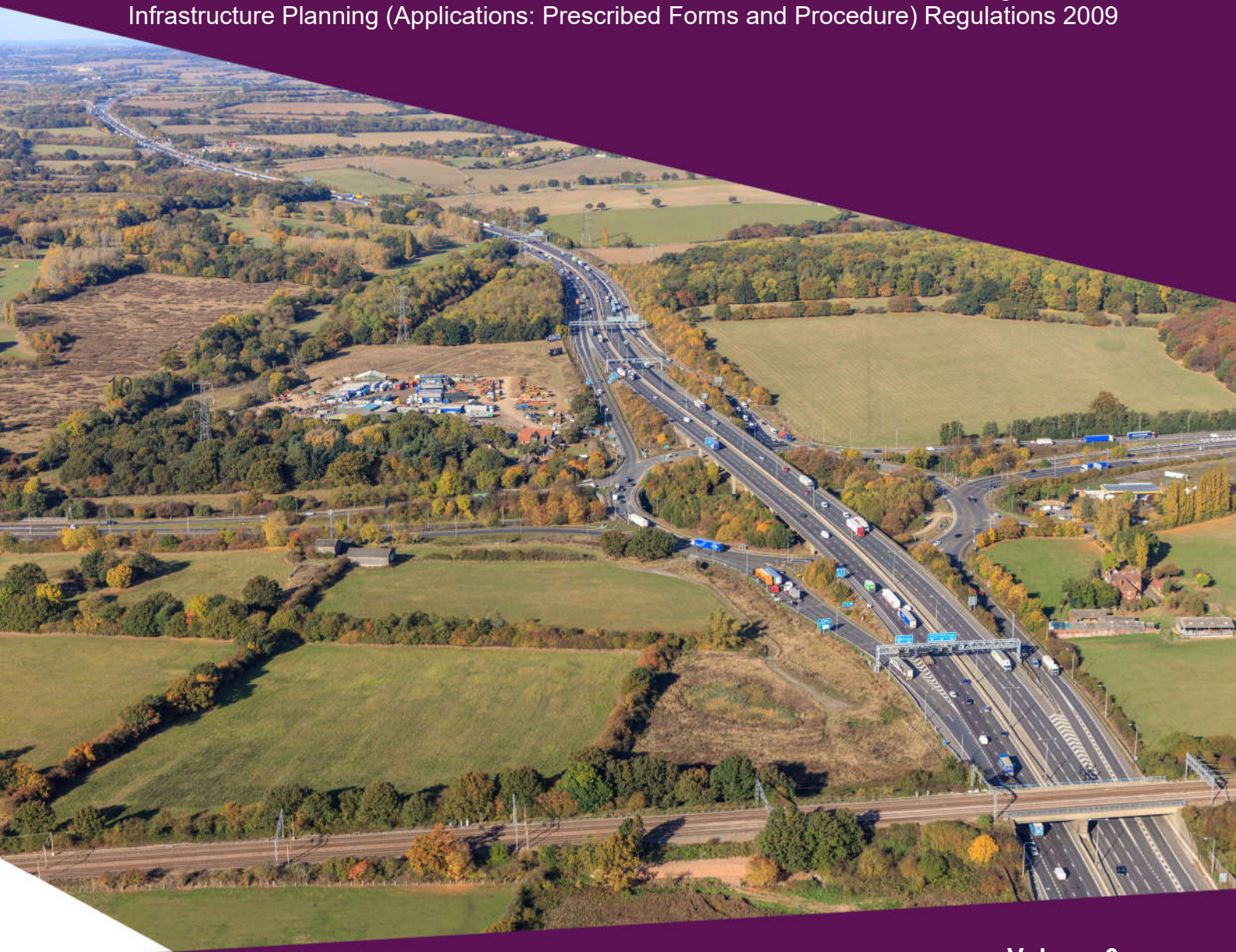
M25 junction 28 improvement scheme
TR010029
6.3 Environmental Statement
Appendix 10.5: UXO risk map

APFP Regulation 5(2)(a)
Planning Act 2008
Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009



Volume 6
May 2020

Infrastructure Planning

Planning Act 2008

The Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

M25 junction 28 scheme
Development Consent Order 202[x]

6.3 ENVIRONMENTAL STATEMENT
APPENDIX 10.5: UXO RISK MAP

Regulation Number:	Regulation 5(2)(a)
Planning Inspectorate Scheme Reference:	TR010029
Application Document Reference:	TR010029/APP/6.3
Author:	M25 junction 28 improvement scheme project team, Highways England

Version	Date	Status of Version
1	May 2020	Application issue

Table of contents

Appendix 10.5
UXO risk map

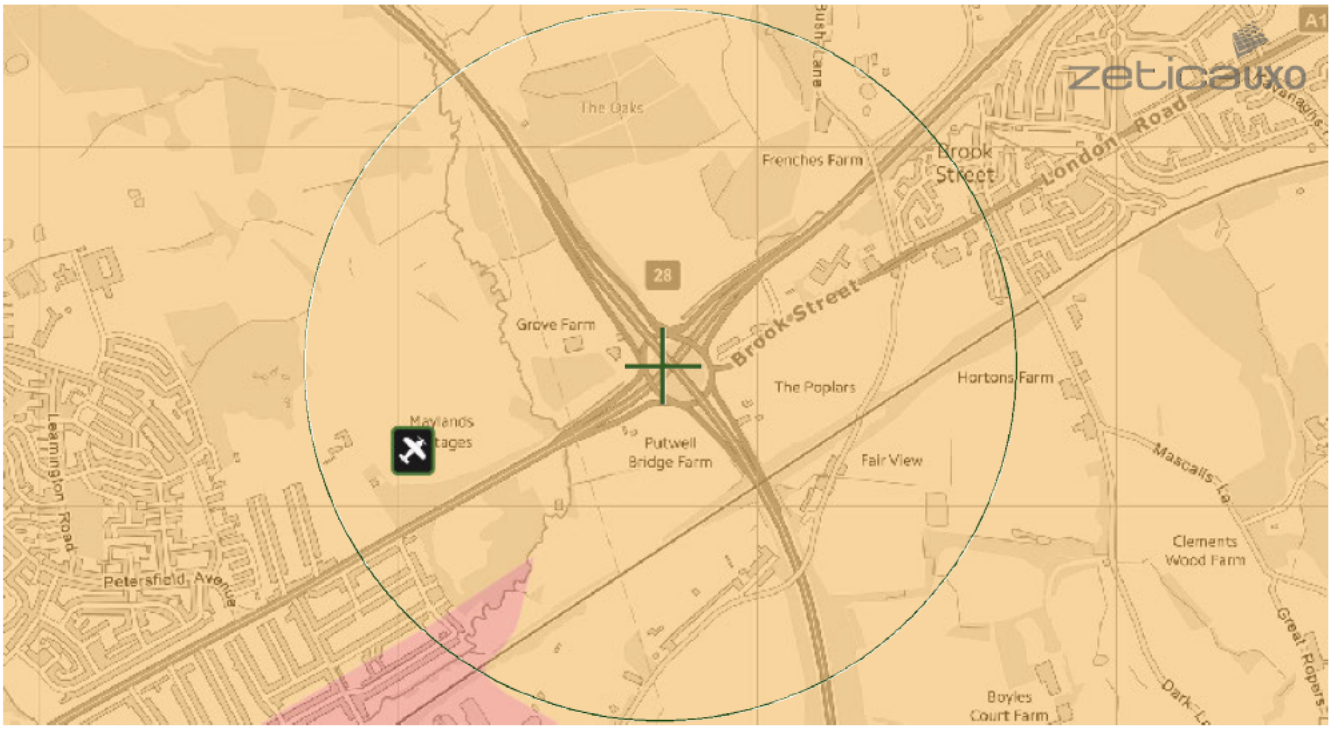
11. UXO risk map

UNEXPLODED BOMB RISK MAP

zeticaUXO

SITE LOCATION

Map Centre: 556744,192396



LEGEND

- **High:** Areas indicated as having a bombing density of 50 bombs per 1000acre or higher.
- **Moderate:** Areas indicated as having a bombing density of 15 to 49 bombs per 1000acre.
- **Low:** Areas indicated as having 15 bombs per 1000acre or less.

miltary | **industry** | **UXO find**

transport | **dock** | **Luftwaffe targets**

utilities | **other**

How to use your Unexploded Bomb (UXB) risk map?

The map indicates the potential for Unexploded Bombs (UXB) to be present as a result of World War Two (WWII) bombing.

You can incorporate the map into your preliminary risk assessment* for potential Unexploded Ordnance (UXO) for a site. Using this map, you can make an informed decision as to whether more in-depth detailed risk assessment* is necessary.

What do I do if my site is in a moderate or high risk area?

Generally, we recommend that a detailed UXO desk study and risk assessment is undertaken for sites in a moderate or high UXB risk area.

More often than not, this further detailed research will conclude that the potential for a significant UXO hazard to be present on your site is actually low.

Never plan site work or undertake a risk assessment using these maps alone. More detail is required, particularly where there may be a source of UXO from other military operations which are not reflected on these maps.

If my site is in a low risk area, do I need to do anything?

If both the map and other research confirms that there is a low potential for UXO to be present on your site then, subject to your own comfort and risk tolerance, works can proceed with no special precautions.

A low risk really means that there is no greater probability of encountering UXO than anywhere else in the UK.

If you are unsure whether other sources of UXO may be present, you can ask for one of our **pre-desk study assessments (PDSA)**

If I have any questions, who do I contact?

tel: **+44 (0) 1993 886682**

email: **uxo@zetica.com**

web: **www.zeticauxo.com**

The information in this UXB risk map is derived from a number of sources and should be used in conjunction with the accompanying notes on our website: **(https://zeticauxo.com/downloads-and-resources/risk-maps/)**

It is important to note that this map is not a UXO risk assessment and should not be reported as such when reproduced.

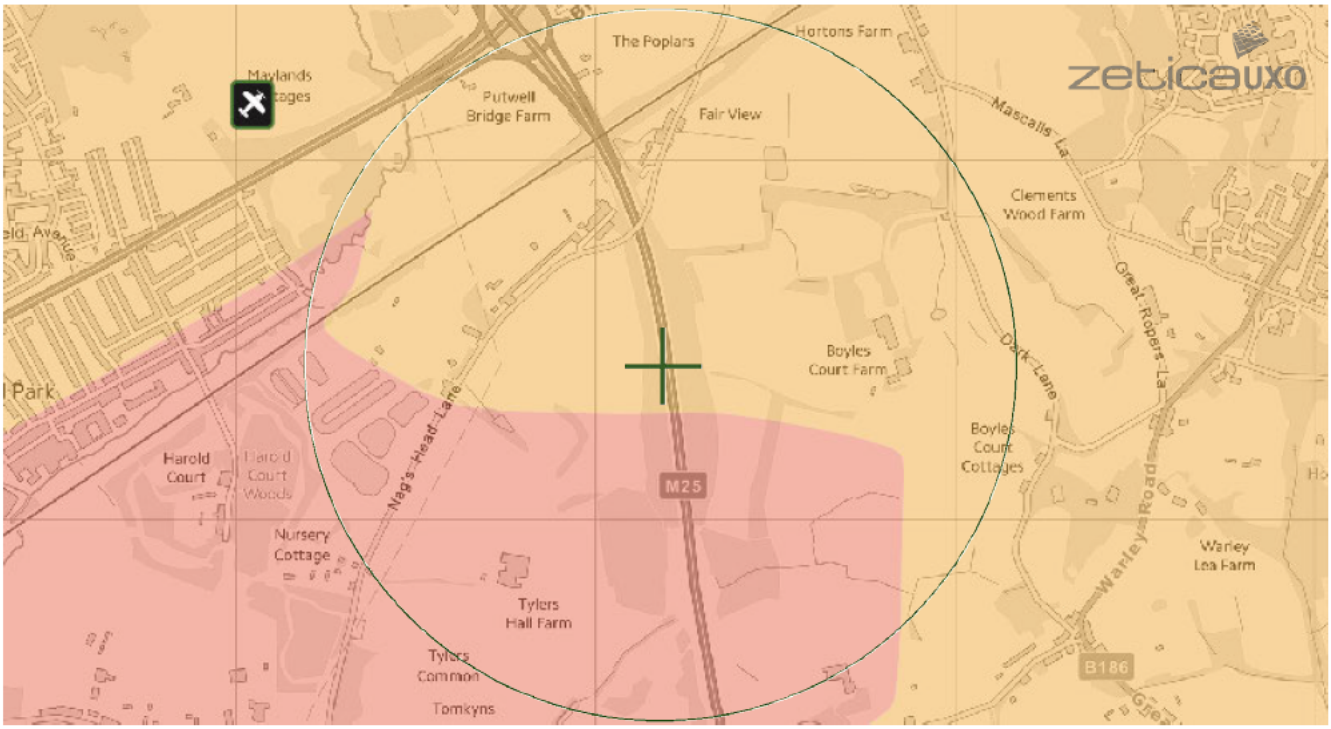
*Preliminary and detailed UXO risk assessments are advocated as good practice by industry guidance such as CIRIA C681 'Unexploded Ordnance (UXO), a guide for the construction industry'.

UNEXPLODED BOMB RISK MAP

zeticaUXO

SITE LOCATION

Map Centre: 557193,191433



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STAGE 2 DETAILED UXO RISK ASSESSMENT

Report Reference: DRA-19-1096

INTEGRITY • PROFESSIONALISM • KNOWLEDGE

STAGE 2 DETAILED UXO RISK ASSESSMENT:

M25 Junction 28, Romford

Prepared For:

Geotechnical Engineering Ltd

Brimstone Site Investigation

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ME4 6AE

Phone: 0207 117 2492
Web: www.brimstoneuxo.com

REPORT REF: DRA-19-1106 | Revision: 0	
Prepared by:	[redacted]
Reviewed by:	
Release Authorised by:	
Report Issue Date:	05/07/2019

EXECUTIVE SUMMARY

RESULT: Brimstone Site Investigation concludes that UXO poses a ***LOW-MODERATE RISK*** to the proposed works.

THE SITE: The Site (centred on the National Grid Ref: TQ 56274 92650) is located between Harold Hill and Brentwood, at the eastern boundary of the London Borough of Havering, adjacent to the Essex County boundary. It is bound to the east by the northbound carriageway of the M25, to the south by the eastbound carriageway of the A12, and to the west by Marylands Golf Club.

The Site is a large area of mainly greenfield land; woodland and grassland. The eastern and southern extents occupy sections of the A12 and M25 highways / slip-roads and vegetated embankments. The northern extent encroaches into the neighbouring golf course, encompassing part of a fairway, sand bunkers and a putting green.

