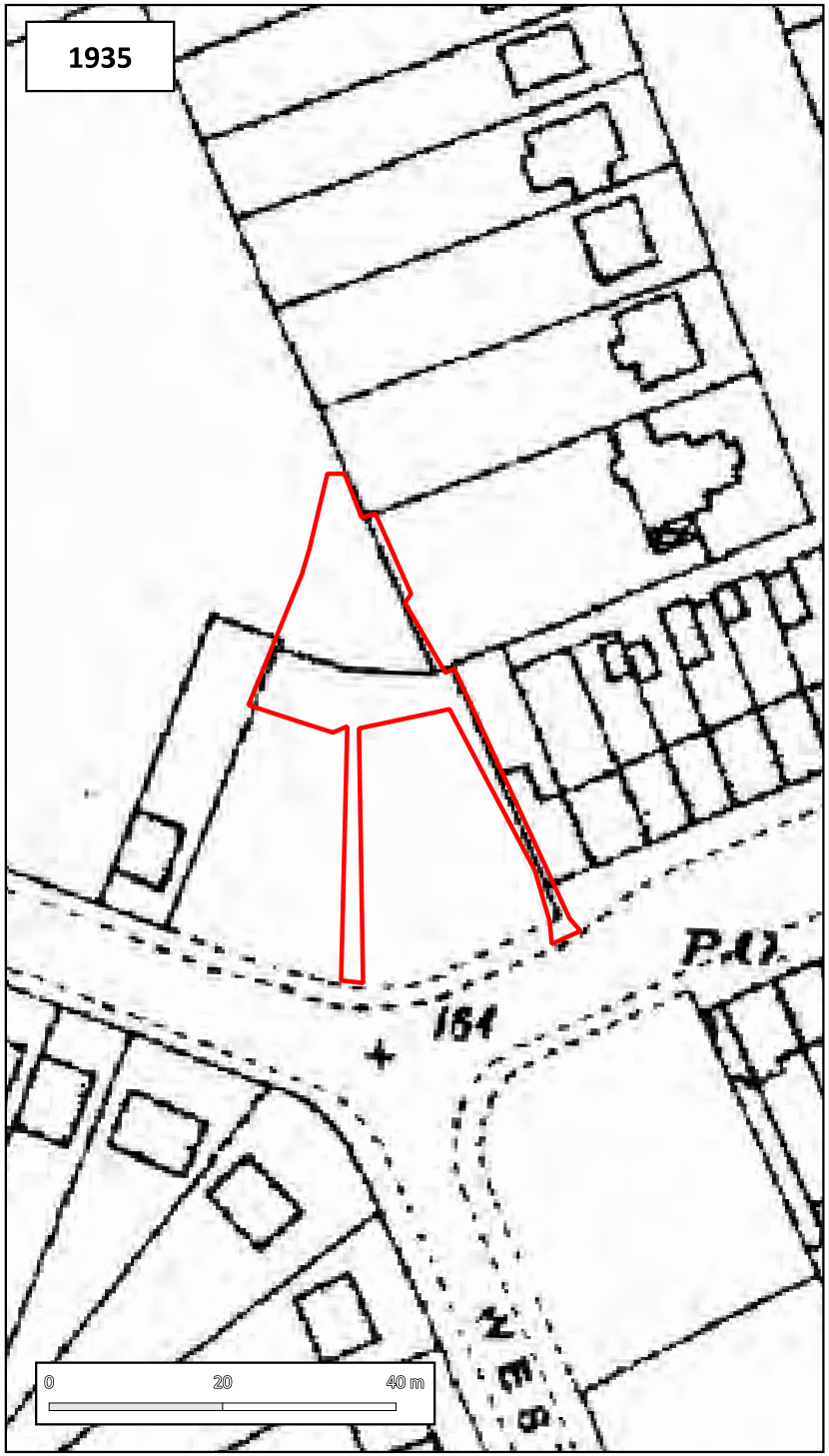

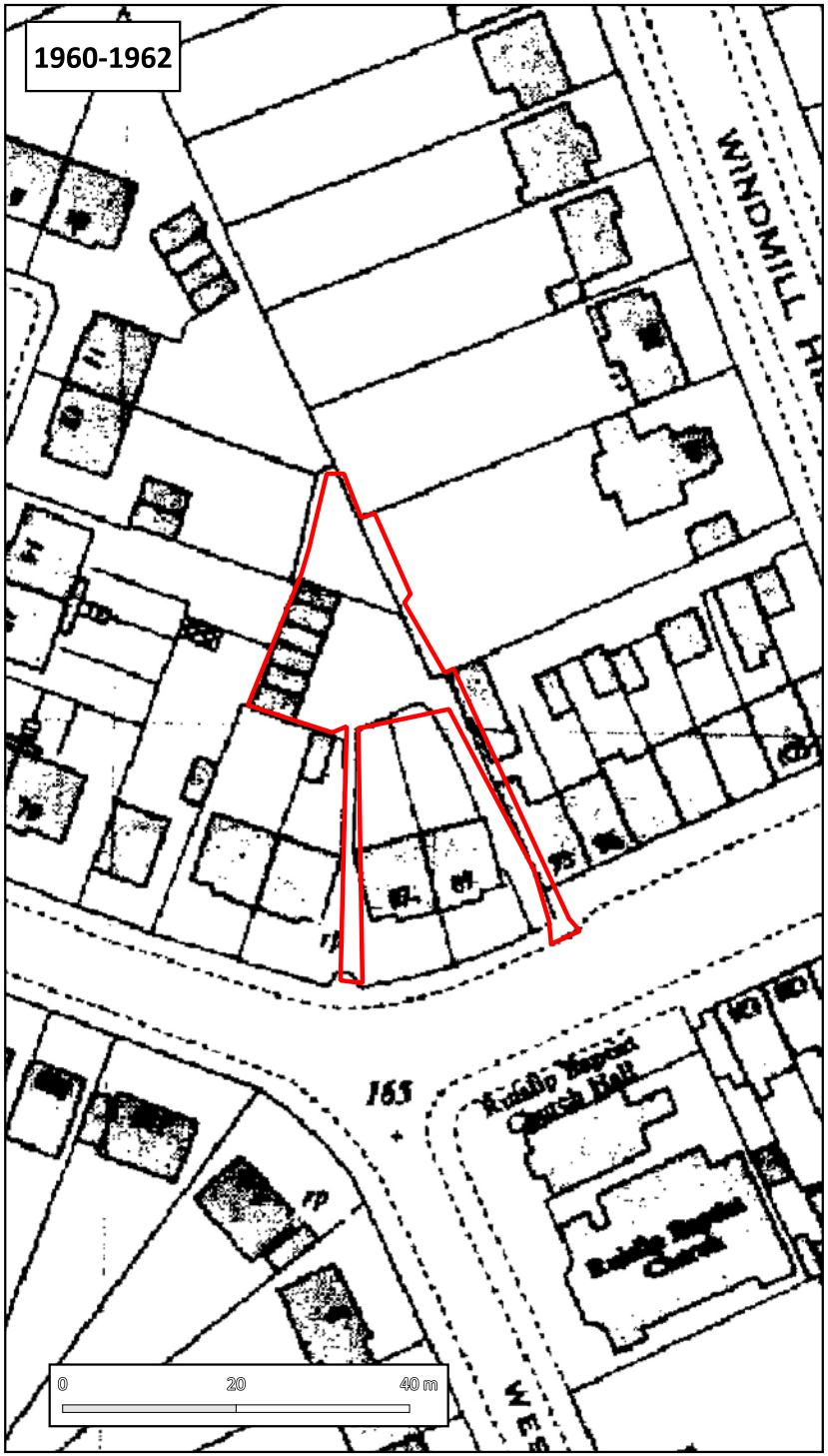

BRIMSTONE

DRA-26-1994

Project: 83-89 Manor Way, Ruislip

Client: JNP Group

Source: ProMaps

Legend:

Site boundary

Notes:

Historical OS Mapping

FIGURE: 3

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Project: 83-89 Manor Way, Ruislip

Client: JNP Group

Source: Britain From Above

Legend:

Site boundary

Notes:

Photography date: May 1934

Historical Aerial Photography

FIGURE: 4.1

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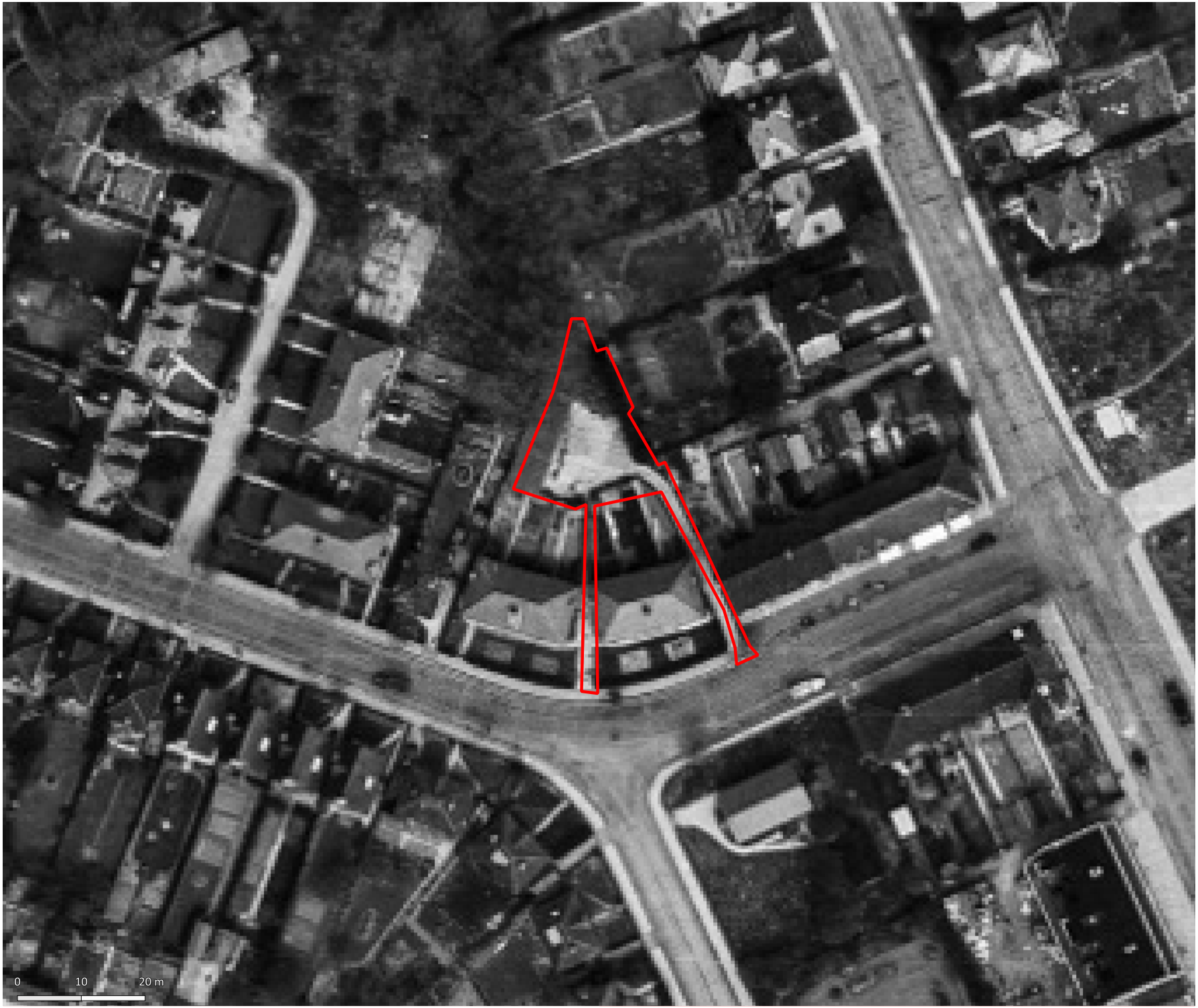

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DRA-26-1994

Project: 83-89 Manor Way, Ruislip

Client: JNP Group

Source: Historic England

Legend:

Site boundary

Notes:

Photography date: 29th April 1947