The central-eastern location is occupied by Grove Farm, a large private property occupied by residential and commercial buildings, a scrap yard, vehicle park, and storage areas. Two waterbodies cross The Site, the Ingrebourne River in the south (from east to west) and Weald Brook which flows north to south, to the west of the M25.

THE PROPOSED WORKS: The proposed upgrade works are associated with a re-design / re-alignment of the M25 / A12 junction. However, no specific details relating to these works were available at the time of writing. Prior to construction, an SI will be carried out. This will include boreholes up to 40m bgl, trial pits to 3.5m bgl and hand-dug inspection pits to 1.20m bgl, with hand-held dynamic probes to 2.0m bgl.

UXO RISK ASSESSMENT:

German UXO:

- The Site was located within an insignificant rural area during WWII, with no confirmed or potential bombing targets in the vicinity. A review of original wartime bombing figures and reports indicates that the wider study area experienced a low to moderate bombing density. No medium or large-scale raids affected The Site, with all local bomb strikes resulting from Tip and Run incidents involving solitary aircraft.
- An aerial photograph of the study area, taken just after WWII, does not exhibit any evidence of HE bomb craters or in-filled craters in the vicinity.
- A complete collection of original bombing incident reports for the wider area (held at local archive level) was reviewed. Two bombing incidents appear to have occurred within 500m of The Site boundary.
- One of these resulted in two parachute mine strikes. During April 1941, the Luftwaffe bomber with the largest bombload could carry a maximum of two parachute mine. Consequently, this incident could not have resulted in any UXB strike on Site. The second incident resulted in one HE bomb strike to the exiting golf course that encroaches into the northern part of The Site.
- The vast majority of The Site was uninhabited, increasing the likelihood of a UXB from the same aircraft falling on Site unobserved. This is further heightened by the fact that this and most of the other local raids occurred during the hours of darkness.
- The records did not contain the detail necessary to establish the precise flight path of the aircraft and therefore, it is possible that the bomber flew over The Site and dropped a UXB. However, the large size of the golf course means it is equally possible that the aircraft did not pass over The Site.

- The vast majority of The Site was occupied by open fields or woodland which would have been neglected for long periods and any UXB entry hole could conceivably have remained undetected here. NB: the diameter of the smallest German HE bomb (which was also the most commonly deployed over Britain) was 200mm; creating a small, easily obscured UXB entry hole. However, as only one potentially significant enemy aircraft sortie has been identified in the vicinity, such a scenario is considered to be a remote possibility.

British / Allied UXO:

- 18 permanent HAA batteries were within range of The Site during WWII. The Luftwaffe were frequently active in the region and therefore these guns would have expended a large quantity of ammunition during WWII. For the same reasons as above, any unexploded AA shell landing in vegetation on Site could have become buried and gone unnoticed.
- Although no specific evidence of WWII Home Guard activity on Site has been located, the possibility cannot be discounted that the unused open ground and woodland on Site was requisitioned temporarily. Alternatively, armed Home Guard soldiers could conceivably have accessed The Site whilst on patrol. Any such activity on Site would raise the risk of associated UXO contamination; chiefly the common practice of unauthorised disposal (burial) of surplus ammunition.

Likelihood of UXO Encounter:

- The greenfield nature of the vast majority of The Site indicates that any buried UXO is likely to remain in-situ. Only within the recently disturbed parts of Grove Farm and within part of Alder Wood, will the risk of shallow buried UXO have been partly mitigated.
- The likelihood of UXO contamination of The Site is neither high nor moderate, however the possibility that an unexploded AA shell or German UXB struck The Site, or that Home Guard ammunition was discarded on Site, cannot be ruled out entirely. There is a very slightly elevated likelihood of such UXO remaining up to the present day within the locations of the proposed ground works. The type of UXO coupled with the historic ground cover means that the area of potential UXO contamination cannot be subdivided into areas of lower or higher risk. Consequently, all the proposed ground works will be exposed to a UXO encounter, albeit not a high or even moderate exposure risk.

RECOMMENDED RISK MITIGATION MEASURES: Brimstone concludes that a shallow-buried UXO encounter cannot be completely ruled out during the proposed works. Consequently, it is recommended that the minimum risk mitigation measure be put in place prior to all planned ground works; **UXO Safety Awareness Briefings** to all Site personnel.

CONTENTS

FIGURES

APPENDICES

1 INTRODUCTION

1.1 BACKGROUND

Geotechnical Engineering Ltd, referred to hereon in as *The Client*, has commissioned Brimstone Site Investigation, referred to hereon in as *BSI*, to carry out a Stage 2 Detailed Unexploded Ordnance (UXO) Risk Assessment of the proposed intrusive ground works at the M25 Junction 28, Romford site, referred to hereon in as *The Site*.

1.2 LEGISLATION

1.2.1 Introduction

There is no legal requirement for assessing the risk posed by UXO at UK construction sites, nor is there any specific legislation covering the management and mitigation of UXO risk. However, there are two main pieces of UK legislation that require responsible parties carrying out ground works to undertake comprehensive and robust assessments of potential risks and hazards to their employees.

1.2.2 Construction (Design & Management) Regulations 2015

Construction Design & Management (CDM) Regulations outlines the responsibilities of all involved parties, primarily the Client, the CDM Co-ordinator, the Designer and the Principal Contractor. CDM2015 states that a party has the 'legal responsibility for the way that a construction project is managed and they are accountable for the health and safety of those working on or affected by the project'. All parties are obliged to:

- Provide an appropriate assessment of potential UXO risks at the site or ensure such 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 presented by the project.
- Ensure the preparation of a suitably robust emergency response plan.

1.2.3 The Health and Safety at Work Act 1974

Section 3 of this legislation covers the general public and other contractors on a site. It states that 'it is the duty of every employer to conduct his/her undertaking in such a way as to ensure,

so far as is reasonably practicable, that persons not in his/her employment who may be affected are not thereby exposed to risks to their health or safety'.

'In such cases as may be prescribed, it shall be the duty of every employer and every self-employed person, in the prescribed circumstances and in the prescribed manner, to give to persons (not being his/her employees) who may be affected by the way in which he/she conducts his/her undertaking, the prescribed information about such aspects of the way in which he /she conducts his/her undertaking as might affect their health or safety'.

1.3 UXO - THE ROLE OF COMMERCIAL CONTRACTORS AND THE AUTHORITIES

1.3.1 Commercial Contractors

If an elevated UXO risk is identified during the Stage 1 and Stage 2 Risk Assessment process, risk mitigation measures will be recommended. Commercial UXO contractors can provide geophysical surveys during the pre-construction phase. Such surveys are designed to identify potential UXO targets which can then be intrusively investigated. Subsequent UXO clearance or avoidance can then be recommended as appropriate.

In addition, EOD Engineers can be deployed to sites before and / or during the construction phase to provide UXO awareness briefings to staff, a watching brief for excavations and reactive response to any suspicious finds.

Having a qualified EOD Engineer on site will avoid unnecessary (potentially costly) call-outs to the authorities when a suspicious item is encountered, as the engineer will be able to identify whether or not the item is UXO and whether or not it is inert or live. If a high risk UXO item is identified the engineer will co-ordinate with the authorities, limiting disruption on site and putting in place safety measures, with immediate effect.

1.3.2 UK Authorities

If a suspected item of UXO is discovered at a UK site where no commercial UXO contractor is in attendance or quickly available, the local Police force will evacuate the site and establish a precautionary safety cordon, which could require the evacuation of neighbouring properties. They will then contact the MOD's Joint Services Explosive Ordnance Disposal (JSEOD) office.

Based on the Police assessment, JSEOD will prioritise the incident based on criteria such as the likely type and size of the item and the site's location / population density in the vicinity. The availability of JSEOD's resources will also be a factor. If an incident is not given high priority, an EOD Engineer may not be made available for up to two days after the find was originally reported. During this period, a Police cordon would likely remain in place.

On assessing the item, the EOD Engineer may need to widen the Police cordon and order an evacuation of a larger area. NB: for German high explosive (HE) UXB finds in urban areas this usually results in the evacuation of thousands of people and the closure of local roads.

At low profile (usually rural) sites where UXO finds are frequent, for example on former military land, JSEOD's limited resources will usually require it to recommend involvement of a commercial UXO contractor to manage the ongoing UXO risk. Most UXO found at such sites is small enough to be covered by the commercial UXO contractor's clearance license, allowing for most, if not all, UXO to be disposed of quickly and safely as and when it is encountered.

1.4 UXO RISK IN THE UK

Fortunately, inadvertent initiations of UXO are rare, however, the legacy of UXO can cause significant delays to construction projects throughout the UK, with associated increases in costs. A list of recent German UXBs finds and examples of WWII UXB detonation incidents can be found at ***APPENDIX 1***. In many cases these unforeseen problems can be avoided if an appropriate risk management procedure has been carried out at the initial stages of the project design process.

Thousands of items of British / Allied UXO and several German UXBs are exhumed by the construction industry and the general public each year, however, the vast majority go unreported in the media due to the potential negative impacts on companies and their projects. NB: the former tends to be smaller in size than German UXBs and therefore pose a relatively smaller threat. In the UK, the origin of buried UXO can be broadly categorised into three families;

1. ***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.

2. ***Allied Military Activity:*** During WWI and WWII several Allied nations used the UK as a staging area for military action in the European Theatre of conflict; most notably the US and Canada.

3. ***UK Military Activity:*** Domestic British Army, Royal Air Force (RAF) and Royal Navy (RN) training activities during peacetime and conflict as well as AA gun and rocket batteries during WWI and WWII.

1.5 UXO DETONATIONS

The effects of a UXO detonation occur extremely quickly and are almost always physically traumatic when personnel are involved. The effects of a detonation are heat, sound, blast and shrapnel. The detonation of a shallow buried 50kg HE bomb would damage masonry up to 16m away and unprotected personnel approximately 70m away. The accepted safety distance for a 500kg WWII HE bomb (with a ~250kg HE fill) is 1,000m.

For a UXO detonation to occur significant stimuli is required; UXO does not spontaneously exploded. WWII-era HE requires a significant quantity of energy to initiate, which is why construction works are particularly vulnerable to UXO. There are three ways in which an item of UXO could initiate:

- ***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 cause 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 designed to provide accurate and authoritative information regarding matters of onshore UK risk in the UK.

2.2 SPRC RISK MODEL

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

Sources: For UK and Allied UXO sources can include; military firing ranges, military bases, military storage depots, munitions factories, wartime anti-aircraft weapons usage, etc. There are a number of ways in which enemy action during WWI and WWII could have resulted in UXO contamination. The source that has produced the most enemy UXO contamination is, by far, Luftwaffe air raids during WWII. This source alone has resulted in a variety of UXO (different types of bombs) each posing a specific hazard.

Pathways: For buried UXO, the pathway describes the activity(s) which results in the hazard (UXO) reaching personnel and / or assets. There are a number of pathways (construction methodologies) which require intrusions into the ground and each has the potential to be a UXO pathway. Common pathways are Ground Investigation (SI) works, Site Enabling Works, Various Excavations (soil stripping, levelling, shallow foundations, services, drainage, etc), pile foundations, etc.

Receptors: On construction sites the receptors are either works specific or external and vary in sensitivity. The former includes site personnel, project specific plant and equipment. The latter incorporates the general public, external structures in the vicinity and environmental receptors (atmosphere, soil, flora and fauna).

Consequence: The consequences of an inadvertent UXO detonation event have the potential to be significant, i.e when they affect human receptors (life or limb). Consequences for non-

human receptors can be wide ranging and also significant. However, in real terms the likelihood of detonating UXO is far lower than that of encountering UXO. NB: a UXO find alone can still have substantial financial consequences due to project delay.

2.3 ASSESSMENT STRUCTURE

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

- The risk that the site was contaminated with UXO; site specific history, conflict history and domestic military history.
- The type(s) of UXO that could have contaminated the site and their associated hazards.
- The risk that UXO remains on the site; post-conflict redevelopment / earthworks and military EOD activity.
- Maximum German UXB pentation depth; site specific calculation if required.
- The risk that UXO may be encountered during the proposed works; the extent of the proposed works.
- Risk Rating Assessment; Risk Mapping if required.
- Risk Mitigation Recommendations; if required.

2.4 INFORMATION SOURCES

In order to carry out an informed and accurate risk assessment *BSI* has sought information from a wide range of sources. In preparation for this assessment *BSI*'s Research Team has undertaken detailed historical research, including access of original archived records. The following is a general list of information sources that are consulted during the research process:

- The National Archives, London.
- The London Metropolitan Archive.
- Local Archive Centres.
- The Ministry of Defence.
- The Council for British Archaeology.
- Groundsure Mapping Services.
- Historical Aerial Photography (Historic England, Britain From Above, Bluesky).

- Google open source mapping.
- The British Geological Society.
- Open sources; published book, articles, web resources.
- Site specific information supplied by *The Client*.
- *BSI*'s library and historical database.
- *BSI*'s ex-servicemen employees (including experienced EOD Engineers).

2.5 ALARP PRINCIPLE

The ALARP (as low as reasonably practicable) principle is a risk principle used in the regulation and management of construction industry risks. The term ALARP originated in UK legislation, namely the Health and Safety at Work Act 1974, which states that risks must be averted unless there is a gross disproportion between the costs and benefits of doing so.

The ALARP principle arises from the fact that infinite time, effort and money could be spent attempting to eliminate a risk entirely. It should not be understood as simply a quantitative measure of benefit against detriment. Instead, a best common practice of judgement, balancing risk and societal benefit.

The objective of a *BSI* risk assessment that identifies an elevated UXO risk is to prevent a client unnecessarily spending a grossly disproportionate sum of money reducing that project specific UXO risk. For a risk to be ALARP, it must be possible to demonstrate that the cost involved in reducing the risk further would be grossly disproportionate to the benefit gained.

2.6 RISK TOLERANCES

The *BSI* risk assessment process divides UXO risk into two tolerances:

Tolerable: Negligible Risk or Low Risk ratings are tolerable. However, for some sites, where the risk cannot be completely discounted at the Stage 2 risk assessment stage, it would be prudent to employ relatively low cost proactive risk mitigation measures prior to undertaking ground works. For example, a UXO Tool Box briefing to site personnel.

Intolerable: Moderate Risk or High Risk Ratings are intolerable. Therefore, pro-active risk mitigation measures should be employed prior to undertaking and / or during ground works;

magnetometer survey and EOD engineer attendance on site respectively.

2.7 RELIANCE AND LIMITATIONS

This report has been prepared using published information and information provided by *The Client* which were made available at the time of writing only. *BSI* is not liable for any information which has become subsequently available. No third party liability or duty of care is extended. Third parties using information contained in this assessment do so at their own risk.