Historical Aerial Photography

FIGURE: 4.2

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Project: 83-89 Manor Way, Ruislip

Client: JNP Group

Source: The National Archives

Legend:

- Site boundary
- HE Bomb Strike

Notes:

Consolidated London Bomb Census Mapping

FIGURE: 5.1

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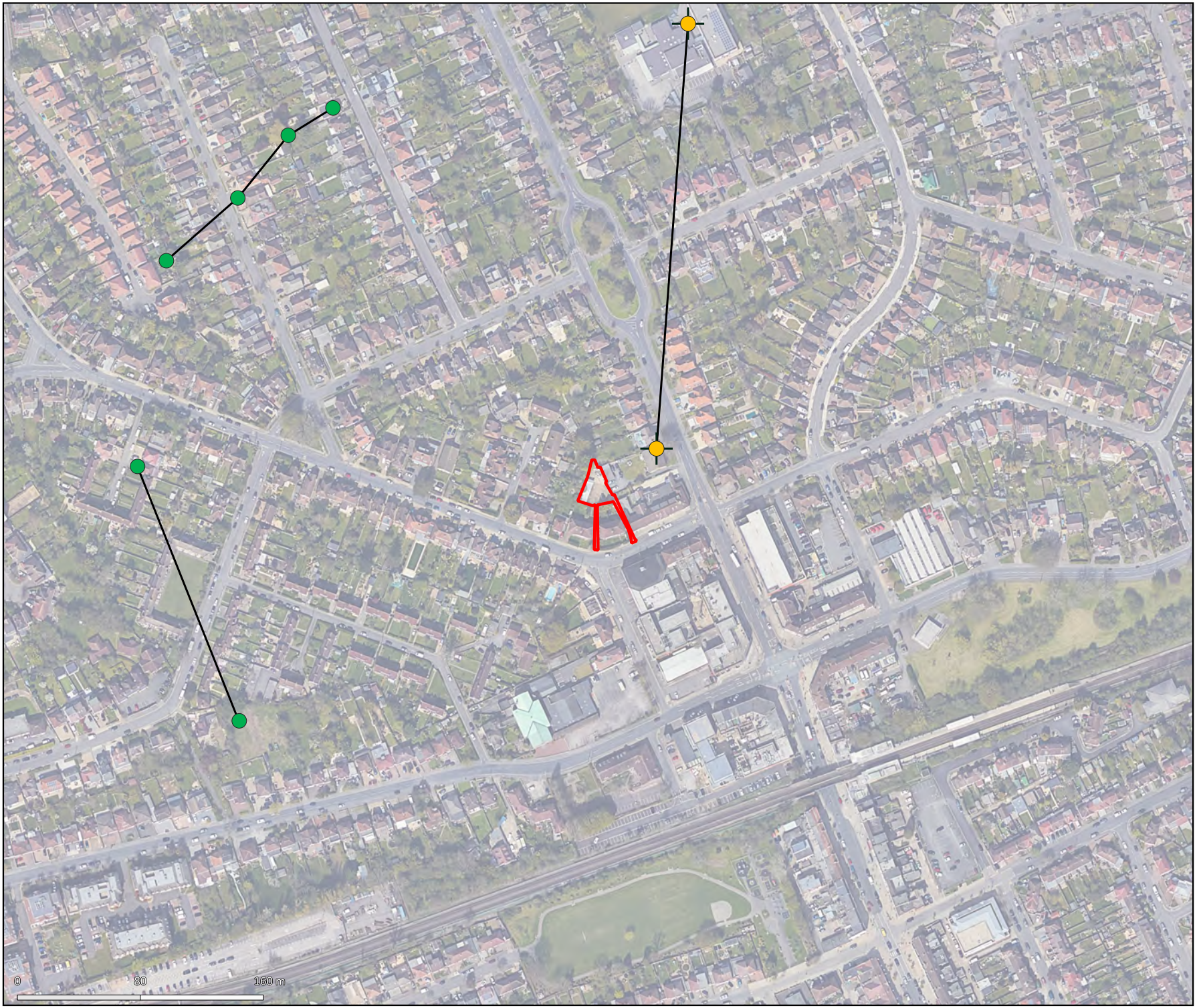

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Project: 83-89 Manor Way, Ruislip

Client: JNP Group

Source: The National Archives

Legend:

- Site boundary
- HE bomb
- UX Oil Bomb
- Bomb-stick

Notes:

The dates of the following bomb sticks are as follows -
Oil bomb stick: 18th - 25th November 1940
HE bomb stick: 24th February - 3rd March 1941

Weekly Bomb Census Mapping Overlay

FIGURE: 5.2

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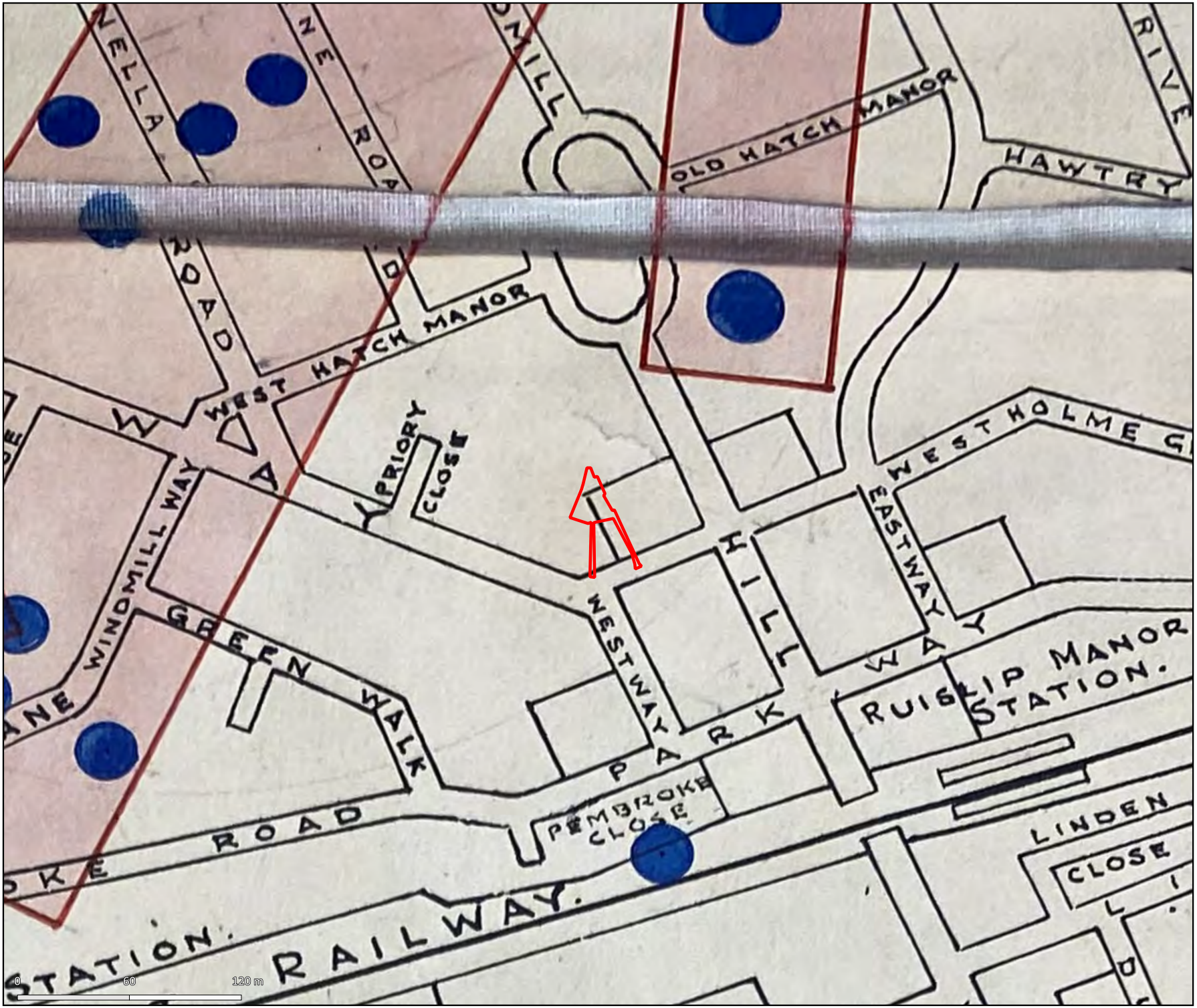