3 THE PROJECT

3.1 THE SITE

The Site (centred on the National Grid Ref: TQ 56274 92650) is located between Harold Hill and Brentwood, at the eastern boundary of the London Borough of Havering, adjacent to the Essex County boundary. It is bound to the east by the northbound carriageway of the M25, to the south by the eastbound carriageway of the A12, and to the west by Marylands Golf Club.

The Site is a large area of mainly greenfield land; woodland and grassland. The eastern and southern extents occupy sections of the A12 and M25 highways / slip-roads and vegetated embankments. The northern extent encroaches into the neighbouring golf course, encompassing part of a fairway, sand bunkers and a putting green. The central-eastern location is occupied by Grove Farm, a large private property occupied by residential and commercial buildings, a scrap yard, vehicle park, and storage areas. Two waterbodies cross *The Site*, the Ingrebourne River in the south (from east to west) and Weald Brook which flows north to south, to the west of the M25.

FIGURE 1: Site Location Maps ***FIGURE 2:*** Recent Aerial Photograph

3.2 THE PROPOSED WORKS

The proposed upgrade works are associated with a re-design / re-alignment of the M25 / A12 junction. However, no specific details relating to these works were available at the time of writing. Prior to construction, an SI will be carried out. This will include boreholes up to 40m

bgl, trial pits to 3.5m bgl and hand-dug inspection pits to 1.20m bgl, with hand-held dynamic probes to 2.0m bgl.

4 SITE HISTORY

4.1 INTRODUCTION

Site specific history can be assessed by reviewing historical OS 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 OS MAPPING

Review of OS Mapping			
Period	**Map Date**	**Map Scale**	**Review**
Post-WWI	**1920**	**1:2,500**	Like today, *The Site* is largely occupied by woodland and fields, with the latter likely belonging to Marylands (farm) to the west of *The Site*. In the south, *The Site* encompasses The Grove (woodland) and in the centre it passes through Alder Wood. The northern extent is marked by the edge of Burnt Wood. The southern *Site* boundary is marked by Roman Road, with Putwell Farm just beyond the boundary. Two, small unidentified clusters of (likely) agricultural buildings are positioned in the south of *The Site*, adjacent to The Grove and Roman Road. Both existing watercourses pass through *The Site*. Two, small (likely) ponds are marked at *The Site* centre. The wider area is predominantly agricultural with larger areas of woodland.
Pre-WWII	**1938**	**1:10,560**	Two unidentified small to medium sized buildings have been constructed on *Site*, immediately west of The Grove.
	1939	**1:2,500**	This map only covers part of *The Site*. The two aforementioned structures adjacent to The Grove do not feature on this map.
	1959	**1:10,560**	***FIGURE 3:*** Parts of *The Site* (in the west) may now be encompassed by the adjacent Golf Course. Two pylons (an overhead power line) have been installed on *Site*.

Post-WWII	1961	1:2,500	The two suspected ponds are labelled Pond and a third Pond is labelled within The Grove. The Golf Course is labelled Marylands Golf Course. A path labelled Cart Track passes through *The Site* (within Alder Wood).
	1968	1:2,500	Roman Road has been redeveloped as a dual carriageway with slip-roads and earth embankments leading to a large roundabout at the south-eastern corner of *The Site*, identified as Brook Street. The unidentified buildings adjacent to The Grove are identified as Grove Farm.
	1985/89	1:10,000	The M25 has been constructed within / adjacent to the eastern *Site* boundary. *The Site* appears as it does today.

4.3 AERIAL PHOTOGRAPHY

Review of Aerial Photography		
Period	**Photo Date**	**Review**
Post-WWII	*circa* 1945	***FIGURE 4:*** This low resolution photograph was taken within months of the end of WWII. *The Site* appears as it does on the 1938 (pre-WWII) OS map. The western part of the southern half of *The Site* appears to be occupied by pasture, with the northern extent (likely today) situated within the adjacent golf course. The temporary structures just west of The Grove are ambiguous in this image. No evidence of German bombing (craters in open ground or demolished buildings) is visible in the vicinity. NB: some bomb craters only persisted temporarily during WWII, particularly on arable (worked) land. They were often in-filled / repaired prior to the available aerial photography.

4.4 ADDITIONAL SITE-SPECIFIC HISTORY

Some sites will have been historically occupied by landmarks or significant buildings and in such cases specific written histories are occasionally available in the public domain. Research has confirmed that Maylands Golf Club was founded in 1937, three years prior to WWII.

Furthermore, the south-western field on *Site* formed part of Maylands Aerodrome, which

operated as a civil airfield between 1928 and 1940. It was originally a site for Essex Flying Services and later used solely by Romford Flying Club. A pre-WWII plan of the airfield labels the aforementioned temporary structures just west of The Grove, as aircraft hangars and fuel storage.

5 UXO RISK - GERMAN BOMBING

5.1 WWII BOMBING HISTORY OF THE SITE

5.1.1 General WWII History of the South-East

In the summer and autumn of 1940, the Luftwaffe targeted the RAF's airfields and support network with the attention 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.

In early September 1940 The Luftwaffe changed their tactics and commenced an indiscriminate carpet-bombing campaign over London. The resulting nine-month Blitz began on the 7th September 1940 and ended on the 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 1942 and 1943 a number of small-scale fighter bomber raids were carried out against the Capital and towns in the Home Counties (including Essex), as well as the Baedeker Blitz against Canterbury. Then in 1944 the Luftwaffe commenced Operation Steinboch. This campaign comprised 31 major raids against London and 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, including Essex. The final Luftwaffe raid on the Capital took place during May 1944.

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 and thousands more landed in the Home Counties, including Essex.

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 and therefore, at V Weapon impact sites, the assessment of pre-1944 UXB risk can be hampered.

5.1.2 Site Specific History

No confirmed primary or secondary Luftwaffe bombing targets (military or civil) or viable sites that would have represented a profitable target were located in the vicinity of *The Site* during WWII. The closest, a wireless station (approximately 3.8km to the north-east) is highlighted on a Luftwaffe target reconnaissance photograph dated 1940.

The insignificant nature of *The Site* and wider area suggests it would have been vulnerable to random 'Tip and Run' bombing incidents only. These occurred when German bombers, harried by RAF fighters or caught in heavy AA fire, would indiscriminately jettison their bomb loads to aid their escape. Luftwaffe and corresponding RAF activity over south-west Essex was high during WWII and therefore such incidents were commonplace.

5.2 BOMBING DECOY SITES:

In mid-1940 the War Office began developing a number of Bombing Decoys with the intention of diverting a proportion of Luftwaffe bombs away from the real civilian and military targets. The decoys used either;

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

Some 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. By the end of 1941, airfield decoy sites had received 359 attacks compared with 358 raids carried out against the real airfields and by June 1944 approximately 730 attacks had been recorded on all decoy site types. No decoys were operational within a significant radius of *The Site* during WWII, the closest being approximately 6.6km to the west.

5.3 WWII BOMBING RECORDS

5.3.1 Introduction

The Bomb Census was undertaken by the Ministry of Home Security during WWII to try to provide a greater understanding of the effects the Luftwaffe bombing campaign was having upon Britain and to provide intelligence relating to bombing raid patterns, types of munitions used and consequent damage. The Bomb Census was compiled using information recorded by ARP wardens based in every bombed location throughout the UK.

Bombing incidents were reported to ARP wardens who kept a written record for their area of responsibility in the form of individual incident reports. In larger urban areas (mainly cities) these reports were used to compile bomb census / plot maps. ARP bombing records were gathered by the Ministry of Home Security and used to calculate bombing density statistics for every administrative area in the UK.

The detail and quality of information recorded by the Bomb Census was inconsistent for the early stages of the war, however, by 1941 procedures had been standardised. The quality of Bomb Census information also varied greatly depending on where in the UK the records were produced.

5.3.2 ARP Bombing Density Statistics

The table below records the Ministry of Home Security's bombing density calculation for the Urban District of Brentwood during WWII. NB: The boundary between this district and Noak Hill Municipal Borough passed through *The Site* historically, however the figures for this area are missing from the record. The table gives a breakdown of the types of large German bombs reported. These figures were sourced from the National Archives, London. NB: 1kg / 2kg

incendiary bombs (IB) and 2kg AP bombs were often too numerous to record accurately and therefore are usually not included.

Record of German Air-Delivered Ordnance	
Administrative Area Acreage	**18,269**
High Explosive Bombs (all types/weights)	744
High Explosive Parachute Mines	14
Flam (Oil) Bombs	34
40kg Phosphorus Incendiary Bombs	28
40kg 'Fire Pot' Incendiary Bombs	0
V1 Flying Bomb	14
V2 Long Range Rocket	24
Total (excluding V-Weapons and 1kg IBs)	820
Bombs Per 1,000 Acres	**44.8**

5.3.3 Essex ARP Bombing Incident Reports

Essex Record Office holds a collection of original bombing incident reports for the Urban District of Brentwood and Noak Hill Municipal Borough. This collection, which is believed to be complete, was reviewed by *BSI* for this assessment. These hand-written reports vary in the level of detail included and their legibility. The following table lists all confirmed bombing incidents within a 1km radius of *The Site*. NB: No original bomb plot map covering the study area exists.

Local bombing Incidents			
Date	**Bombs**	**Location (relative to *The Site*)**	**Result**
15th Aug 40 22:30hrs	3 x IBs	Open ground, near Old Vicarage, Vicarage Lane, South Weald (>800m east).	No fires or casualties. Only two of the IBs subsequently found.
31st Aug 40 00:55hrs	HE bombs	In field near Rochetts Farm (800m to 1km north-east).	Slight damage to property.
8th Sep 40 05:36hrs	1 x IB	In the South Weald area (>500m east).	No casualties or damage.

17th Sep 40 00:35hrs	3 x HE bombs	In field north side of railway, south-east of Nags Head Ln (>600m east).	South side of railway damaged.
14th Oct 40 19:53hrs	3 x HE bombs	In the South Weald area (>500m east).	No casualties or damage.
20th Oct 40 21:50hrs	Incendiaries	Harold Park (300m to 1.3km south-west).	No damage.
11th Nov 40 19:15hrs	4 x HE bombs	In field south of Weald Rd, in between Spital Ln and Vicarage Ln, in the South Weald area (1.2km north-east).	No casualties or damage.
15th Nov 40 21:55hrs	2kg IBs	West of Vicarage Lane, Brook Street (300m to 700m east).	No casualties or damage
28th Nov 40 19:20hrs	1 x HE bomb	Outside sewage farm, Nags Head Ln (>600m south).	Road blocked, superficial damage to property, telephones lines down.
30th Nov 40 19:35hrs	Multiple IBs	Fell in open ground, South Weald area (>500m east).	No casualties or fires
11th Dec 40 19:50hrs	2 x HE bombs	Court Av, Harold Park (1km south-west).	Extensive damage to David Av, Colchester Rd and Court Av.
12th Jan 41 21:30hrs	1 x HE bomb	Maylands Golf Course (on *Site* or within 700m, to the west).	Two cottages badly damaged. No casualties.
20th Apr 41 04:10hrs	2 x PMs	Poplar's Farm, Brook Street (>100m south-east).	None.
30th July 44 01:00hrs	V1 Bomb	Nags Head Lane, Brook Street (>500m east).	Damage to LNER line and telephone wires.

All the reported bombing incidents resulted in small numbers of bombs dropped. It can therefore be safely assumed that these were Tip and Run incidents. Most of the aircraft had likely already dropped part of their bombloads elsewhere.

5.3.4 Anecdotal Evidence

A search of online resources was carried out with the intention of locating any anecdotal / eye witness accounts of local bombing incidents. Two references[1] to an additional bombing

1 *www.ukairfieldguide.net/airfields/Maylands and www.nwamuseum.co.uk/WEST%20ESSEX%20AIRFIELDS.pdf*

incident in the vicinity was located:

'It seems that all their aircraft were destroyed by an incendiary bomb dropped on the 6th February 1940. This incident seems to have closed the airfield and amongst the casualties was Miss Jean Battens D.H.60M Moth G-AARB'.

'The majority of the buildings were supposed to have been finally destroyed by fire when German bombs were dropped on February 6, 1940. Many sources pour scorn on this explanation for the subsequent losses in aircraft and hangers, but in the absence of proven alternatives, the losses remain ascribed to enemy action'.

However, this alleged bombing incident is discredited by its date of occurrence. The first German bombs dropped on the wider region occurred towards the end of May 1940. The Luftwaffe were only engaged in supporting the land battles on the continent during February 1940.

5.3.5 Abandoned Bombs Register

Evidence of suspected UXB strikes was reported to an ARP warden who in turn reported its location to the local BDU. Occasionally, a combination of factors meant that the BDU had to simply record its location on an Abandoned Bomb Register and leave it buried in situ. The reasons for abandoning a UXB could be; a relatively safe location / position, access problems or a likely extreme depth of burial. Furthermore, BDUs in the most heavily bombed areas were constantly overstretched during WWII and therefore had limited resources available.

The Archive Office of the British Army's 33rd Engineer EOD Regiment holds an Abandoned Bomb Register for Britain, a copy of which *BSI* has obtained. Considering the inaccuracy of WWII records the locations included in this register cannot be considered definitive, nor the list exhaustive and some of these Abandoned Bombs are known to have been since recovered or discounted. The Department of Communities & Local Government also holds an Abandoned Bomb Register for the UK. No Abandoned Bombs are noted either on or in close proximity to *The Site*.

5.4 LIKELIHOOD OF UXB CONTAMINATION

Several factors govern the likelihood of a UXB actually striking a specific site during WWII. In parts of the UK where detailed bombing records exist it is possible to accurately predict whether any UXBs could have actually contaminated the area of the proposed works. These factors are discussed in the following table:

Density of Bombing	
Number of Air Raids in the Vicinity:	13 confirmed raids affecting an area within 1km of *The Site*. However, only two of these likely resulted in bomb strikes within 500m of *The Site* boundary.
Intensity of these Air Raids:	Small scale raids, all executed by solitary bombers.
Bomb Strike Positions	
Distance between recorded Bomb Strikes and *The Site*:	Unknown. One HE bomb could have struck the north-west part of *The Site* (on the golf course).
Alignment of recorded Bomb Strikes:	None of the written records include the level of detail required for this analysis. NB: one of the two closest air raids resulted in two parachute mine strikes. During April 1941, the Luftwaffe bomber with the largest bombload could carry a maximum of two parachute mines. Consequently, this incident could not have resulted in any UXB strike on *Site*.
Bomb Failure Rate	
Evidence to suggest that the generally accepted failure rate of 10% differs in the vicinity of *The Site*:	No evidence
UXBs recorded in close proximity to *The Site*:	No evidence

5.5 LIKELIHOOD OF SUBSEQUENT UXB DETECTION

Many factors govern the likelihood of a UXB strike being observed either during its occurrence or subsequently. These are discussed in the following table. NB: it should be noted that assessing the precise conditions that existed on a site >70 years ago can be problematic, especially in urban environments where the number of variables is great.