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Project: 83-89 Manor Way, Ruislip

Client: JNP Group

Source: Hillingdon Archive

Legend:

- Site boundary
- Weekly raid
- HE Bomb Strike

Notes:

Weekly raid dates:

Right - 21st November 1940

Left - 28th February 1941

Ruislip Bomb Map

FIGURE: 6

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Project: 83-89 Manor Way, Ruislip

Client: JNP Group

Source: The National Archives

Legend:

- Site boundary
- Category 1
- Category 2
- Category 3

Notes:

Middlesex County Council Damage Mapping

FIGURE: 7

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APPENDICES: 1 - 5

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Recent German UXB Finds in the UK + Historical Analysis

The Ministry of Defence (MOD) says that bomb disposal teams around the UK deal with approximately 60 German WWII-era UXBs per year.

- ***20th February 2024*** – An SC500 (standard 500kg HE bomb) was found during shallow excavations in a residential garden in Keyham, Plymouth. *Historical Analysis: The UXB landed in a small residential back garden belonging to an undamaged terraced house. It came to rest at approximately 1 to 2m bgl.*
- ***10th February 2023 –*** An SC250 (standard 250kg HE bomb) was dredged out of the River Yare in Great Yarmouth. The UXB detonated unexpectedly in situ during an attempt to disarm it. *Historical Analysis: The UXB landed in the River Yare; the precise location of its initial impact is unknown. UXBs in water are often affected by migration, whereby the item can travel along the riverbed.*
- ***26th February 2021 –*** An SC1000 (standard 1,000kg HE bomb) was discovered during shallow excavations in Exeter, adjacent to the University of Exeter. The item was detonated in situ and caused structural damage to nearby properties, leaving some inhabitable. *Historical Analysis: The UXB landed in undeveloped land of no obvious significance. It came to rest at approximately 2 to 3m bgl with its nose facing upwards, highlighting the potential of J-curve occurring.*
- ***23rd May 2019*** - An SC250 (standard 250kg HE bomb) was found during shallow excavations at a building site in Kingston upon Thames, London. *Historical Analysis: The UXB landed in a small residential back garden belonging to an undamaged terraced house. It came to rest approximately 3 to 4m bgl.*
- ***11th February 2018*** – An SC500 (standard 500kg bomb) was discovered in George V Dock in London during planned work at London City Airport. *Historical Analysis*: *George V Dock was identified as a primary target by the Luftwaffe during WWII and was bombed on multiple occasions.*
- ***15th May 2017 -*** An SC250 (standard 250kg HE bomb) was found during shallow excavations at a building site in Aston, Birmingham. *Historical Analysis: The UXB landed in a small back garden belonging to a terraced house, part of a row. It J-Curved under a neighbouring garden and came to rest at just 1.4m bgl. NB: These houses had not sustained bomb damage.*
- ***2nd March 2017 -*** A 250kg HE bomb was found during deep excavations at a building site in Brondesbury Park, London. *Historical Analysis: UXB landed in a large residential back garden. A single storey building was built on top of the UXB post-WWII.*

Recent Allied UXB finds in Europe

- ***27th June 2024*** – A 250kg HE UXB of Allied origin was discovered in a wooded area in Gruenheide (Germany).
- ***26th April 2024*** – A 500kg American HE UXB was discovered during construction work in Mainz (Germany), nearby the MEWA Arena stadium.
- ***3rd April 2024 –*** A 500kg UXB of Allied origin was discovered during construction work on a shipping channel in Deutz, Cologne (Germany). The device was defused in situ.
- ***28th March 2024*** – A 500lb American HE UXB was discovered during construction work in Aachen (Germany). The device was defused in situ.
- ***11th August 2023 –*** A 250kg HE UXB of Allied origin was discovered in Lublin (Poland). The device was discovered in an area where an aircraft factory had been located prior to WWII.
- ***8th August 2023*** – An unexploded "one-tonne shell" (1000kg HE UXB) of anticipated Allied origin was discovered near Dusseldorf city zoo (Germany).
- ***5th July 2023*** – A UXB of unspecified origin and calibre (alleged to have been Russian but no confirmation) was discovered on a construction site in Hohenschönhausen, Berlin (Germany). The device was defused in situ.
- ***17th March 2022*** – A farmer ploughing a field discovered a British INC30 (incendiary) bomb, which contained phosphorous, in Viersen (Germany). The plough became embedded in the device, which did not explode.

NB: Domestic UXO finds in the UK are too numerous to list. Between 2006 and 2009, over 15,000 items of British / Allied UXO (excluding small arms ammunition) were found on UK construction sites (CIRIA).

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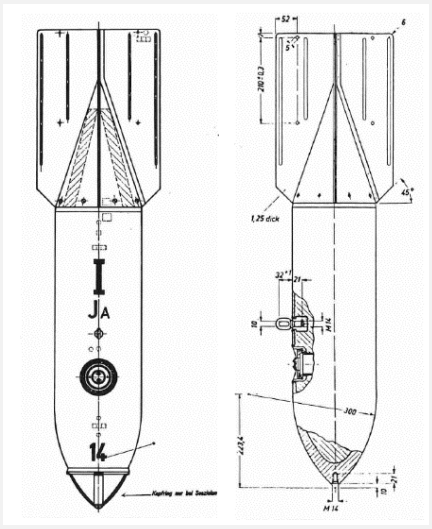
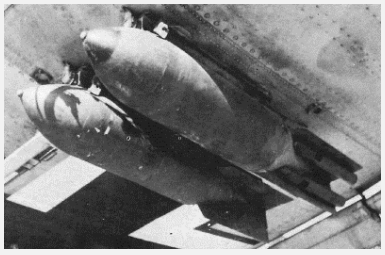
SC 50

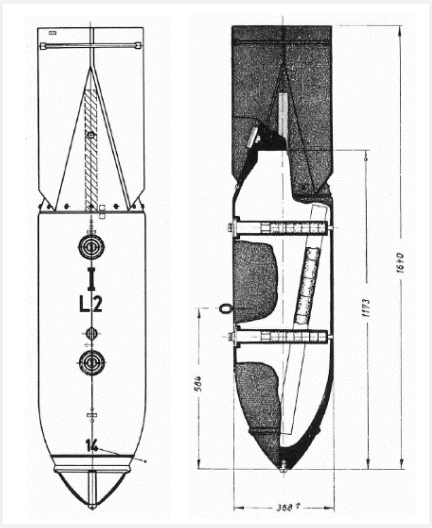
Bomb Weight:	40-54kg (110-119lb)
Explosive Weight:	25kg (55lb)
Filling:	TNT, Amatol or Trialen
Charge/Weight Ratio:	46%
Fuse Type:	Electrical impact fuse or mechanical delayed action fuse
Body Dimensions:	1,100mm length x 200mm diameter
Appearance:	Bomb body and tail painted grey/green with a yellow stripe on the tail unit. Steel construction.
Variants:	8 x variants. Additional fittings: Kopfring nose for limited penetration and Stabbo nose for dive-bombing.





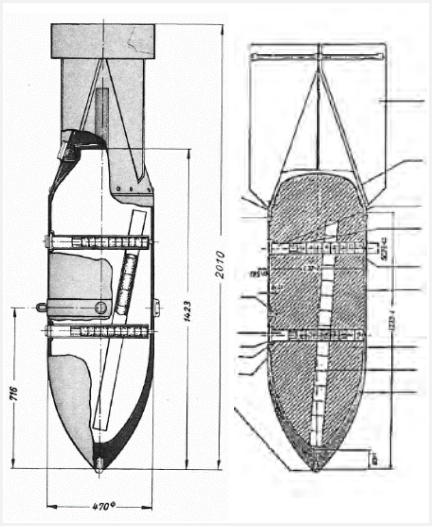
SC 250

Bomb Weight:	245-256kg (540-564lb)
Explosive Weight:	125-130kg (276-287lb)
Filling:	TNT, Amatol and Trialen mix
Charge/Weight Ratio:	44%
Fuse Type:	1 or 2 electrical impact fuse(s) or mechanical delayed action fuse(s)
Body Dimensions:	1,173mm length x 368mm diameter
Appearance:	Bomb body and tail painted grey/green with a yellow stripe on the tail unit. Steel construction.
Variants:	8 x variants. Kopfring nose for limited penetration. Stabbo nose for dive-bombing.