Historic Site Access
A UXB falling on a site which was frequently accessed would have had a greater chance of being observed during its descent or subsequently. In frequently bombed residential areas, ARP Wardens carried out post-raid searches for UXBs. The importance of a site or facility is an important consideration. Many factories, gas works, power stations, docks, etc had teams of Fire Watchers tasked with extinguishing 1kg IBs and reporting UXBs.
The vast majority of *The Site* was rural and uninhabited during WWII. This increases the likelihood of any German UXB fall occurring unobserved. Especially considering that 12 of the 13 local bombing incidents occurred during the hours of darkness. The area occupied by Grove Farm, Putnell Farm and the main road in the south would have seen some access and any daytime raids in the vicinity are more likely to have been observed, with any resulting bomb strikes subsequently investigated. NB: Maylands Aerodrome is understood to have been abandoned during the war. Some of the fields on *Site* may have been agricultural and therefore would have seen some access, however only infrequently, being neglected for long periods.

Bomb Damage
A type of WWII specific ground cover, substantial bomb damage to a site will have resulted in conditions that would make the identification of a subsequent UXB strike extremely difficult. A HE bomb striking soft ground will have thrown up a large quantity of soil, as well as producing a crater. If this ground disturbance was not immediately repaired, any subsequent UXB strike could have been overlooked.
No credible evidence of bomb craters or bomb damaged buildings on *Site* was found.

Ground Cover Type
The type of ground cover at a site during WWII is significant as differing types will have had differing effects on the visual evidence of a UXB entry hole. Evidence of a UXB strike to manmade structures and hard-standing will have been long lasting and easily identifiable. A UXB strike to dense vegetation or very soft ground (marshland) could have easily been overlooked. In the extreme, a UXB landing in a body of water would have been immediately obscured from view and is highly unlikely to have been accurately reported and therefore recovered.
A UXB entry hole within unmaintained pasture, dense crop growth, grassland or woodland could have easily been overlooked. NB: the diameter of the smallest German HE bomb (which was also the most commonly deployed over Britain) was 200mm; creating a small, easily obscured UXB entry hole. After a time, environmental conditions could cause such a hole to close up / become in-filled, erasing evidence of the UXB. A UXB strike to undamaged buildings or hardstanding on *Site* would have caused incontrovertible damage or a clean, easily recognisable entry hole which would have been reported and dealt with at the time.

5.6 BOMBING DURING WWI

During 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 IBs 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.

A review of written reports of bombing incidents within the wider area has not identified any incidents in the vicinity. The closest bomb strikes likely occurred >5km to the south of *The Site*. At approximately 23:40hrs on the 23rd September 1916, Zeppelin L.33 dropped 6 x HE bombs on South Hornchurch. Consequently, the risk associated with WWI UXBs is considered negligible.

5.7 WWII GERMAN MUNITIONS

5.7.1 Bombs Dropped on the UK

The Luftwaffe deployed a wide variety of ordnance against the UK during WWII. The design and specific usage of the various air-delivered munitions differs greatly. Some bombs achieved significant ground penetration and are therefore more likely to remain buried in the ground today. The design of each weapon allows an informed assessment of the hazards posed by a UXB. Data sheets on those bombs most likely to be encountered today are included at ***APPENDIX 2***. Descriptions of the various families of bombs are presented below:

NB: the Italian Air Force's CAI participated in air raids against targets in Essex and Kent during the Battle of Britain in 1940. However, the CAI was a small force, dropping a fraction of the ordnance that the Luftwaffe deployed.

- ***HE Bombs*** - ***Moderate charge / weight ratio:*** The most common type of HE bombs dropped were the SC (general purpose) and SD (semi-armour piercing) series of bombs. The charge / weight ratios were between 30% and 50% allowing for penetration through multiple floors / basements of buildings and fragmentation of the thick steel shell to create an AP shrapnel hazard. The most common weights were 50kg, 250kg and 500kg. Although six additional models between 1,000kg and 2,500kg were also deployed, ~70% of HE bombs dropped on the UK were of the 50kg type.
- ***HE Bombs*** - ***High charge / weight ratio:*** Blast Bombs, Parachute Mines or Land Mines had thin steel walls allowing for larger HE charges which detonated above ground, producing a far greater blast effect than general purpose bombs. These large weapons were parachute retarded with a ~40 mph rate of descent resulting in very limited or no ground penetration, depending on the ground cover. Therefore, it is highly unlikely that any unexploded blast bombs remain buried underground in the UK today.
- ***HE Bombs*** - ***Low charge / weight ratio:*** The PC series of bombs (500kg and 1,000kg) were armour piercing bombs used against heavily fortified defences and deep buried, reinforced bunkers, as such they were not commonly used over the UK. Charge / weight ratios were approximately 15%.
- ***Small Incendiary Bombs*** - ***sub-munitions:*** The B1E (1kg) and B2E (2kg) series of sub-munitions were the most commonly dropped bomb of all types. Up to 620 x 1kg incendiaries could be packed into the largest 'AB' series cluster bomb canisters, which opened at a pre-determined height scattering the incendiaries over a wide area. These small bombs could fully penetrate soft ground due to their small diameter. The longer 2kg model incorporated an additional HE hazard, in the form of a small anti-tampering charge with a delay fuse. Over 100,000 were dropped on London alone during the Blitz.
- ***Large Incendiary Bombs - Thick skinned:*** The Brand C50 A had a thick steel body similar to an SC 50 but contained a mixture of incendiary liquids and Phosphorus. The C50 B was the same size but incorporated mostly White Phosphorus as its fill. The Sprengbrand C50 Firepot bomb also had an SC 50 shell but contained both Thermite incendiary containers (Firepots) and a small HE charge.

- ***Large Incendiary Bombs - Thin skinned:*** The Flam 250 and Flam 500 (Oil bomb) models had thin steel bodies enabling them to break up on impact and spread their oil incendiary mixture across the ground. As such they are unlikely to remain buried today. Furthermore, their unreliability resulted in them being withdrawn from frontline use by January 1941.
- ***Anti-Personnel (AP) Bombs***: The SD2 'Butterfly' bomb was a 2kg sub-munition dropped on several British cities and towns. It contained 225grams of Amatol however, had no ground penetration ability and therefore any unexploded SD2s would have been recovered during WWII, unless they fell into water.
- ***V1 Flying Bombs and V2 Long Range Rockets:*** In the final year of WWII Germany began using pilotless weapons against England, launched from sites in occupied Europe. Both V Weapons had 1,000kg HE warheads however, were thin-skinned constructions and therefore any that failed to detonate would have broken up on impact, resulting in a large debris field of incontrovertible evidence. As such, there is no risk from unexploded V Weapons today. Thousands landed in south-east England causing widespread damage in London especially.

5.7.2 Bomb Failures

Original War Office statistics record a daily average of 84 large German UXBs (not including 1kg and 2kg sub-munitions) dropped on civilian targets throughout Britain between 21st September 1940 and 5th July 1941. 1 in 12 of these were Delayed Action (time delay fuses) bombs and therefore exploded sometime later, with the remainder being unintentional UXBs.

By the end of WWII empirical evidence indicated a (generally accepted) 10% failure rate for German HE bombs dropped on the UK as whole. However, it should be noted that this estimate is based on BDU figures collected during the war and therefore will not have taken account of the unknown numbers of UXBs that went unreported, i.e the German UXBs that are found every year by the construction industry. UXBs occur for one of the following four reasons:

- Failure of the aircraft's crew to properly arm the bombs (charging the electrical condensers) due to human error or equipment defect.

- Failure of the clockwork mechanism in the fuses of Delayed Action bombs.
- Jettisoning the bomb from a very low altitude. Most likely if the bomber was under attack or crashing.
- Fuse malfunction due to a fault during the manufacturing process. This could be the result of accidental faulty installation or sabotage by POWs put to work in German factories.

5.8 WWII UXB GROUND PENETRATION

5.8.1 Introduction

During WWII the Research & Experiments Department of the Ministry of Home Security was tasked with analysing the varying penetration depths achieved by the Luftwaffe's HE bombs. The Army's Bomb Disposal Headquarters provided details of 1,304 UXB clearance tasks carried out on bombs which had penetrated undeveloped land (soil). In addition, the Research & Experiments Department carried out their own tests; 24 bombs were dropped into Chalk, under controlled conditions.

Records held at the National Archive include the results of this analysis. Once a pattern was ascertained from the 1,304 datasets, each bomb weight was amplified to produce a table of anticipated bomb penetration depths (below), including both average maximums and probable maximums.

Bomb weight (kg)	SANDSTONE		SAND		GRAVEL		CHALK		CLAY	
	Average (m)	Max (m)	Average (m)	Max (m)	Average (m)	Max (m)	Average (m)	Max (m)	Average (m)	Max (m)
50	2.7	6.0	2.8	7.8	2.8	7.8	3.5	7.7	4.0	9.1
250	4.6	10.3	4.8	13.7	4.8	13.7	6.0	13.1	6.8	15.8
500	5.8	13.1	6.0	17.3	6.0	17.3	7.6	16.4	8.7	19.8
1,000	7.3	16.4	7.6	21.9	7.6	21.9	9.6	20.7	10.9	24.9

As the 1,304 datasets involved broadly homogenous geologies, the penetration depths given above are likely to be different for situations where a bomb firstly penetrates through superficial deposits or made ground and then through bedrock, as would be the case for many locations in the UK which were bombed. Furthermore, some locations in the UK are underlain by geology not included in the table above and therefore informed calculations of bomb

penetration cannot be made.

In both cases, the above WWII-era data should be coupled with knowledge of the strength of various rock types to make inferences on likely maximum bomb penetration depths. To calculate a maximum bomb penetration depth for a specific site, one must use a number of assumptions based on the most likely WWII German bombing scenario:

- ***UXB Impact Velocity:*** The majority of German HE bombs dropped over the UK resulted from mass carpet bombing raids. These attacks were carried out at altitudes in excess of 5,000m which would have resulted in a 500kg HE UXB impacting the ground at an approximate velocity of 260m/s.
- ***UXB Impact Angle:*** Luftwaffe high altitude bombing resulted in 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 limit ground penetration. It must be assumed that no such retarder units were fitted to the bomb.

5.8.2 The 'J-Curve' Effect

During WWII, BDUs reported that most deep buried German HE UXBs were found to be in a horizontal or up-turned orientation. This observation confirmed the presence of the J-Curve Effect. As a HE bomb penetrates the ground, slightly offset from the vertical, its trajectory through the underlying geology curves towards the surface.

This phenomenon can be significant to a risk assessment as the J-Curve Effect results in a horizontal offset from the point of UXB entry. This is typically a distance of about one third of the bomb's penetration depth. In the extreme, a low altitude attack resulting in a low angle UXB strike could produce even greater horizontal offset, up to 15m.

5.8.1 Site Specific Geology

WWII-era Site Geology		
British Geological Survey (BGS) 1:50,000 scale Mapping:	***Superficial Deposits:*** Alluvium and Head (Clay, Silt, Sand and Gravel) associated with Weald Brook.	***Bedrock:*** London Clay Formation (Clay, Silt and Sand).
Previous SI Data:	No recent SI data was provided by *The Client*. However, BGS logs of *The Site* were reviewed. Below is a general summary of the encountered ground conditions on *Site*: Through the mapped superficial Head deposit: <0.5m of Topsoil 1.0m of stiff sandy silty CLAY with fine gravel 0.4 of stiff sandy silty CLAY with 'ghosts' of decomposed chalk 3.5m of firm to soft to firm fissured CLAY 4.0m of stiff slightly silty CLAY Through the mapped bedrock only: <0.5m of Topsoil 2.7m of firm to stiff slightly sandy silty CLAY 3.6m of stiff to firm slightly silty CLAY 3.7m of stiff silty CLAY	

5.8.2 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 Maximum Bomb Penetration Depth assessment.

The variation in shallow geology on *Site* makes calculating an accurate maximum bomb penetration depth difficult. NB: the empirical 1940s evidence appears to record UXBs travelling through geology of only one type. Each lithology will have had a differing decelerating effect on a HE UXB, both individually and in combination, thereby complicating the estimation of burial depth.

Taking into account the above-mentioned factors, it has been assessed that a 500kg HE bomb would have had a maximum bomb penetration depth of ***10-12m*** below WWII ground level and the average depth of HE UXBs would be approximately ***6m*** below WWII ground level.

NB: Theoretically penetration depths could be greater if the UXB was larger, however, 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%.

6 UXO RISK - BRITISH / ALLIED MILITARY ACTIVITY

6.1 SOURCES OF UXO

The table below lists all the modern and historical facilities and activities that could have potentially resulted in localised British / Allied UXO contamination in the UK. Those which are relevant to *The Site* have been discussed in the subsequent section(s).

POTENTIAL UXO SOURCE	DOES THE SOURCE HAVE THE POTENTIAL TO AFFECT THE SITE IN QUESTION?
Existing or historic Army or RAF Training Areas / Ranges	✗
Existing or historic Military Bases and Other Installations	✗
Existing or historic Munitions or Explosives Factories	✗
Existing or historic Military Storage Depots	✗
Existing or historic Military Defensive Fortifications	✗
Sites requisitioned by the military during conflict	✗
WWII Pipe Mined Locations and Beach Minefields	✗
WWII Light and / or Heavy Anti-Aircraft Fire	✓
WWII Home Guard activity	✓

6.2 INTRODUCTION

Research for this assessment has not located any evidence of British or Allied army military activity specifically within *The Site* boundary. The only significant potential sources of UXO contamination on *Site* (AA fire and Home Guard activity) are described under the headings below.

The RAF did not requisition Maylands Aerodrome for military use during WWII. Romford and

Burntwood were both designated Category 'A' Nodal Points within the War Office's anti-invasion strategy, during WWII. As a result, they were fortified and well defended. Although there is evidence of WWII fortifications in the wider area (the closest being >900m to the east), it is considered unlikely that the defence perimeters of these towns passed though *The Site*.

During WWII, Weald Country Park (1km to the east / north-east) was requisitioned by the army and used for various training activities. This represents the closest examples of a military training area (likely including weapons ranges).

6.3 WWII ANTI-AIRCRAFT BATTERIES

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 some 7,000 UX 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***.

1. ***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.

2. ***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.

3. ***Z (Rocket) Batteries*** - A Z-Battery comprised a grid formation of 64 rocket projectors which fired 2" and later 3" Unrotating 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 nose first, AA shells and rockets were not designed to hit the ground and therefore unexploded AA munitions do not necessarily land nose first. This coupled with the lower mass of AA UXO resulted in shallower ground penetration depths. Although, in very soft conditions, unexploded WWII AA munitions were observed to penetrate to >1.5m bgl.

18 HAA batteries were constructed within a 15km radius of *The Site* during WWII. No evidence of LAA gun positions within range of *The Site* was found. The Luftwaffe were frequently active in the region and therefore these guns would have expended a large quantity of ammunition over the wider area. Any unexploded AA shell landing in the soft ground on *Site* could have become shallow buried and remained there undetected.

6.4 WWII HOME GUARD ACTIVITY

The Home Guard, originally the Local Defence Volunteers, was formed in the summer of 1940. It was a volunteer force comprising men who were either too young, too old, or in reserved occupations (those jobs vital to the war effort). Battalions were established in most urban areas and some large organisations (such as railway networks) created their own platoons.

Their main purpose was to bolster regular Army units in the event of German invasion. By the end of June 1940, over one million had signed up. Initially, only shotguns, old hunting rifles, bayonets, knives and an array of improvised weapons were available, however by mid WWII, conventional weapons were available and some were even designed specifically for the Home Guard; such as SIP grenades (Molotov Cocktails) and the Northover anti-tank Projector. Furthermore, ammunition in very short supply during 1940 became more readily available.

Home Guard units had a variety of responsibilities; road patrols, manning Observation Posts at commanding points, reporting on enemy airborne landings, delaying the enemy at specified road-blocks, and organising mobile fighting patrols to harry the enemy.

The 5th Essex (Brentwood) Battalion comprised several Companies one of which would have been responsible for the study area. A search of Home Guard records (held at the local archive) did not identify any documents referencing the battalion's training areas or any other activity in the vicinity of *The Site*.

Although no specific evidence of Home Guard activity on *Site* has been identified, it is known that the Home Guard often carried out manoeuvres in open ground on the outskirts of urban areas and sometimes within close proximity to civilian life. Official records of day to day activity were rarely kept by the Home Guard and therefore any present-day evidence of their activities is usually only anecdotal.

The parts of *The Site* in use for agriculture during WWII are unlikely to have been requisitioned for Home Guard training. However, the woodland on *Site* would have provided a good environment for training and therefore could conceivably have been utilised during local defence exercises. Although, local Home Guard troops likely utilised Weald Country Park for training. Even if this didn't occur, it is quite possible that armed Home Guard soldiers accessed *The Site* whilst on patrol.

Recent WWII land service and small arms ammunition finds in England indicate an ill disciplined 'out of sight out of mind' culture in the army during WWII. It would appear that faulty or partially spent ammunition was sometimes simply discarded in seemingly random locations, becoming buried over time. Similarly, there are many examples of surplus (boxed)

ammunition simply buried as a hassle-free means of disposal, likely when the Home Guard was disbanded in 1944. Such a scenario on *Site* can therefore not be completely discounted.

6.5 LAND SERVICE AMMUNITION (LSA)

6.5.1 General

Land Service Ammunition (LSA) is a broad military term relating to a wide variety of weapons primarily deployed for land use. NB: Similar weapons (particularly artillery guns) were also deployed on naval platforms historically. LSA encompasses those types of ammunition that can be placed, thrown or propelled and as such is broken down into five main munitions families; Grenades, mortar bombs, artillery projectiles, anti-tank rockets and landmines.

The former three (detailed below) were produced / deployed in the greatest numbers historically and therefore are more likely to be encountered on UK sites today.

Anti-tank rockets were portable infantry weapons, however saw only limited service in the latter years of WWII. As such, the US made Bazooka and British made PIAT were deployed in relatively small numbers.

Landmines (both anti-personnel and anti-tank) were used by the British Army to fortify English beaches against an anticipated German invasion during WWII. However, as expected, each minefield was well documented and subsequently cleared during the 1940s.

Like German UXBs, LSA does not lose its effectiveness with age. Decades of burial can cause ammunition to become less stable and more sensitive. The potentially fragile state of expended, yet unexploded LSA, coupled with the relatively shallow burial state of such items, makes for a particularly hazardous scenario as LSA is more likely to be encountered and tampered with by unqualified personnel.

Data sheets on the most likely types to be encountered today and / or the most hazardous are included at ***APPENDIX 4***.

6.5.2 Grenades

A grenade is a short-range infantry weapon, essentially a small bomb, typically thrown by hand

or launched from rifles or dedicated grenade launchers. A wide variety of grenades have been deployed in the UK historically, the most common being explosive (fragmentation or blast / concussion) grenades designed to detonate after impact or after a set amount of time.

They are divided into two categories; HE and Carrier (chiefly smoke for signalling and white phosphorus). Grenades were designed for both anti-personnel and anti-tank roles.

The Mills Bomb was the first modern fragmentation grenade produced for the British Army, and was used in the WWI trenches from 1915. Updated Mills models were the mainstay of the Army throughout WWII and into the post-war period.

The striker of a Grenade (found buried on site today) may either be in contact with the detonator or still be retained by a spring under tension. As a result, any shock or vibration may cause it to function.

One primitive incendiary grenade produced in vast number during WWII was the SIP grenade. Unlike most grenades, these had no explosive element, relying instead on a chemical reaction between phosphorus and air to produce an intense incendiary effect and resulting burns hazard.

6.5.3 Mortars

A mortar is a simple infantry weapon that fires a projectile (mortar bomb) in a high-arcing ballistic trajectory, at low velocity, to a relatively short range. It is a compact, easily transportable weapons system used by British and Allied armies since WWI, when the British Stokes Trench Mortar became the first truly portable infantry mortar.

During WWII British mortars had a rate of fire of 30 bombs per minute with ranges in excess of 2km. The 2” and 3” mortars were the most common types used by the British Army.

Ammunition for mortars generally comes in two main varieties: fin-stabilized and spin-stabilized. Examples of the former have short fins on their posterior portion, which control the path of the bomb in flight. Spin-stabilized mortar bombs rotate as they travel along and leave the mortar tube, which stabilizes them in much the same way as a rifle bullet. Both types of bomb come in a variety of types; high explosive, smoke, parachute illumination, inert practice.

The mortar bomb is almost always nose fused with the tail piece comprising a ‘spigot tube’ (housing the propellant charge) screwed or welded to the rear end of the main body. A mortar relies on a striker hitting a detonator for explosion to occur. Like grenades, the striker of an expended but unexploded mortar bomb may now be in a very fragile state, after decades exposed to environmental conditions.

6.5.4 Artillery Projectiles

Anti-tank guns and Howitzers have been in use with the British Army for over a hundred years. The former ranged from the Ordnance QF 2 Pounder (40mm) to the Ordnance QF 17 Pounder (76mm) in calibre. The latter ranged from the Ordnance QF 25 Pounder (87.6mm) to the BL 60 Pounder (127mm).

A wide variety of artillery projectiles have been deployed in the UK historically, by British and Allied Armies. In general, projectiles fall into two categories; Shot and Shell. The former are inert; solid metal projectiles containing no hazardous element, whereas the latter are hollow (like bombs), containing a variety of potentially hazardous fills.

Solid shot falls into four categories, mainly for gun proofing and target practice, however as they are inert they are relatively irrelevant with regards to present day UXO risk. Historically, there were three types of WWII-era British artillery shell:

- ***Bursting Type*** - The filling (or part of it) caused the shell to burst. The most common filling was HE where the shell caused damage to material by the force of the burst or to personnel and aircraft by fragmentation of the shell casing producing shrapnel. NB: bursting shells were also used with chemical fillings.
- ***Shrapnel Type*** - These usually burst in the air and projected their 'payload' forwards acting like a shotgun. The usual payload was shrapnel bullets however Thermite 'pots' were used during WWI. By the start of WWII shrapnel shells were obsolete for field artillery.
- ***Carrier Type*** - These also burst in the air, however ejected their payload backwards after blowing the base plate off the shell. The most common fills used were smoke, star and flare shells. The latter two being designed to illuminate an area or target. Smoke shells

were used to produce smoke screens and used various fillings (the common being white Phosphorus).

Artillery projectiles were always painted, this protected the steel from rust but was also used to indicate the nature of the ammunition. The basic body colours for artillery were; Yellow (HE), Light Green (smoke), Black (Flare / Star) and Grey (chemical).

Most artillery shells have a similar appearance and therefore the 3.7" AA shell shown in *Appendix 3* is a good example of a WWII-era artillery projectile.

NB: artillery shell fuses found on their own do not represent a significant hazard. A fuse from an unspent shell will only contain a very small quantity of gunpowder in the detonator.

6.6 20MM AUTOCANNON AMMUNITION

During WWII, a number of RAF and USAAF fighters were fitted with 20mm autocannons; manufactured by the Swiss company Oerlikon and the French company Hispano-Suiza. These weapons were also used by UK based Army and Navy units in the LAA role. An autocannon is essentially a larger calibre machine gun utilising fused (not solid shot) ammunition.

Although cannon ammunition looks very similar to SAA, some projectiles incorporate a small, simple impact fuse and an approximately 4gram HE and / or incendiary fill. Although small, when compared with artillery shells, each bursting charge still has the potential to cause serious injury.

During WWII, Hispano-Suiza and Oerlikon produced a variety of 20mm ammunition types; High Explosive, High Explosive Incendiary, Armour-Piercing, Armour Piercing Incendiary, Target Practice (inert), Target Practice Tracer (inert). Each type was distinguished by the painted colour of the projectile head and colours varied between the two manufactures.

On some projectiles, the tracer became a self-destruct mechanism, detonating the bullet if no impact occurred after five seconds. This resulted in the potential for less collateral damage and far less unexploded 20mm rounds falling back to earth.

A data sheet on 20mm ammunition is included at ***APPENDIX 5***.

6.7 SMALL ARMS AMMUNITION (SAA)

Small arms ammunition is primarily cartridge-based, solid shot ammunition with a calibre <20mm. It covers ammunition used for side arms, rifles and light to heavy machine guns. Each 'round' of ammunition comprises a cartridge case, solid shot projectile (bullet), propellant and primer.

The most common types of SAA to be encountered in the UK are 0.303" calibre (the standard British and Commonwealth military cartridge from 1889 until the 1950s), 0.30" calibre (the standard American cartridge used during WWII) and 0.5" calibre (used by machine guns deployed on USAAF bombers based in Britain during WWII).

As solid shot, spent SAA rounds do not pose a hazard. Unspent rounds comprise a small propellant charge within the cartridge, however SAA is generally stable and relatively safe to handle. NB: Unspent rounds can function if subjected to high heat, such as fire. Any detonation however would not be contained within a barrel and would only result in local, minor overpressure.

7 UXO RISK MITIGATING CIRCUMSTANCES

7.1 INTRODUCTION

Subsequent works on a UXO contaminated site could have resulted in the partial or complete removal of this UXO risk. Various construction works or earthworks could have uncovered UXO which would then have been reported and removed by the authorities. Alternatively, a site may have been subject to a military Explosive Ordnance Clearance (EOC) task, involving surveying, subsequent target investigation and removal.

7.2 EXPLOSIVE ORDNANCE CLEARANCE TASKS

The British Army, RAF and Royal Navy all have EOD units that are responsible for carrying out UXO clearance on their own bases and training areas. UXO found on civilian land is dealt with by whichever EOD unit is local and available.

BSI has access to a database of historic EOC tasks carried out by the British Army's Royal

Engineer EOD unit; the 29th Regiment. NB: 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*. The closest tasks occurred in Weald Country Park where hundreds of items of expended and live UXO were recovered from the lake in the 1980s.

UXO encounters on civilian land are often reported in the media and therefore a web search of local media outlets was also carried out. No evidence of recent UXO finds on *Site* was found.

7.3 GROUND WORKS

No post-war development has occurred at the locations of the proposed works. Aside from the construction of the A12, the M25 and their junction, the only ground disturbance on *Site* is likely to be associated with the Grove Farm scrap yard and two electricity pylons, which required the partial clearance of woodland. No evidence of substantial post-war earthworks on *Site* was found, however a small former landfill site likely existed at Grove Farm.

7.4 DEDUCTIONS

The greenfield nature of the vast majority of *The Site* indicates that any buried UXO is likely to remain in-situ. Only within the recently disturbed parts of Grove Farm and within part of Alder Wood, will the risk of shallow buried UXO have been partly mitigated.

8 CONCLUSION

8.1 ACCURACY OF THE HISTORICAL RECORDS

Occasionally, the accuracy of some historical records can be proven to be poor, when compared with other records. One significant consequence of this can be the possibility of unrecorded German bomb strikes in the vicinity of a study area. A review of the records gathered for this assessment has not highlighted any significant inconsistencies.

8.2 THE RISK OF UXO CONTAMINATION ON SITE

8.2.1 Key Findings - German UXO Risk

- *The Site* was located within an insignificant rural area during WWII, with no confirmed or potential bombing targets in the vicinity. A review of original wartime bombing figures and reports indicates that the wider study area experienced a low to moderate bombing density. No medium or large-scale raids affected *The Site*, with all local bomb strikes resulting from Tip and Run incidents involving solitary aircraft.
- An aerial photograph of the study area, taken just after WWII, does not exhibit any evidence of HE bomb craters or in-filled craters in the vicinity.
- A complete collection of original bombing incident reports for the wider area (held at local archive level) was reviewed. Two bombing incidents appear to have occurred within 500m of *The Site* boundary.
- One of these resulted in two parachute mine strikes. During April 1941, the Luftwaffe bomber with the largest bombload could carry a maximum of two parachute mine. Consequently, this incident could not have resulted in any UXB strike on *Site*. The second incident resulted in one HE bomb strike to the exiting golf course that encroaches into the northern part of *The Site*.
- The vast majority of *The Site* was uninhabited, increasing the likelihood of a UXB from the same aircraft falling on *Site* unobserved. This is further heightened by the fact that this and most of the other local raids occurred during the hours of darkness.
- The records did not contain the detail necessary to establish the precise flight path of the aircraft and therefore, it is possible that the bomber flew over *The Site* and dropped a UXB. However, the large size of the golf course means it is equally possible that the aircraft did not pass over *The Site*.
- The vast majority of *The Site* was occupied by open fields or woodland which would have been neglected for long periods and any UXB entry hole could conceivably have remained undetected here. NB: the diameter of the smallest German HE bomb (which was also the most commonly deployed over Britain) was 200mm; creating a small, easily obscured UXB entry hole. However, as only one potentially significant enemy aircraft sortie has been identified in the vicinity, such a scenario is considered to be a remote possibility.