SC 500

Bomb Weight:	480-520kg (1,058-1,146lb)
Explosive Weight:	220kg (485lb)
Filling:	TNT, Amatol and Trialen mix
Charge/Weight Ratio:	44%
Fuse Type:	2 electrical impact fuses or mechanical delayed action fuses
Body Dimensions:	1,423mm length x 470mm diameter
Appearance:	Bomb body and tail painted grey/green or buff with a yellow stripe on the tail unit. Steel construction.
Variants:	3 x variants. Kopfring nose for limited penetration.



Project:	**83-89 Manor Way, Ruislip**
Client:	**JNP Group**
Report Ref:	**DRA-26-1994**
Info Source:	*W, Ramsey.1988 / various news sources*

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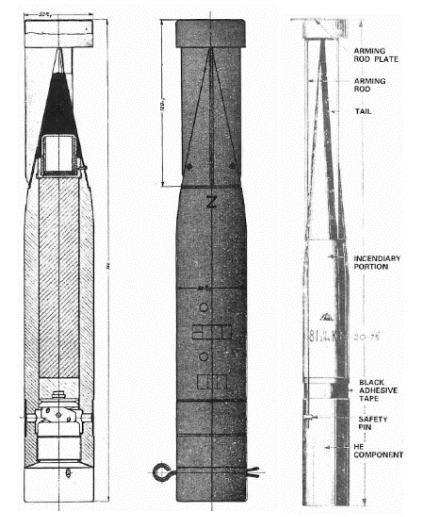
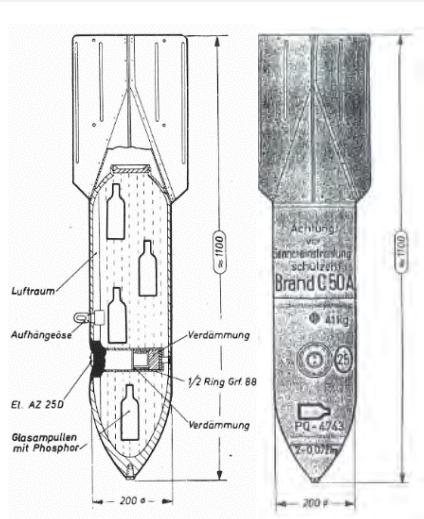
B-1E Sub-Munition

Bomb Weight: 1-1.3kg (2.2-2.87lb)
Incendiary Weight: 680g (1.4lb)
Filling: Thermite
Fuse Type: Simple impact fuse
Body Dimensions: 247mm length x 50mm diameter
Appearance: Grey body and dark green painted tail unit. Magnesium alloy case.
Operation: Small percussion charge ignites Thermite (>1,000°C burn).
Variants: Most common variant: B 2EZ (2kg) included a small HE charge
Remarks: Drop containers varied in size. The smallest cluster bomb held 36 x B-1Es and the largest 620 x B-1Es.



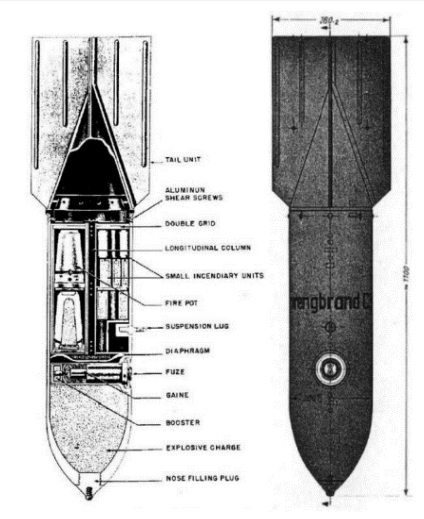
Brand C50

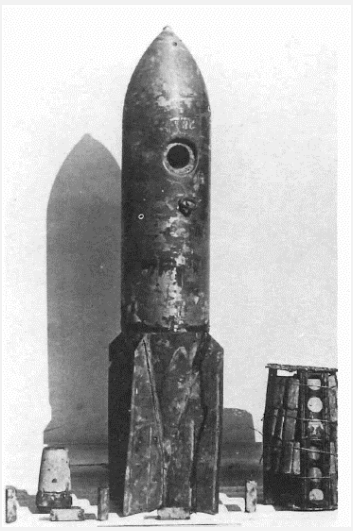
Bomb Weight: 41kg (90.4lb)
Incendiary Weight: 13kg (30lb)
Filling: Main fill (86% Benzine, 10% Rubber) plus 4% Phosphorus in glass bottles
Fuse Type: 1 x electrical impact fuse
Bomb Dimensions: 762mm length x 203mm diameter
Appearance: bomb body and tail painted grey or green with the rear of the bomb painted red and a red band around the centre of the body.
Variants: C 50 B: 77% White Phos fill
C 250 A: 87.7% Petroleum, 11.7% Polystyrene, 0.5% White Phos (185kg version)



Spreng-Brand C50 - *Fire Pot*

Bomb Weight: 34kg (75lb)
Explosive Weight: 9kg (20lb)
Filling: TNT burster charge, 6 x Thermite containers (fire pots) and 67 x small triangular incendiary elements.
Fuse Type: 1 x electrical impact fuses or aerial burst fuse
Bomb Dimensions: 711mm length x 203mm diameter
Appearance: Bomb body and tail painted grey/green or pale blue with red base plug and red or green incendiary markings. Steel construction.
Operation: A charge blows off the base plate, firing a plume of incendiary mixture 100 yds. Approx 1 second later the HE charge detonates.