8.2.2 Key Findings - British UXO Risk

- 18 permanent HAA batteries were within range of *The Site* during WWII. The Luftwaffe were frequently active in the region and therefore these guns would have expended a large quantity of ammunition during WWII. For the same reasons as above, any unexploded AA shell landing in vegetation on *Site* could have become buried and gone unnoticed.
- Although no specific evidence of WWII Home Guard activity on *Site* has been located, the possibility cannot be discounted that the unused open ground and woodland on *Site* was requisitioned temporarily. Alternatively, armed Home Guard soldiers could conceivably have accessed *The Site* whilst on patrol. Any such activity on *Site* would raise the risk of associated UXO contamination; chiefly the common practice of unauthorised disposal (burial) of surplus ammunition.

8.3 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)	Likely deep burial (>3m)	HIGH RISK
WWII British Heavy Anti-Aircraft Shells	1.1kg - 1.7kg	Shallow burial (<1.5m)	MODERATE-HIGH RISK
WWII British Land Service Ammunition	<2kg	Shallow burial (<1.5m)	
WWII German 2kg Incendiary / HE Bombs	680g incendiary hazard + ~500g explosive hazard	Shallow burial (<1.5m)	
WWII German 1kg IBs	680g (incendiary, not explosive hazard)	Shallow burial (<1.5m)	MODERATE RISK
WWII British Light Anti-Aircraft Shells	4g - 70g	Very shallow burial (<1m)	LOW-MODERATE RISK

8.4 THE LIKELIHOOD OF UXO ENCOUNTER

8.4.1 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. Naturally, the greater the number, volume and depth of intrusions, the greater the likelihood of UXO being encountered, assuming UXO resides on site.

Within an area of elevated UXO contamination risk (delineated at ground level), 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.

8.4.2 German UXBs

Although most German HE 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 interception and / 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 HE bomb nosecones meant they were susceptible to deflection when striking surface or shallow sub-surface obstacles, occasionally resulting in shallow burial or even UXBs skidding across hard-standing, roads, etc.
- ***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 tailfins, which meant they landed nose first, which in soft ground could result in full penetration of the bomb below the surface. Therefore, such items are usually found close to the surface.

8.4.3 British / Allied UXO

The nature of British / Allied military activity involving LSA / 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, unless any post contamination fill material has raised the ground level, effectively burying the UXO even deeper.

Domestic military LSA and SAA contamination will either be the result of expending dud ammunition (shells) 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.

8.4.4 Deductions

The likelihood of UXO contamination of *The Site* is neither high nor moderate, however the possibility that an unexploded AA shell or German UXB struck *The Site*, or that Home Guard ammunition was discarded on *Site*, cannot be ruled out entirely. There is a very slightly elevated likelihood of such UXO remaining up to the present day within the locations of the proposed ground works. The type of UXO coupled with the historic ground cover means that

the area of potential UXO contamination cannot be subdivided into areas of lower or higher risk. Consequently, all the proposed ground works will be exposed to a UXO encounter, albeit not a high or even moderate exposure risk.

8.5 OVERALL RISK RATING

Ratings for the likelihood of UXO contaminating *The Site*, remaining on *Site* up to the present day and being encountered during the proposed works, inform the overall risk rating. The UXO risk to the proposed works on *Site* has been assessed as **Low to Moderate**:

RISK TABLE: LOW RISK TO MODERATE				
UXO TYPE (ASSOCIATED HAZARD)	LIKELIHOOD OF UXO CONTAMINATION	LIKELIHOOD OF UXO REMAINING	LIKELIHOOD OF ENCOUNTER	OVERALL RISK RATING
WWII German General Purpose HE Bombs	LOW-MODERATE	HIGH	LOW	LOW RISK
WWII British Heavy Anti-Aircraft Shells	MODERATE	MODERATE	LOW	
WWII British Land Service Ammunition	LOW-MODERATE	MODERATE	LOW-MODERATE	LOW-MODERATE RISK
WWII German 2kg Incendiary / HE Bombs	LOW	LOW	LOW	LOW RISK
WWII German 1kg Incendiary Bombs	LOW	LOW	LOW	
WWII British Light Anti-Aircraft Shells	LOW	LOW	LOW	

9 RISK MITIGATION RECOMMENDATIONS

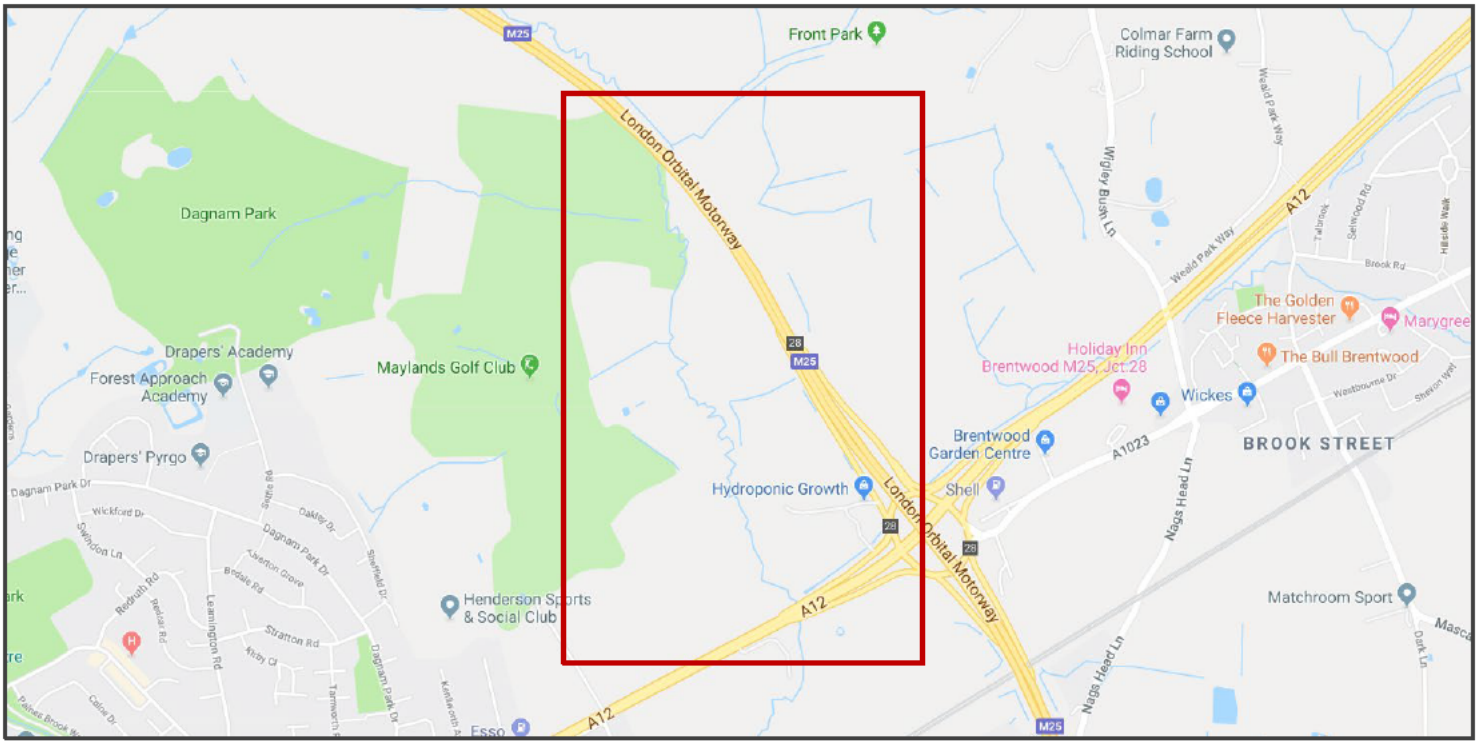
BSI concludes that a British (shallow buried) UXO encounter cannot be ruled out during the proposed works and therefore a Low-Moderate UXO risk exists. It is therefore recommended that the minimum risk mitigation measure be put in place prior to works commencing:

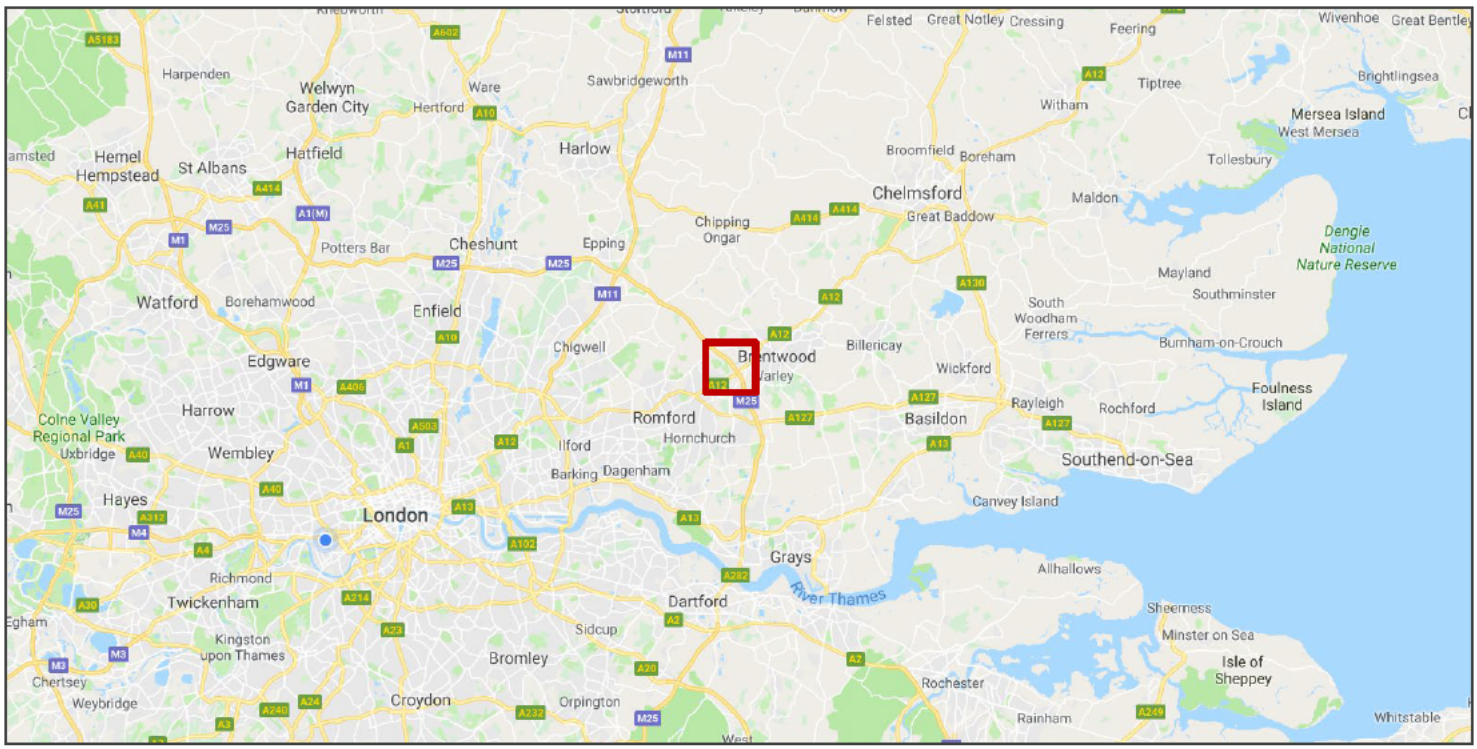
Risk Mitigation Measure	Recommended For?
UXO Safety Awareness Briefings: To all personnel conducting intrusive works on site. An essential part of the Health & Safety Plan for a site. Conforms to the requirements of CDM2015.	Ahead of all intrusive works

FIGURES: 1 - 4

BRIMSTONE
SITE INVESTIGATION
1-3 Manor Road, Chatham,
Kent, ME4 6AE
+44 (0) 207 117 2492
www.brimstoneuxo.com
enquire@brimstoneuxo.com

Title:	SITE LOCATION MAPS	FIGURE: 1





N	Project	M25 Junction 28, Romford
	Client:	Geotechnical Engineering Ltd
	Report Ref:	DRA-19-1106
	General Site Location	Info Source: Google (open-source)

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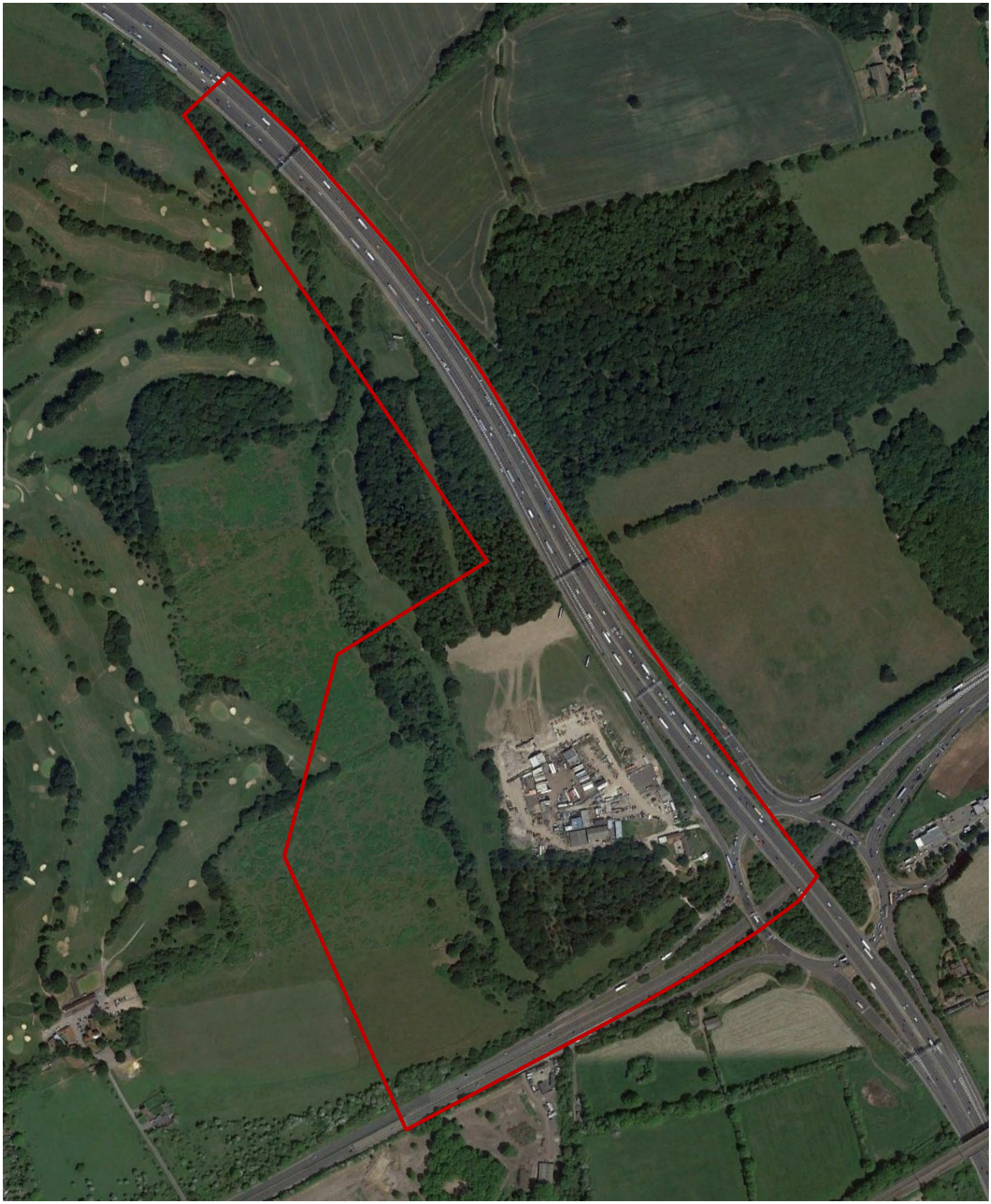
Title:	RECENT AERIAL PHOTOGRAPH	FIGURE: 2



N

Project	M25 Junction 28, Romford
Client:	Geotechnical Engineering Ltd
Report Ref:	DRA-19-1106
Approx. Site Boundary	Info Source: Google (open-source)

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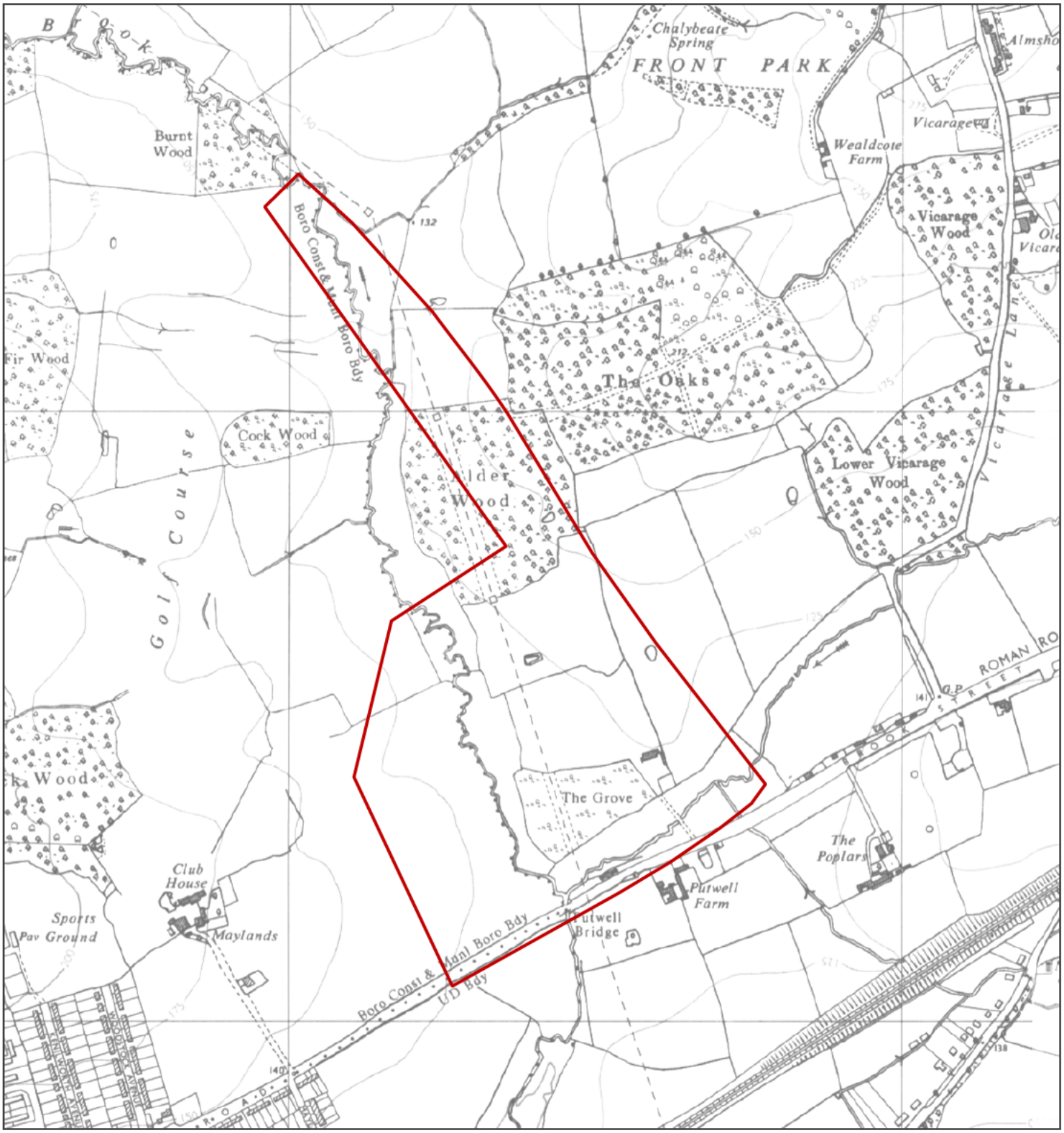
Title:	HISTORICAL OS MAPPING - 1959	FIGURE: 3



N	Project	M25 Junction 28, Romford
	Client:	Geotechnical Engineering Ltd
	Report Ref:	DRA-19-1106
	Approx. Site Boundary	Info Source: Groundsure

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Title:	HISTORICAL AERIAL PHOTOGRAPHY - *circa* 1945	FIGURE: 4

N

Project	M25 Junction 28, Romford
Client:	Geotechnical Engineering Ltd
Report Ref:	DRA-19-1106
Approx. Site Boundary	Info Source: GetMapping

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APPENDICES: 1 - 7

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Recent German UXB Finds in the UK + Historical Analysis

- ***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.*
- ***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.*
- ***19th January 2017*** - An SD50 (semi-armour piercing 50kg HE bomb) was dredged from the Thames during barge dredging works near Westminster Bridge, London.
- ***12th May 2016*** - A 500kg HE bomb was found buried just 1m below the playground of the former Royal High Junior School in Bath. *Historical Analysis: The UXB landed in a plot of neglected, unmaintained vegetation in between the school gym and main school building.*
- ***23rd September 2015*** - A 1,000kg HE bomb was encountered by a mechanical excavator on a building site in Paradise Street, Coventry. *Historical Analysis: the UXB landed in a large residential back garden occupied by dense vegetation. A two storey building was built on top of the UXB post-WWII.*
- ***10th August 2015*** - A 250kg HE bomb was found immediately beneath a basement floor during refurbishment works in Temple Street, Bethnal Green (London). *Historical Analysis: The UXB struck a house that had been damaged beyond repair during a previous air raid. The existing house was then built on top of UXB post-WWII.*
- ***21st May 2015*** - An SC50 (general purpose 50kg HE bomb) was found during deep excavations at a construction site in Wembley, London. *Historical Analysis: UXB landed in a large residential back garden.*
- ***23rd March 2015*** - A 250kg HE bomb was found during deep excavations at a building site in Grange Walk, Bermondsey (London). *Historical Analysis: inconclusive - reported UXB position is likely inaccurate.*

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).

Initiation of WWII Allied Bombs

- ***6th January 2014*** - Mechanical excavator stuck a WWII bomb in Euskirchen (Germany) causing it to explode, killing the operator and injuring 13 more, two critically. The explosion was so large it damaged buildings 400m away.
- ***1st March 2013*** - During piling at a construction site in Ludwigshafen (Germany) a small buried WWII bomb exploded, injuring one worker.
- ***2nd June 2010*** - A British 500kg bomb detonated whilst being defused, killing three EOD engineers in Goettingen, Germany. The bomb was found as builders dug the foundations for a new sports hall. Several houses had their fronts blown off by the blast.
- ***19th September 2008*** - Seventeen people were injured and buildings were damaged when an excavator apparently drove over and set off a 250kg American bomb at a construction site in Hattingen, Germany.
- ***23rd October 2006*** - A construction worker breaking up tarmac at the side of a highway near the south-western German town of Aschaffenburg was killed when his machine struck and detonated a WWII bomb. In addition, the blast injured several motorists who were driving past.
- ***2006*** - A piling rig and dump truck were destroyed when a piling rig struck an Allied bomb on a construction site in Austria.
- ***2003*** - In the Austrian city of Salzburg, two people were killed while attempting to defuse a 250kg Allied bomb.
- ***1994*** - At a central Berlin construction site a piling rig struck a large WWII Allied bomb. 3 were killed and 14 more were injured. Dozens of cars in a 250m radius were wrecked, the top 10 floors of neighbouring office building collapsed and human remains were found 100m away.
- ***1990*** - In Wetzlar (Germany) two EOD engineers were blown up as they removed the detonator of an allied WWII UXB.

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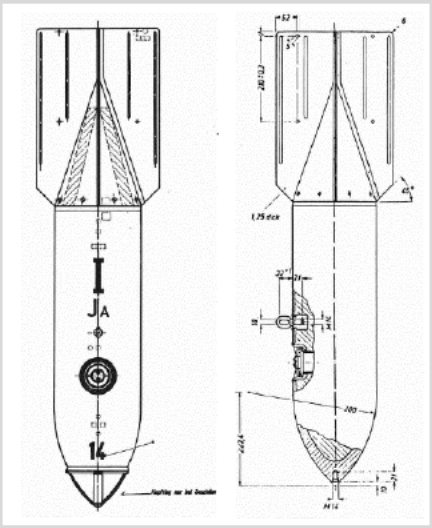
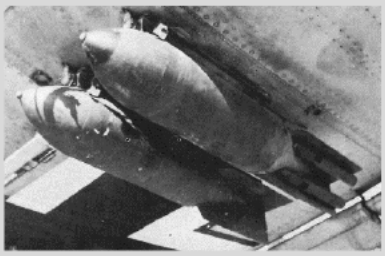
SC 50

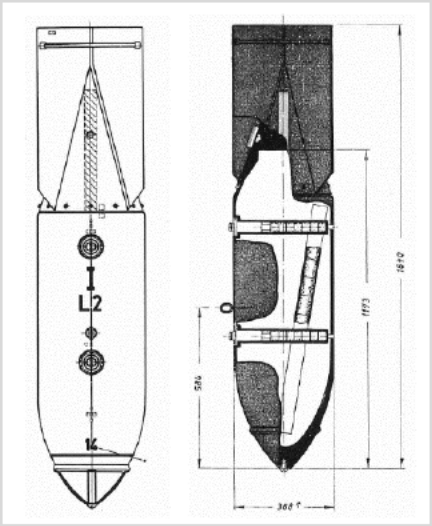
Bomb Weight:	40-54kg (110-119lb)
Explosive Weight:	25kg (55lb)
Filling:	TNT, Amatol or Trialen
Charge/Weight Ratio:	46%
Fuse Type:	Electrical impact fuse or mechanical delayed action fuse
Body Dimensions:	1,100mm length x 200mm diameter
Appearance:	Bomb body and tail painted grey/green with a yellow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





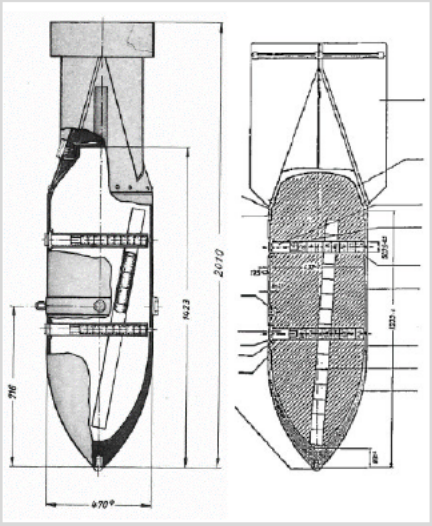
SC 250

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.



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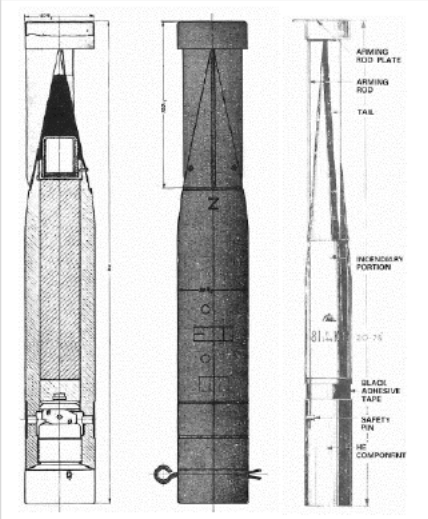
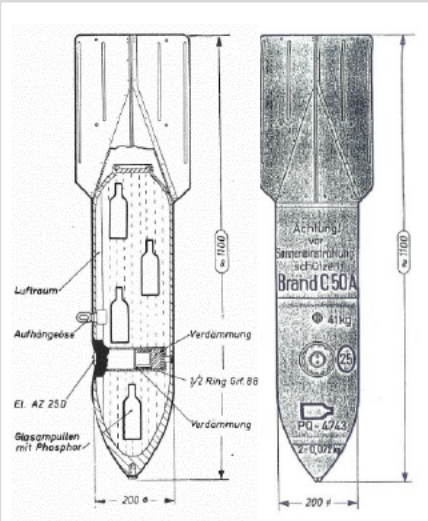
B-1E Sub-Munition

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.