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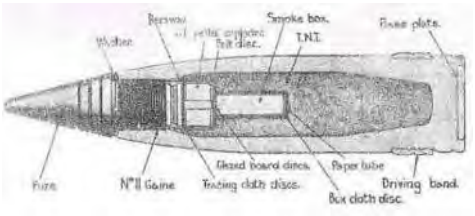
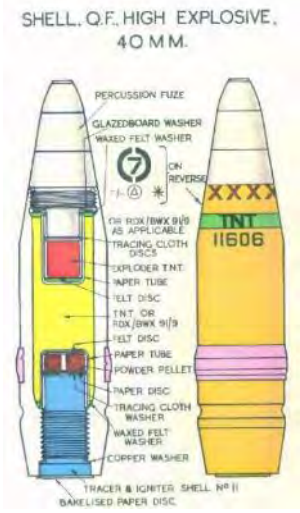
HAA Battery - 3.7" QF Shell

Shell Weight:	12.7kg
Shell Dimensions:	94mm x 438mm
Fill Weight:	1.1kg
Fill Type:	TNT
Fuse Type:	Mechanical Time Delay fuse
Appearance:	Grey body, copper driving bands, brass neck
Rate of Fire:	10 - 20 rpm
Ceiling:	9,000 - 18,000m
Variants:	HE or shrapnel shells. Note, the 4.5" gun was also used in an HAA role throughout the UK.



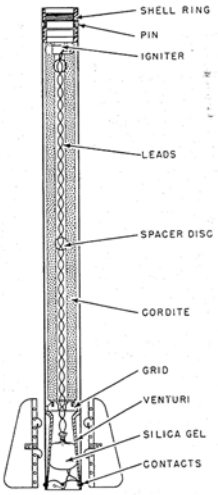
LAA Battery - 40mm Bofors Shell

Shell Weight:	0.84kg
Shell Dimensions:	40mm x 180mm
Fill Weight:	70g
Fill Type:	TNT
Fuse Type:	Impact fuse
Appearance:	Grey body, copper driving bands, brass neck
Rate of Fire:	120 rpm
Ceiling:	7,000m
Variants:	HE or AP shells. Both with rear tracer compartment



Z Battery - 3" U.P Rocket

Rocket Weight:	24.5kg
Warhead Weight:	1.94kg
Filling:	TNT warhead. Black Powder solid fuel rocket motor.
Fuse Type:	Mechanical Time Delay fuse
Rocket Dimensions:	1,930mm x 76mm
Ceiling:	6,770m
Operation:	Fired from single, tandem and (later) 36 x rail launchers (Z Batteries). Limited use throughout the UK.



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AA	*Anti-Aircraft (defences)*
AFS	*Auxiliary Fire Service*
AP	*Anti-Personnel*
ARP	*Air Raid Precautions*
ASW	*Anti-Submarine Warfare*
BDU	*Bomb Disposal Unit (historic term for EOD)*
Bgl	*Below Ground Level*
EOC	*Explosive Ordnance Clearance*
EOD	*Explosive Ordnance Disposal*
FP	*Fire Pot (German bomb)*
GI	*Ground Investigation*
HAA	*Heavy Anti-Air (gun battery)*
Ha	*Hectare (10,000m2)*
HE	*High Explosive*
IB	*Incendiary Bomb*
Kg	*Kilogram*
LAA	*Light Anti Air (gun battery)*
LCC	*London County Council*
LRRB	*Long Range Rocket Bomb (V2)*
LSA	*Land Service Ammunition*
Luftwaffe	*German Air Force*
OB	*Oil Bomb (German bomb)*
PM	*Parachute Mine (German bomb)*
RAF	*Royal Air Force*
RFC	*Royal Flying Corps*
RN	*Royal Navy (British)*
RNAS	*Royal Naval Air Service*
ROF	*Royal Ordnance Factory*
SAA	*Small Arms Ammunition*
SD2	*2kg AP bomb (German bomb)*
SI	*Site Investigation*
U/C	*Unclassified (German) bomb*
UP	*Unrotating Projectile (British 3" AA rocket)*
USAAF	*United States Army Air Force*
UX	*Unexploded*
UXB	*Unexploded Bomb*
UXO	*Unexploded Ordnance*
V1	*German Flying (pilotless) bomb - "Doodlebug"*
V2	*German LRRB - "Big Ben"*
WAAF	*Women's Auxiliary Air Force*
WWI	*World War One*
WWII	*World War Two*

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