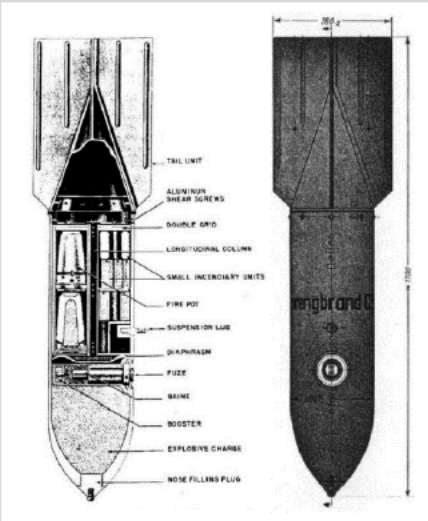
Brand C50

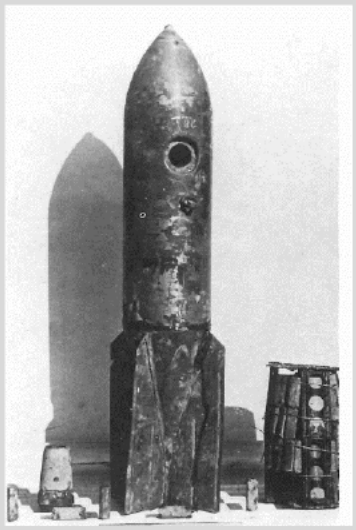
Bomb Weight:	41kg (90.4lb)
Incendiary Weight:	13kg (30lb)
Filling:	Main fill (86% Benzine, 10% Rubber) plus 4% Phosphorus in glass bottles
Fuse Type:	1 x electrical impact fuse
Bomb Dimensions:	762mm length x 203mm diameter
Appearance:	bomb body and tail painted grey or green with the rear of the bomb 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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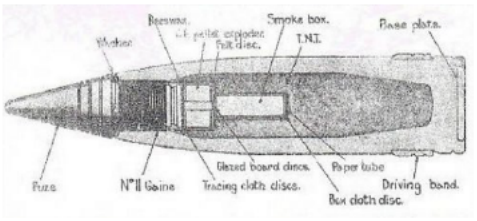
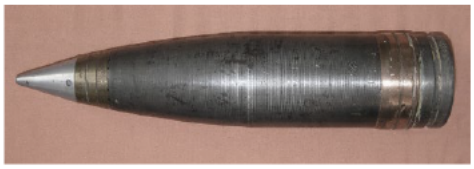
HAA Battery - 3.7" QF Shell

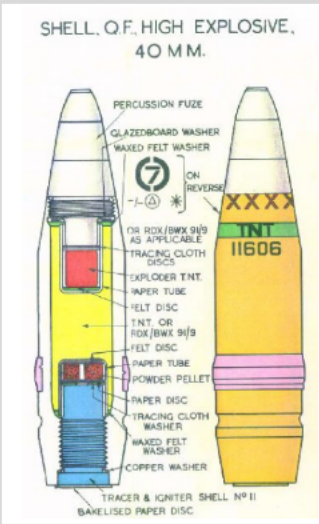
Shell Weight:	12.7kg
Shell Dimensions:	94mm x 438mm
Fill Weight:	1.1kg
Fill Type:	TNT
Fuse Type:	Mechanical Time Delay fuse
Appearance:	Grey body, copper driving bands, brass neck
Rate of Fire:	10 - 20 rpm
Ceiling:	9,000 - 18,000m
Variants:	HE or shrapnel shells. Note, the 4.5" gun was also used in an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





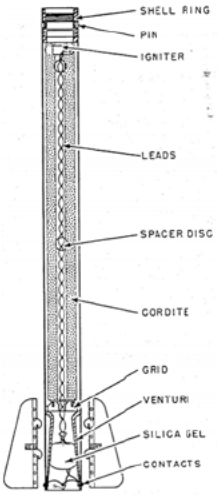
LAA Battery - 40mm Bofors Shell

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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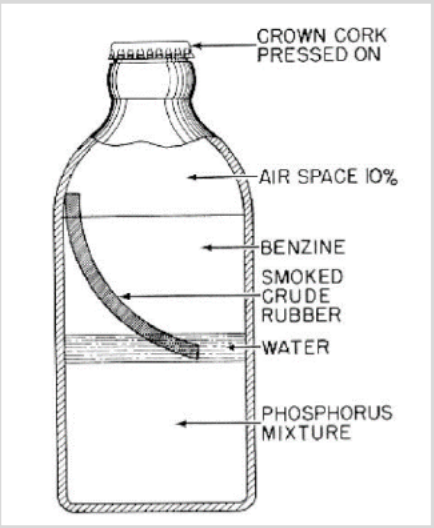
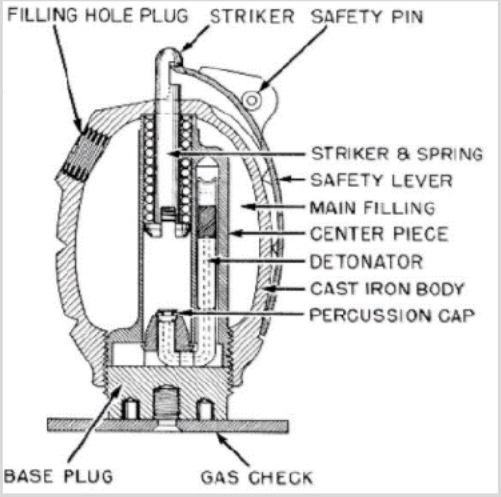
No. 76 Self Igniting Grenade (SIP)

Construction:	Glass bottle and metal stopper
Weight:	0.59kg
Dimensions:	152mm x 63mm
Hazardous Fill:	White Phosphorus and Benzene
Fuse:	n/a
Appearance:	White / off yellow milk bottle
Hazards:	Choking fumes of Phosphorus Pentoxide and Sulphur Dioxide, as well as heat. Severe burns if comes into contact with skin.
Remarks:	By August 1941 well over 6,000,000 of these grenades were available and mainly issued to the Home Guard.



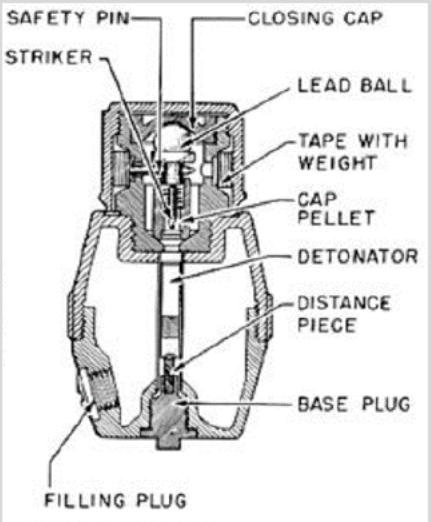
No. 36 Hand Grenade (Mills Bomb)

Construction:	Metal
Dimensions:	95mm x 61mm
Weight:	760g
Fill weight:	71g
Hazardous Fill:	Baratol
Fuse:	Percussion cap and 4 second time delay fuse
Hazards:	Blast, fragmentation. ~30m effective range.
Remarks:	>70 million were produced between 1915 and the 1980s



No. 69 (Blast) Hand Grenade

Construction:	Bakelite (plastic)
Dimensions:	114mm x 60mm
Weight:	383g
Fill weight:	92g
Hazardous Fill:	Baratol, Amatol or Lyddite
Fuse:	'All-Ways' Impact fuse
Hazards:	Blast effect. <20m effective range.
Remarks:	Green bands around the grenade signified a HE fill.



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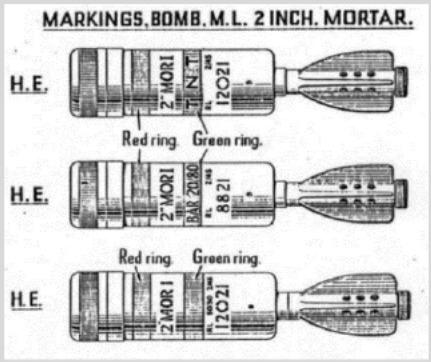
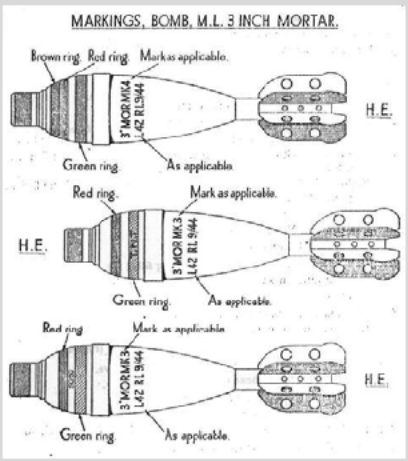
2" ML Mortar - High Explosive

Weight:	1.02kg
Dimensions:	51mm x 290mm
Hazardous Fill:	200g of RDX/TNT
Fuse:	Impact fuse
Appearance:	Cylindrical shape. Brown body, green and red bands, five finned tail
Variants:	Several smoke, inert practice and parachute illumination versions were manufactured
Remarks:	Common anti-personnel weapon in use with British Army throughout WWII. >12.5 million HE rounds were produced in 1942 alone



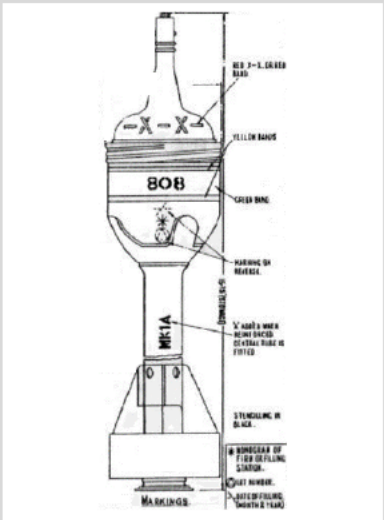
3" ML Mortar - High Explosive

Weight:	4.5kg
Dimensions:	81mm x 490mm
Hazardous Fill:	882g of RDX/TNT
Fuse:	Impact fuse
Appearance:	Pear-drop shape. Brown body, green and red bands, five finned tail
Variants:	Several smoke, white Phosphorus, inert practice and parachute illumination versions were manufactured
Remarks:	Common anti-personnel weapon in use with British Army throughout WWII. >6.5 million HE rounds were produced in 1942 alone



PIAT Anti-Tank Weapon

Projectile Type:	HEAT - shaped charge
Projectile Dimensions:	400mm x 90mm
Hazardous Fill:	Hollow HE charge and small solid propellant charge
Fill Weight:	1.13kg (charge)
Fuse:	Impact fuse
Remarks:	115,000 launchers were produced in Britain during WWII and the PIAT was used by most Allied armies during this conflict



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20mm Cannon Ammunition (various)

Cartridge Weight: 256g (approx.)

Total Cartridge length: 182mm (approx.)

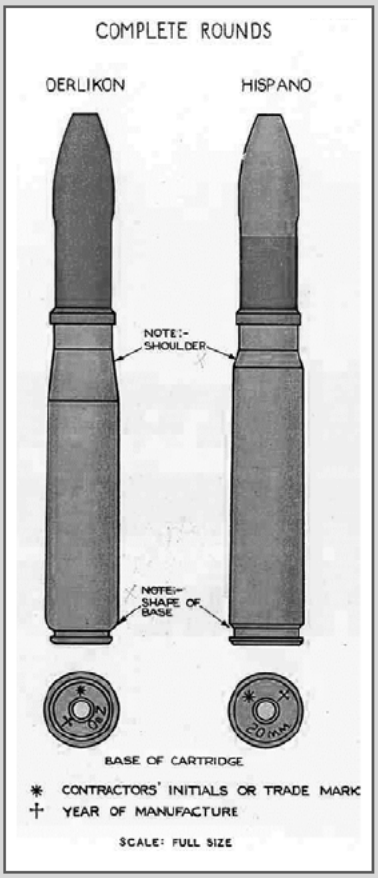
Hazardous Fill: Various HE, incendiary and tracer compositions. Typically TNT, Tetryl and Pentolite.

Fuse: Impact fuse

Appearance: Cylindrical shape. Brown body, green and red bands, five finned tail

Variants: Oerlikon and Hispano 20mm ammunition was deployed in the UK during WWII. These varied slightly in shape and also in the colours used to identify different projectile types.

Remarks: Today, 20mm rounds of WWII vintage may be found unexpended as full single cartridges or in belts of multiple cartridges. Or expended, i.e just the fused projectile without the brass base.

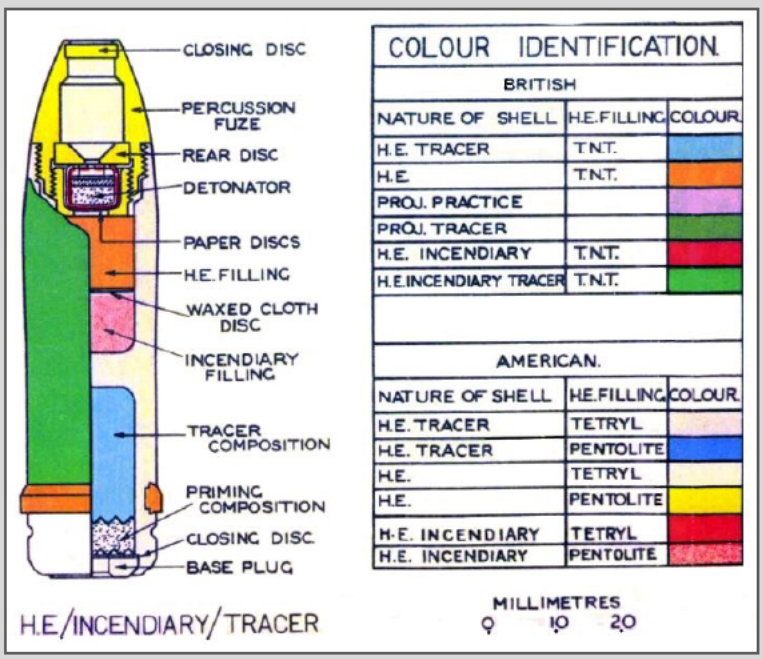



WWII belted 20mm rounds

Recent WWII 20mm rounds find

Bottom Right: Colour identification of Hispano rounds

Bottom Left: Colour identification of Oerlikon rounds



COLOUR IDENTIFICATION

BRITISH

NATURE OF SHELL	H.E. FILLING	COLOUR
H.E. TRACER	T.N.T.	
H.E.	T.N.T.	
PROJ. PRACTICE		
PROJ. TRACER		
H.E. INCENDIARY	T.N.T.	
H.E. INCENDIARY TRACER	T.N.T.	

AMERICAN.

NATURE OF SHELL	H.E. FILLING	COLOUR
H.E. TRACER	TETRYL	
H.E. TRACER	PENTOLITE	
H.E.	TETRYL	
H.E.	PENTOLITE	
H.E. INCENDIARY	TETRYL	
H.E. INCENDIARY	PENTOLITE	


20mm x 110mm Hispano Armour Piercing - 1935 > Present


20mm x 110mm Hispano High Explosive - 1935 > Present


20mm x 110mm Hispano High Explosive Incendiary - 1935 > Present


20mm x 110mm Hispano High Explosive Incendiary Tracer - 1935 > Present


20mm x 110mm Hispano High Explosive Tracer - 1935 > Present

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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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